INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC Scientific Review Board (SRB012) – A Collection of Published Meeting Documents

19 – 21 June 2018, Seattle, WA

DISTRIBUTION: NONE
Available for download at www.iphc.int.
Last updated: 21 May 2018

BIBLIOGRAPHIC ENTRY
IPHC Secretariat. 2019. Int. Pac. Halibut Comm. A Collection of Published Meeting Documents.

INTERNATIONAL PACIFIC HALIBUT COMMISSION

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INTERNATIONAL PACIFIC HALIBUT COMMISSION

IPHC-2018-SRB012-01

Late updated: 16 March 2018

<u>DRAFT</u>: AGENDA & SCHEDULE FOR THE 12th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB012)

Date: 19–21 June 2018
Location: Seattle, Washington, U.S.A.
Venue: IPHC Board Room, Salmon Bay
Time: 12:00-17:00 (19th), 09:00-17:00 (20th), 09:00-14:00 (the 21st)
Chairperson: Dr Sean Cox (Simon Fraser University)
Vice-Chairperson: Nil

1. OPENING OF THE SESSION

2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION

3. IPHC PROCESS

3.1. Update on the actions arising from the 11th Session of the SRB (SRB011) (D. Wilson)
3.2. Outcomes of the 94th Session of the IPHC Annual Meeting (AM094) (D. Wilson)
3.3. IPHC Rules of Procedure (2017): Proposed amendments (D. Wilson)
3.4. SRB annual workflow (D. Wilson)

4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS)

4.1. Methods for spatial setline survey modelling – Program of work for 2018 (R. Webster)

5. PACIFIC HALIBUT STOCK ASSESSMENT: 2018

5.1. Data source development (I. Stewart)
5.2. Modelling updates (I. Stewart)

6. MANAGEMENT STRATEGY EVALUATION: UPDATE

6.1. Outcomes of MSAB10 (A. Hicks)
6.2. Updates to MSE framework and closed-loop simulations (A. Hicks)
6.3. MSAB Program of Work and delivery timeline for 2018 and beyond (A. Hicks)
6.4. Interim distribution procedures 2019-2020 (A. Hicks)

7. BIOLOGICAL AND ECOSYSTEM SCIENCE PROGRAM RESEARCH UPDATES

7.1. Five-year research plan and management implications (J. Planas)
7.2. Progress on ongoing research projects (J. Planas)
    7.2.1. Discard Mortality Rates
    7.2.2. Juvenile growth studies
    7.2.3. Reproductive assessment
7.3. Presentation of planned future research projects (J. Planas)
    7.3.1. Growth-thermal history
    7.3.2. Larval connectivity
    7.3.3. Others

8. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 12TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB012)

DRAFT: SCHEDULE FOR THE 12th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB012)

Tuesday, 19 June 2018		
Time	**Agenda item**	**Lead**
12:00-12:30	Arrival (light lunch provided)	
12:30-12:45	1. OPENING OF THE SESSION 2. ADOPTION OF THE AGENDA AND ARRANGEMENTS FOR THE SESSION	S. Cox & D. Wilson
12:45-13:15	3. IPHC PROCESS 3.1 Update on the actions arising from the 11th Session of the SRB (SRB011) 3.2 Outcomes of the 94th Session of the IPHC Annual Meeting (AM094) 3.3 IPHC Rules of Procedure (2017): Proposed amendments (D. Wilson) 3.4 SRB annual workflow (D. Wilson)	D. Wilson
13:15-15:00	4. IPHC FISHERY-INDEPENDENT SETLINE SURVEY (FISS) 4.1 Methods for spatial setline survey modelling – Program of work for 2018	R. Webster
15:00-15:30	5. PACIFIC HALIBUT STOCK ASSESSMENT: 2018 5.1 Data source development 5.2 Modelling updates	I. Stewart
15:30-15:45	Break	
15:45-17:00	5. PACIFIC HALIBUT STOCK ASSESSMENT: 2018 (continued)	I. Stewart
Wednesday, 20 June 2018		
Time	**Agenda item**	**Lead**
09:00-10:00	Review of Day 1 and discussion of SRB Recommendations	Chairperson
10:00-10:30	6. MANAGEMENT STRATEGY EVALUATION: UPDATE 6.1 Outcomes of MSAB10 6.2 Updates to the MSE framework and closed-loop simulations	A. Hicks
10:30-10:45	Break	
10:45-12:30	6. MANAGEMENT STRATEGY EVALUATION: UPDATE 6.2 Updates to the MSE framework and closed-loop simulations (cont.) 6.3 MSAB Program of Work and delivery timeline for 2018 and beyond 6.4 Interim distribution procedures 2019-2020	A. Hicks
12:30-13:30	Lunch	

13:30-15:30	7. BIOLOGICAL AND ECOSYSTEM SCIENCE PROGRAM RESEARCH UPDATES 7.1 Five-year research plan and management implications 7.2 Progress on ongoing research projects 7.3 Presentation of planned future research projects	J. Planas
15:30-15:45	Break	
15:45-16:30	7. BIOLOGICAL AND ECOSYSTEM SCIENCE PROGRAM RESEARCH UPDATES (continued)	J. Planas
16:30-17:00	SRB drafting session	SRB members
Thursday, 21 June 2018		
Time	**Agenda item**	**Lead**
09:00-10:30	Review of Day 2 and discussion of SRB Recommendations	S. Cox
10:30-10:45	Break	
10:45-12:30	SRB drafting session	SRB members
12:30-13:30	Lunch	
13:30-14:00	8. REVIEW OF THE DRAFT AND ADOPTION OF THE REPORT OF THE 12th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB012)	S. Cox

DRAFT: LIST OF DOCUMENTS FOR THE 12th SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB012)

Document	Title	Availability
IPHC-2018-SRB012-01	DRAFT: Agenda & Schedule for the 12th Session of the Scientific Review Board (SRB012)	✓ 16 Mar 2018
IPHC-2018-SRB012-02	DRAFT: List of Documents for the 12th Session of the Scientific Review Board (SRB012)	✓ 21 May 2018
IPHC-2018-SRB012-03	Update on the actions arising from the 11th Session of the SRB (SRB011) (IPHC Secretariat)	✓ 17 May 2018
IPHC-2018-SRB012-04	Update on the actions arising from the 94th Session of the Commission (AM094) (D. Wilson)	✓ 16 May 2018
IPHC-2018-SRB012-05	Methods for spatial setline survey modelling – Program of work for 2018 (R. Webster)	✓ 21 May 2018
IPHC-2018-SRB012-06	Data source development (I. Stewart)	✓ 17 May 2018
IPHC-2018-SRB012-07	Modelling updates (I. Stewart, A. Hicks)	✓ 21 May 2018
IPHC-2018-SRB012-08	Management Strategy Evaluation: Update for 2018 (A. Hicks, I. Stewart)	✓ 21 May 2018
IPHC-2018-SRB012-09	Report on current and future biological research activities (J. Planas)	✓ 21 May 2018
Information papers		
IPHC-2018-SRB012-INF01	NPRB1704 Grant Proposal	✓ 16 May 2018
IPHC-2018-SRB012-INF02	Saltonstall-Kennedy Grant Proposal	✓ 16 May 2018

UPDATE ON ACTIONS ARISING FROM THE 11TH SESSION OF THE IPHC SCIENTIFIC REVIEW BOARD (SRB011)

PREPARED BY: IPHC SECRETARIAT (17 MAY 2018)

PURPOSE

To provide the Scientific Advisory Board (SRB) with an opportunity to consider the progress made during the intersessional period, on the recommendations/requests arising from the SRB012.

BACKGROUND

At the SRB011, the members recommended/requested a series of actions to be taken by the IPHC Secretariat staff, as detailed in the SRB011 meeting report (IPHC-2017-SRB011-R) available from the IPHC website, and as provided in Appendix A.

DISCUSSION

During the 12th Session of the SRB (SRB012), efforts will be made to ensure that any recommendations/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 (such as the IPHC Staff or SRB officers);
3) a desired time frame for delivery of the action (such as by the next session of the SRB or by some other specified date).

RECOMMENDATION/S

That the SRB:

1) **NOTE** paper IPHC-2018-SRB012-03, which provided the SRB with an opportunity to consider the progress made during the inter-sessional period, in relation to the consolidated list of recommendations/requests arising from the previous SRB meeting (SRB011).
2) **AGREE** to consider and revise the actions as necessary, and to combine them with any new actions arising from SRB012.

APPENDICES

Appendix A: Update on actions arising from the 11th Session of the IPHC Scientific Review Board (SRB011)

APPENDIX A
Update on actions arising from the 11th Session of the IPHC Scientific Review Board (SRB011)

RECOMMENDATIONS

Action No.	Description	Update
SRB11–Rec.01 (para. 14)	**Pacific halibut stock assessment (2017): Data source development** The SRB **RECOMMENDED** continuing to down-weight terminal year fishery CPUE in the annual stock assessment because terminal and post-season CPUE may be substantially different. Generating and presenting the conditional distribution for post-season CPUE given terminal CPUE, should be undertaken as a way to improve communication about most recent fishery CPUE values.	**Completed**.
SRB11–Rec.02 (para. 25)	**Management Strategy Evaluation: A description of the closed-loop simulations** The SRB **RECOMMENDED** that the IPHC Secretariat and Management Strategy Advisory Board collaborate to: a) further clarify and improve the presentation of the Harvest Strategy Policy (Appendix IV). This would improve not only transparency of the existing interim harvest policy, but also of the MSE process for evaluating alternatives. b) Review harvest policies from other bodies to develop an objectives hierarchy that explicitly prioritizes long-term conservation over short-/medium-term (e.g., 3-8 years) catch performance.	**Pending**. The MSAB had no suggestions for improving the Harvest Strategy Policy figure, but IPHC Secretariat has been working with MSAB members to create a figure describing the TCEY distribution component. The figures will be updated as needed. The review of harvest policies from other bodies is currently in progress. A review of other MSE's is also in progress to determine how they report long- and short-term statistics.
SRB11–Rec.03 (para. 29)	The SRB **RECOMMENDED** that the IPHC Secretariat hire a modeler/programmer to support MSE work so that timely feedback can be given the MSAB in the MSE process.	**Pending**. The IPHC Secretariat is currently drafting a document for the Commission that will outline the deliverables expected from a MSE researcher.

Action No.	Description	Update
SRB11–Rec.04 (para. 36)	**Biological and ecosystem science program: Presentation of potential future research projects** The SRB **RECOMMENDED** that IPHC consider hiring a life-history modeler to provide more explicit linkage between the empirical biological program and the applied assessment and MSE modeling programs.	**Pending**. The IPHC Secretariat is exploring possibilities for conducting the recommended modeling work.

REQUESTS

Action No.	Description	Update
SRB11–Req.01 (para. 7)	**IPHC fishery-independent setline survey: Methods for spatial survey modelling** The SRB **REQUESTED** that the IPHC Secretariat present a form of Table 1 to Commissioners, adding a column for Qualitative Cost (e.g., High, Low given sampling intensity, fishing cost, etc.).	**Completed.** The requested column was added for the annual meeting, but Commissioners did not appear to find it helpful, preferring to see a precise estimation of costs instead.
SRB11–Req.02 (para. 9)	The SRB **REQUESTED** that the following be maintained on the IPHC Program of Work: (i) examination of revenue and cost-recovery (i.e., cost benefit analyses), (ii) forecast the effect on CV of the presence or absence of expansion FISS stations, (iii) plotting relative error against number of stations, and (iv) comparison of frequency of zeros between standard and expansion FISS stations.	**Pending**. As discussed at SRB11, this work will be undertaken as part of the full evaluation following completion of the setline survey expansion in 2019.
SRB11–Req.03 (para. 12)	**IPHC fishery-independent setline survey: Preliminary FISS results** The SRB **REQUESTED** continuing research – subsequent to the 94th Annual Meeting of the IPHC (AM094) - on the effect of other covariates such as dissolved oxygen on the IPHC fishery-independent setline survey catch rates, and for any results to be presented at SRB12.	**Ongoing**. Work on modelling covariates is underway, with a focus on dissolved oxygen in Regulatory Area 2A. Results to date to be discussed at SRB12.
SRB11–Req.04 (para. 15)	**Pacific halibut stock assessment (2017): Data source development** The SRB **REQUESTED** continuing research on discrepancies between Estimated and Measured weights of Pacific halibut, be presented at SRB12.	**Pending**. The IPHC Secretariat anticipates further data collection through 2018 is needed to fully address spatial and inter-annual patterns.

Action No.	Description	Update
SRB11–Req.05 (para. 21)	**Size limit analysis for 2017: Update** **NOTING** the thoughtful and detailed presentation on the potential impacts of changing the minimum size limit presented in Appendix E (*Evaluation of adaptive management approaches*) of paper IPHC-2017-SRB11-07, the SRB **REQUESTED** that the IPHC Secretariat, between now and SRB12, seek feedback from the Commissioners, Conference Board, Processors Advisory Board, and the Management Strategy Advisory Board, on a modified version of Appendix E. In particular, a modified version would include (i) a process for starting and possibly ending an experiment, (ii) performance metrics, and (iii) criteria for making conclusions based on the experimental outcomes.	**Completed.** AM094–Rec.04 (para. 89) The Commission **NOTED** report IPHC-2018-AM094-14, which indicated that the performance of the management procedure is dominated by management decisions other than the size limit, (e.g. removal of the size limit is likely to result in minimal changes in yield) and **RECOMMENDED** that the size limit remain unchanged.
SRB11–Req.06 (para. 27)	**Management Strategy Evaluation: A description of the closed-loop simulations** The SRB **REQUESTED** that a quasi-extinction threshold be established so that: a) simulation replicates can be flagged when projected spawning biomass drops below this threshold; b) parameter sets causing quasi-extinction in the historical period can be dropped from the operating model initialization.	**Pending**. IPHC Secretariat plans to work with the SRB in identifying appropriate quais-extinction thresholds for the simulations. Currently, any parameter sets with steepness less than 0.6 are removed.
SRB11–Req.07 (para. 28)	The SRB **REQUESTED** that the MSE simulation initialize the operating model biomass in the current year from the more precise Ensemble distribution of the current state (e.g., 2017) rather than the wider distribution obtained from the Operating model.	**Pending**. The IPHC Secretariat plans to discuss an approach to reporting short- and long-term performance metrics that will address this issue.

Action No.	Description	Update
SRB11–Req.08 (para. 32)	**Biological and ecosystem science program: Progress on ongoing IPHC-funded research projects** The SRB **REQUESTED** that the IPHC Secretariat prepare a presentation for SRB12, on the overall research initiatives to show how stock assessment, biology, and policy are integrated. Ultimately, such an integrated presentation should be a key component of science presentations at future IPHC Annual Meetings. For example, all research presentations would have been more effective had there been: a) more precise linkages among key knowledge gaps within the biology, annual stock assessment, and MSE simulations; b) a specific suite of questions to be discussed during the SRB meeting; c) sufficient background material provided such that the SRB can provide informed comment and advice related to the specific questions in (b).	**Completed**. The IPHC Secretariat will present an integrated scheme of biological research with stock assessment and policy at SRB12. A draft of this integrated scheme was presented at the AM094 (IPHC-2018-AMP094-13).
SRB11–Req.09 (para. 33)	**NOTING** that some of the biological science work is externally funded and peer-reviewed, the SRB **REQUESTED** that future background papers include successfully funded proposals so that the SRB has sufficient detail to review implementation and progress of the work.	**Completed**. The IPHC Secretariat has included the funded grant proposals as information papers IPHC-2018-SRB012-INF01 and IPHC-2018-SRB012-INF02.
SRB11–Req.10 (para. 34)	The SRB **REQUESTED** that the IPHC Secretariat provide specific advice about the SRB's role in reviewing the design, analytical methods, and implementation of internally-funded projects.	**Completed**. The IPHC Secretariat has provided specific advice from the SRB regarding specific research questions
SRB11–Req.11 (para. 35)	**Biological and ecosystem science program: Presentation of potential future research projects** **NOTING** the presentation of project timelines and milestones, the SRB **REQUESTED** that timelines also be included for incorporating biological research results into the stock assessment and MSE work.	**Completed**. The IPHC Secretariat will include in the presentation at SRB12 a timeline of the integrated scheme of biological research with stock assessment and policy.

OUTCOMES OF THE 94TH SESSION OF THE IPHC ANNUAL MEETING (AM094)

PREPARED BY: IPHC SECRETARIAT (16 MAY 2018)

PURPOSE

To provide the SRB with the outcomes of the 94th Session of the IPHC Annual Meeting (AM094) relevant to the mandate of the SRB.

BACKGROUND

The agenda of the Commission's Annual Meeting (AM094) included several agenda items relevant to the SRB:

6. STOCK STATUS OF PACIFIC HALIBUT (2017) & HARVEST DECISION TABLE (2018)

7. MANAGEMENT STRATEGY EVALUATION

10. IPHC RESEARCH AND 5-YEAR RESEARCH PROGRAM

DISCUSSION

During the course of the 94th Session of the IPHC Annual Meeting (AM094) the Commission made a number of specific recommendations and requests for action regarding the stock assessment, MSE process, and 5-year research program. Relevant sections from the report of the meeting are provided in Appendix A for the SRB's consideration.

RECOMMENDATION

That the SRB:

1) **NOTE** paper IPHC-2018-SRB012-04 which details the outcomes of the 94th Session of the IPHC Annual Meeting (AM094) relevant to the mandate of the SRB.

APPENDICES

Appendix A: Excerpts from the 94th Session of the IPHC Annual Meeting (AM094) Report (IPHC-2018-AM094-R).

APPENDIX A
Excerpt from the 94th Session of the IPHC Annual Meeting (AM094) Report (IPHC-2018-AM094-R).

Recommendations and Requests
RECOMMENDATIONS

Review of fishery goals and objectives: Commission directive

AM094–Rec.01 (para. 36) The Commission **RECOMMENDED** that the draft goals, objectives, and performance metrics, as detailed in Appendix IV, IPHC-2017-MSAB10-R be used for ongoing evaluation in the MSE process, and that they may be refined in the future. The objectives should be evaluated in a hierarchal manner, with conservation as the first priority.

AM094–Rec.02 (para. 39) The Commission **RECOMMENDED** that the IPHC Secretariat consider the setline survey WPUE grid across the fishery as well as other biological factors (e.g. habitat configuration, size distribution in the region etc.) and provide alternatives to the current management areas (e.g. biological regions), and that the MSAB consider additional ways to incorporate biological information into TCEY distribution procedures.

AM094–Rec.03 (para. 44) The Commission **RECOMMENDED** that long- and mid-term performance metrics for conservation objectives be considered in the MSE process for conservation objectives, and that short-term metrics be included for fishery-related objectives in the MSE process, via the MSAB.

Evaluation of the IPHC's 32" minimum size limit

AM094–Rec.04 (para. 89) The Commission **NOTED** report IPHC-2018-AM094-14, which indicated that the performance of the management procedure is dominated by management decisions other than the size limit, (e.g. removal of the size limit is likely to result in minimal changes in yield) and **RECOMMENDED** that the size limit remain unchanged.

REQUESTS

Reports of the 10th Session of the IPHC Management Strategy Advisory Board (MSAB10)

AM094–Req.01 (para. 31) The Commission **REQUESTED** that the MSAB look at SPR values consistent with recent estimated SPR values from the assessment model and lower. This would mean expanding the lower range of SPR values to below 40%.

Review of fishery goals and objectives: Commission directive

AM094–Req.02 (para. 37) The Commission **REQUESTED** that the objectives related to distributing the TCEY, as detailed in Circular IPHC-2017-CR022, be presented at MSAB11 for further stakeholder feedback.

AM094–Req.03 (para. 38) The Commission **REQUESTED** that the proposed TCEY distribution methodology of the Harvest Strategy Policy reflect an understanding of both stock distribution and fishery management distribution procedures.

Supporting report text

7. MANAGEMENT STRATEGY EVALUATION

7.1 IPHC Management Strategy Evaluation: update

27. The Commission **NOTED** paper IPHC-2018-AM094-12 which provided an update on the progress of the IPHC Management Strategy Evaluation process and seeks recommendations for future work, including a review of goals and objectives defined by the MSAB, an overview of the simulation framework to evaluate the fishing intensity and harvest control rules in the IPHC harvest strategy policy, results from the closed-loop simulations, ideas for distributing the TCEY to Regulatory Areas, and a five-year work plan.

28. The Commission **CONSIDERED** the following items:

    a) The simulation framework and assumptions as described, including introducing variability to the Operating Model, simulating weight-at-age and an environmental regime, and allocation of the Total Mortality to sectors;

    b) The long-term results looking at the outcomes of various management procedures and the trade-offs among them;

    c) Management procedures (e.g. values of SPR in combination with a control rule threshold) that would meet the goal and objectives important to the Commission, based on the results shown, and additional procedures that may be of interest to evaluate in 2018;

    d) Whether the clear separation of stock distribution (a scientific product), and distribution procedures (management decision) satisfies the Commission's recommendation to replace apportionment with a more suitable term; and

    e) The concept of distributing the TCEY to biological regions defined here as a method to satisfy the Commission's request to "initiate a process to develop alternative, biologically based stock distribution strategies."

7.2 Reports of the 10th Session of the IPHC Management Strategy Advisory Board (MSAB10)

29. The Commission **NOTED** the Report of the 10th Session of the IPHC Management Strategy Advisory Board (MSAB10) (IPHC-2017-MSAB10-R) which was presented by Mr Adam Keizer (Canada). The MSAB consists of 20 board members, 19 of which attended the Session from the two (2) Contracting Parties. A total of five (5) individuals attended the Session as Observers. In addition, two (2) IPHC Commissioners were in attendance, Mr Paul Ryall (Canada) and Mr Bob Alverson (U.S.A.).

30. The Commission **AGREED** to the updated Program of Work provided at Appendix VI of IPHC-2017-MSAB10-R.

31. The Commission **REQUESTED** that the MSAB look at SPR values consistent with recent estimated SPR values from the assessment model and lower. This would mean expanding the lower range of SPR values to below 40%.

7.3 Review of fishery goals and objectives: Commission directive

32. The Commission **NOTED** the current fishery goals, objectives, and performance metrics identified by the MSAB for the MSE process, as detailed in Appendix IV of the MSAB10 report (IPHC-2017-MSAB10-R).

33. The Commission **NOTED** the summary presentation which was in response to Circular IPHC-2017-CR022 requesting stakeholder feedback on objectives proposed by a USA Commissioner related to distributing the TCEY presented at IM093. These objectives were categorized under the overarching goals defined by the MSAB for AM094.

34. The Commission **NOTED** the other concepts proposed by a USA Commissioner related to distributing the TCEY were not stated as measurable objectives but may be useful when developing management procedures to evaluate.

35. The Commission **NOTED** that:

a) the Commission objectives related to distributing the TCEY may be presented at MSAB11 for further stakeholder feedback.

b) the intent of the "other Commission concepts" could be further clarified and incorporated into the MSAB process, and can be converted to measurable objectives.

c) the MSAB may develop measurable outcomes and performance metrics associated with these Commission objectives.

36. The Commission **RECOMMENDED** that the draft goals, objectives, and performance metrics, as detailed in Appendix IV, IPHC-2017-MSAB10-R be used for ongoing evaluation in the MSE process, and that they may be refined in the future. The objectives should be evaluated in a hierarchal manner, with conservation as the first priority.

37. The Commission **REQUESTED** that the objectives related to distributing the TCEY, as detailed in Circular IPHC-2017-CR022, be presented at MSAB11 for further stakeholder feedback.

38. The Commission **REQUESTED** that the proposed TCEY distribution methodology of the Harvest Strategy Policy reflect an understanding of both stock distribution and fishery management distribution procedures.

39. The Commission **RECOMMENDED** that the IPHC Secretariat consider the survey WPUE grid across the fishery as well as other biological factors (e.g. habitat configuration, size distribution in the region etc.) and provide alternatives to the current management areas (e.g. biological regions), and that the MSAB consider additional ways to incorporate biological information into TCEY distribution procedures.

40. The Commission **NOTED** that the current procedure to distribute the TCEY could be replaced by an interim procedure to be developed in the near term while the MSAB completes their Program of Work to deliver guidance in 2021 on scale and TCEY distribution.

41. The Commission **AGREED** to meet via an inter-sessional electronic meeting (soon after the AM094), along with the IPHC Secretariat, to discuss TCEY distribution procedures to use in the interim while long-term distribution procedures are being developed by the MSAB. MSAB representatives and the IPHC Secretariat will inform the Commission of what guidance the MSAB may be able to provide to help develop an interim distribution strategy, and how the development of an interim harvest procedure may affect the MSAB's current Program of Work.

42. The Commission **AGREED** that distributing the TCEY to regions does not necessarily need to be the first step of the TCEY distribution procedure, and other biological factors, such as habitat and size distribution, be considered.

43. The Commission **NOTED** that the work the MSAB has already completed on distribution procedures may help to inform the development of an interim distribution strategy. MSAB representatives and the IPHC Secretariat will advise the Commission of how this may affect their current Program of Work, and what guidance they may be able to provide to help develop an interim distribution strategy.

44. The Commission **RECOMMENDED** that long- and mid-term performance metrics for conservation objectives be considered in the MSE process for conservation objectives, and that short-term metrics be included for fishery-related objectives in the MSE process, via the MSAB.

10. IPHC RESEARCH AND 5-YEAR RESEARCH PROGRAM

10.4 Evaluation of the IPHC's 32" minimum size limit

86. The Commission **NOTED** paper IPHC-2018-AM094-14 which provided a response to the Commission request made during the 2016 Interim Meeting (IPHC 2016):

IM092–Req.07 (para. 73) "*The Commission REQUESTED that a review of the analysis of the effectiveness of size limits be undertaken by the IPHC Staff throughout 2017, for consideration by the Commission at its annual meeting in 2018*."

87. The Commission **NOTED** the work of the IPHC Secretariat during 2017, and the challenges to an evaluation of the Minimum Size Limit (MSL).

88. The Commission **AGREED** that consideration of the magnitude of current discard mortality, the potential change in fishery yield, uncertainty in the market value of Pacific halibut below the current MSL and potential changes in fishery practices in response to a change in the MSL represent the primary trade-offs identified.
89. The Commission **NOTED** report IPHC-2018-AM094-14, which indicated that the performance of the management procedure is dominated by management decisions other than the size limit, (e.g. removal of the size limit is likely to result in minimal changes in yield) and **RECOMMENDED** that the size limit remain unchanged.
90. The Commission **AGREED** that the work of the IPHC Secretariat has satisfied the Commission’s request, and directed the IPHC Secretariat to postpone further investigation of the MSL until such time as either additional information or changes in the fishery, markets, or Pacific halibut stock warrant additional work.

Methods for spatial survey modelling - program of work for 2018

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER; 20 MAY 2018)

PURPOSE

To present results on spatio-temporal survey modelling undertaken to date in 2018, and describe plans for the remainder of the year.

BACKGROUND/INTRODUCTION

In 2016, IPHC Secretariat staff began using a space-time modelling approach to estimate indices of density and biomass for use in stock assessment modelling and estimation of stock distribution. Survey station weight and number per unit effort (WPUE and NPUE) indices are used as input data, following a standardisation for competition for baits among Pacific halibut and other species. Prior to the introduction of the space-time modelling, this standardisation was calculated from data aggregated across all IPHC setline survey stations within each Regulatory Area, rather than at the level of survey station. The adjustments are calculated from the proportion of baits returned on each setline survey station, and the proportions themselves are calculated from data obtained from the first 20 hooks on each skate rather than the full 100 hooks otherwise used for data on Pacific halibut. An exception is Regulatory Area 2B, where returned baits have been counted on 100% of hooks on the setline survey since 2003 (with the exception of 2013). An analysis of the Regulatory Area 2B data (Webster and Leaman 2014) showed that, with data aggregated across the Regulatory Area, 20-hook-count estimates of the proportion of baits returned were unbiased and precise relative to the 100% hook counts. In this report, we revisit the Regulatory Area 2B bait return data to assess whether the use of 20-hook counts in other Regulatory Areas is likely to affect the density index estimates from the space-time model.

The use of environmental covariates to improve the space-time model has been discussed at previous meetings of the Scientific Review Board. The IPHC uses water column profilers on each setline survey station to record several environmental variables, including dissolved oxygen, temperature and salinity. Due to a hypoxic event off the Washington coast, the effect of dissolved oxygen on Pacific halibut density in Regulatory Area 2A in 2017 has been subject to much discussion, and this variable is therefore of particular interest to us when examining how environmental covariates can be used to improve the density index estimates from the space-time model. We summarize results of exploratory modelling of relationships between O32 WPUE and bottom dissolved oxygen and temperature for Regulatory Area 2A, and describe a proposed framework for including these variables in models for the full 1993-2017 data. For the latter, we note that wide-scale use of the water column profilers began in 2009, and that since 2009, profiler data are missing at many fished setline survey stations and unavailable when expansion stations are not fished. The method used should avoid omitting Pacific halibut data even in the absence of corresponding environmental data.

EFFECT OF USING 20-HOOK COUNTS ON WPUE

Data from Regulatory Area 2B were used to compare the output from space-time models using hook competition standardisation based on data from 20 hooks/skate, and from the output using adjustments based on 100% of hooks. Figure 1 compares the estimated WPUE time series from the space-time model using 20 hooks versus 100%. The two time series are very close, with differences well within 95% credible intervals.

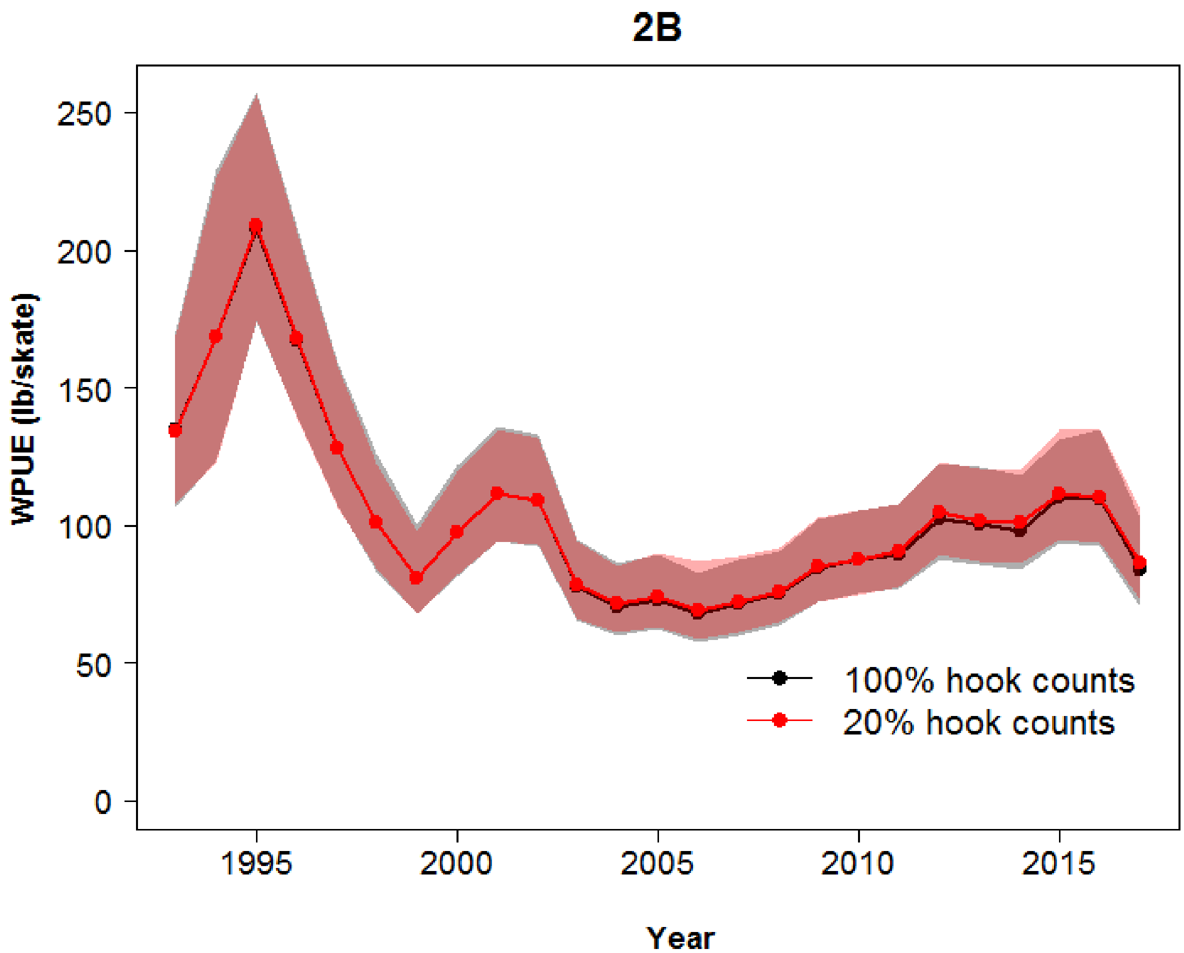

Figure 1. Space-time model posterior means and 95% credible intervals of O32 WPUE in Regulatory Area 2B with hook competition standardisations based on 100% of hooks and 20 hooks/skate.

From 2003, when 100% hook sampling was implemented, the 20-hook-count series is consistently slightly above the 100% series (Figure 1), which at face value may imply a very small positive bias in using data from just 20 hooks/skate. However, some slight difference is almost guaranteed because of the way the hook competition standardisation is calculated to accommodate the case of zero baits returned on a station. Recall that in computing the standardisation at each station, the quantity *Z* is required:

$$Z = \log\left(\frac{h}{b}\right)$$

where *h* is the number of hooks on a set and *b* is the number of baits returned. To avoid division by zero when no baits are returned, we add a small quantity δ to both *h* and *b*:

$$Z = \log\left(\frac{h+\delta}{b+\delta}\right)$$

where $\delta = h/100$. This choice means δ is proportional to the number of hooks set, ensuring that if no baits are returned, *Z* will be the same for sets of different lengths (e.g., 5 skates vs 6 skates). The adjustment factor for the standardisation is given by

$$f_H = \frac{Z}{1-e^{-Z}}$$

When 20 hooks are used instead of 100%, there is a far greater chance that any given station has zero or close to zero baits returned, likely leading to a larger adjustment factor for that station than if 100% sampling had been used. This greater chance of a larger adjustment factor is the cause of the very slightly higher WPUE values for 20 hooks in Figure 1. No value of δ is going to lead to 20 hooks and 100% giving the same adjustments on average all the time, and our experiments with alternative values (e.g., $\delta = 1$ or something intermediate to this and the current choice) led to time series that differed by a greater amount.

Our conclusion is that the very small difference between the series based on data from 20-hook and 100% hook sampling is not meaningful for scientific and management purposes, and is not sufficient to justify the additional expense of sampling 100% of hooks in all Regulatory Areas.

ENVIRONMENTAL COVARIATES IN SPACE-TIME MODELS

In this section we outline a proposed approach to including environmental data from the setline survey's water column profilers as covariates in space-time models. The focus here is on Regulatory Area 2A, due in part to the apparent large effect of dissolved oxygen on this area's WPUE motivating the desire to explore such models, and that for Regulatory 2A, space-time models can be run relatively quickly, allowing us to fit and compare several models more easily.

We began by fitting exploratory models using observed data only. That is, if a setline survey station has missing covariate information, it was excluded from the modelling. Thus, we are only using setline survey WPUE from 2009 onwards, and exclude a number of stations for which technical or data quality problems meant no reliable covariate data were available. The advantage of starting with the observed data is that models can be fit very quickly to this smaller data set, while the results can demonstrate if it is worthwhile trying to fit models with all the data from 1993-2017. Exploratory models included covariates for bottom temperature, which previous models fitted to Bering Sea data showed was an important predictor in that region, and dissolved oxygen. All models also included the depth and latitude covariates used in the modelling of the full 1993-2017 data, and considered base-model covariates for Regulatory Area 2A. Model fit was compared using the Deviance Information Criterion (*DIC*), with lower values indicating better fitting models.

Table 1 presents the *DIC* for the models exploratory models we fitted to the Regulatory Area 2A data. The space-time models include two components, one for modelling the probability of zero WPUE, and a gamma model for non-zero WPUE observations. Each component can include covariates, and unless indicated by “z” or “nz”, covariates were included in both.

Table 1 Deviance Information Criterion values for models fitted to observed setline survey data in Regulatory Area 2A (2009-2017).

Model	*DIC*	Notes
Base model (depth + latitude)	8605.9	
Base + temp	8603.7	
Base + $temp^2$	(Did not converge)	Correlation with depth?
Base + $temp^2$(z) + temp(nz)	8605.5	
Base + $temp^2$(nz)	8605.7	
Base + O_2	8593.7	
Base + $I(O_2 < 0.9)$(z) + O_2(nz)	8590.2	

Note that I( ) is the indicator function, taking values of 1 is the statement is true, and zero otherwise. In our model, this was used to create a binary variable with value 1 if dissolved oxygen was less than 0.9 (the level previous work and last year’s data showed led to zero or almost zero halibut) and value zero otherwise. In that model, non-zero WPUE was modelled as linearly dependent (on the log scale) on dissolved oxygen.

The results in Table 1 show little evidence for the importance of bottom temperature as a covariate in WPUE, although we note the linear temperature model had a slightly lower *DIC* than the baseline. Inclusion of dissolved oxygen led to a much larger decrease in *DIC*, with the model with the binary variable for the probability of zero halibut having the lowest *DIC* of those we considered. In summary, dissolved oxygen is a promising variable for inclusion in models which use the full 1993-2017 WPUE data set.

Next we must find an approach which allows for inclusion of environmental covariates without excluding any of the Pacific halibut catch data. The first step is to impute values for stations with missing data from 2009-2017. To do this efficiently, we chose to fit simple exponential spatial models to the dissolved oxygen data for each year separately, and then predicted dissolved oxygen at stations with missing values (including stations unsurveyed in a given year). Dissolved oxygen has a relatively smooth spatial distribution, and predictions within the spatial range of observed data are likely quite good. For consistency, we also replaced observed values with predicted values, although these were almost always very similar.

The next step is to construct a model for the relationship between WPUE (both zero and non-zero components) and dissolved oxygen that does not require having environmental data prior to 2009. For this, we need to define the dummy variable D as $D = 0$ if year < 2009 and $D = 1$ if year ≥ 2009. Then the covariate model including dissolved oxygen is:

$$\text{(intercept + other covariates)} + \beta_0 D_i + \beta_1 X_i D_i$$

where β_0 is the intercept difference for stations with dissolved oxygen values, β_1 is the slope of the linear relationship, and X_i is the value of dissolved oxygen for the ith station in a given year. Thus in the absence of dissolved oxygen values, the model defaults to the base model, which (as above) includes depth and latitude as covariates. Non-linear relationships, and other more general models can be also be constructed using the same dummy variable.

Such covariate models are currently being fitted to the full 1993-2017 data, and it is expected that some results will be available for presentation at SRB012. Based on the final results and SRB input, a decision will be made as to whether to include dissolved oxygen as a covariate in space-time models for Regulatory Area 2A in 2018.

One point of discussion that we would appreciate SRB input on is how to account for variables such as dissolved oxygen in estimating the WPUE time series from the space-time model. Two approaches have been discussed among staff and stakeholders. The first is that we simply estimate WPUE at the values of dissolved oxygen used in the original modelling, so that the purpose of adding this variable is to add information that leads to improved estimation of WPUE. The second option is to predict WPUE at a fixed value of dissolved oxygen for all years and stations, leading to a WPUE index that has been adjusted for variation in dissolved oxygen. The argument for the latter approach is that years of very low dissolved oxygen are anomalous and that by "adjusting away" the effect of this variable, the resulting WPUE series will provide a better index when estimating stock distribution to inform management decisions for the following the year. A counter-argument is that the WPUE index should reflect the underlying Pacific halibut density in each year, and not some hypothetical density under environmental conditions which were not in fact observed.

SPACE-TIME MODELLING CHANGES AND PLANS FOR 2018

The following is a list of other potential changes to the space-time modelling in 2018, and other work related to these models:

- Noting that three Pacific halibut were found near the outside of Kotzebue Sound in a 1998 trawl survey, we will examine adding geographic area in the southern Chukchi Sea to Area 4CDE space-time models. We note that no Pacific halibut were found during the 2012 National Marine Fisheries Survey of the Chukchi Sea.
- Summarise measures of geographic area currently used by other fisheries organisations when estimating stock distribution among management areas. The IPHC

uses the geographic area of the ocean surface in each Regulatory Area to create coastwide indices of density and estimate stock distribution, but Commissioners have directed staff to consider alternative metrics that account for the slope or rugosity of the ocean bottom. Examining current practice elsewhere is the first step.

- Use a version of the space-time models to study the spatial distribution of Pacific halibut larvae, with particular focus on differences between warm and cold periods, and between the Bering Sea and the Gulf of Alaska. This work is in progress at present in collaboration with Lauri Sadorus (IPHC staff) and scientists from NMFS.
- In 2018, the IPHC revised the criteria for effectiveness of setline survey sets given evidence of whale depredation. Once databases have been updated to reflect this change, we intend to examine its effect on space-time model estimates of density indices.
- Report on the results of the setline survey expansions in Regulatory Area 2B and 2C in 2018, and incorporate all new data into the 2018 space-time modelling for these areas.

Reference

Webster, R. A. and Leaman, B. M. 2014. Setline survey hook counts: are the first 20 hooks sufficient? Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2013: 421-432.

Recommendation/s

The IPHC secretariat requests that the SRB:

NOTE this document summarising spatial survey modelling updates for 2018.

NOTE any discussion occurring during SRB012, and **RECOMMEND** any conceptual or technical improvements for survey modelling.

Data source development

PREPARED BY: IPHC SECRETARIAT (I. STEWART; 17 MAY 2018)

PURPOSE

To provide the Scientific Review Board (SRB) a summary of anticipated data source development in support of the 2018 and 2019 stock assessment and harvest strategy analyses.

INTRODUCTION

Updates and improvements to the data sources supporting the annual stock assessment and harvest policy analyses are made each year as new information and new processing of older information becomes available. These changes, and their effects on the stock assessment results are routinely presented at both the June and September SRB meetings depending on when the analyses are completed (Stewart 2017a, Stewart 2017b, Stewart and Webster 2018).

During 2017, specific changes included:

- Updating the Fishery-Independent Setline Survey (FISS) time series from the Space-Time (S-T) model to include the years 1993-1997, which had been previously unavailable, and also had a small effect on the rest of the time series.
- Including biological information (age and lengths) from FISS expansion stations sampled since 2014.
- Using the individual halibut weights measured by port samplers in place of weights predicted by the length-weight relationship where available for analysis of commercial fishery data.
- Expanding the reporting of commercial fishery CPUE time-series to facilitate better understanding of fishery and spatial patterns as well as to better describe the consistent bias associated with incomplete records at the time the data sources are closed for the stock assessment in early November each year.

Ongoing avenues of data development, specific changes anticipated for inclusion into 2018 models, and changes planned for 2019 are described in this document.

ONGOING DEVELOPMENT

Measured individual fish weights

As documented during SRB011 (Stewart 2017b), the stock assessment and related analyses based on commercial fishery individual weight data now utilized measured rather than predicted values. During 2017 the IPHC continued to collect length-weight information, and a renewed investigation of the relationship is anticipated in the near future when sufficient data are available to describe the range of spatial and inter-annual variability present in the population.

Continued investigation of historical bycatch estimates and length-frequency data

Although bycatch accounting in Alaska in conducted by the National Marine Fisheries Service (NMFS), historically the IPHC has updated historical mortality estimates with estimated rather than predicted Discard Mortality Rates (DMRs) after all annual data have become available. Efforts have been underway for several years (Stewart 2017b) to investigate the full time-series of estimates currently available for the stock assessment, and to update the mortality estimates where appropriate.

Length-frequency data by Regulatory Area has historically been summarized by the IPHC on an *ad hoc* basis. We currently use a time-series consisting of aggregate estimates with little to no meta-data and likely differing methods of aggregation in different years (e.g., catch weighted, raw length-frequencies, projected values from incomplete data, etc.). These data are currently used in the stock assessment model to inform the selectivity curve describing bycatch removals, but are down-weighted due to these concerns over standardization (Stewart and Martell 2016). Several improvements are needed before the treatment of annually variable bycatch in the assessment models can be made more explicit: 1) identifying raw data sets suitable for inclusion, 2) re-estimating length-frequency distributions using standardized methods for all available years, 3) recording meta-data and results such that they can be recreated if changes to the analysis approach are desired in the future, and 4) updating the stock assessment model inputs to reflect the best available series, potentially increasing the weight on these data, while allowing for an appropriate degree of temporal variability in selectivity to reflect differences among areas, fishing fleets and other factors.

Updated bycatch mortality estimates and appropriately weighted length frequency data would benefit the annual stock assessment, harvest policy and MSE analyses, as well as ongoing support of domestic efforts such as the North Pacific Fisheries Management Council's investigation of Abundance-Based Prohibited Species Catch Limits. Due to continued staffing changes within the IPHC secretariat, there has been no additional progress on this effort since it was identified several years ago. Hiring during 2018 may provide for renewed efforts in the near future.

Effective skate calculations

Recent research comprising a portion of Cole Monnahan's PhD thesis (University of Washington; June, 2017) re-evaluated the hook-spacing/power relationship used to standardize commercial Pacific halibut fishery logbook records (Monnahan and Stewart 2015). This work has now been published (Monnahan and Stewart 2018), and the IPHC Secretariat is in the process of developing a plan for updating the historical relationship currently used for all database calculations. This effort is likely to entail:

1. Creating a development copy of the commercial logbook data.
2. Implementing the new hook-spacing relationship.
3. Re-running all catch-rate summaries.
4. Comparing the results for use in the stock assessment and other potential database artifacts.
5. Replacing the database code for routine use.
6. Updating all existing data sets and summaries and conveying any changes during the annual management process.

Although the improved estimate is not identical to the *status quo* relationship, it is very similar, and the likely effect on current analysis methods is small (i.e., Figure 4 in Monnahan and Stewart 2018).

DEVELOPMENT FOR 2018

Space-Time modelling improvements

Improvements to the S-T model are anticipated for 2018, and are outlined in a separate document (see IPHC-2018-SRB12-06). Pending SRB review of these changes, if results are available in September, they will be included in stock assessment models for review during SRB13.

Enhanced reporting of commercial fishery Catch-Per-Unit-Effort (CPUE) indices

During 2017, the SRB recommended a method for describing the recurring bias observed in commercial fishery logbook CPUE trends due to incomplete information at the time of the annual stock assessment (IPHC 2017, Stewart and Webster 2018). Several related issues were also discussed, including the partitioning and description of tribal and non-tribal fisheries in Regulatory Area 2A, treatment of differences in CPUE among gear types, as well as the application of model vs the simple analysis method currently employed. The SRB did not prioritize moving forward with a more sophisticated model-based standardization approach such as that provided in Monnahan and Stewart (2015) and later expanded by Cole Monnahan (PhD, University of Washington, June, 2017) to include an explicitly spatial method. The Secretariat has therefore focused subsequent efforts on more effectively reporting commercial catch rate trends.

Historical indices in all Regulatory Areas other than 2A and 2B have included only fixed hook logbook information (Stewart and Webster 2018) due to differential catchability (Clark 2006) and the potential for misconstruing trends in gear usage with trends in the underlying population. This has led to concerns from snap (and other) fishermen that their data are not being considered, and general concern that signals in the fixed hook data may not accurately represent the entire fishery, despite analysis indicating very similar trends when all gear were analyzed simultaneously (Monnahan and Stewart 2015). For 2018, catch rates (and variance) have been summarized and reported by gear type. Observed trends are very similar for most Regulatory Areas (**Appendix A**), and the additional information is anticipated to provide for increased and better informed discussion during the 2019 Interim and Annual Meetings (IM094 and AM095).

Data status and trend summary tools

The IPHC Secretariat is moving forward with the development of presentation tools for use during meetings, as well as through the new website. As the complexity of supporting analyses and the number of diverse data sets considered during the annual management process has increased, it has become more challenging to provide the information in easily accessible and efficient formats. Inspired by approaches first encountered through the North Pacific Fishery Management Council’s (NPFMC; https://www.npfmc.org/) Ecosystem report and other National Marine Fisheries Service presentations, one potential tool to condense both trend and status information is to ‘map’ data sources into simple quadrants. This approach will be more fully discussed during SRB12, but a simple example is provided in **Appendix B**.

Routine updates

As is the case each year, all time-series and other annually collected sources of information will be updated for the fall of 2018, following established and documented methods (Stewart and Webster 2018).

Although in previous years, some updated information has been available for the fall SRB meetings (held in October prior to 2017), now that the meetings are held in September, this is generally not possible. Of note in 2018 is that the Commission, during the 2018 Annual Meeting (AM094), agreed to publish the results of the FISS as soon as available in the fall (Para. 8; IPHC 2018), and no later than 1 November. This is anticipated to provide additional time for public consideration of annual survey results prior to the release of the stock assessment results during the Interim Meeting held later in November. It will therefore be important to clearly highlight the delineations among raw survey results, S-T model results, and the population trends estimated in the stock assessment.

DEVELOPMENT PROPOSED FOR 2019

A full assessment analysis and review is planned for 2019 (see discussion in IPHC-2018-SRB12-07), which will allow more in-depth investigation and model-based evaluation of the new and/or revised data outlined below.

Whale depredation during FISS sampling

During 2018, the survey team initiated a review of the criteria used to define whale depredation during routine survey operations. This review led to a revision of the criteria for the 2018 sampling season. During this process, it was noted that although recent levels of depredation are low (<5%) based on the new criteria, there is a need to reclassify all survey activity currently used in the S-T model to ensure comparability throughout the time-series. A summer intern project will assist in recovering the records needed to retrospectively apply the revised criteria, and the time series of effective and ineffective stations will be provided for analysis in 2019.

Sex-ratio of the commercial landings

As has been identified in recent analyses, the sex ratio of the commercial fishery catch represents an extremely important source of uncertainty in the annual stock assessment (Stewart and Hicks 2018). Because landed halibut are dressed at sea, this information has been unavailable for sampling in port, but tissue samples have been collected for all halibut selected for biological sapling starting in 2017 (Erikson and Kong 2018). Although the results of the voluntary marking program conducted coastwide during the 2017 fishing season (Loher et al. 2017) are still pending, there is the potential for genetic sex assignment of all commercial samples. The results of the voluntary program in tandem with additional genetically validated samples, as needed, will be available for use in creating landings by age and sex (from 2017) for use in the 2019 stock assessment.

SUMMARY

This document serves to update the ongoing data improvement efforts by the IPHC Secretariat. Continued refinement of the data sources feeding in to the stock assessment models, the harvest policy analyses, and the management structure remains a priority. Changes for 2018 are anticipated to be small, and primarily related to effective reporting and summary, while changes for 2019 are more likely to have broader implications for the stock assessment and harvest policy analyses (Table 1).

As has been the standard practice since 2015, all changes to data sources will be presented during the fall SRB meeting (SRB13) or reported directly in the stock assessment depending on the completion date of each source. Any questions and/or clarifications will be provided for the SRB during the annual conference call held in December (after the IPHC's Interim Meeting IM094, and before the IPHC's Annual Meeting AM095).

TABLE 1. Summary of data development.

Improvement	Rationale	Timeline
Refinement of the length-weight relationship	The Commission has been routinely collecting length-weight observations since 2016.	Uncertain pending further data collection and analysis prioritization.
Historical bycatch data	Re-analysis of historical mortality and biological data is needed to reconcile observed DMRs and ensure length-frequency data have been summarized consistently.	Potential for inclusion in the 2019 stock assessment analyses depending on IPHC Secretariat staffing.
Effective skate calculations	A revised hook-power relationship was published in 2018.	The newly revised relationship will be evaluated for inclusion in the IPHC's standard database calculations.
Space-time model changes	Continued refinement of modelling methods.	To be included for 2018 pending review.
Commercial fishery CPUE summary by gear type	Trends in fixed hook and snap gear catch rates in the commercial fishery are of interest to participants.	Clearer delineation of this information has been developed for the 2018 process.
Data summary tools	Continued improvement in the summary and accessibility of data sources is important.	To be explored in 2018.
Routine updates	Time-series are extended each year for the annual process.	To be completed in fall 2018.
Revised whale depredation	New criteria adopted for 2018 need to be applied to the entire time-series for	Anticipated to be available for

criteria	consistency	2019.
Genetically identified commercial sex ratios	This information addresses a crucial source of uncertainty in the stock assessment.	Anticipated to be available for 2019.

RECOMMENDATION/S

That the SRB:

1. **NOTE** paper IPHC-2018-SRB012-06 that summarized ongoing, pending and future data source development efforts by the IPHC Secretariat.
2. **RECOMMEND** any suggested changes to the process of updating and improving data for use in the stock assessment and related analyses.
3. **NOTE** any discussion occurring during SRB012, and **RECOMMEND** any improvements to and/or new tools for summarizing and presenting data sources, including recent trends and relative status of all data sources, as well as detailed information on commercial catch rates.
4. **RECOMMEND** any additional specific research avenues to be prioritized for inclusion in the 2019 stock assessment.

References

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Stewart, I., and Hicks, A. 2018. Assessment of the Pacific halibut (*Hippoglossus stenolepis*) stock at the end of 2017. IPHC-2018-AM094-10. 25 p.

Stewart, I., and Webster, R. 2018. Overview of data sources for the Pacific halibut stock assessment, harvest strategy policy, and related analyses. IPHC-2018-AM094-09. 83 p.

Stewart, I.J., and Martell, S.J.D. 2016. Appendix: Development of the 2015 stock assessment. IPHC Report of Assessment and Research Activities 2015. p. A1-A146.

APPENDICES

Appendix A: Expanded reporting of commercial fishery catch-rates.

Appendix B: Example of qualitative data 'mapping'.

APPENDIX A

Expanded reporting of commercial fishery catch-rates.

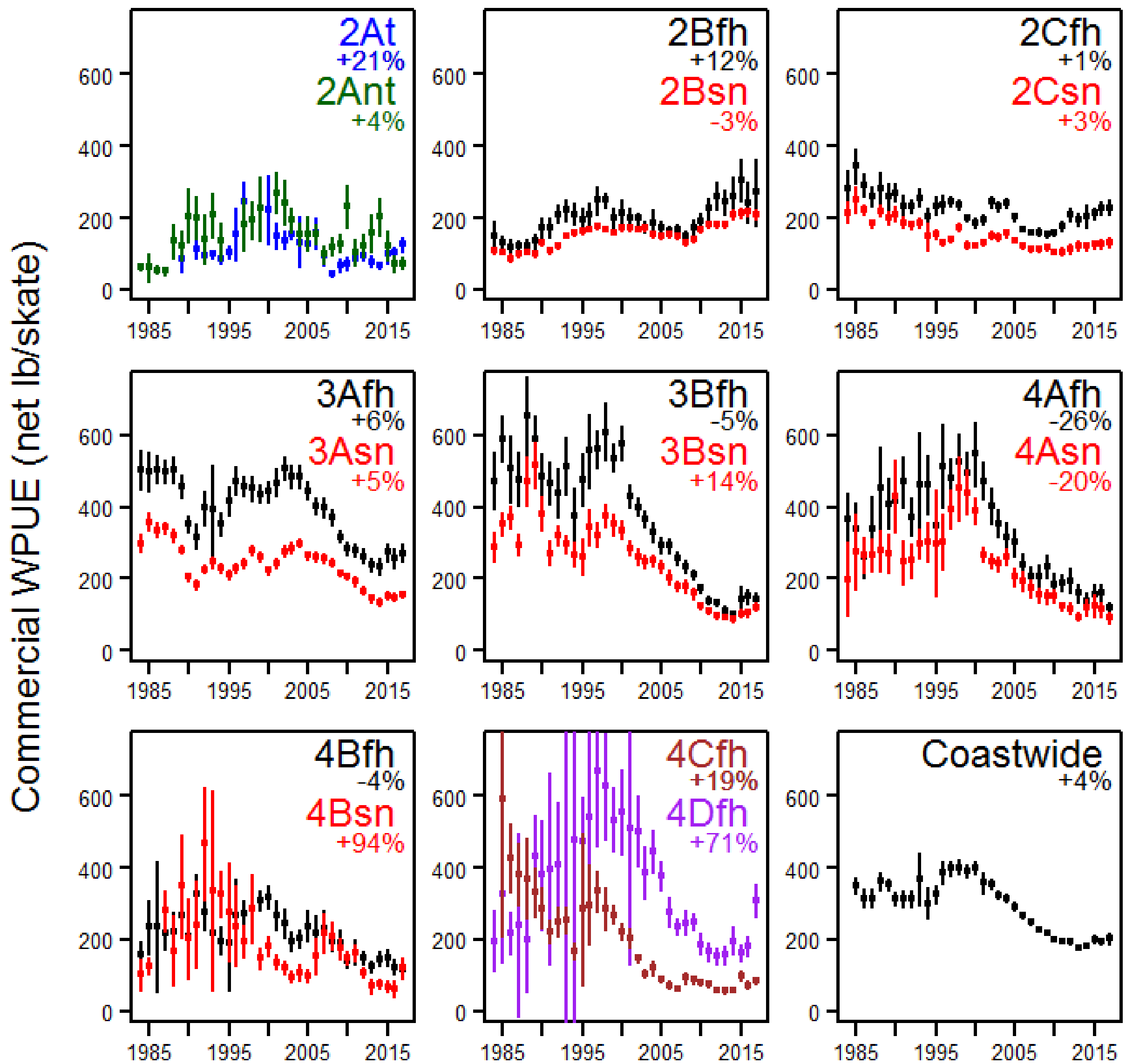

Figure A1. Commercial WPUE: Area 2A delineated by fishery (t = tribal, nt = non-tribal), Areas 2B-4B delineated by gear type (fh = fixed-hook, sn = snap gear) and Area 4CDE delineated by Area (4C, 4D; too few snap gear data to summarize). Percentages indicate the change from 2016-2017; vertical bars an approximate 95% confidence interval based only on between-set variability.

APPENDIX B

Example of qualitative data mapping where “status” is determined relative to the time-series mean, and recent trend is relative to the most recent five years. It may be desirable to provide a small set of panels, or perhaps colored series (by data type) on a single panel reporting trends across a variety of data sources for simultaneous evaluation. Provided below is a single example, where the FISS catch rate estimates from the S-T model (Figure B1) are ‘mapped’ ad labelled (Figure B2).

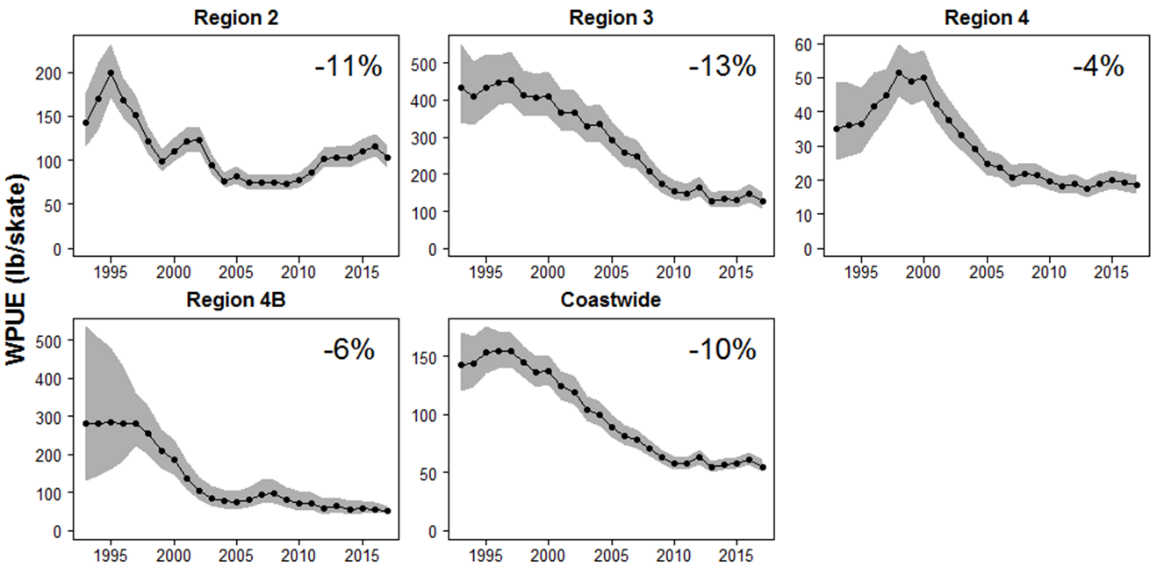

Figure B1. Survey WPUE by Region. Percentages indicate the change from 2016-2017; shaded area indicates an approximate 95% credible interval.

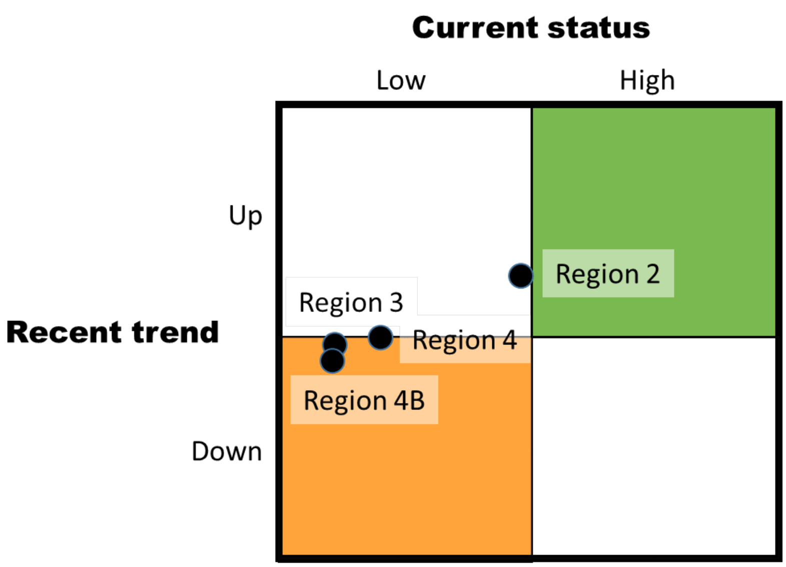

Figure B2. Survey WPUE by Region (From Figure B1) ‘mapped’ to provide an alternative vehicle for presentation.

Modelling updates

PREPARED BY: IPHC SECRETARIAT (I. STEWART AND A. HICKS; 20 MAY 2018)

PURPOSE

To provide the Scientific Review Board (SRB) a summary of anticipated modelling development in support of the 2018 and 2019 stock assessment and harvest policy analyses.

INTRODUCTION

Brief history of SRB stock assessment review

The ensemble approach to modelling Pacific halibut stock dynamics (Stewart and Martell 2015) was initiated during the 2012 stock assessment in direct response to two factors: 1) a recurring retrospective bias in previous models (Stewart and Martell 2014b), and 2) an external performance review of the IPHC process recommending a more clear and transparent delineation of scientific and management aspects of the harvest policy, necessitating both a better characterization of scientific uncertainty and a decision table approach to providing annual catch 'advice.'

At that time, the IPHC did not have an established process for independent peer review, having held only one recent review specific to the stock assessment model in June 2007 (IPHC 2008). Therefore, an *ad hoc* review was conducted during October 2012 (Stewart et al. 2012). At that time, the assessment consisted of three alternative models characterized by three levels of female natural mortality (Stewart et al. 2013). The IPHC's independent Scientific Review Board (https://iphc.int/library/documents/meeting-documents/scientific-review-board-srb) was formally initiated during 2013, with a stock assessment review occurring in October 2013. The stock assessment was extended at that time to include three separate models differing in structure, data use, and programming platform (Stewart and Martell 2014a). In order to reflect the compressed timeline of data availability and the stock assessment process, a second SRB meeting (via conference call) was added to the annual process between the IPHC's Interim and Annual meetings, in December 2013. During 2014, the stock assessment ensemble underwent a full revision of data processing procedures, and another expansion to include the four models used in subsequent years. These models were evaluated by the SRB in June and October of 2014. That year marked the first cycle of what has since become the standard meeting schedule: review and research planning in June, review and final model refinements in October (shifting to late September starting in 2016), and follow-up opportunity for evaluation in December after all data sources have been finalized and initial results presented to the public.

For 2015, full technical documentation of all four models, their data components, the ensemble approach, harvest policy calculations, and projection methods was provided for SRB review during the June meeting (Stewart and Martell 2016). These four models have been subsequently updated, without major structural changes, through the SRB review processes in 2016 and 2017. All incremental changes to data sources have been reported and reviewed, with 'bridging' analyses illustrating assessment model response to each change documented each year.

The 2018 and 2019 stock assessments

This document summarizes ongoing avenues of modelling development, specific changes anticipated for inclusion into updated 2018 models and presentation material, as well as changes planned for evaluation in 2019. A full assessment evaluation, documentation and review (similar to that conducted in 2015) is planned for the 2019 SRB process, in order to capitalize on important new data anticipated to be available (described below). The 2019 process also provides the best opportunity for assessment model revision to integrate with Management Strategy Evaluation efforts shifting from consideration of coastwide to more spatially explicit management procedures, thus necessitating a change to operating models less closely linked to the tactical assessment ensemble.

ONGOING DEVELOPMENT

Model weighting methods

Equal weighting of the four models contributing to the stock assessment ensemble has been maintained since 2015. Each year, evaluation of alternative approaches has not generated any appreciable indication that different weighting is warranted based on the fit of each model to the survey index, the predictive performance of the fit to the survey, or the retrospective behavior. If or when additional models are added to the ensemble or model performance-based weighting approaches suggest differing model weights this topic may need to be revisited. A manuscript reporting alterative weighting methods remains in preparation.

Bayesian integration

Work by Cole Monnahan (PhD Thesis, University of Washington, June 2017) included development of an alternative Markov Chain Monte-Carlo (MCMC) search algorithm implemented in Automatic Differentiation Model Builder (ADMB; Monnahan et al. 2016). ADMB is the underlying code for the stock synthesis model, on which the current Pacific halibut stock assessment models are based, as well as many other stock assessment models around the world. Further work on regularization – adding informative priors and/or tactically reducing complexity to improve estimation performance – continues, using the short coastwide Pacific halibut model as one of a set of illustrative examples. An additional manuscript is in preparation (Cole Monnahan, pers. comm.). This work, in concert with some of the options available in the new stock synthesis version (see section below) may provide avenues for improved efficiency in implementing Pacific halibut models in a fully Bayesian framework.

A previously undocumented inconsistency in the ADMB software when MCMC integration is performed (but not affecting maximum likelihood estimates) was recently discovered, and pending its resolution it may not be advisable to use the posterior distributions from any model (including stock synthesis) that includes "dev_vectors" (https://github.com/admb-project/admb/issues/107). The two long-time-series Pacific halibut models use this feature. Further investigation into Bayesian integration of the Pacific halibut models remains an open avenue for development, as true probability distributions (rather than asymptotic approximations) are desirable for calculating probabilistic management results, and diagnosis of posterior convergence can be a highly informative tool for improving maximum likelihood estimation as well.

Ensemble stability

A potential and previously unexplored benefit of using a stock assessment ensemble is inter-annual stability in stock assessment results. Stability may be created via two avenues: the inclusion of new alternative models into each year's analysis while still including existing models (rather than through changes to a single base-case model), and from the buffering effect of characterizing the central tendency (or distribution) of management quantities with a set of models. This last benefit – temporal stability against the addition of new data – although logically appealing, has not been evaluated in the context of fisheries stock assessment. The IPHC Secretariat has developed a draft manuscript that evaluates the results from the International Pacific Halibut Commission's stock assessment ensemble as an example of the stability created by multiple models, and provides a simple simulation and analytical framework to explore general ensemble behavior. Counter-intuitively, we found little stability benefit in the IPHC's current ensemble due to high temporal correlations among individual models as annual data are added. However, we also found that even a small number of models with low among-model correlations could have a substantial stability benefit. We suggest that among-model temporal correlations may be a valuable ensemble diagnostic that warrants consideration by analysts developing ensembles, and also those performing sensitivity testing of single-model assessments.

DEVELOPMENT FOR 2018

Software updates

Recent Pacific halibut stock assessment models have used stock synthesis (Methot Jr and Wetzel 2013) version 3.24u. For the features that are currently included in these models there are no identified bugs that have required updating the IPHC's application to a newer version. However, a substantially revised version of Stock Synthesis (3.30.11 as of 14 May 2018) has now gone through approximately 1.5 years of code development. Several U.S. west coast and Alaska stock assessments have been conducted using the new software. To date, the IPHC has delayed full implementation of the software largely in order to avoid the efficiency costs of development and testing of new and revised features.

During 2018, the IPHC Secretariat performed extensive comparative analyses to the conversion of all major features currently implemented in the four Pacific halibut stock assessment models contributing to the ensemble. Although there are changes to the input and output structure, and many additional options for structural approaches (Methot et al. 2018), all have a backward-compatible analog to earlier versions. Sequential testing of features including the implementation of weight-at-age, the stock-recruitment equations including equilibrium offsets and environmental covariates, time-varying catchability, error distributions, and others revealed no issues. However, several key features used in the Pacific halibut models are currently not fully functional in SS3.30.11 (as of May 2018); these include the option for female selectivity offset to male selectivity (used in defining the selectivity of the commercial fishery discards), and the age-based double normal selectivity (used for all fleets in the halibut model). These issues have been reported, and are under development; it is likely that they will be fully functional in time for use during the IPHC's 2018 assessment cycle.

If implementation of all features is completed soon, the 2018 Pacific halibut stock assessment is likely to be able to update to the new software with diminutive change to the results of management quantities. This is essential to provide compatibility with MSE development during the same time period. The IPHC Secretariat will continue to work with the developers of the stock synthesis software, perhaps utilizing the IPHC's pending programming position if necessary, to ensure that a clear transition can be made. If this is not possible during 2018, it will be logical to include any remaining transition in the full analysis planned for 2019, when additional model structural evaluation and changes are already anticipated (see below).

'Replay' analyses

During recent years' annual processes a number of questions have arisen regarding the utility of creating 'replays' of the estimated historical time series of biomass under different management actions. Specifically, one recurrent interest is how the biomass trajectory would be estimated to have evolved under catch limits following exactly the IPHC's harvest strategy policy in each year. A conceptual framework for this type of analysis is represented by the following steps:

1) Begin with the maximum likelihood estimates (MLEs) from each of the models for all parameters.
2) Fix the model parameters at MLEs and substitute an alternative set of removals representing a different management decision for the first year of the 'replay.'
3) Recalculate the harvest strategy policy calculations for the second (and subsequent) years of the replay, and substitute them into the removals in a sequential fashion until the current year is reached.
4) Re-integrate the ensemble time-series under the 'replay' conditions.
5) Compare the 'replay' to the actual estimated ensemble time-series of biomass and the actual removals from each year.

In order to implement this approach, at least several implicit assumptions and caveats would be required: variance calculations would be unavailable (although they could be substituted from the actual estimated time series), spatially generated feedback mechanisms (e.g., changes in productivity due to the region in which catch was taken) are unknown, and would have to be assumed to be unimportant, and the stock-recruit relationship would be ignored.

Details yet to be worked out include the appropriate description of this analysis in terms of the trade-offs between foregone yield and stock status. Discussion of this topic during SRB12 is planned.

Phase plots and status indicators

The IPHC Secretariat introduced a number of new approaches for summarizing stock assessment results with regard to current status and recent trend during the 2017 process. These include a summary table, intended to more closely resemble those produced by other international organizations and those produced domestically in the U.S. and Canada (Table A1, Appendix A). Because the IPHC's harvest policy is currently evolving, and has never included some reference points common in other processes (e.g., an explicit overfishing limit), the choice of metrics is challenging. As the MSE process continues, it will be logical to include reference points and performance metrics developed in that context. In the interim, discussion of metrics and approaches for describing status and trend is ongoing; guidance from the SRB on this topic could be very helpful for the 2018 assessment cycle.

The SRB last discussed the use of a phase plot for Pacific halibut in October 2015. Although complex due to the quantity of information contained in current status, recent trend, and uncertainty associated with each, many processes routinely use a phase plot (sometimes recently called a 'Kobe plot') as part of an executive summary of stock assessment and harvest policy results.

The IPHC's stock assessment ensemble and current harvest policy present several challenges to the generation of a 'standard' phase plot:

1) There is no overfishing limit, and so only one horizontal reference line.
2) The reference F_{SPR} is not formally considered a target or limit, so the implications of a level of fishing intensity that exceeds $F_{46\%}$ are unclear (and thus do not lend to unambiguous color-coding).
3) The calculation of reference points (i.e., relative fishing intensity, relative spawning biomass) is not integrated within all four of the stock assessment models. This means that although the variance of each quantity can be approximated (and therefore the variance of the ensemble value), the covariance between the two axes is unknown.
4) The level of uncertainty relative to the range of recent historical values (estimated by all four stock assessment models included in the ensemble) is very large.

An example phase plot, illustrating the adopted catch limits and estimated stock status for 2018 was produced following the methods employed by various other fisheries management bodies (Figure A2, Appendix A). In order to approximate the covariance between axes the average value from the long time series models was applied to the results from each of the four models. This leads to the potential for small differences between the marginal probabilities of exceeding a reference level (e.g., $P(SB<SB_{30\%})$), and the joint probabilities reported in the phase plot. If this approach is deemed to warrant further consideration, additional code development, particularly internal calculation of reference points, variances, and covariances could improve these approximations. Further discussion of this topic during SRB12 is planned.

Web-based projection tools

Under development for the 2018 process is an interactive tool for rapid evaluation of alternative projected catch and catch distribution. In the past, alternative projections were provided to advisory bodies and stakeholders as needed; however, this process was time-consuming and somewhat limiting in the range of options that could be provided. An interactive tool, with Catch Sharing Plans delineating all allocations among fishery components within all Regulatory Areas, a fitted (non-linear) relationship between SPR and total mortality based on a wide grid of previously produced results, as well as projection figures from those results, is anticipated to be posted to the IPHC's website prior to the 2019 Annual Meeting (AM095).

DEVELOPMENT PROPOSED FOR 2019

Model structure

A full stock assessment analysis presented for the June SRB Meeting in 2019 will allow review of several important structural aspects of the Pacific halibut models identified in previous efforts (Stewart and Martell 2016). Of particular interest are features that will have newly available data (see IPHC-2018-SRB12-06) and/or new options for parameterization in the more recent version of stock synthesis, including:

- Data weighting, including alternative error distributions (e.g., the Dirichlet for compositional data).

- The treatment of constraints on time-varying processes such as selectivity, with the potential for explicitly estimating and including the uncertainty in the degree of temporal variability (sigmas).
- Age-based discarding and discard mortality estimation within the assessment models to better propagate uncertainty associated with these estimates.
- Incorporation of new sex-ratio information from the commercial fishery and perhaps greater estimation of related selectivity parameters (including some new parameterizations) with commensurately improved characterization of uncertainty.
- More control over the modelled timing of the catch and surveys, allowing investigation of the importance of interannual variability.

A discussion of these topics in order to expand this list for evaluation in the 2019 assessment is anticipated for SRB12.

Renewed spatial model development

The modelling with an explicitly spatial framework that was conducted by the IPHC Secretariat through 2016 will be updated and extended to provide a starting point for use as an MSE operating model. At this time, it is not anticipated that a parallel model will be developed for tactical use in the annual management process.

SUMMARY

Model development during 2018 is largely focused on refinement of existing approaches, and preparing for a full assessment and review during 2019 (Table 1). This parallels the approach taken for data sources (see IPHC-2018-SRB12-07).

As has been the practice for all recent stock assessments, any available modelling updates in preparation for the 2018-2019 annual process will be presented to the SRB at the October 2018 meeting (SRB13).

TABLE 1. Summary of model development

Improvement	Rationale	Timeline
Model weighting methods	Weighting approaches are important in determining ensemble results.	Evaluation of alternative methods will be continued; publication of these approaches is planned.
Bayesian integration	Better represents probability distributions for management use.	Ongoing.
Ensemble stability	This is a novel aspect of ensemble application.	Ongoing.
Software updates	Current stock synthesis version still being tested.	Possible inclusion in 2018, pending resolution of a small number of incomplete features.
'Replay' analyses	Represents a frequently asked avenue of questioning regarding the performance of recent management.	Further refinement and possible presentation in 2018.
Phase plots and status indicators	Ongoing effort to simplify and make more accessible key assessment results.	Further improvement and use in 2018.
Web-based tools	Capitalizing on the shift toward electronic support material for the IPHC process.	To be added in 2018.
Model structural investigation	New features available in the stock synthesis platform and new data anticipated for 2019 may allow improved structural assumptions.	Anticipated exploration and review in 2019.
Spatial model development	This level of model complexity will be required in order to evaluate some MSE objectives.	Continued development is planned for 2019 in support of the MSE process.

RECOMMENDATION/S

The IPHC secretariat requests that the SRB:

NOTE this document summarizing ongoing, pending and future model development efforts by the IPHC Secretariat.

NOTE any discussion occurring during SRB12, and **RECOMMEND** any conceptual or technical improvements for conducting and reporting 'replay' analyses.

NOTE any discussion occurring during SRB12, and **RECOMMEND** any suggestions for simple summary tools applicable to stock assessment estimates of status and trend.

RECOMMEND any specific avenues for model development in preparation for the inclusion of new data and for the full stock assessment documentation and review anticipated for 2019.

RECOMMEND any additional specific research avenues to be prioritized for inclusion in the 2019 stock assessment.

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Appendices

<u>Appendix A</u>: Stock status and trend summary information, example phase plot of fishing intensity and spawning biomass.

APPENDIX A

Stock status and trend summary information.

TABLE A1. Status summary of Pacific halibut in the IPHC Convention Area at the end of 2017.

Indicators	Values	Trends	Status
Total mortality 2017: Retained mortality 2017: Average mortality 2013-17:	42.44 Mlbs, 19,250 t[1] 35.29 Mlbs, 11,864 t 43.34 Mlbs, 19,659 t	Mortality stable 2014-17	**2017 MORTALITY BELOW 100-YEAR AVERAGE**
SPR_{2017}: P(SPR<46%): P(SPR<limit):	40% (29-58%)[2] 75% Limit not specified	Fishing intensity increased from 2016 to 2017	**FISHING INTENSITY HIGHER THAN REFERENCE LEVEL[3]**
SB_{2018} (Mlb): SB_{2018}/SB_0: $P(SB_{2018}<SB_{30})$: $P(SB_{2018}<SB_{20})$:	202 Mlbs (148–256) 40% (26-60%) 6% <1%	SB decreased from 2017 to 2018	**NOT OVERFISHED[4]**
O32 stock distribution: All stock distribution:	See Table A2 and Figure A1.	Distribution stable 2013-17	**REGION 2 ABOVE, REGION 3 BELOW HISTORICAL VALUES**

[1] Weights in this document are reported as 'net' weights, head and guts removed; this is approximately 75% of the round (wet) weight).
[2] Ranges denote approximate 95% confidence intervals from the stock assessment ensemble.
[3] Status determined relative to the IPHC's interim reference Spawning Potential Ratio level of 46%.
[4] Status determined relative to the IPHC's interim management procedure biomass limit of $SB_{20\%}$.

TABLE A2. Recent regional stock distribution estimates based on modelling of the fishery-independent setline survey data.

	O32 stock distribution				All sizes stock distribution			
Year	Region 2 (2A, 2B, 2C)	Region 3 (3A, 3B)	Region 4 (4A, 4CDE)	Region 4B	Region 2 (2A, 2B, 2C)	Region 3 (3A, 3B)	Region 4 (4A, 4CDE)	Region 4B
2013	29.6%	45.9%	18.7%	5.8%	25.4%	50.1%	19.6%	4.9%
2014	28.8%	46.5%	19.8%	4.9%	24.2%	52.8%	19.1%	4.0%
2015	30.4%	44.2%	20.5%	4.9%	25.7%	51.4%	18.9%	4.0%
2016	30.0%	46.8%	18.6%	4.5%	25.9%	52.8%	17.4%	3.9%
2017	29.7%	45.6%	20.0%	4.8%	25.9%	50.7%	19.2%	4.2%

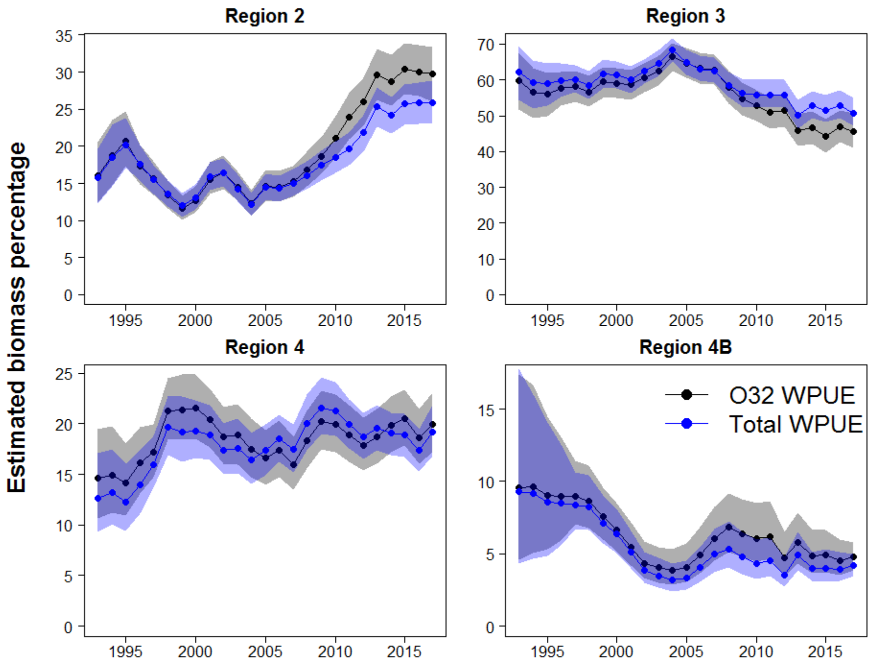

FIGURE A1. Estimated stock distribution (1993-2017) based on setline survey catch of O32 (black series) and all sizes (blue series) of Pacific halibut. Shaded zones indicate approximate 95% credibility intervals.

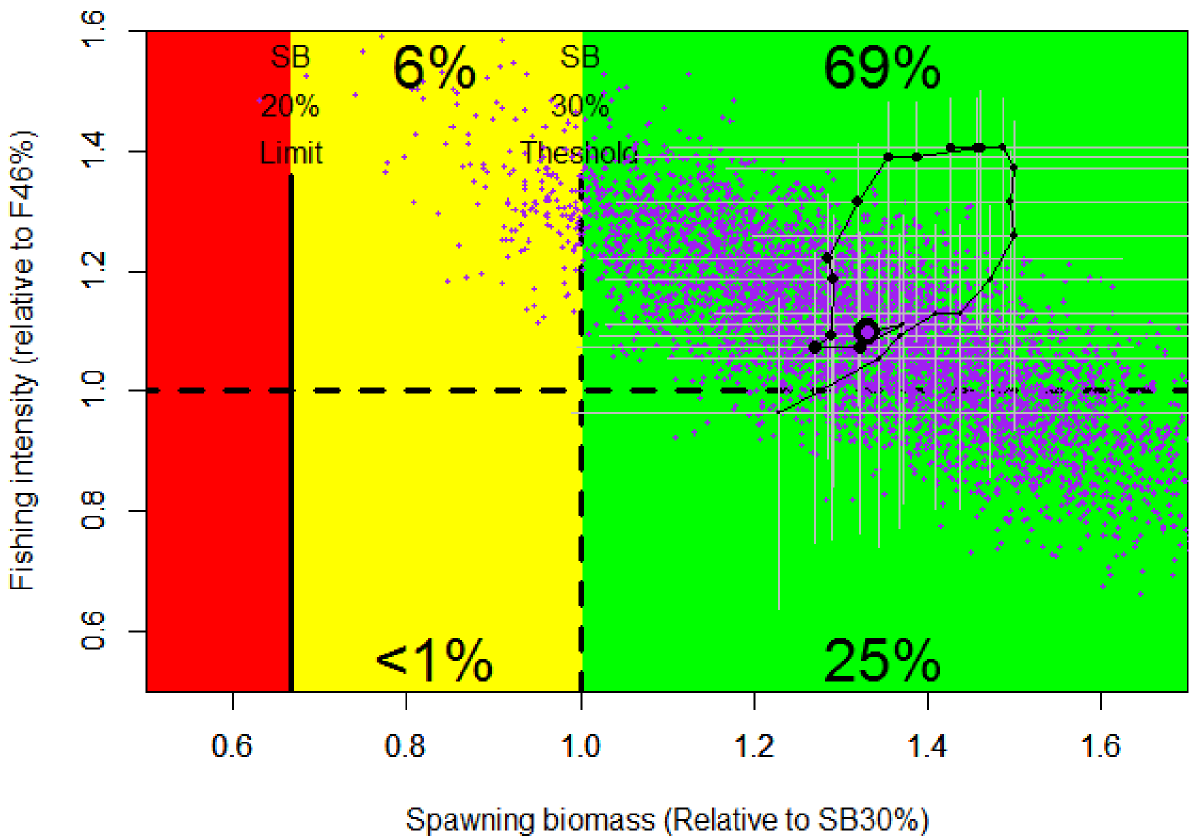

Figure A2. Example phase plot based on data from the 2017 stock assessment: Time-series of relative spawning biomass (spawning biomass divided by SB30%) and relative fishing intensity (1-SPR/1-46%). Horizontal dashed line indicates the reference SPR = 46%; vertical solid line indicates the SB20% biomass limit and vertical dashed line indicates the SB30% biomass threshold. Black points indicate the relative status in each year from 1996 through 2018 (largest point with purple center). Light lines indicate uncertainty in annual status through 2017; purple points indicate the probability distribution for the biomass and adopted catch limit in 2018. Percentages indicate the relative probability of the 2018 status falling into each quadrant.

IPHC Management Strategy Evaluation: Update for 2018

PREPARED BY: IPHC SECRETARIAT (A. HICKS AND I. STEWART; 20 MAY 2018)

1 PURPOSE

To provide an update on the progress of the IPHC Management Strategy Evaluation process and seek guidance from the SRB regarding the following topics.

- Appropriate biological sustainability objectives, as well as biological reference points
- Conditioning the OM
- Introducing estimation error
- Simulation of weight-at-age
- Presentation of short-, medium-, and long-term results
- The TCEY distribution framework

Also, the MSAB requested that the SRB clarify paragraphs 24 and 28 of the report from SRB011 (IPHC-2018-SRB011-R).

2 INTRODUCTION

At the 2017 Annual Meeting (AM093) Commissioners supported a revised harvest policy that separates the scale and distribution of fishing mortality (Figure 1). Furthermore, the Commission identified an interim "hand-rail" or reference for harvest advice based on a status-quo SPR, which uses the average estimated coastwide SPR for the years 2014–2016 from the stock assessment. The justification for using an average SPR from recent years is that this corresponds to fishing intensities that have resulted in a stable or slightly increasing stock, indicating that, in the short-term, this may provide an appropriate fishing intensity that will result in a stable or increasing spawning biomass.

The 2017 stock assessment updated the population estimates and determined that the SPR resulting from actual total mortality from all sources in 2017 was 40%, instead of the 45% adopted by Commissioners at AM093. This was an example of estimation error and something that is inherent in the process due to uncertainty in the data. The SPR of 40% was well within the confidence bounds for SPR reported in the 2017 stock assessment (30-59%), and was most likely less than the adopted SPR because of the updated estimation of recent poor recruitment. The estimation may easily go either way (above or below the adopted value).

This document for the Scientific Review Board (SRB) focuses on the six topics listed above, and provides the necessary background, or reference to documents, needed to discuss those six topics. Useful documents to reference are IPHC-2018-MSAB011-07 for a description of objectives (with an update in Appendix Va in IPHC-2018-MSAB011-R, and reproduced here in Appendix II), IPHC-2018-MSAB011-08 for a description of the simulation framework, and IPHC-2018-MSAB011-09 for a discussion of the TCEY distribution framework. The 5-year program of work is described in document IPHC-2018-MSAB011-10, with a detailed description of deliverables up to and including the Annual Meeting in 2021 (AM097).

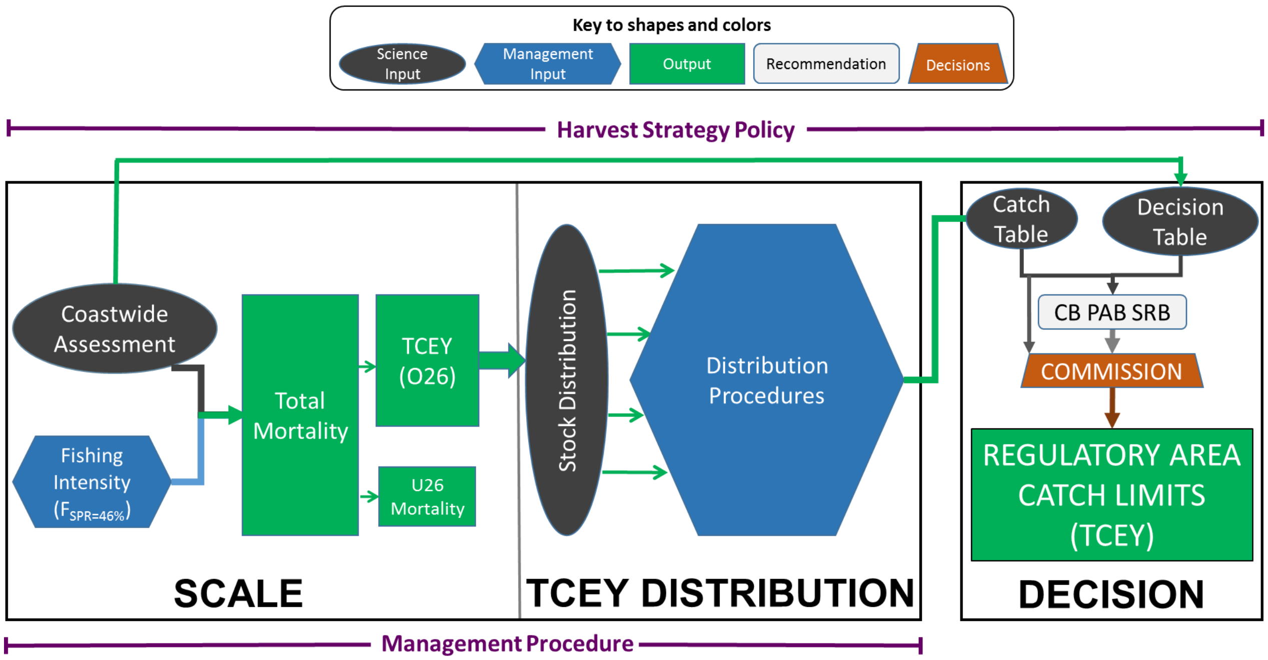

Figure 1: A pictorial description of the interim IPHC harvest strategy policy showing the separation of scale and distribution of fishing mortality. The "decision step" is when policy and decision making (not a procedure) influences the final mortality limits.

The six topics above were also highlighted at the 11th Management Strategy Advisory Board meeting (MSAB011). Specific paragraphs from the MSAB011 report (IPHC-2018-MSAB011-R) mentioning the SRB are included in Appendix I.

3 Goals and Objectives

Defining goals and objectives is a necessary part of a management strategy evaluation (MSE) which should be revisited often to make sure that they are inclusive and relevant. The MSAB has developed five goals with multiple objectives for each (Appendix II). Performance metrics have also been developed from the goals and objectives by defining a measurable outcome, a tolerance (i.e., level of risk), and time-frame over which it is desired to achieve that outcome.

The five goals defined by the MSAB are:

- biological sustainability,
- fishery sustainability, access, and stability,
- minimize discard mortality,
- minimize bycatch and bycatch mortality, and
- serve consumer needs.

This section will focus on the biological sustainability goal and its related objectives.

3.1 BIOLOGICAL SUSTAINABILITY

There are currently two general objectives defined for the biological sustainability goal (Appendix I). These are 1) keep the biomass above a critical limit, and 2) mitigate for uncertainty. The MSAB is currently redefining these with more meaningful descriptions, but the intent is as follows.

3.1.1 Keep spawning biomass above a critical limit

For the general objective of keeping the spawning biomass above a critical limit, the intent is to avoid low coastwide spawning biomass levels, below which severe consequences to the population may occur. IPHC uses the term "biomass limit" to describe this level, and has been using a value of 20% of unfished equilibrium spawning biomass. The probability of the spawning biomass going below the biomass limit should be low, and the MSAB has adopted a tolerance of 5% for that probability.

3.1.2 Mitigate for uncertainty

The intent of the general objective "mitigate for uncertainty" is to buffer against uncertainty in the assessment process and avoid reducing the spawning biomass to near critical levels. Due to uncertainty, it may not be realized that the stock is near critical levels, thus a threshold is defined (greater than the limit) that is not necessarily a target, but is a spawning biomass level that is more acceptable.

There are two measurable objectives associated with this general objective. The first is to maintain the spawning biomass mostly above a biomass threshold. This is similar to the measurable objective of keeping the spawning biomass above a biomass limit, except that the tolerance is higher and the threshold is greater than the limit. The MSAB has requested that the SRB comment on appropriate biomass limit and biomass threshold values. The second measurable objective is to limit the probability of declines in spawning biomass when the spawning biomass is between the biomass limit and the biomass threshold. In other words, when the spawning biomass is below the biomass threshold, the stock should increase towards the biomass threshold. This makes the biomass threshold similar to a target. However, the tolerance for declines is a sliding scale that is higher when the spawning biomass is closer to the biomass threshold.

The IPHC has the opportunity to define a biomass limit and biomass threshold to meet the management objectives for the Pacific halibut fishery. The biomass limit has specific biological meaning because it is a critical level, which may be interpreted as a level below which recruitment would be severely impaired, a level from which the population has a low chance of recovery, or another definition related to the population's ability to recover. The biomass threshold can be interpreted in many ways. It may be a target, as mentioned earlier. Or it may be a value associated with a tolerance of being below it (for example, a value expected to be above 80% of the time). Appropriate thresholds can be informed by science but are also dependent on the biological sustainability objectives.

3.1.3 Preserving Biocomplexity

An additional objective, preserve biocomplexity, was considered at MSAB009, but no measurable objectives were associated with it. Preserve biocomplexity would fit best as an objective under the goal of biological sustainability, but before defining measurable objectives for preserving biocomplexity, it may help to understand what is meant by preserve biocomplexity.

The term biocomplexity does not have a simple definition, as it spans across many scientific disciplines. The National Science Foundation describes biocomplexity as referring "to phenomena that arise from the dynamic interactions that take place between biological systems, including the influence of humans and the physical environment."[1] The Oxford dictionary defines biocomplexity as "complexity as exhibited by living organisms in their structure, composition, function, and interactions; complexity of a kind considered distinctive of biological systems." It also mentions that the term biocomplexity became more common in the 1980s. It is important to note that biodiversity has a slightly different definition that typically refers to different species. The Oxford dictionary defines biodiversity as "the variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable."

In the context of Pacific halibut, preserving biocomplexity would be a useful objective to buffer against potential changes in environmental conditions. The current understanding of biocomplexity across the geographic range of the Pacific halibut stock indicates that IPHC Regulatory Areas do not represent relevant segments of the population (Seitz et al. 2017). Even with migration along the entire coast (Valero and Webster 2012; Webster et al 2013), there are hydrographic and bathymetric obstacles that appear to delineate spawning components in the Gulf of Alaska (GOA), Bering Sea (BS), and Aleutian Islands (AI) (Seitz et al. 2017). Genetic evidence further suggests weak population structure (Drinan et al. 2016).

Population structure and spawning components are likely to buffer a population against changes in the environment. Hilborn et al. (2003) concluded that biocomplexity in stock structure plays a critical role in stability and sustainability of a fish stock. Furthermore, preserving biocomplexity in a fish stock may buffer against population declines in a variable or changing environment. Schindler et al (2010) presented evidence that population diversity within sockeye salmon has reduced the variability in the population and reduced the frequency of fishery closures. This concept can be extended to multiple species in an ecosystem (biodiversity) providing ecosystem stability, just as a diversity of assets adds stability to a financial portfolio. Schindler et al (2010) referred to the diversity in a population or in an ecosystem as a "portfolio effect."

There is evidence of population structure in the population of Pacific halibut, but it is not completely understood. Recruitment to the Pacific halibut population is variable, and it is not clear what the major driving force to recruitment success is. It could be that subcomponents of the population have varying success rates in different environmental instances. Balancing the removals against the current stock distribution to preserve biocomplexity is likely to protect against localized depletion of spatial and demographic components of the stock that may produce differential recruitment success under changing environmental and ecological conditions. This approach could also provide an additional precautionary buffer against spatial recruitment overfishing and may maintain sub-population structure that is not completely understood, but important to the long-term health of the coastwide population.

The structure of two of the four current stock assessment models is developed around identifying portions of the data (both FISS and fishery) that correspond to differing biological and population processes within the larger Pacific halibut stock. This approach, referred to as "Areas-As-Fleets," is commonly used in stock assessments (Waterhouse et al. 2014), and was recommended by the SRB during review of models developed in 2014 (Cox et al. 2016, Stewart and Martell 2015, 2016). This led to defined areas that are referred to as biological Regions.

[1] https://www.nsf.gov/news/news_summ.jsp?cntn_id=100687&org=NSF&from=news

Biological Regions (hereafter referred to as Regions) were defined with boundaries that matched IPHC Regulatory Areas to correspond to biological differences. The boundaries of IPHC Regulatory Areas were used for many reasons. First, data (particularly historical data) for stock assessment and other analyses are most often reported at the IPHC Regulatory Area scale and are largely unavailable for sub-Regulatory Area evaluation. Particularly for historical sources, there is little information to partition data to a portion of a Regulatory Area. The use of these data is mainly a stock assessment issue. Second, it is necessary to distribute TCEY to IPHC Regulatory Area for quota management, and the final outcome of a distribution procedure will reflect this. If a Region is not defined by boundaries of IPHC Regulatory Areas (i.e. a single IPHC Regulatory Area is in multiple Regions) it will be difficult to create a distribution procedure that accounts for biological stock distribution and distribution of the TCEY to Regulatory Areas for management purposes. Overall, it is highly unlikely that there is a set of Regions that perfectly delineates the stock biologically since different aspects of the stock differ over varying scales, and movement occurs between Regions. However, if the goal is to preserve biocomplexity across the entire range of the Pacific halibut stock, Regions are considered by the IPHC Secretariat to be the best option for biologically-based areas to meet management needs.

Each Region had some qualities that identified it as differing biologically from adjacent Regions, despite clear evidence from tagging studies of movement among all areas at some point in the life cycle of Pacific halibut (Valero and Webster 2012; Webster et al 2013). These qualities include sex ratios, age composition, size-at-age, historical trends, and others that could be indicative of important diversity within the greater Pacific halibut population. The four Regions are labeled as follows and composed of the listed IPHC Regulatory Areas (Figure 1):

Region 2: 2A, 2B, and 2C
Region 3: 3A and 3B
Region 4: 4A and 4CDE
Region 4B: 4B

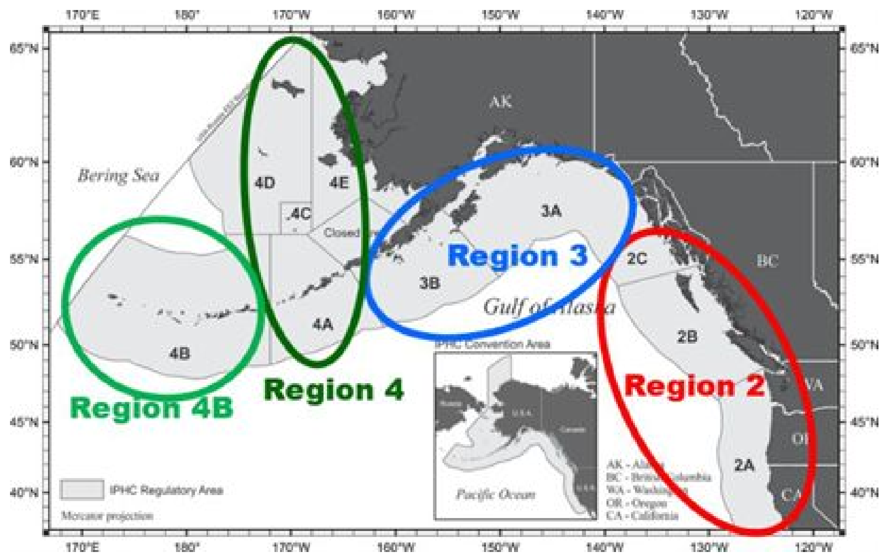

Figure 2. Four biological Regions. They are overlaid on IPHC Regulatory Areas with Region 2 comprised of 2A, 2B, and 2C, Region 3 comprised of 3A and 3B, Region 4 comprised of 4A and 4CDE, and Region 4B comprised solely of 4B.

4 Simulation Framework

The framework of the closed-loop simulations is a map to how the simulations will be performed (Figure 3). There are four main modules to the framework:

1. The **Operating Model (OM)** is a representation of the population and the fishery. It produces the numbers-at-age, accounting for mortality and any other important processes. It also incorporates uncertainty in the processes and may be composed of multiple models to account for structural uncertainty.
2. **Management Procedure**
    a. **Monitoring (data generation)** is the code that simulates the data from the operating model that is used by the estimation model. It can introduce variability, bias, and any other properties that are desired.
    b. The **Estimation Model (EM)** is analogous to the stock assessment and simulates estimation error in the process. Using the data generated, it produces an annual estimate of stock size and status and provides the advice for setting the catch levels for the next time step. However, simplifications may be necessary to keep simulation times within a reasonable time.
    c. **Harvest Rule** is the application of the estimation model output along with the scale and distribution management procedures (Figure 1) to produce the catch limit for that year.

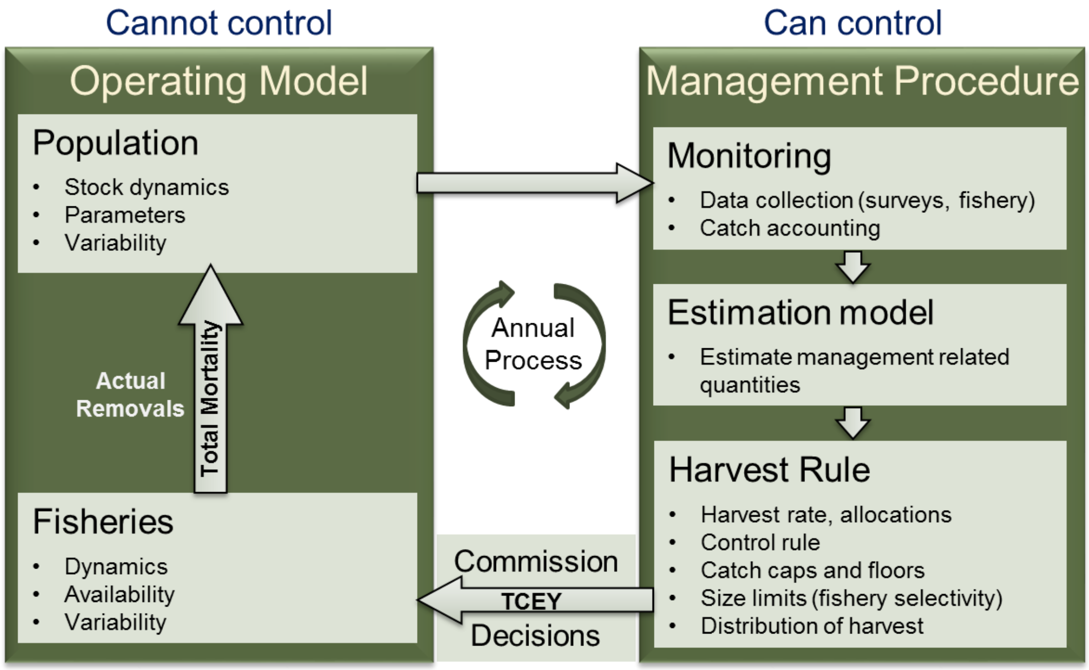

Figure 3: Diagram of the relationship between the four modules in the framework. The simulations run each module on an annual time-step, producing output that is used in the next time-step. See text for a description of operating model, monitoring, estimation model, and harvest rule.

4.1 OPERATING MODEL

For the simulations to investigate a coastwide fishing intensity, the stock synthesis (Methot and Wetzel 2013) assessment software was used as an operating model. This platform is currently used for the stock assessment, and the operating model was comprised of the two coastwide assessment models (short and long time-series) currently used in the ensemble. For future MSE evaluations (in particular, investigating the Distribution component of the harvest policy) a more complex operating model will be developed that can provide outputs by defined areas or regions and can account for migration between these areas. This model has been referred to as a multi-area model.

The current stock assessment ensemble, composed of four different assessment models, includes a cross between coastwide or fleets-as-areas structuring of the data, and the length of the time series. Using an areas-as-fleets model would require generating data and distributing catch to four areas of the coast, which would involve many assumptions. In addition, without a multi-area model, there would not be feedback from migration and productivity of harvesting in different areas. Therefore, only the two coastwide models were used, but with additional variability. These models are structured to use five general sources of removals (these are aggregated for modelling purposes and do not necessarily correspond to specific fisheries or sectors): the directed commercial halibut fishery (including research landings), commercial discard mortality (previously known as wastage), bycatch (from non-halibut-target fisheries), recreational, and subsistence. The TCEY was distributed to each source in an ad hoc manner using current available information (see below).

4.1.1 Conditioning the Operating Model

The operating model (OM) should be a reasonable depiction of reality with an appropriate level of uncertainty, which is accomplished through a process called conditioning. Each individual model (i.e., the two coastwide models) is conditioned by fitting to the same data used in the 2016 stock assessment (Stewart & Hicks 2017), which will be updated to use the 2017 stock assessment (Stewart & Hicks 2018). To evaluate and choose management procedures that are robust to uncertainty in future states of the population, many assumptions in the assessment model were freed up to characterize a wider range of possibilities in the future. Estimating natural mortality for both sexes in both models and estimating steepness were the only changes to estimated parameters from the assessment model when conditioning.

Parameter variability was characterized by randomly sampling parameters for each simulation from a truncated multivariate normal distribution conditioned to data. Unrealistic simulated historical trajectories were eliminated, and were defined by the criteria:

- the population could not support the observed catch
- the steepness parameter was less than 0.6 (based on investigations of what was causing the population trajectories to crash given observed catch)

The SRB requested that a quasi-extinction threshold be established to eliminate OMs that do not meet this criteria in the historical period. The above criteria is an extinction criteria and the IPHC Secretariat is currently working on defining a quasi-extinction level for the historical period to improve the process of conditioning the operating model.

The conditioned OM has a considerable amount of extra variability compared to the ensemble stock assessment (Figure 4). The assessment ensemble contains four individual models while the OM contains only two, which is why the trend at the end of the time series is slightly different, although well within the uncertainty.

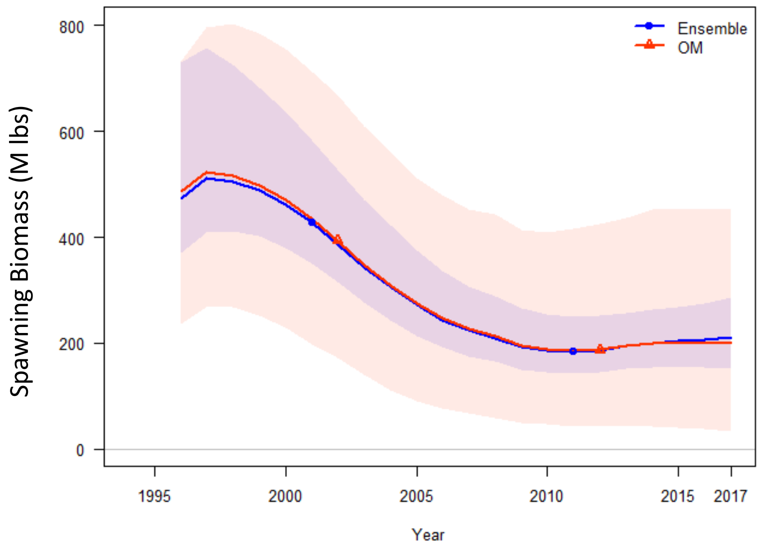

Figure 4: The conditioned operating model (red) compared to the stock assessment ensemble (blue) with 95% confidence intervals.

A potential issue highlighted at SRB11 was that starting the OM in 2017 with such a wide range of uncertainty will not adequately characterize our best knowledge of the near future (short-term) and the medium-term. However, the long-term results are appropriate since the current state would not affect long-term, equilibrium results, and the wide range of uncertainty is a result of the chosen uncertainties to evaluate harvest strategies against. One solution to provide short-term results would be to use predictions from the assessment model and its uncertainty (the blue shaded region in Figure 4) just as is done for annual decision making (i.e., decision table), except present short-term performance metrics (1-3 years from the end of the time-series; 8-11 years from the most recent information on recruitment) associated with MSAB objectives. This method can be used to evaluate the immediate consequences to the fishery that would result if a particular management procedure were implemented.

Medium-term results are more problematic because we have very little predictive power for that time period. In the short-term, we have an idea of where we currently are and what may occur in the next few years (e.g., we have some data indicating recent recruitment and weight-at-age). In the long term, we are summarizing statistics over a wide range of uncertainty and all possible states (we do not need to know anything about the current state of the population). Figure 5 shows the hypothetical utility of the assessment model and the operating model for a range of time frames, and shows that neither model has high utility in the medium term. However, that uncertainty is not well described in the medium term because it is partially dependent on the current state and may show artificial transitory effects from assumptions made to start the OM (cyclical behaviors), but is also affected by the wide range of variability in the OM.

It could be misleading to simply present medium-term results from the OM simulations as unbiased and informative predictions. However, describing the trends of various trajectories (e.g., catch or spawning biomass) between the short term or long term may be useful, and reporting selected medium-term performance metrics for combinations of weight-at-age and recruitment regime (e.g., four combinations of low/high weight-at-age and low/high recruitment) will provide insight into the possible range of outcomes in the medium-term.

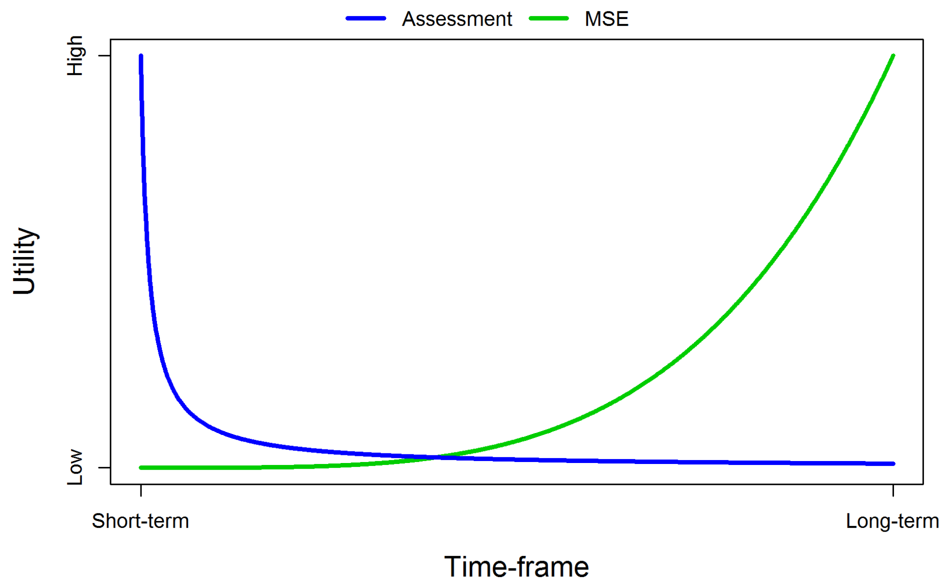

Figure 5: The hypothetical utility of the assessment model (blue with high utility in the short-term) and the operating model in the MSE (green with high utility in the long-term).

4.2 MANAGEMENT PROCEDURE

The elements of the management procedure are described in reverse order because it is easier to understand the decisions made for modelling them since they are dependent on each other. Therefore, the harvest rule is presented first, followed by the estimation model, and finishing with monitoring.

4.2.1 Harvest Rule

The generalized management procedure to evaluate is shown in Figure 1, but the focus will be on the Scale portion to produce results for the MSAB to evaluate before AM095 in 2019. Specifically, the portion of the management procedure being evaluated is a harvest control rule (Figure 6) that is responsive to stock status and consists of a procedural SPR determining fishing intensity, a fishery trigger based on stock status that determines when the fishing intensity begins to be linearly reduced (note that this may differ from the biological threshold), and a fishery limit that determines when there is theoretically no fishing intensity (this may differ from the biological limit). For these simulations, the two coastwide models were used, thus mortality only needed to be distributed to the five coastwide sources of mortality (directed commercial, discard mortality, bycatch mortality, recreational, and subsistence).

Simulations have been used to evaluate a range of SPR values from 25% to 60% and trigger values of 30% and 40% (IPHC-2017-MSAB10-09 Rev 1). Those simulations provided insight into how those different levels of SPR would meet the objectives defined by the MSAB, but few values of SPR below 40% were tested. Future simulations will use a finer resolution of SPR values ranging from 30% to 55% and fishery trigger points of 30% and 40%.

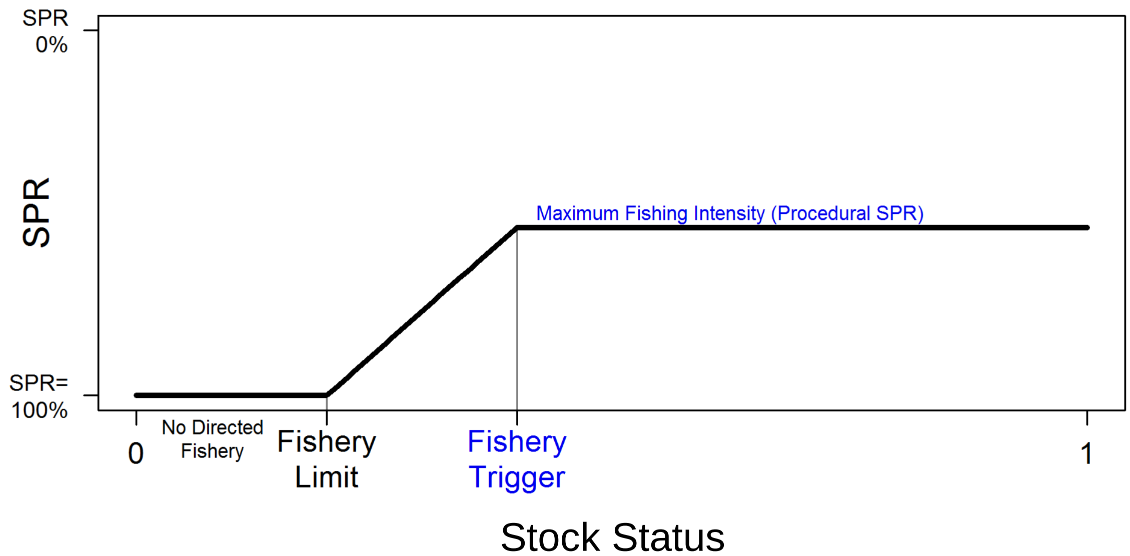

Figure 6: A harvest control rule responsive to stock status that is based on Spawning Potential Ratio (SPR) to determine fishing intensity, a fishery trigger level of stock status that determines when the fishing intensity begins to be linearly reduced, and a fishery limit based on stock status that determines when there is theoretically no fishing intensity (SPR=100%). In reality, it is likely that only the directed fishery would cease. The Procedural SPR and the Fishery Trigger (in blue) are the two values that were evaluated.

4.2.2 Estimation Model

Of the four options to simulate an estimation model presented in IPHC-2017-MSAB10-09 Rev1, the No Estimation Model (previously called Perfect Information) option was used in past simulations. The No Estimation Model method assumes that the population values needed to apply the management procedure are exactly known (e.g., spawning biomass). This option is useful as a reference to better understand the performance with and without uncertainty in an estimation model. Due to time constraints, the only other option to be considered for simulations in 2018 is the Simulate Error option, which will be suitable to understand the effects of estimation error. This method is described after the harvest rule section below.

The harvest control rule contains two components that have estimation error. The first component is the estimated total mortality determined from the specified SPR. The second component is the estimated stock status that is used to reduce the fishing intensity when stock status is low (fishery trigger and fishery limit). These components are dependent on the estimated biomass, but it is more straightforward and computationally efficient to introduce error into these two components, rather than introducing error on the estimated biomass and then determining the resulting estimates of total mortality and stock status.

The 2017 stock assessment (Hicks & Stewart 2018) was used to determine a reasonable amount of variability in these two components. First, they are each investigated separately, and then, because they are intrinsically linked, the bivariate variability is also investigated.

4.2.2.1 Error in Total Mortality

The error in total mortality was determined by fixing the SPR at 46% in the stock assessment and the allocation between sectors at recent levels to determine the estimated total mortality and variability. This is slightly different than how the assessment provides annual catch advice, which uses a fixed total mortality (since that is what decision makers can control) and estimates the variability in the SPR associated with that total mortality. Determining the variability in the total mortality with a fixed SPR is the difference between tactical decision making (short-term, assessment) and strategic decision making (long-term, focused on a harvest strategy).

The coefficient of variation (CV) for estimated total mortality in 2018 for an SPR equal to 46% was 14.1% and includes within- and between-model uncertainty. A boxplot of the estimates of total mortality, standardized to its mean, from the ensemble of four models is shown in Figure 7.

4.2.2.2 Error in stock status

Stock status (measured as dynamic relative spawning biomass, dRSB) is subject to estimation error. Using stock synthesis, dRSB is simply the current biomass divided by dynamic B0. Unfortunately, there is no easily available estimate of error for dRSB or dynamic B0 from stock synthesis, and an assumption had to be made.

The assumption was made that the relative error in dRSB is the same as the error in the current spawning biomass, and was determined by the following logic. Relative spawning biomass is calculated as the current spawning biomass divided by unfished spawning biomass (equilibrium or dynamic). In the equilibrium calculation, B0 is determined separately from current spawning biomass but there is likely covariance between the two. In the dynamic calculation, the covariance is likely greater because the dynamic B0 is calculated in a similar manner as the current spawning biomass, except that fixed catch is set to zero. The calculation is complicated, but if the two quantities vary similarly then the ratio of the two variables should have a similar CV as each variable on its own.

The CV for the estimated spawning biomass in 2018 is 13.7% including within- and among-model uncertainty.

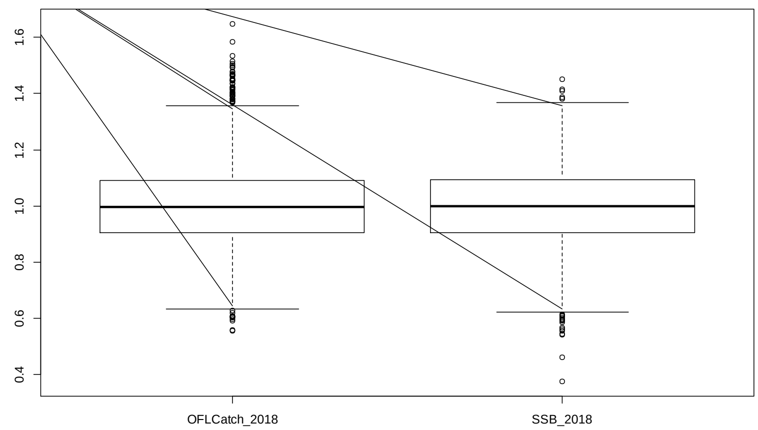

Figure 7: Boxplots of the catch level for 2018 determined for an SPR equal to 46% and 2018 female spawning biomass, each standardized to their respective means.

4.2.2.3 Bivariate Error in Total Mortality and dRSB

Using 2018 spawning biomass as a proxy for dRSB, the bivariate distribution of total mortality and spawning biomass predicted for 2018 is shown in Figure 8. The two quantities are positively correlated with a correlation of 0.51.

4.2.2.4 Autocorrelation for the error in Total Mortality and dRSB

Assessment errors are likely autocorrelated in time because the assessment uses the same historical data with few updates other than an additional year of data. Therefore, there are likely a periods of time where the error is persistently negative or positive. Autocorrelation is likely a very important process to consider in these simulations because it will capture trends in error that has important feedback to a management procedure.

We have not investigated autocorrelation or implemented autocorrelation in the MSE simulation framework. However, we plan to investigate autocorrelation in the assessment, although details have not been determined. We also plan to implement autocorrelation through a random walk or similar procedure that will introduce persistent time periods of negative or positive errors.

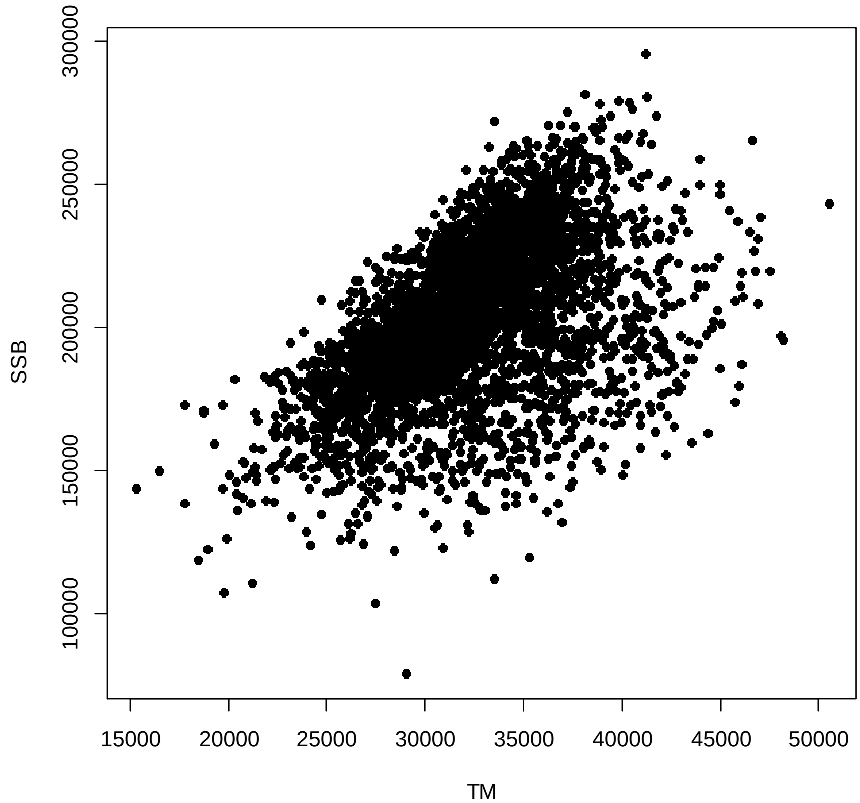

Figure 8: Scatterplot of estimates of total mortality (TM) for 2018 with SPR=46% and female spawning biomass (SSB) in 2018.

4.2.2.5 Introducing Estimation Error in the MSE simulations

The simulations can use each source of error independently, or the bivariate distribution of error to account for correlation between the two. The bivariate distribution is most representative of stock assessment error, but investigating the effect of each source of error would provide a better understanding of the effects of these two sources of error. Assessment error is much more complicated than described by this bivariate distribution and includes many more factors which make it nonparametric and dependent on the data being input. Time permitting, assessment error from an assessment model runs may be introduced into the simulations in the future or as comparison cases.

Using the correlation and CVs, the covariance matrix can be calculated and the simulations can simulate the error using a bivariate normal distribution (in log space) that scales with the level of “perfect information” current spawning biomass and “perfect information” total mortality.

Overall, there are many assumptions in this incorporation of estimation error, but we are only trying to determine a reasonable amount of error for the simulations. Other levels of error would likely be simulated to determine how sensitive the results are to the estimation error.

4.2.3 Monitoring (Data Generation)

The simplified incorporation of estimation error will be used due to time constraints, thus no data are required to be generated. However, if a stock assessment were simulated, there would be many sources of data to generate.

4.3 Summary of the Framework

A summary of the major specifications for each component is provided below, with the components listed in a specific order where the next component is dependent on the decisions for the previous components.

1) Operating Model
   a) Stock synthesis, based on coastwide assessment models (short and long models).
   b) Five fleets, as in the assessment models (commercial, discards, bycatch, sport, personal use).
   c) Uncertainty incorporated through parameter uncertainty and model uncertainty. See Scenarios.
2) Management Procedure
   a) Estimation Models
      i) Perfect Information (as a reference if we knew population values exactly when applying the harvest rule).
      ii) Simulate error in total mortality and spawning biomass from the simulated time-series to mimic a stock assessment.
   b) Data Generation
      i) Not needed at this time.
   c) Harvest Rule
      i) Coastwide fishing intensity (F_{SPR}) using a procedural SPR.
      ii) A fishing trigger to reduce the fishing intensity (increase SPR) when stock status is below a specified level.
      iii) A fishing limit to cease directed fishing when the stock status is less than a specified value (20%).
      iv) Catch assigned to sectors based on historical information (with variability).

5 Scenarios and Variability

Scenarios are alternative states of nature in the operating model, which are represented by parameter and model uncertainty, as described in Hicks (2017). These alternative states of nature integrate over the uncertainty in the system that we cannot, or choose not to, control. The scenarios for the MSE simulations include variability in the operating model processes as described in Table 1.

Table 1: Processes and associated variability in the operating model (OM). TM refers to total mortality.

Process	Uncertainty
Natural Mortality (M)	Estimate appropriate uncertainty when conditioning OM
Recruitment	Random, lognormal deviations
Size-at-age	Annual and cohort deviations in size-at-age with bounds
Steepness	Estimate appropriate uncertainty when conditioning OM
Regime Shifts	Autocorrelated indicator based on properties of the PDO for regime shift
TM to sectors	See section on allocating TM to sectors
Proportion of TCEY	Sector specific. Sum of mortality across sectors may not equal coastwide TM

5.1 ALLOCATING SIMULATED TOTAL MORTALITY TO SECTORS

The simulated management strategy returns a coastwide recommended TCEY, which is then allocated to each of the five sectors, with variability. The MSAB09 meeting in May 2017 noted that catch history, in conjunction with uncertainties and sensitivities, can be used to allocate TM to each sector. Recent sector-specific mortality or proportions of TM for each sector were used to guide the allocation using relationships between the sector-specific mortality or proportions to the TM. For example, at low TM the bycatch is likely a larger proportion. Figure 9 shows the percentage of TM attributed for each sector for the past 40 years.

A summary of the methods used to allocate total mortality to the five sources is provided in Table 2. Additional details can be found in IPHC-2017-MSAB10-09.

Due to specified minimum levels of subsistence and bycatch mortality, as well as random variability, it is possible that, at low levels of total mortality, there is no directed commercial mortality and that the actual total mortality exceeds the mortality determined from the management procedure. Expected values of the mortality and proportion by source plotted against Total Mortality is shown in Figure 10.

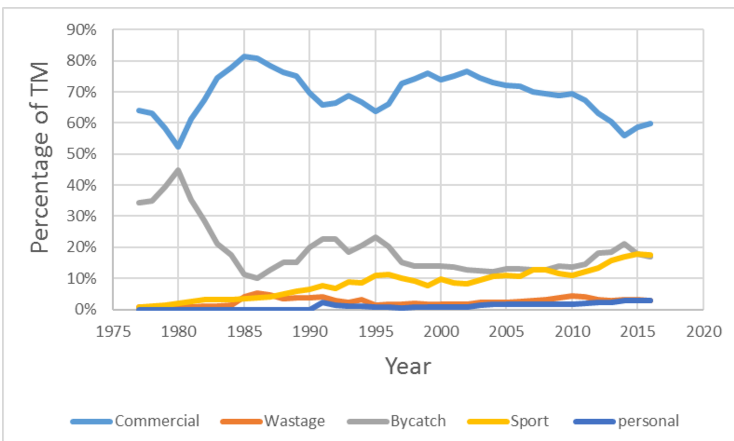

Figure 9: Percentage of Total Mortality (TM) for each sector used in the assessment model from 1976 to 2016.

Table 2: A summary of the methods to allocate total mortality to each of the five sources used in the operating model.

Source	Method of allocating Total Mortality
Subsistence	Randomly drawn from a lognormal distribution with a median of 1.2 million pounds (544 t) and a coefficient of variation (CV) of 15%. The 5th and 95th percentiles are approximately 0.9 million pounds (410 mt) and 1.5 million pounds (680 mt), respectively.
Bycatch	The non-directed component of the total mortality is randomly drawn from a lognormal distribution with a median of 7.0 million pounds (3,175 mt) and a CV of 20%. The 5th and 95th percentile are approximately 5.0 million pounds (2,300 mt) and 9.7 million

	pounds (4,400 mt), respectively. Potential improvements to the simulation of bycatch mortality will be discussed.
Recreational	The percentage of recreational mortality was linearly decreasing with total mortality when the total mortality was less than 57 million pounds (25,855 mt). The recreational mortality was randomly drawn from a lognormal distribution with a median of 7.7 million pounds (3,493 mt) and a CV of 20% when the total mortality was greater than 57 million pounds (25,855 mt).
Discard Mortality	The discard mortality was modelled as a function of the commercial plus discard mortality (total mortality minus subsistence, bycatch, and recreational mortality) and the size at age 8 for a male Pacific halibut (smaller fish likely results in more discard mortality).
Commercial	The commercial mortality is the remainder of the total mortality after subtracting the subsistence, bycatch, sport, and discard components. In reality, there is a slight difference between the Total Mortality (TM) and the TCEY because of shortfalls and overages, and adding variability here could simulate this process.

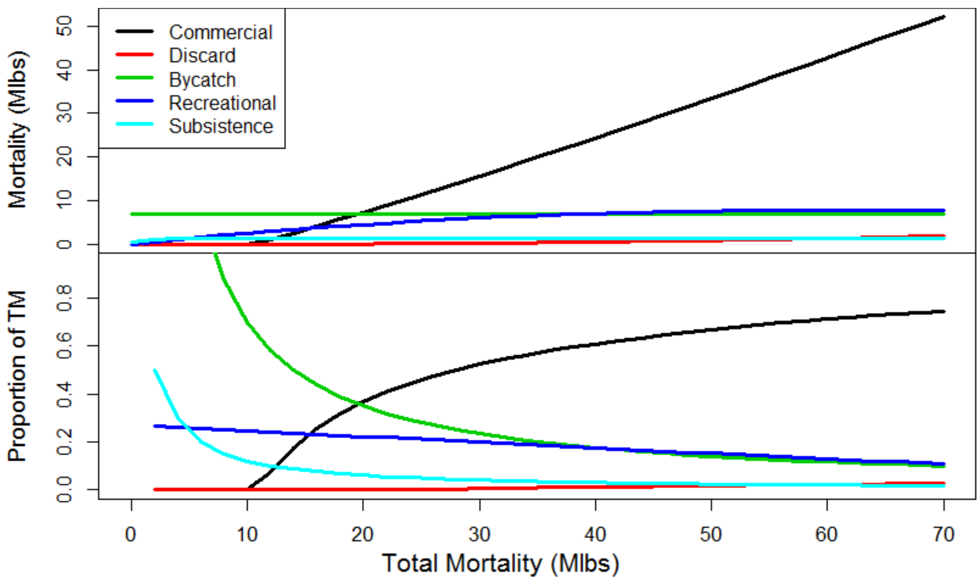

Figure 10: Average sector specific mortality (top, millions of pounds) and the sector-specific proportion of Total Mortality (TM) plotted against TM. For plotting purposes, age 8 males are 6 pounds and random variability is not included.

5.2 SIMULATING WEIGHT-AT-AGE

It is important to simulate time-varying weight-at-age because it is an influential contributor to the yield and status of Pacific halibut. There are 82 years of weight-at-age observations in the long time-series assessment models, with an observed wide range over the years (Figure 11 and Figure 12). Many years of these data have been estimated from sparse data, and the entire time-series has been smoothed to eliminate large deviations from year to year.

Important behaviors of the historical weight-at-age time-series to consider when simulating future weight-at-age are

1. the age-specific weights-at-ages tend to increase and decrease in the same year (little evidence of lags due to specific cohort effects; Figure 11 upper plot),
2. the time-series appears to be similar to a random walk with smooth trends and few large jumps in observations (partly due to the smoothing that was done; Figure 11), and
3. there appears to be some ages that do not strictly follow the general trend (evident at the end of the time series where the sampling was likely greater; Figure 11 lower plot).

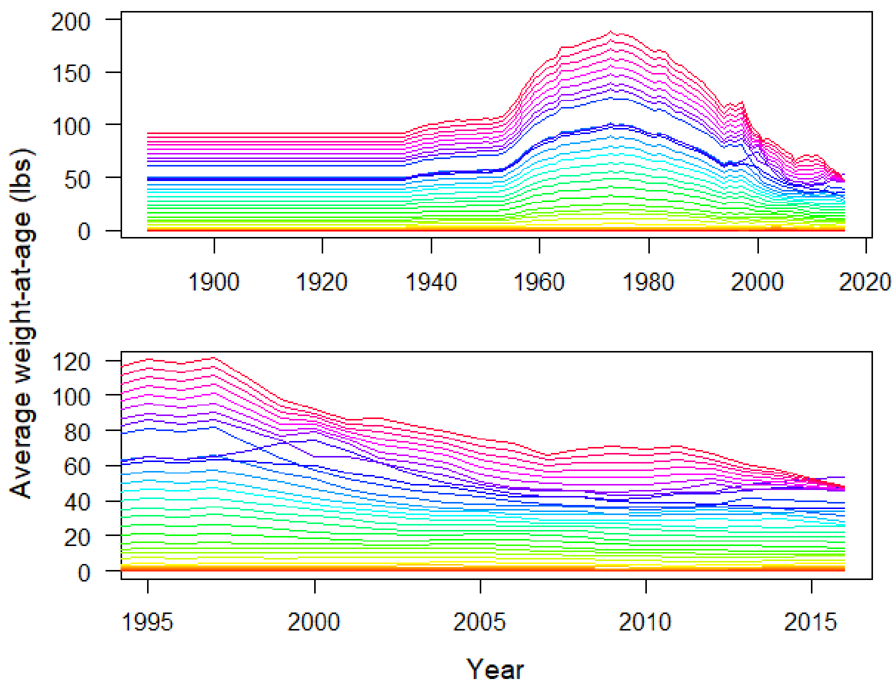

Figure 11: Historical female weight-at-age as used in the long time-series assessment models. Note that the observations are smoothed over years to reduce spurious observations.

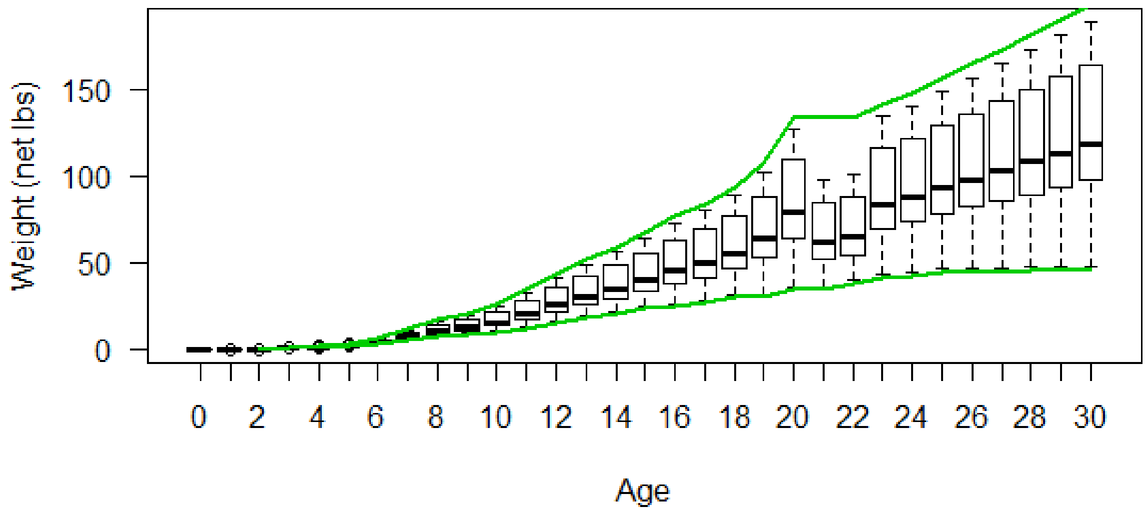

Figure 12: Boxplots of female weight at ages 0 to 30 over all historical years. The green line shows the lower and upper bounds used in the simulations.

The method used to simulate weight-at-age addressed each of these behaviors in the following ways.

1. A single deviation was generated from a normal distribution with a constant standard deviation (0.05), and was a multiplier on the current year's weight-at-age to determine the weight-at-age in the next year. This made all weights for each age increase or decrease similarly.
2. A random walk was used where the weight-at-age in the next year was generated from the weight-at-age in the current year. The deviation in (1) was also correlated with past deviations to simulate periods of similar trends (ρ=0.5).
3. Deviations for each age 6 and greater were generated from a normal distribution with a constant coefficient of variation for each age (0.01), resulting in standard deviations scaled by the mean weight-at-age observed over all historical years with observations. This allows for larger deviations for older fish and provides a mechanism for the mean weight of a specific age to depart from the overall trend simulated in step 1.

The random walk could potentially traverse to extremely high values or low values (obviously negative weight-at-age is not valid). Therefore, boundary conditions were set to limit the range over which weight-at-age could vary. The boundary limits were determined from the observed range of weight at each age, and expanded 5% beyond the minimum and maximum weight at each age observed. Two upper boundaries (ages 21 and 22) were expanded further to equal the upper boundary of age 20 (Figure 12). The random walk simulations remained within the bounds by applying the following algorithm.

1. If a weight-at-age was simulated to be beyond the bounds, the deviations for only the ages where the age-specific bounds were exceeded were reduced by one-half and applied again to determine if it still exceeded the bounds.
2. Repeat step (1) until no age-specific bounds were exceeded.

Example simulated weight-at-age time series are shown in Figure 13.

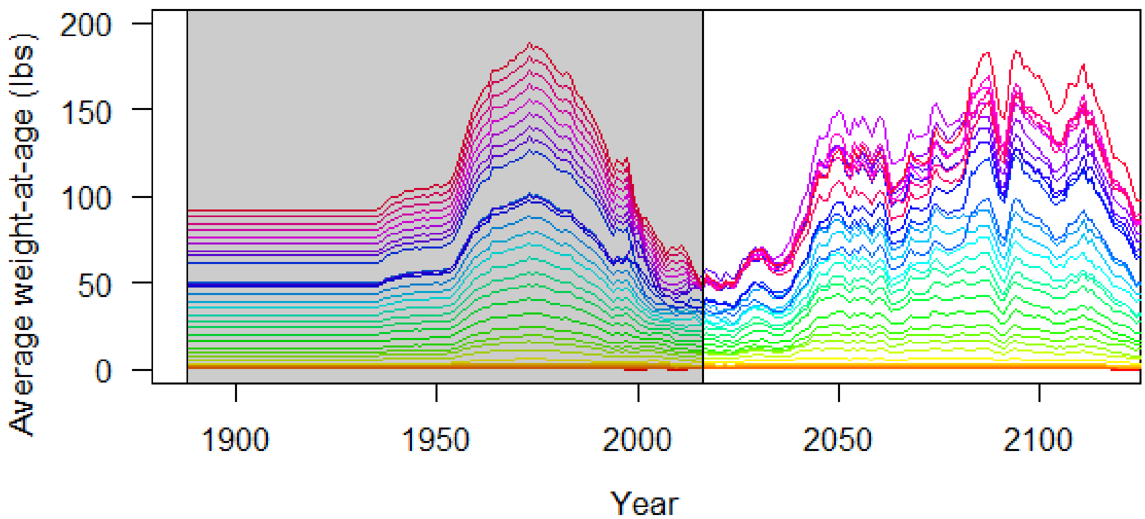

Figure 13: One potential simulated female weight at age in the historical period (1888-2016, shaded) and the simulated period (2017-2116).

5.3 Simulating Regime Shifts

An environmental regime is used in the stock assessment to determine if average recruitment is high or low. This is based on the Pacific Decadal Oscillation (PDO, http://research.jisao.washington.edu/pdo/, Mantua et al. 1997, Figure 14) and the value is 0 or 1 depending on classified cool or warm years, respectively (Figure 15).

The regime was simulated in the MSE by generating a 0 or 1 to indicate the regime in that future year. To encourage runs of a regime between 15 and 30 years (an assumption of the common periodicity, although recent years have suggested less), the environmental index was simulated as a semi-Markov process, where the next year depends on the current year. However, the probability of changing to the opposite regime was a function of the length of the current regime with a probability of changing equal to 0.5 at 30 years, and a very high probability of changing at 40 years.

The simulated length of a regime was most often between 20 and 30 years, with occasional runs between 5 and 20 years.

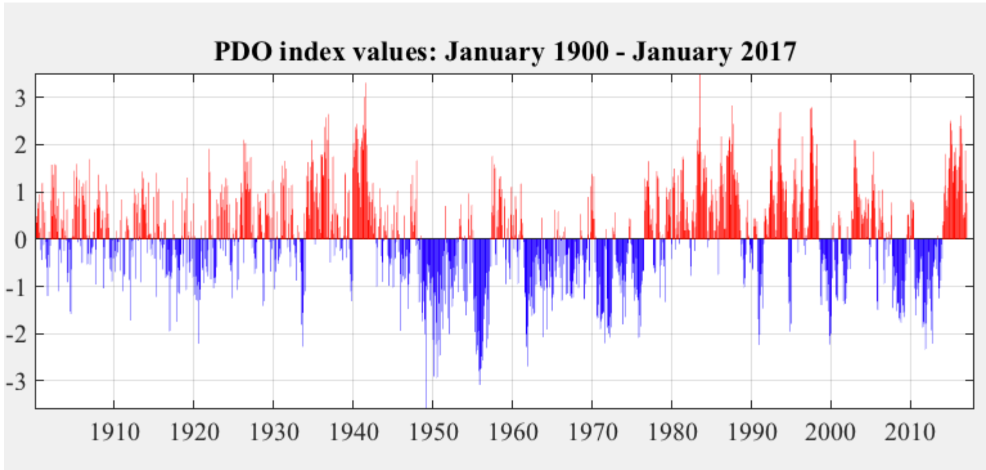

Figure 14: Pacific Decadal Oscillation (PDO) (figure from http://research.jisao.washington.edu/pdo/).

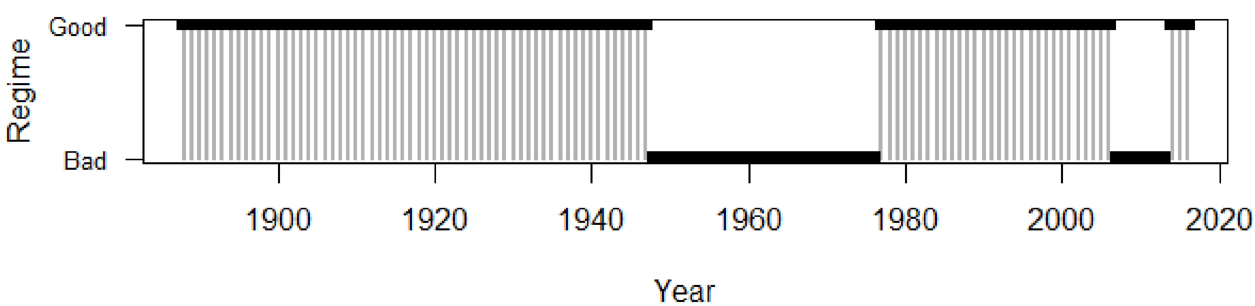

Figure 15: Good and bad regimes in the Pacific halibut stock assessment for 1888-2016.

5.4 Some Additional Scenarios Not Currently Considered

Some scenarios that were not considered, but will likely be considered in the future are:

Selectivity: It may be desirable for the time-varying selectivity for at least commercial gears to be linked to changes in weight-at-age. Also, changes in technology to avoid bycatch could also lead to changes in selectivity.

Migration: Migration will require a multi-area model and hypotheses about movement. A multi-area model is being developed with four regions. Migration hypotheses will be informed by tagging data as well as other observations from various fisheries and surveys.

5.5 MSE Results

Results from the simulations will report short-term and long-term performance statistics, and qualitatively describe transitions from the short- to long-term. More specifically, the short-term will use the assessment ensemble and a three-year projection to calculate MSAB determined objectives. The long-term will summarize performance statistics over the last 10 years of 100-year simulations.

Results from initial simulations were provided at MSAB010. Preliminary results from additional simulations incorporating estimation error are presented here for comparison. The SPR was fixed at 46% and the 30:20 control rule was used. Estimation error was introduced for two cases: error in only the total mortality (CV=0.1), and error in both total mortality and stock status (CV=0.1 for both). Autocorrelation in errors was not simulated. Performance metrics associated with these two cases are compared to the "No Estimation Error" case in **Table 3**.

Table 3: Performance metrics for simulations with no estimation error, error in only total mortality (CV=0.1), and error in total mortality and stock status (CV=0.1 for both).

Metric	**No Estimation Error**	**TM Error = 0.10**	**Both Error = 0.10**
Median average SPR	0.47	0.47	0.43
Biological Sustainability			
Median average dRSB	0.40	0.40	0.31
Median average # mature females	7.38	7.50	6.39
P(all dRSB<20%)	0.04	0.04	0.05
P(all dRSB<30%)	0.09	0.10	0.45
Fishery Sustainability			
Median average TM (Mlbs)	35.68	38.94	38.31
10th and 90th TM (Mlbs)	12 &103	12 & 101	12 & 109
Median average FCEY (Mlbs)	28.65	31.81	31.20
P(all Comm=0)	0.11	0.10	0.18
P(all FCEY < 50.6 Mlbs)	0.71	0.70	0.68
P(all decrease TM > 15%)	0.06	0.18	0.30
median AAV TM	0.06	0.14	0.31

6 DISTRIBUTION OF THE TCEY

A considerable amount of discussion related to a description of the harvest strategy policy occurred at previous MSAB meetings. Figure 1 shows an updated depiction of the harvest strategy policy with terms describing the various components. These terms are defined in the IPHC glossary[2], but of note for this paper are TCEY distribution, stock distribution, and distribution procedures. The management procedure is the sequence of elements including the assessment, fishing intensity, stock distribution, and distribution procedures. The goal of the MSAB is to define a management procedure that will be used to output O26 mortality limits for each Regulatory Area that meet the long-term objectives of managers and stakeholders. The "decision" step on the right of Figure 1 is where a deviation from the management

[2] https://iphc.int/the-commission/glossary-of-terms-and-abbreviations

procedure may occur due to input from other sources and decisions of the Commissioners that may reflect current biological, environmental, social, and economic conditions.

As tasked by the Commission, an evaluation of the previous IPHC informal “harvest policy” was undertaken and presented at MSAB08. That harvest policy used a procedure that took the coastwide stock assessment as an input, and output 1) the coastwide Total Constant Exploitation Yield (TCEY) (across all Regulatory Areas), and 2) the TCEY and Fishery Constant Exploitation Yield (FCEY) for each Regulatory Area. The integral input to that harvest policy was the coastwide stock assessment. The scaling of catch for that harvest policy revolved around the concept of exploitable biomass (EBio) and defined harvest rates. EBio was based on numbers-at-age, weight-at-age, and externally derived selectivity-at-age.

Given the complex but static definition of EBio, there was a divergence between EBio and the assessment which updated selectivity each year, and later allowed it to vary over time. In other words, EBio was not representative of the stock assessment results because the selectivity curves used to define EBio were out of date. It is difficult to exactly characterize what EBio is because it is a single value meant to describe a complex amalgamation of fleets, areas, stock size, and size-at-age. Ebio was not the biomass of fish over 26 inches (O26, 66 cm) or 32 inches (O32, 81 cm), and it was not the biomass of the stock that is encountered by the fisheries.

Ebio was apportioned to IPHC Regulatory Areas using the estimated distribution of O32 biomass from the setline survey. Then, IPHC Regulatory Area-specific catch levels (TCEY) were calculated from defined harvest rates. A harvest rate of 16.125% was used for western areas (3B, 4A, 4B, and 4CDE) and 21.5% for eastern areas (3A, 2C, 2B, and 2A). These harvest rates were based on the selection of O26 fish for TCEY (Hare 2011) and were converted from values originally based on O32 fish, reflecting the size limit (Clark and Hare 2006). They were lower in the west due to the presence of small fish, a lower estimated yield-per-recruit, and greater uncertainty in historical analyses. These harvest rates were explicitly linked to EBio.

In 2017, the Commission agreed to move to an SPR-based management procedure to account for the mortality of all sizes and from all fisheries. The procedure uses a coastwide fishing intensity based on spawning potential ratio (SPR), which defines the “scale” of the coastwide catch. This eliminates the use of EBio and area-specific absolute harvest rates. Therefore, there are currently two inputs to the current management procedure for distributing the TCEY among IPHC Regulatory Areas: 1) the current estimated stock distribution and 2) relative target harvest rates.

6.1 A Background on Stock Distribution

The IPHC uses a space-time model to estimate annual Weight-Per-Unit-Effort (WPUE) for use in estimating the annual stock distribution of Pacific halibut (Webster 2018). Briefly, observed WPUE is fitted with a model that accounts for correlation between setline survey stations over time (years) and space (within Regulatory Areas). Competition for hooks by Pacific halibut and other species, the timing of the setline survey relative to annual fishery mortality, and observations from other fishery-independent surveys are also accounted for in the approach. This fitted model is then used to predict WPUE (relative density) of Pacific halibut for every setline survey station in the design (including all setline survey expansion stations), regardless of whether it was fished in a particular year. These predictions are then averaged within each IPHC Regulatory Area, and combined among IPHC Regulatory Areas, weighting by the “geographic extent” (calculated area within the survey design depth range) of each IPHC Regulatory Area. It is important to note that this produces relative indices of abundance and biomass, but does not produce an absolute measure of abundance or biomass because it is weight-per-unit-effort scaled by the geographic extent of each IPHC Regulatory Area. These indices are useful for determining trends in stock numbers and biomass, and are also useful to estimate the geographic distribution of the stock.

6.2 Using Relative Harvest Rates

The distribution of the TCEY for 2018 was shifted from the estimated stock distribution to account for additional factors related to productivity and paucity of data in each IPHC Regulatory Area. Previously, this was accomplished by applying different harvest rates in western areas (16.125% in IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE)) and eastern areas (21.5% in IPHC Regulatory Areas 2A, 2B, 2C, and 3A). However, with the elimination of EBio and the use of SPR-based fishing intensity to determine the coastwide scale, the TCEY, rather than the esoteric concept of exploitable biomass was distributed. Therefore, an absolute measure of harvest rate is not necessary, but it may still be desired to shift the distribution of the TCEY away from the estimated stock distribution to account for other factors. Consistent with the previous approach, relative harvest rates were used with a ratio of 1.00:0.75, being equal to the ratio between 21.5% and 16.125%. This application shifted the target TCEY distribution away from the stock distribution by moving more TCEY into IPHC Regulatory Areas 2A, 2B, 2C, and 3A and less TCEY from IPHC Regulatory Areas 3B, 4A, 4B, and 4CDE (Table 4), thus harvesting at a higher rate in eastern IPHC Regulatory Areas.

Table 4: IPHC Regulatory Area stock distribution estimated from the 2017 space-time model O32 WPUE, IPHC Regulatory Area-specific relative target harvest rates, and resulting 2018 target TCEY distribution based on the IPHC’s 2018 interim management procedure (reproduced from Table 1 in IPHC-2018-AM094-11 Rev_1).

	2A	2B	2C	3A	3B	4A	4B	4CDE	Total
O32 stock distribution	1.7%	11.3%	16.6%	35.6%	10.0%	6.6%	4.8%	13.3%	100.0%
Relative harvest rates	1.00	1.00	1.00	1.00	0.75	0.75	0.75	0.75	--
Target TCEY Distribution	1.9%	12.4%	18.2%	38.9%	8.2%	5.4%	3.9%	10.9%	100.0%

6.3 Redefining the TCEY Distribution Procedure

TCEY distribution is the part of the management procedure for distributing the TCEY among Regulatory Areas and is composed of a purely scientific component to distribute the TCEY in proportion to its estimated biomass in each area (stock distribution) and steps to further modify the distribution of the TCEY based on additional considerations (distribution procedures). Those two components are described below.

6.3.1 Redefining Stock Distribution

Emerging understanding of biocomplexity across the geographic range of the Pacific halibut stock indicates that IPHC Regulatory Areas should only be considered as management units and do not represent relevant sub-populations (Seitz et al. 2017). Balancing the removals against the current stock distribution is likely to protect against localized depletion of spatial and demographic components of the stock that may produce differential recruitment success under changing environmental and ecological conditions. Biological Regions, defined earlier and shown in Figure 2, are considered by the IPHC Secretariat to be the best option for biologically-based areas to meet management needs.

The overarching conservation goal for Pacific halibut is to maintain a healthy coastwide stock. However, given the wide geographic range of the Pacific halibut stock, there likely is stock structure that we do not fully understand, and this stock structure may be important to coastwide stock health. Therefore, conservation objectives relate to where harvesting occurs, with an objective to retain viable spawning activity in all portions of the stock. One method for addressing this objective is to distribute the fishing mortality relative to the distribution of observed stock biomass. This requires defining appropriate areas for which the distribution is to be conserved. Splitting the coast into many small areas for conservation objectives can result in complications including being cumbersome to determine if conservation objectives are met, being difficult to accurately determine the proportion of the stock in that area, being subject to inter-annual variability in estimates of the proportion, forcing arbitrary delineation among areas with evidence of strong stock mixing, and not being representative of biological importance. Therefore, Biological Regions represent the most logical scale over which to consider conservation objectives related to distribution of the fishing mortality. Adjusting the distribution of the TCEY among Biological Regions to account for additional considerations, and further distributing the TCEY to IPHC Regulatory Areas would be done through steps defined in the Distribution Procedures component (Figure 1).

In addition to using Biological Regions for stock distribution, the “all sizes” WPUE from the space-time model (Figure 16), which is largely composed of O26 Pacific halibut (due to selectivity of the setline gear), is more congruent with the TCEY (O26 catch levels) than O32 WPUE. Therefore, when distributing the TCEY to Biological Regions, the estimated proportion of “all sizes” WPUE from the space-time model should be used for consistency.

6.4 Distribution Procedures

Distribution Procedures contains the steps of further modifying the distribution of the TCEY among Biological Regions and then distributing the TCEY among IPHC Regulatory Areas within Biological Regions (Figure 17). Modifications at the Biological Region or IPHC Regulatory Area level may be based on differences in production between areas, observations in each area relative to other areas (e.g., WPUE), uncertainty of data or mortality in each area, defined allocations, or national shares. Data may be used as indicators of stock trends in each Region or IPHC Regulatory Area, and are included in the Distribution Procedures component because they may be subject to certain biases and include factors that may be unrelated to biomass in that Biological Region or IPHC Regulatory Area. For example, commercial WPUE is a popular source of data used to indicate trends in a population, but may not always be proportional to biomass. Types of data may be used include fishery WPUE, survey observations (not necessarily the IPHC fishery-independent setline survey), age-compositions, size-at-age, and environmental observations.

The steps in the Distribution Procedures may consider conservation objectives, but they will mainly be developed with respect to fishery objectives. Yield and stability in catch levels are two important fishery objectives that often contradict each other (i.e. higher yield often results in less stability). Additionally, area-specific fishery objectives may be in conflict across IPHC Regulatory Areas. Pacific halibut catch levels are defined for each IPHC Regulatory Area and quota is accounted for by those Regulatory Areas. Therefore, IPHC Regulatory Areas are the appropriate scale to consider fishery objectives.

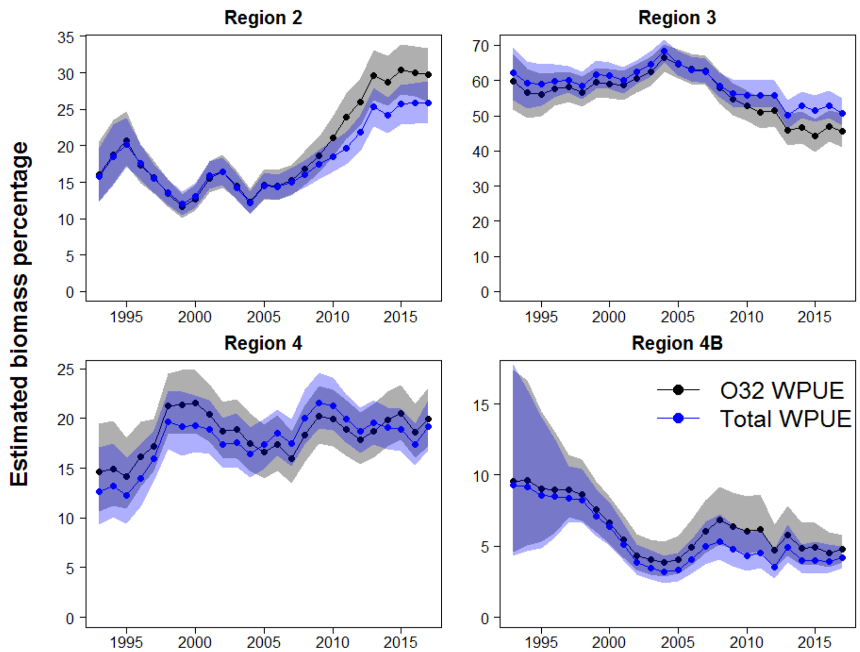

Figure 16: Estimated stock distribution (1993-2017) based on estimate WPUE from the space-time model of O32 (black series) and all sizes (blue series) of Pacific halibut. Shaded zones indicate 95% credible intervals.

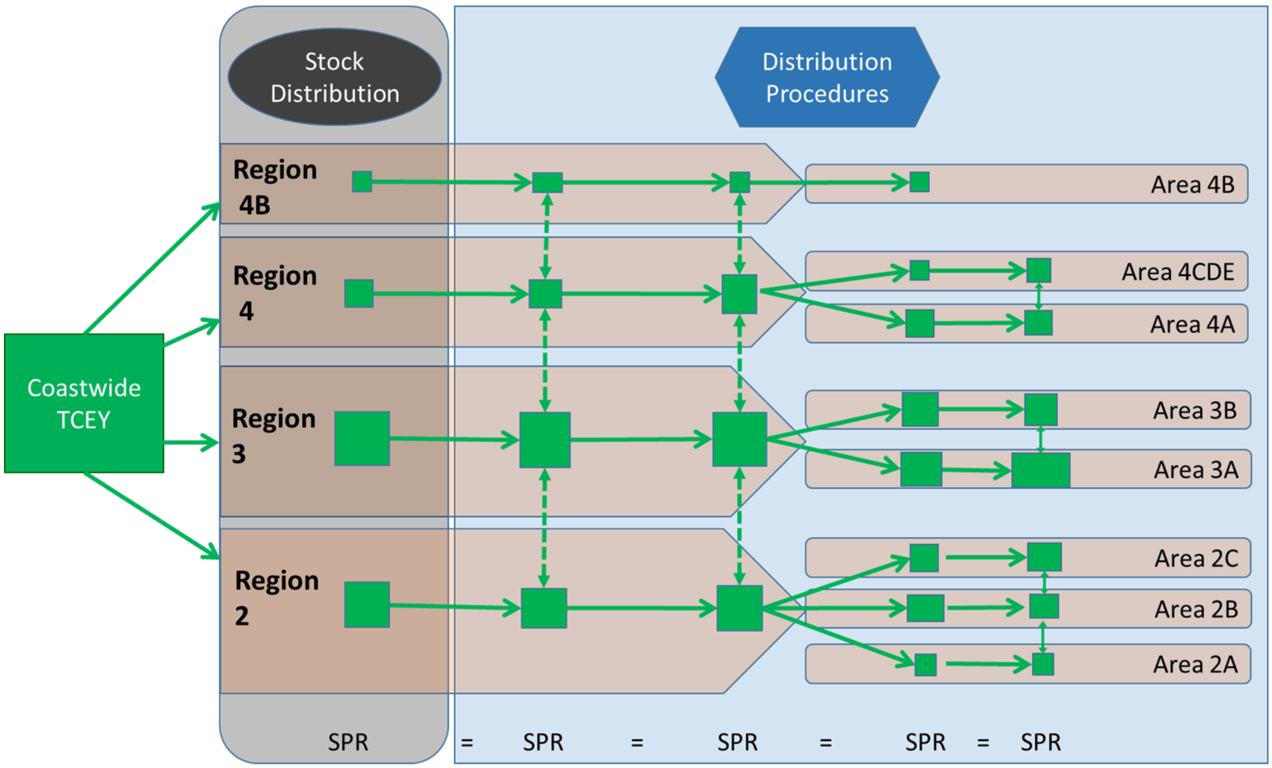

Figure 17: The process of distributing the TCEY to Regulatory Areas from the coastwide TCEY. The first step is to distribute the TCEY to Biological Regions based on the estimate of stock distribution. Following this, a series of adjustments may be made based on observations or social, economic, and other considerations. Finally, the adjusted regional TCEY's are allocated to IPHC Regulatory Areas. The allocation to IPHC Regulatory Areas may occur at any point after regional stock distribution. The dashed arrows represent balancing that is required to maintain a constant coastwide SPR.

6.5 A Summary of the Management Procedure for Distributing TCEY Across the Coast

The harvest strategy policy begins with the coastwide TCEY determined from the stock assessment and fishing intensity determined from a target SPR (Figure 1). When distributing the TCEY among regions, stock distribution occurs first to distribute the harvest in proportion to biomass and satisfy conservation objectives, and then is followed by adjustments across Regions and Regulatory Area based on distribution procedures to further encompass conservation objectives and consider fishery objectives. The key to these adjustments is that they are relative adjustments such that the overall fishing intensity (target SPR) is maintained (i.e., a zero sum game). Otherwise, the procedure is broken and it is uncertain if the defined objectives will be met.

A framework for a management procedure that ends with the TCEY distributed among IPHC Regulatory Areas and would encompass conservation and fishery objectives is described below.

1. **Coastwide Target Fishing Intensity:** Determine the coastwide total mortality using a target SPR that is most consistent with IPHC objectives defined by the Commission. Separate the total mortality in ≥26 inches (O26) and under 26 inches (U26) components. The O26 component is the coastwide TCEY.
   1.1. Target SPR is scheduled for evaluation at the 2019 Annual Meeting. The current interim target SPR is 46%.
2. **Regional Stock Distribution:** Distribute the coastwide TCEY to four (4) biologically-based Regions using the proportion of the stock estimated in each Biological Region for all sizes of Pacific halibut using information from the IPHC setline survey and the IPHC space-time model.
   2.1. Four Regions (2, 3, 4, and 4B) are defined above (Figure 2).
3. **Regional Allocation Adjustment:** Adjust the distribution of the TCEY among Biological Regions to account for other factors.
   3.1. For example, relative target harvest rates are part of a management/policy decision that may be informed by data and observations. This may include evaluation of recent trends in estimated quantities (such as fishery-independent WPUE), inspection of historical trends in fishing intensity, recent or historical fishery performance, and biological characteristics of the Pacific halibut observed in each Biological Region. The IPHC Secretariat may be able to provide Yield-Per-Recruit (YPR) and/or surplus production calculations as further supplementary information for this discussion. The regional relative harvest rates may also be determined through negotiation, which is simply an allocation agreement for further Regional adjustment of the TCEY.
4. **Regulatory Area Allocation:** Apply IPHC Regulatory Area allocation percentages within each Biological Region to distribute the Region-specific TCEY's to Regulatory Areas.
   4.1. This part represents a management/policy decision, and may be informed by data, based on past or current observations, or defined by an allocation agreement. For example, recent trends in estimated all sizes WPUE from the setline survey or fishery, age composition, or size composition may be used to distribute the TCEY to IPHC Regulatory Areas. Inspection of historical trends in fishing intensity or catches by IPHC Regulatory Area may also be used. Finally, agreed upon percentages are also an option. This allocation to IPHC Regulatory Areas may be a procedure with multiple adjustments using different data, observations, or agreements

The four steps described above would be contained within the IPHC Harvest Strategy Policy as part of the Management Procedure, and are pre-determined steps that have a predictable outcome. The decision making process would then occur (Figure 1).

5. **Seasonal Regulatory Area Adjustment**: Adjust individual Regulatory Area TCEY limits to account for other factors as needed. This is the policy part of the harvest strategy policy and occurs as a final step where other objectives are considered (e.g. economic, social, etc.).
   5.1. Departing from the target SPR may be a desired outcome for a particular year (short-term, tactical decision making based on current trends estimated in the stock assessment), but would deviate from the management procedure and the long-term management objectives. Departures from the management procedure may result in unpredictable outcomes, but could also take advantage of current situations.

7 RECOMMENDATION/S

That the SRB:

1) **NOTE** paper IPHC-2018-SRB011-08 which provided an update on the IPHC management strategy evaluation.
2) **CONSIDER** the goals and objectives listed in Appendix II and the definitions of biological and fishing reference points.
3) **RECOMMEND** appropriate biological sustainability objectives and biological reference points from a scientific point of view.
4) **CONSIDER** the simulation framework and assumptions as described, including introducing variability to the OM, simulating weight-at-age and environmental regimes, and distribution of the Total Mortality to different sources of mortality.
5) **RECOMMEND** improvements to conditioning the operating model, simulating variability in different processes (especially weight-at-age), and introducing estimation error into the simulations.
6) **CONSIDER** the interpretation of short-term, medium-term, and long-term results.
7) **RECOMMEND** additional methods for presenting short-, medium-, and long-term results.
8) **CONSIDER** the distribution frame-work and the separation of scientific and management elements of distribution procedures, and how distributing the TCEY may contribute to conserving the coastwide stock of Pacific halibut.
9) **RECOMMEND** modifications that may improve the TCEY distribution framework and which components the MSAB should consider when developing management procedures to evaluate.
10) **CLARIFY** paragraphs 24 and 28 of the report from SRB011 (IPHC-2018-SRB011-R).

8 ADDITIONAL DOCUMENTATION / REFERENCES

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9 APPENDICES

Appendix I MSAB requests requesting SRB input

Appendix II Measurable objectives and associated performance metrics

APPENDIX I: MSAB REQUESTS REQUESTING SRB INPUT

28. The MSAB **REQUESTED** that the IPHC Secretariat continue to discuss the Biological Sustainability (conservation) objectives with the IPHCs Scientific Review Board (SRB), including the appropriate female spawning biomass limit and female spawning biomass threshold.

41. The MSAB **REQUESTED** that the IPHC Secretariat present the methods for producing short-, medium-, and long-term results to the SRB for their review and comment.

45. The MSAB **REQUESTED** that the SRB clarify the meaning of paragraphs 24 and 28 in the SRB report, IPHC-2017-SRB011-R.

54. The MSAB **AGREED** that estimation error should be simulated from a joint distribution representing error in the estimated Total Mortality and the estimated stock status, with autocorrelation. The MSAB **REQUESTED** that the SRB review these methods to incorporate estimate error.

60. The MSAB **REQUESTED** that the simulations incorporate:

d) autocorrelation at a level determined appropriate by the IPHC Secretariat and the SRB.

61. The MSAB **REQUESTED** that when reporting results:

a) the long-term be represented by 100 simulated annual cycles from the Operating Model and performance metrics summarized over the 10 annual cycles.
b) short- and medium-term performance metrics be presented for management procedures that meet long-term objectives.
c) the short-term be represented by the assessment ensemble and performance metrics presented for the immediate three years. These performance metrics are not necessarily the same as for long-term metrics, and may be actual values (e.g. catch in 2019) instead of a summary over years.
d) the medium-term be summarized qualitatively by describing the transition from the short-term to the medium-term using the closed-loop simulations. Sensitivities (e.g. holding weight-at-age at low levels or constant) can help to inform the medium-term transitions.
e) phase-in procedures are considered when appropriate.

62. The MSAB **REQUESTED** that IPHC Secretariat discuss the time-frames detailed in paragraph 61, with the SRB

63. The MSAB **REQUESTED** that the IPHC Secretariat consider the following improvements to the simulation framework:

a) investigate improvements to simulating weight-at-age with input from the SRB.

64. The MSAB **NOTED** that the Operating Model and how it is conditioned is adequate for the evaluation of the HCR, and **REQUESTED** that the IPHC Secretariat present these methods to the SRB.

69. The MSAB **NOTED** that:

a) if the goal of a procedure is to maintain a constant SPR through all steps of distributing the TCEY, then a change in distribution may change the total coastwide mortality to maintain that SPR.

b) there are science-based and management-derived elements in the TCEY distribution procedure. Some distribution procedures may incorporate one or both elements.

c) stock distribution is science-based and is linked to biological sustainability objectives. WPUE from the space-time model is used to determine stock distribution to biological regions, and using “all sizes” in the calculation of WPUE is more congruent with the TCEY, while acknowledging that the IPHC fishery-independent setline survey catches a small number of Pacific halibut below 26 inches.

d) the IPHC Secretariat has described four biological Regions (consistent with IPHC Regulatory Area boundaries) based on the best available science, and will be used for stock distribution as the first step, after which distribution procedures would distribute the TCEY to meet fishery objectives.

e) relative harvest rates among Regions are science-based and management-derived, and within Regions are management-derived. Science-based foundations could include productivity analyses, while management-derived elements may include quantity and quality of data in each area and other area-specific objectives.

f) many more elements of the TCEY distribution procedure may be developed and include management-derived elements.

g) TCEY distribution procedures are to be evaluated against objectives and reported at AM097 in 2021. Biological sustainability objectives are related to biological Regions and Fishery objectives are related to IPHC Regulatory Areas. Because IPHC Regulatory Areas are nested within Regions, distribution to Regions can affect fishery objectives.

70. The MSAB **NOTED** that the proposed TCEY distribution procedure contains four main components, each of which may contain multiple elements. These four components are listed below and have a computational outcome:

a) **Coastwide Target Fishing Intensity**: this defines the TCEY to be distributed.

b) **Regional Stock Distribution**: this distributes the TCEY to biological Regions to satisfy the Biological Sustainability objective of preserving biocomplexity.

c) **Regional Allocation Adjustment (optional)**: this adjusts the distribution of the TCEY among Regions to account for additional Biological Sustainability objectives and fishery objectives.

d) **Regulatory Area Allocation**: this distributes the TCEY from Regions to Regulatory Areas to satisfy fishery objectives.

71. The MSAB **NOTED** that the output of the TCEY distribution procedure will be a catch table describing proposed mortality (allocation) in each IPHC Regulatory Area…

72. The MSAB **REQUESTED** that the proposed TCEY distribution framework described in paragraphs 69, 70 and 71, be reviewed by the SRB in 2018.

APPENDIX II
MEASURABLE OBJECTIVES AND ASSOCIATED PERFORMANCE METRICS

GOAL: Biological Sustainability

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	NEGATIVE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRICS
1.1. KEEP BIOMASS ABOVE A LIMIT TO AVOID CRITICAL STOCK SIZES	Maintain a minimum spawning stock biomass above a biomass limit reference point	RSB < Biomass Limit	Long-term 10 year period	0.05	$P(dRSB < Limit)$
1.2. MITIGATE FOR UNCERTAINTY	Maintain spawning stock biomass mostly above a biomass threshold reference point to avoid stock sizes that could become critical	RSB < Biomass Threshold	Long-term 10-year period	0.25	$P(dRSB < Threshold)$
	When the Estimated Biomass < Biomass Threshold, limit the probability of declines	SSB declines when RSB < Biomass Threshold	Long-term 10 year period	0.05-0.5	$P(SSB_{i+1} < SSB_i)$ given *RSB* < biomass threshold
ABSOLUTE MEASURE	An absolute measure	Number of mature female halibut	Long-term 10 year period	NA	Median $\overline{MatureFemales}$
ABSOLUTE MEASURE	An absolute measure	Spawning Biomass	Long-term 10 year period	NA	Median $\overline{RSB}$

GOAL : Fishery Sustainability, Stability, and Access

General Objective	Measurable Objective	Negative Outcome	Time-frame	Tolerance	Performance Metrics
2.1. Maintain an economically sufficient level of catch (i.e, target) across regulatory areas	Maintain an average catch	FCEY <- averageCatch	Long-term, 10 yr Short-term, 3 yr	?? ??	$P(FCEY < AvCatch)$
	Maintain a minimum catch	FCEY < min	Long-term, 10 yr Short-term, 3 yr	?? ??	$P(FCEY < min)$
	Maintain an above average catch	< 70% of historical 1993-2012 average	Long-term, 10 yr Short-term, 3 yr	0.1 ??	$P(FCEY < 70\%)$
	Maintain a consistent level of catch	Outside of ±10% of 1993-2012 average	Long-term, 10 yr Short-term, 3 yr	0.1 0.	$P(FCEY > 110\%$ or $FCEY < 90\%$
2.2. Limit catch variability	Limit annual changes in TAC, coast-wide and/or by Regulatory Area	Change in Mortality > 15%	Long-term, 10 yr Short-term, 3 yr	?? ??	$P\left(\frac{FCEY_{i+1} - FCEY_i}{FCEY_i} > 15\%\right)$
		AAV > 15%	Long-term, 10 yr Short-term, 3 yr	?? ??	$P(AAV > 15\%)$
Absolute measure	An absolute measure	Mortality (TM, TCEY, FCEY, Commercial)	Long-term, 10 yr Short-term, 3 yr	NA	Median $\overline{Mort}$
Absolute measure	An absolute measure	Range of mortality	Long-term, 10 yr Short-term, 3 yr	NA	5th and 75th percentiles of mortality
Absolute measure	An absolute measure	Variability in mortality (TM, TCEY, FCEY, Commercial)	Long-term, 10 yr Short-term, 3 yr	NA	Median Average Annual Variability (AAV)

STATISTIC	Chance of being "on the ramp"	Estimated stock status is below the fishery trigger	Long-term, 10 yr Short-term, 3 yr	NA	$P(\widehat{dRSB} < Trigger)$

GOAL : Minimize Discard Mortality

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	NEGATIVE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRICS
3.1. HARVEST EFFICIENCY	Discard mortality is a small percentage of the longline fishery annual catch limit	>10% of annual catch limit	Long-term, 10 yr Short-term, 3 yr	0.25	$P(DM > 10\%FCEY)$
ABSOLUTE MEASURE	Absolute	Discard Mortality (DM)	Long-term, 10 yr Short-term, 3 yr	**NA**	Median $\overline{DM}$

GOAL : Minimize Bycatch and Bycatch Mortality

GENERAL OBJECTIVE	MEASURABLE OBJECTIVE	NEGATIVE OUTCOME	TIME-FRAME	TOLERANCE	PERFORMANCE METRICS

DRAFT: Progress Report on Biological Research Activities at IPHC

PREPARED BY: IPHC SECRETARIAT (J. PLANAS, L. SADORUS, C. DYKSTRA, T. LOHER; 21 MAY 2018)

PURPOSE

To provide the Scientific Review Board with a description of current progress on research projects conducted by the Biological and Ecosystem Science Research Program.

BACKGROUND

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

1) identify and assess critical knowledge gaps in the biology of the Pacific halibut;
2) understand the influence of environmental conditions; 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 proposed Five-Year Research Plan for the period 2017-2021, as summarized in a previous document IPHC-2017-SRB10-INT02. These activities can be summarized in five broad categories: 1) Reproduction, 2) Growth and Physiological Condition, 3) Discard Mortality Rates (DMRs) and Survival, 4) Migration and 5) Genetics and Genomics, and have been selected for their important management implications, as follows.

1) The studies conducted on Reproduction are aimed at providing information on the sex ratio of the commercial catch and to improve current estimates of maturity.
2) The studies conducted on Growth 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.
3) The proposed work on DMRs is aimed at providing updated estimates of DMRs in both the longline and the trawl fisheries.
4) The studies conducted on Migration are aimed at further understanding reproductive migration and identification of spawning times and locations as well as larval and juvenile dispersal.
5) The studies conducted on Genetics and Genomics 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.

UPDATE ON PROGRESS ON NEW AND CONTINUING BIOLOGICAL RESEARCH PROJECTS

For 2018, two new projects were approved that cover specific research needs related to larval migration and distribution (Project 650.22) and thermal growth history (Project 673.15) (Appendix I).

Project 650.22 ("*Larval connectivity*") proposes to study the movement and connectivity of Pacific halibut larvae both within and between the Gulf of Alaska and the Bering Sea. Larval abundance and distribution in the Gulf of Alaska and the Bering Sea will be modeled over time and over oceanographic and environmental conditions.

Project 673.15 ("*Influence of thermal history on growth*") proposes to study the thermal profile experienced by fish at sea as assessed by electronic archival tagging and otolith microchemistry in order to investigate the relationship between growth patterns (or productivity) and both spatial and temporal variability in environmental conditions for growth. This study will allow us to relate temperature histories that are experienced by individual fish to the growth patterns that they display, examine spatial and temporal trends in rearing conditions and growth, and to extend thermal analyses to untagged Pacific halibut via otolith microchemical analyses. In addition, the data are expected to provide information regarding dispersal of U32 halibut, both seasonally and ontogenically.

Furthermore, twelve continuing projects were approved, including one project dealing with sex identification (621.16) and one dealing with reproductive maturity estimations (674.11), two projects monitoring the Pacific halibut population for mercury and *Ichthyophonus* contamination (642.00, 661.11), three projects continuing migration-related research with the use of wire and satellite tagging and tail imaging (650.21, 670.11, 675.11), one project dealing with the identification of markers for growth-related studies (673.14), one project investigating condition factor indices in wire-tagged fish (672.12), one project dealing with discard mortality rates in the longline fishery (672.13), one project continuing the sequencing of the Pacific halibut genome (673.13), and one project finalizing work conducted on the reevaluation of the weight-length relationship (669.11) (Appendix I). An update on progress on selected projects is provided below:

Project 621.16 ("*Development of genetic sexing techniques*") proposed to identify molecular markers for sex in order to provide a genetic validation of the physical marking of sex at sea (**Project 621.15**) and to provide a method for sex determination in settings in which direct observations of sex cannot be obtained. Three single nucleotide polymorphisms (SPNs) were identified to be associated with sex and molecular assays were developed for two of the identified SNPs. These assays were estimated to have an accuracy of 97.5% in a comparison between assayed sex and visually-determined sex in a sample of 199 fish, based on an assumption that no process or recording errors existed within the visually-determined data (Drinan et al., 2018). The assay was subsequently used to evaluate the accuracy of commercial sex-marking at sea, described below in Subsection 1.1 of "**PROGRESS ON THE MAIN RESEARCH ACTIVITIES**".

Project 642.00 ("*Assessment of mercury and other contaminants*") and **Project 661.11** ("*Ichthyophonus incidence monitoring*") were proposed to monitor levels of mercury contamination and *Ichthyophonus* prevalence, respectively, in Pacific halibut. Tissue samples for monitorization of these two parameters were collected in IPHC's fishery-independent setline survey in 2017.

Project 650.21 ("*Investigation of Pacific halibut dispersal on Bowers Ridge via Pop-up Archival Transmitting (PAT) tags*") proposed to study the migratory behavior of O32 Pacific halibut residing in summer on Bowers Ridge in IPHC Regulatory Area 4B, at both seasonal and interannual time scales. The primary goal of the project is to evaluate relative connectivity between Bowers Ridge, the western Aleutian Islands, and the broader eastern Pacific. Results will be placed in the context of data obtained from prior satellite-tagging experiments in which more than 200 O32 Pacific halibut have been tagged in the eastern Bering Sea and Aleutian Islands region. In July of 2017, a total of 22 fish (13 female; 8 male; 1 of unknown sex) were successfully tagged on Bowers Ridge, with 16 of the PAT tags programmed to detach from their host fish and report via satellite on 15 January 2018 and the remaining six tags programmed to detach and report in July of 2018 (i.e., after 365 days at liberty). To date, broadcasts have been received from 15 tags, which reported between 24 December 2017 and 22 January 2018. Five fish remain at liberty with tags programmed to report from 5-10 July 2018.

Project 669.11 ("*At-sea collection of Pacific halibut weights to reevaluate conversion factors*") proposed to continue collecting round weights at sea to reevaluate the relationship between fork length and net weight. Data has been collected in IPHC's fishery-independent setline survey in 2017.

Project 670.11 ("*Wire tagging of Pacific halibut on NMFS trawl and setline surveys*") proposed to tag U32 Pacific halibut in order to further understand coastwide migratory and growth patterns of young Pacific halibut. In 2017, a total of 1,469 Pacific halibut were tagged on the NMFS trawl survey (713 in the Gulf of Alaska and 756 from the Bering Sea) and 1,927 Pacific halibut were tagged on the IPHC's fishery-independent setline survey.

Project 672.12 ("*Condition Factors for Tagged U32 Fish*") is continuing to study the relationship between the physiological condition of fish and migratory performance as assessed by tagging in U32 fish in order to better understand the potential use of quantitative physiological indicators in predicting migratory (as well as other types of) performance. Sample collection will continue on the 2018 IPHC fishery-independent setline survey.

Project 672.13 ("*Discard mortality rates and injury classification profile by release method*") proposed to study the relationship between hook release methods in the longline fishery and associated injuries with the physiological condition of fish in order to improve our understanding of factors influencing post-release survival in the directed fishery. Implementation of this project took place in early fall of 2017 during two trips of a chartered vessel, Various hook release methods were alternated randomly at each skate and electronic monitoring was conducted throughout the study (please see below for a full description).

Project 673.13 ("*Sequencing of the Pacific halibut genome*") proposed to characterize for the first time the genome of the Pacific halibut and provide genomic resolution to genetic markers for sex, reproduction, and growth that are currently being investigated in other projects. A first round of genomic sequencing has been performed resulting in a broad but discontinued coverage of the Pacific halibut genome. Further sequencing with more powerful sequencing technologies is currently being planned to achieve full coverage of the Pacific halibut genome.

Project 673.14 ("*Identification and validation of markers for growth in Pacific halibut*") proposed to identify and validate molecular and biochemical profiles that are characteristic of specific growth patterns and that will be instrumental to describe different growth trajectories in the Pacific halibut population and evaluate potential effects of environmental influences on growth. We have already initiated research to study somatic growth in juvenile Pacific halibut and its regulation by temperature and are in the process of identifying molecular signatures of slow versus fast growth patterns that will be used to describe environmental influences on growth trajectories (please see below for a full description).

Project 674.11 ("*Full characterization of the annual reproductive cycle in adult female Pacific halibut*") proposed to study the annual reproductive cycle of female and male Pacific halibut in order to further our understanding of sexual maturation in this species and to improve maturity assessments and maturity-at-age estimates. Sample collection in the Portlock area in central Gulf of Alaska began in September 2017 and is continuing on a monthly basis through August 2018 on chartered vessels (please see below for a full description).

Project 675.11 ("*Tail pattern recognition analysis in Pacific halibut*") is the continuation of a pilot study conducted in 2017 that investigated the identification of individual fish by way of photographic recognition of tail patterns to complement migratory studies. Various pattern-recognition software were used to examine uniqueness and longevity of patterns in both the blind and colored side of the tail, showing relative promise for identifying the same individuals over time. Cameras will be deployed on several vessels during the fisheries-independent setline survey in 2018 and tail images of wire tagged U32 fish will be collected and used to start building a database of tail images.

PROGRESS ON THE MAIN RESEARCH ACTIVITIES

1. Reproduction. Efforts at IPHC are currently underway to address two critical issues in stock assessment based on estimates of female spawning biomass: the sex ratio of the commercial catch and maturity estimations.

   1.1. Sex ratio of the commercial catch. In the commercial fishery, Pacific halibut are eviscerated at sea and male and female fish cannot be distinguished at the shore-side processing plants, where biological information is collected by IPHC samplers. Therefore, the sex ratio of the commercial catch has not been determined to date. In order to obtain accurate sex information, IPHC initiated efforts to establish protocols for sex marking fish at sea aboard commercial longline vessels and to develop molecular assays to accurately determine the genetic sex in fin clip samples from offloaded fish. If protocols for sex marking at sea in commercial vessels prove to be successful, at-sea sex marking might be routinely employed to generate sex-ratio data for commercial offloads and genetic sex assays (see "**UPDATE ON PROGRESS ON NEW AND CONTINUING BIOLOGICAL RESEARCH PROJECTS",** Project 621.16, above) could then be used as a validation tool to determine and monitor the sex-marking accuracy. In 2015, a sex-marking protocol was developed that consisted of identifying females by making cuts in the dorsal fin and males by a cut in the operculum (McCarthy 2015). In 2016, at-sea marking was implemented aboard commercial longline vessels in a voluntary fashion in British Columbia (Loher et al., 2017). A total of 10 commercial vessels participated in the study by sex marking a total of 325 Pacific halibut that were sampled for fin clips at the ports by IPHC port samplers. The two molecular (SNP) assays were then applied to fin clip samples taken from the fish that had been marked at sea in order to identify their genetic sex. By comparing the sex-related markings to the genetic sex for each of these fish, and assuming 100% sexing accuracy via genetic assay, commercial sex-marking accuracy was determined to be 79% overall and varied from 48-100% among participating vessels. In 2017, the sex-marking project requested voluntary participation from the commercial longline fleet coastwide. During the course of the commercial season, a total of 929 samples were obtained from 84 sex-marked offloads coastwide.

Sex (SNP) assays on these samples are being conducted at the new biological laboratory at IPHC. At-sea marking has been halted pending analysis of 2017 results by the Quantitative Sciences Branch and their subsequent determination regarding the most appropriate direction in which to proceed in order to obtain the quality of sex-ratio data required for assessment and policy analysis.

1.2. Maturity estimations. Each year, the fishery-independent setline survey collects biological data on the maturity of female Pacific halibut that are used in the stock assessment. In particular, a female maturity schedule is used to estimate spawning stock biomass. Currently used estimates 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 of the ovaries collected in the field, implying a relative level of uncertainty associated with the employed semi-quantitative assessment. Furthermore, estimates of maturity-at-age have not been revised in recent years and may be outdated. For this reason, current research efforts are devoted to understand reproductive development and maturity in female Pacific halibut.

A recently completed project provided a first description of the changes that take place in the ovary during reproductive development leading to spawning in Pacific halibut by comparing oocyte stages and characteristics between fish caught during the non-spawning season (summer) and the spawning season (winter) in three different spawning areas (eastern Bering Sea, central Gulf of Alaska, and southern Gulf of Alaska) (Planas et al., 2017). In order to further characterize the gonadal maturation schedule, the IPHC is undertaking a full characterization of the annual reproductive cycle in female and male Pacific halibut. At monthly intervals, female (N=30) and male (N=30) Pacific halibut have been captured from the Portlock region in the central Gulf of Alaska and a variety of samples are being collected for physiological analyses of reproductive parameters throughout an entire annual reproductive cycle. Each individual gonad will be staged according to standard staging criteria, photographed, and weighed (in addition to the round weight of the fish) in order to calculate the gonadosomatic index. Individual gonad (ovary and testes) samples are being collected for histology by fixation in 10% buffered formalin and subsequently embedded in paraffin and stained with hematoxylin and eosin for staging. Gonad and pituitary samples are also being collected in RNAlater for transcriptomic analyses by RNAseq and individual gene expression by qPCR in order to identify changes in the expression of reproductive genes throughout the reproductive cycle. In addition, plasma samples (from 0.5 – 1ml of blood) are being collected from the caudal vein and will be used to measure the levels of reproductive hormones (i.e. sex steroids, prostaglandins, etc.) and nutrients (i.e. glucose, lipids) in order to characterize the activity of the endocrine system in relation to maturation and gonadal development. The combination of these various parameters will substantially improve the accuracy of current staging techniques of reproductive status, in addition to update current estimates of maturity-at-age and of the incidence of skipped spawning. Overall, the current effort to engage in a comprehensive reproductive monitoring of the adult Pacific halibut population will result in improved estimates of the actual spawning biomass.

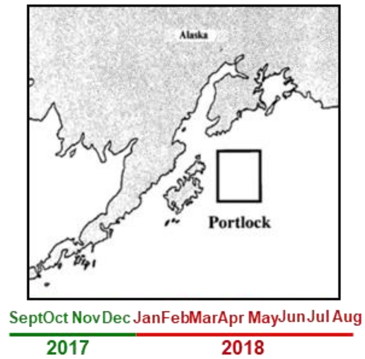

Figure 1. Pacific halibut monthly sampling schedule and location.

2. Growth. Important research efforts are aimed at understanding the possible role of somatic growth variation in the observed changes in size-at-age (SAA) and to develop tools for measuring growth and physiological condition in Pacific halibut. Changes in SAA in Pacific halibut have been hypothesized as being attributable to a variety of causes, including changes in population dynamics of the Pacific halibut stock due to a density effect, whereby high population densities would negatively affect growth, as well as changes in extrinsic factors (Loher, 2013). It is believed that extrinsic factors such as fishing can directly and indirectly impact SAA through size-selective harvest (as is the case in the Pacific halibut fishery), leading to the selective removal of faster growing individuals, and by its ability to alter ecological interactions, respectively. Importantly, environmental and ecological influences in the form of environmental changes (e.g. temperature) or in the competitive interaction with other species can have a direct impact on SAA by regulating somatic growth. Although other factors may be contributing, the results of a previous study funded by the North Pacific Research Board (NPRB) that had IPHC participation strongly suggested that temperature changes may have influenced halibut growth (Kruse et al., 2016). In view of our limited knowledge on the underlying physiological basis of somatic growth and, importantly, on the possible contribution of growth alterations in driving changes in SAA, we have initiated studies to develop and apply tools to evaluate spatial, temporal, and age-specific growth patterns and their response to environmental influences in Pacific halibut. The IPHC is leading efforts in this area within the framework of a 2-yr research project partially funded by NPRB that is led by the IPHC in collaboration with Dr. Thomas Hurst at the Hatfield Marine Science Center - Alaska Fisheries Science Center in Newport, OR. The awarded NPRB grant (NPRB 1704) period is from 1 September 2017 until 31 August 2019 (Appendix II) and its main aim is to investigate the effects of temperature, population density, social structure, and stress manipulations on biochemical and molecular indicators of somatic growth (IPHC-2018-SRB012-INF01). This study is expected to improve significantly our understanding of the physiological mechanisms regulating growth in the Pacific halibut in response to environmental and ecological influences but also, importantly, to identify molecular and biochemical growth signatures characteristic of growth patterns that could be used to monitor growth patterns in the Pacific halibut population. The specific objectives are (1) to investigate the physiological effects of **temperature** on growth in juvenile Pacific halibut by describing specific biochemical, transcriptomic (gene expression) and proteomic (protein) responses to temperature in skeletal muscle and liver, two key tissues that participate in growth regulation;

(2) to investigate the physiological effects of population **density** and **dominance hierarchies** on growth potential in order to understand how density and social interactions may influence growth potential in the nursery areas and (3) to investigate the physiological effects of **handling stress** on growth in juvenile Pacific halibut in order to understand the potential effects of handling-related stress on growth potential (Figure 2).

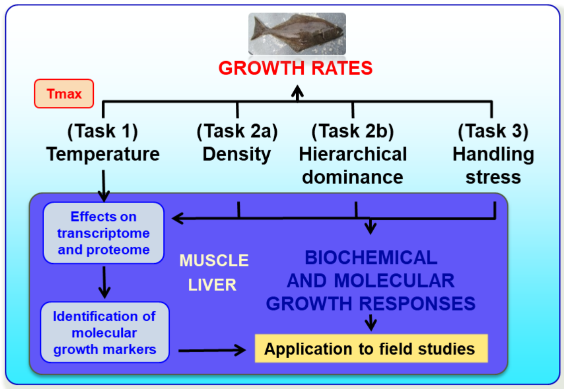

Figure 2. Diagram of the objectives of the NPRB project with indication of the different tasks.

Investigations on the effects of **temperature** variation on growth potential (Objective 1) are intended to show temperature-induced molecular and biochemical differences between juvenile Pacific halibut growing at different rates. The proposed experiments are aimed at describing molecular and biochemical features of skeletal muscle that are characteristic of growth patterns. The identified growth signatures will then be used as markers for growth in Pacific halibut in future studies aimed at understanding possible spatial and temporal changes in growth and, therefore, productivity.

Juvenile Pacific halibut (age 0, 5-7 cm length) were caught off Kodiak, AK and transferred to the aquatic facilities of the Hatfield Marine Science Center in Newport, OR. Fish were individually tagged (PIT tags) and acclimated at 9°C for 4 weeks. After the acclimation period, fish were divided into 2 groups (N=30 per group) and reared at 2°C and 9°C in triplicate tanks (N=10 per tank) for 8 weeks. After 2 weeks at each of these temperatures, fish were measured for weight and length (time 0) and growth monitored every 2 weeks, (at 4, 6, and 8 weeks from the beginning of the temperature experiment). During the experiment fish were fed ad-libitum daily rations. At the end of the experiment (week 8), 15 fish from each group were sacrificed by an overdose of anesthetic (MS-222), and muscle and liver samples were excised with one set of samples preserved for molecular analyses in RNAlater and stored at -20°C and a second set of samples frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses. Subsequently, the temperature in the tanks containing the remaining fish at 2°C was gradually increased to 9°C and growth monitored every 2 weeks (at 2, 4, 6 and 8 weeks from the beginning of the temperature-switch experiment). As in the previous experiment, after the 8 week period at 9°C, fish were sacrificed by an overdose of anesthetic (MS-222), and muscle and liver samples were excised with one set of samples preserved for molecular analyses in RNAlater and stored at -20°C and a second set of samples frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses.

The results of this study indicate that after subjecting juvenile fish to two different temperatures (2ºC and 9ºC) for a period of 8 weeks, a clear suppressive effect of low temperature on the specific growth rate (SGR) is induced. In addition, when juvenile halibut that were previously acclimated to 2ºC for 8 weeks were subsequently acclimated gradually to 9ºC for an additional period of 6 weeks, a significant increase in SGR, representing compensatory growth, was observed (Figure 3). Therefore, these results validate the experimental design and confirm the ability of temperature to manipulate growth rates in the Pacific halibut.

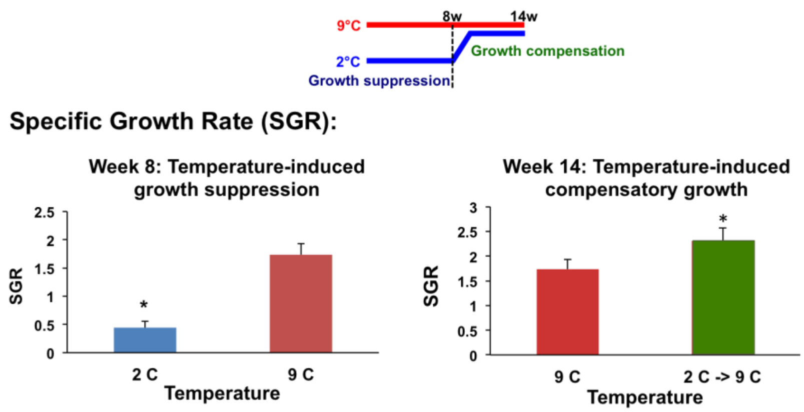

Figure 3. Effects of temperature manipulation on specific growth rate in juvenile Pacific halibut.

In order to identify molecular markers for growth, we initially set out to investigate changes in the expression of genes in skeletal muscle of juvenile Pacific halibut in response to the two growth manipulations: growth suppression by low temperature acclimation and growth stimulation by temperature-induced compensatory growth. A transcriptomic profiling approach was used by which RNA from skeletal muscle from individual fish from each group was extracted and sequenced. As a result of comparing the skeletal muscle transcriptome of fish acclimated at 2ºC with that of fish acclimated at 9ºC, we identified 1,187 genes that were differentially expressed in the temperature-induced growth suppression experiment. Among this gene set, 511 genes showed increased expression (up-regulated) and 676 genes showed decreased expression (down-regulated) under growth suppression. Functional classification of down-regulated genes revealed that categories of genes involved in muscle development and contraction, transcription and translation, protein and carbohydrate metabolism, energy metabolism and transfer, cell division and stress and immune response were all down-regulated under growth suppression. Analysis of the skeletal muscle transcriptome under growth stimulation conditions revealed that 610 genes were differentially expressed. Among this gene set, 202 genes were up-regulated and 408 genes were down-regulated under growth stimulation. Again, functional classification of up-regulated genes revealed that categories of genes involved in muscle development and contraction, protein metabolism and modification, carbohydrate metabolism for ATP generation, iron transport and binding, hemoglobin synthesis, cell adhesion and proliferation and transcription and translation were all up-regulated under growth stimulation. Therefore, there is a clear correspondence of biological processes that are affected under growth suppression and growth stimulation. Consequently, we have initiated the identification of genes that show changes in expression under both growth manipulations and that are consistent with the type of growth modification (i.e. down-regulated under growth suppression and up-regulated under growth stimulation). A set of 13 genes has already been identified that show expression patterns consistent with the type of growth modification and that can be considered the first set of potential molecular markers for somatic growth.

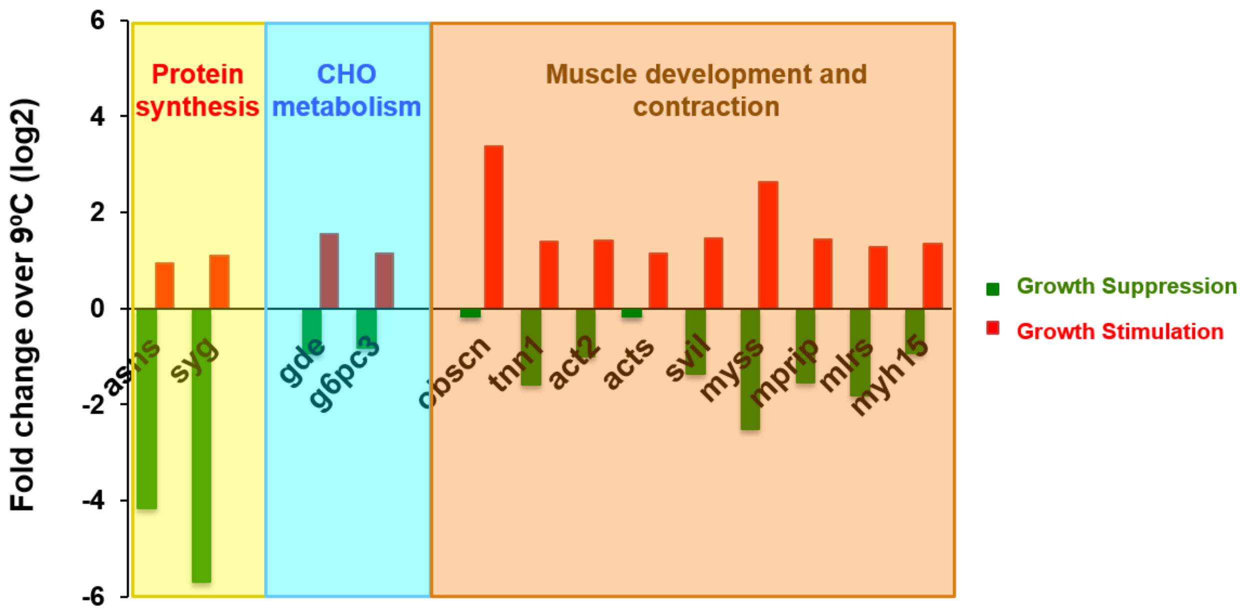

Figure 4. Expression pattern of individual genes under growth suppression and growth stimulation conditions. Genes are grouped according to their biological function.

At the present time, we are conducting investigations on the effects of **density** on growth. In a first set of experiments, fish were held in groups of 8 fish per tank (with 4 replicate tanks), 4 fish per tank (with 4 replicate tanks) and also individually (with 10 replicate tanks) under restricted feeding (at 50% of maximal feeding rate) for a period of 6 weeks. Growth data is currently being analyzed.

3. <u>Discard Mortality Rates (DMRs) and Survival</u>. DMRs are calculated from data that are collected by observers regarding the release viability or injury characteristics of Pacific halibut post-capture and are used to estimate the percentage of incidentally caught fish that die after release. Currently, post-capture DMR estimates are based on qualitative assessments of the physical condition of the fish (e.g., minor/moderate/severe/dead for longline gear) and have a certain degree of uncertainty associated with them, which represents a source of uncertainty in the estimation of total mortality within current stock assessment models. In

practice, assigned DMRs and their uncertainty translate into *a priori* adjustments to expected mortality in each upcoming year, and to the catch limits that are thereafter assigned to each harvest sector. Given current low halibut yields relative to long-term mean productivity, this potential to translate uncertainty into catch limit reductions can place undue hardship on some sector(s) relative to others. Therefore, there is an urgent need to improve our estimates of DMR as well as to provide strategies to improve survival of incidentally-caught Pacific halibut after release.

In order to address this important issue, we are conducting investigations to understand the relationship between fish handling practices and fish physical and physiological condition and survival post-capture as assessed by tagging in order to better estimate post-release survival in Pacific halibut caught incidentally in the directed and bycatch longline fisheries. The rationale of the proposed research is based on the notion that by understanding the relationship between handling practices, injury levels, and physiological condition, on one hand, and between these and post-release survival, on the other hand, estimates of DMR could be improved. An important underlying topic in this proposed research is to better understand how a detailed assessment of physiological condition prior to release can improve our estimates of survival after release. This research will attempt to develop and introduce quantitative measurable factors that are linked to fish handling practices, physiological condition and ultimately survival in order to improve current DMR estimates. These investigations are being conducted within the framework of a 2-yr project partially funded by the Saltonstall-Kennedy Grant Program that is led by IPHC in partnership with the Alaska Pacific University with a grant period of 1 September 2017 – 31 August 2019 (Appendix II) (IPHC-2018-SRB012-INF02). The specific objectives of this project are (1) to evaluate the effects of fish handling practices on injury levels and their association with the physiological condition of captured Pacific halibut, (2) to investigate the effects of fish handling methods and associated injury level and physiological condition on post-release survival, (3) to apply electronic monitoring in associating fish handling methods to survival in vessels without observer coverage and (4) to develop non-invasive methods for quantifying measurable physiological factors indicative of stress and physiological disturbance. The tasks delineated to pursue the abovementioned objectives are the following:

3.1. Evaluation of the effects of **hook release techniques** on injury levels and association with the physiological condition of captured Pacific halibut. The work involved evaluating the effects of different release techniques on injury levels and associated physiological condition levels from the large (16/0) circle hooks used in the Pacific halibut longline fishery.

Fish capture. One vessel chartered to operate in Alaskan waters (off Chignik, AK, within IPHC´s Regulatory Area 3B) was used for the study. The fishing location was selected based on the potential to catch adult fish of both legal (82 cm and above in length) and sub-legal (under 82 cm in length) sizes at rates that facilitate efficient completion of project goals. Functionally, however, the fleet has a tendency to discard fish under 84 cm to avoid landing fish that would appear to be sublegal (owing to shrinkage) post icing. Therefore, discarded fish were considered to be all fish under 84 cm in length. The vessel operated following the standard practices of the commercial Pacific halibut fleet; namely, in terms of the procedures and times of setting, soaking, and hauling baited longline gear. Two fishing trips consisting of 6 fishing days per trip, were conducted. On each day, 3 hauls of 8 standard skates (i.e., 100 hooks) each were fished for a total of 288 skates of gear. The vessel had a secondary roller with automatic hook-removal setup inboard of the outboard roller, and a ramp through the gunwhale to prevent damage from landing the fish. A total of 2,487 Pacific halibut were caught, of which 79 were tagged and released with a motion sensing accelerometer tag (96-day deployments) and 1,048 were tagged and released with a traditional wire tag (fishery recovered).

Hook release techniques. Pacific halibut were released from the hook using two different careful release methods as well as by the use of automated hook-stripping devices (i.e. hook stripper), yielding a total of three (3) treatments. Careful release methods included: careful shaking and gangion cutting (approved under IPHC regulation and described in detail in Kaimmer and Trumble, 1998). Hook straightening is also a permitted release method, but is not used to release sub-legal fish in the directed fishery (sub-legal fish do not have enough mass to straighten the hook but instead the hook tears straight out when force is applied), so this treatment was not continued after an initial day of testing. Hook release with the use of automated hook-stripping devices was also evaluated given that, although this is not an accepted hook release method, it occurs nevertheless whenever fish fail to be manually released. The rate at which this occurs in both directed and non-directed longline fisheries is currently unknown, but patterns associated with the occurrence of prior-hooking injuries (Dykstra 2016) suggests that hook-stripping may be more prevalent than is currently assumed and may also vary spatially. Given that hook-stripping is likely to induce the highest DMRs in longline fisheries and that its occurrence might be easy to quantify via electronic monitoring, obtaining baseline data for this release method was important. For this experiment, five skates of careful shaking, two skates of hook stripping, and one skate of gangion cutting where randomly assigned by skate of gear.

Hook injury assessment. All captured fish corresponding to each of the hook release techniques or treatments were sampled for length and weight, and the extent of the current hooking injury was recorded. We followed the hook injury classification scheme initially outlined by Kaimmer (1994) and expanded by Kaimmer and Trumble (1998) into 14 different categories (i.e. injury codes) corresponding to four major severity levels (e.g., minor, moderate, severe, and dead).

Blood determinations. After assessing injury levels of Pacific halibut released using each of the three above-mentioned treatments, a blood sample was taken from each fish for hematocrit determinations and for extracting the plasma. The levels of stress and physiological disturbance indicators (e.g., cortisol and catecholamines as endocrine indicators of stress responses, lactate and glucose as biochemical indicators of catabolic responses to stress, sodium, potassium ions and osmolarity as biochemical indicators of cellular disturbance; and pH) will be measured in plasma samples.

Monitoring of environmental conditions. In addition to recording the time elapsed between hook removal and return of tagged fish back into the ocean, sea bottom temperature was recorded with the use of dataloggers (Vemco Minilog-II), as well as ambient temperature, fish temperature, and sea state (Beaufort scale).

Assessment of physiological condition. The physiological condition of each selected fish from each of the three release techniques with associated injury levels will be determined in two different ways. First, we will calculate two different condition factor indices (i.e. Fulton's K, relative K) that express differently the relationship between length and weight and that have been recently used to evaluate the condition of landed Pacific halibut (Briones Ortiz, 2017). Second, we measured the energy (fat) levels by using a microwave-based device (Distell Fish Fatmeter, model 692, Distell, West Lothian, Scotland) that is applied directly onto the skin of the fish allowing energy determinations in the musculature without the need to sample tissues. This was a direct, non-invasive and harmless measure of energy levels that can be taken from live fish and that has also been recently used at IPHC to measure fish condition and shown to correlate well with relative K condition index as well as with the hepatosomatic index (Briones Ortiz, 2017). Surface body temperature was recorded with the use of a hand-held infrared thermometer.

3.2. <u>Investigations on the effects of fish handling methods and associated injury level and physiological condition on **post-release survival**</u>. In order to evaluate the survival of discarded fish, two types of tagging approaches were used: 1) mark-and-recapture of released fish with wire tags and 2) biotelemetric monitoring of released fish with the use of satellite-transmitting electronic archival tags equipped with accelerometers.

Mark and recapture of released fish with wire tags. All fish of 84 cm in length or less were assessed for injury levels, tagged using wire tags (as previously described by Forsberg et al., 2016) and released. In brief, wire tags were inserted between the opercular bones of the eyed side of the fish and the two ends of the tag were twisted together around the operculum. The use of wire tags has the potential to allow for the long-term assessment of survival in the ocean; however, we do not expect to recover enough wire tags from this study to formally estimate rates associated with various survival covariates, and that estimates of survival rates using this approach are confounded by natural mortality and variable reporting rates. Releases conducted during this study should be viewed as a foundation upon which additional releases might be added in the future.

Biotelemetric monitoring of released fish with the use of satellite-transmitting archival tags. A subset of captured Pacific halibut identified to be in excellent condition (e.g., minor injury category) were tagged with sPAT archival tags equipped with accelerometers (Wildlife Computers "survivorship PAT" tag, or sPAT) in order to evaluate post-release mortality rate, time elapsed between capture and inferred mortality, and post-release dispersal. Only the excellent viability category was studied because the cost of deploying sPAT tags (~ $4000 US per tag) prevents large sample sizes and restricts the scope of such studies. The excellent category was chosen as it represents the vast majority of targeted-fishery discards and, hence, the bulk of assumed mortality. Additionally, uncertainty regarding the survivorship of halibut that are discarded in excellent condition has the greatest impact upon current estimates of survivorship in the remaining viability categories. This is because the latter estimates have been derived by comparing tag recovery rates from fish tagged within these categories to the rate of recovery of tags from excellent fish, where the expected tag return rate for fish in excellent condition was modelled on the basis of assumed rates of natural mortality, fishing mortality, and tag reporting rates. In the current study, Pacific halibut were tagged with sPATs programmed to detach and report after 96 days at liberty. Although this exceeds the 60-day survival period recently used to study trawl DMRs (Rose et al., in preparation), shorter-period survivorship can be accurately calculated using longer time-series data if desired. The longer recording period will allow us to conduct DMR analysis that is comparable to that referenced in the trawl study while expanding the scope of the work to gain greater insight into the possibility of delayed mortality, as well as time-course to recovery or normal behavior, in individuals whose records exceed 60 days. A total of 79 Pacific halibut ranging from 53-81 cm FL were tagged from 20 October to 2 November, 2017. Sex of the fish was unknown at time of tagging, but fin clips were collected so that genetic sex can be determined *post* hoc via using molecular techniques (Drinan et al., 2018). One tag released from its host fish immediately likely due to a tethering failure and one tag failed to produce sufficient satellite uplinks to determine its location or download any archived acceleration data. As such, data from 77 tags are available for analysis. Times at liberty ranged from 43-96 days and straight-line displacement between tagging and reporting locations ranged from 0-1,042 km. Seven tags detached from their host fish prematurely, after periods ranging from 43-95 days, and therefore may have represented post-release mortalities. However, inspection of the acceleration data from these tags indicates that four of the fish were active through tag release (i.e., up to and including the last recording period prior to the tag reaching to sea surface) and the tags therefore most likely shed from live individuals. As such, excellent-condition longline DMR of U32 Pacific halibut in this experiment is estimated to be 4%.

Figure 4. Schematic diagram of the workflow of activities in Tasks 1 and 2.

3.3. Application of **electronic monitoring** (EM). In this project, a profile of injuries associated with different release methods is being developed, while at the same time quantifying the accuracy of EM in enumerating release methods, and fish conditions (Figure 5). Both of these aspects will be necessary to transform EM imagery into useable/actionable data. The work involved three different aspects. First, installation of an EM System involving a standard 3-camera EM system (Archipelago Marine Research Ltd). Second, the development of an injury profile by release method whereby Pacific halibut caught on fixed gear were evaluated for viability and subsequent survival for the three release methods implemented. Third, evaluation of EM data whereby reviewers recorded the release method and condition of released fish. This data set will be compared to those collected by personnel at sea as part of their tagging efforts (equivalent to the human observer data).

4. Migration

Knowledge of Pacific halibut migration throughout all life stages is necessary in order to gain a complete understanding of stock distribution and the factors influencing that distribution. There are a number of projects currently taking place that address migration and distribution at various stages of Pacific halibut development.

4.1. Overall larval distribution, differences in distribution related to environmental factors, and modelling the magnitude of connectivity between the Gulf of Alaska and Bering Sea populations through larval drift. The major Gulf of Alaska currents (primarily the Alaska Coastal Current) flow westward and eventually through Aleutian Island passes into the Bering Sea (Stabeno et al. 2002). Unimak Pass is the easternmost conduit between the two basins and is also the only direct linkage between the Gulf of Alaska and Bering Sea continental shelves. This work involves using data collected by NOAA during their ichthyoplankton surveys in the Gulf of Alaska and Bering Sea from 1972-2015, and examines the connectivity of the two Pacific halibut sub-populations through larval flow via Unimak Pass. The data include standardized catch (# organisms/m^2) for each tow and a subsample of larval lengths. The standardized catch is used as a proxy for abundance when comparing over time and space. All organisms caught during these surveys are sampled and enumerated, but the surveys are designed to target species other than Pacific halibut such as pollock, salmon, and cod. As a result, annual station location design has fluctuated somewhat to target these various species, creating a mismatch in geographic scope over time.

While basic descriptions of larval distribution overall can be accomplished with the standardized data, comparisons over time and space using multi-year subsets are more difficult. As a solution, the IPHC-developed spatial model was utilized to help analyze these subsets. Comparisons within the model include averages of density and distribution between warm (2001-2005) and cold (2007-2013) stanzas and differences between the ocean basins. While density estimates of larvae were slightly different (i.e. higher in warm years than in cold years), there was also high variability and the estimates were well within the confidence intervals, thus it was concluded that there was no difference. However, the model did detect local differences in densities, specifically higher densities in warm years compared to cold around Unimak Pass, Shelikof Strait, and north of Kodiak Island, and lower densities further west in the Bering Sea.

The next step, in collaboration with researchers at NOAA/EcoFOCI is to use a NOAA-created larval transport model to examine differences in currents during different climatic regimes (e.g. warm vs cold) and the resulting differences in larval advection. Of particular interest is the differences in magnitude of larval transport through Unimak Pass, the likelihood that larvae will be transported onto the Bering Sea shelf vs westward toward Russia, and how far east in the Gulf of Alaska a Pacific halibut larva can originate and still make it through Unimak Pass prior to settlement. The advection modeling portion of this project is tentatively scheduled for Fall 2018.

Also of interest is the catch weighted mean length by month, the developmental stages encountered in each basin for each month, and whether timing of development might differ between basins. Laboratory growth studies (e.g. Liu et al. 1994, McFarlane et al. 1991) will be used to develop length proxies for age in order to analyze this component.

4.2. Migration studies targeting U32 Pacific halibut. Migration of O32 Pacific halibut has been the focus of numerous studies over the years, but less is known about the migration habits of U32 fish. Research in this category is designed to study the migration of the **post-settlement component of the population and includes** investigations of the dispersal of individuals not yet recruited to the commercial exploitation (U32). This category contains a mixture of both immature (juvenile) and mature individuals considering that a portion of the female Pacific halibut stock matures at lengths >32” FL while male maturity is currently understood to be largely complete at much smaller sizes. As such, the maturity ogive for male Pacific halibut falls entirely within the U32 category and for females occurs largely within O32.

Wire tagging of U32 Pacific halibut. NMFS trawl surveys tend to catch Pacific halibut ranging in size from about 20-100 cm FL, with the majority of the catch in the lower end of the range. The IPHC deploys a sea sampler aboard one of these vessels for each survey specifically to carry out biological sampling of Pacific halibut. The surveys include the Bering Sea annually, the Gulf of Alaska biennially, and the Aleutian Islands biennially. A total of 50% of the Pacific halibut caught on the IPHC-staffed vessel are randomly selected for the wire tagging, and all U32 fish in that sample that are viable according to NMFS observer criteria for trawls, are tagged and released. Beginning in 2017, NMFS also agreed to tag Pacific halibut on the vessel in the Bering Sea survey that did not have an IPHC sampler aboard. The tagging there is more opportunistic due to other demands on their time, but the goal is the same as on the IPHC-staffed vessel. From 2015 through 2017, a total of 4,040 tags were released from all trawl surveys combined: 2,204 in the Gulf of Alaska, 1,666 in the Bering Sea, and 170 in the Aleutian Islands. A total of 24 tags have been recovered thus far. The project is expected to continue for the next several years.

In addition to wire tagging on the trawl surveys, U32 Pacific halibut caught during the IPHC setline surveys are also tagged in areas where otolith sampling is less than 100% (Forsberg 2018). In these areas, U32 Pacific halibut are selected randomly for tagging at area-specific rates with the goal of tagging 500 U32 fish per Regulatory Area. This tagging project began in 2016 on a pilot basis and coastwide in 2017, and was designed to complement the trawl tagging effort. The U32 Pacific halibut caught during the setline surveys tend to have fork lengths near the upper end of the U32 size range. To date, 2,096 Pacific halibut have been tagged and released. Of those, 11 have been recovered. All current wire tagging efforts are intended as ongoing and decadal-scale efforts that will provide a general understanding of dispersal patterns (*sensu* Hilborn et al. 1995) and insight regarding the possibility that long-term changes in dispersal may occur at coastwide or basin-specific scales.

Electronic archival tagging. This study is scheduled to begin in summer 2018, and is expected to provide novel information regarding ontogenic and seasonal dispersal of U32 halibut. With respect to the ontogenic dispersal, it is generally understood that Pacific halibut conduct contranatant migrations to the south and east (Hilborn et al.

1995) and mark-recovery data can provide an indication of the total magnitude of dispersal during an individual's period at liberty. However, conventional tag data provide no information regarding annual redistribution when periods at liberty are in excess of one year. Dispersal-at-age is an important function whose form and magnitude must be specified in spatially-explicit population models that allow for migration among areas. Electronic archival tags allow for daily light-based geopositioning to be conducted, thereby allowing dispersal to be estimated on annual and sub-annual scales. Additionally, recorded depths allow for seasonal migration to be quantified and associated with age and sex. Adult Pacific halibut are known to undertake cyclic onshore-offshore migrations that correspond to the species' annual spawning cycle (Loher 2011) and that the nature of these migrations relative to commercial fishing periods can influence area-specific realized exploitation rates relative to those that are estimated assuming that the stock is non-migratory during the course of each fishing season (Leaman et al. 2002). It is currently unknown at what age Pacific halibut begin to undertake such migrations and whether the initiation, timing, and frequency of seasonal migration might vary according to sex.

4.3. Migration research on O32 Pacific halibut. Studies designed to examine migration have focused upon quantifying seasonal migratory periods and the potential for seasonal fisheries interception, identification of spawning sites, and describing seasonal and interannual dispersal within the Bering Sea and between the Bering Sea and Aleutian Islands (BSAI) region and the Gulf of Alaska. This work has employed PAT tags and has been conducted incrementally given that the high cost of these tags prevents large-scale, coastwide deployments. To date, approximately 400 PAT tags have been deployed to study O32 migration, with more than half of those tags deployed in the BSAI. These deployments have expanded our understanding of the geographic extent of halibut spawning at the southern end of the range (Loher and Blood 2009) as well as on the Bering Sea shelf edge and in the Aleutian Islands (Seitz et al. 2011); have indicated apparent basin-scale segregation of spawning stock (Loher and Clark 2010, Seitz et al. 2017); provided observational data that are consistent with genetic results (Drinan et al. 2016) in suggesting relative isolation of Pacific halibut in the western Aleutian Islands; and confirmed mixing of stock between the Salish Sea and outer coastal population (Loher and Soderlund in review). Tag deployments on Bowers Ridge in 2017 (**Project 650.21**, above) were conducted in this context and future deployments are anticipated that will fill additional geographic gaps in this program; in particular, in northern California (Area 2A), Bering Sea coastal waters (4E), and the far northern Bering Sea shelf edge (4D).

ADDRESSING PARTICULAR REQUESTS RESULTING FROM SRB11

A diagram representing the integration of biological research activities conducted in the five main research areas at IPHC with stock assessment and harvest policy was initially presented at the AM094 and is shown in Appendix III.

In addition to reviewing current and planned research activities conducted by the Biological and Ecosystem Science Branch, the IPHC Secretariat would like to seek guidance from the SRB and engage in discussion regarding the following topics:

- Linking current work on migration, growth, and physiological condition of Pacific halibut to spatial and temporal changes in productivity of the stock.
- Gaps in our knowledge regarding our understanding of (1) spawning site contributions to nursery/settlement areas in relation to year-class and recruit survival and strength and (2) the relationship between nursery/settlement origin and adult distribution and abundance over temporal and spatial scales.
- Application of genetic approaches to address management-relevant questions on population structure, distribution, etc.

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APPENDICES

Appendix I: Summary of new and continuing research projects approved for FY2018

Appendix II: Summary of external research projects awarded for funding

Appendix III: Integration of biological research, stock assessment and harvest policy

APPENDIX I

Summary of new and continuing research projects approved for FY2018

Project #	Project Name	Priority	Budget (US$)	Principal Investigator	Management implications
New Projects					
673.15	Influence of thermal history on growth	High	136,004	Loher	Changes in biomass/size-at-age
650.22	Larval connectivity	High	20,000	Sadorus	Larval distribution
Continuing Projects					
621.16	Development of genetic sexing techniques	High	146,107	Loher	Sex composition of catch
642.00	Assessment of Mercury and other contaminants	Medium	8,400	Dykstra	Environmental effects
650.21	Investigation of Pacific halibut dispersal on Bowers Ridge	High-Medium	124,527	Loher	Spawning areas
661.11	*Ichthyophonus* Incidence Monitoring	Medium	8,055	Dykstra	Environmental effects
669.11	At-sea Collection of Pacific Halibut Weight to Reevaluate Conversion Factors	High	1,500	Soderlund	Length-weight relationship
670.11	Wire tagging of Pacific halibut on NMFS trawl and setline surveys	High	12,000	Forsberg	Juvenile and adult distribution
672.12	Condition Factors for Tagged U32 Fish	High	13,000	Dykstra	DMR estimates
673.13	Sequencing the Pacific halibut genome	High	22,500	Planas	Population estimate
673.14	Identification and validation of markers for growth	High	27,900	Planas	Changes in biomass/ size-at-age
673.13	Sequencing the Pacific halibut genome	High	22,500	Planas	Population estimate
674.11	Full characterization of the annual reproductive cycle	High	123,988	Planas	Maturity assessment
675.11	Tail pattern recognition analysis in Pacific halibut	High	2,370	Dykstra	Adult distribution
	Total - New Projects		**297,518**		
	Total - Continuing Projects		**202,482**		
	Overall Total (all projects)		**500,000**		

APPENDIX II

Summary of external research projects awarded for funding

Project #	Grant agency	Project name	Partners	IPHC Budget ($US)	PI	Management implications	Grant period
1	**S-K NOAA**	Improving discard mortality rate estimates in the Pacific halibut by integrating handling practices, physiological condition and post-release survival (Award No. NA17NMF4270240)	Alaska Pacific University, Anchorage, AK	$286,121	Planas (lead PI) Dykstra Loher Stewart Hicks	Bycatch estimates	September 2017 – August 2019
2	**NPRB**	Somatic growth processes in the Pacific halibut (*Hippoglossus stenolepis*) and their response to temperature, density and stress manipulation effects (Award No. 1704)	AFSC-NOAA-Newport, OR	$131,891	Planas (lead PI) Rudy Loher	Changes in biomass/size-at-age	September 2017 – August 2019
			Total awarded ($)	**$418,012**			

APPENDIX III

Integration of biological research, stock assessment and harvest policy

Research areas	Research outcomes	Relevance for stock assessment	Inputs to reduce stock assessment uncertainty	MSE development	Inputs to inform MSE development	MSE goals
Reproduction	Sex ratio Spawning output Age at maturity	Spawning biomass scale and trend Stock productivity Recruitment variability	Sex ratio Maturity schedule Fecundity	Operating Model Management Procedures	Sex ratio Maturity schedule Fecundity	Biological sustainability
Growth	Identification of growth patterns Environmental effects on growth Growth influence in size-at-age variation	Temporal and spatial variation in growth Yield calculations Effects of ecosystem conditions Effects of fishing	Predicted weight-at-age	Operating Model Management Procedures	Predicted weight-at-age Mechanisms for changes in weight-at-age	Biological sustainability
Discard Survival	Bycatch survival estimates Discard mortality rate estimates	Scale and trend in mortality Scale and trend in productivity	Bycatch and discard mortality estimates	Operating Model Management Procedures	Bycatch and discard mortality estimates Variability in bycatch and uncertainty in discard mortality estimates	Minimize bycatch mortality Minimize discard mortality
Migration	Juvenile and adult migratory behavior and distribution Larval distribution	Stock distribution Geographical selectivity	Information for structural choices Recruitment indices	Operating Model Management Procedures	Information for structural choices Migration pathways and rates Timing of migration	Biological sustainability Preserve biocomplexity
Genetics and Genomics	Genetic structure of the population Sequencing of the Pacific halibut genome	Spatial dynamics Management units	Information for structural choices	Operating Model Management Procedures	Information for structural choices	Biological sustainability Preserve biocomplexity

Signature Page
Proposal No: 1375 **Submitted:** Dec 14, 2016
Start Date: Sep 2017 **End Date:** Aug 2019
Title: Somatic growth processes in the Pacific halibut (Hippoglossus stenolepis) and their response to temperature, density and stress manipulation effects
Applicant: Dr. David T. Wilson, International Pacific Halibut Commission
Principal Investigator(s): Dr. Josep V. Planas (Lead) , josep@iphc.int, International Pacific Halibut Commission Dr. Thomas P. Hurst, thomas.hurst@noaa.gov, Alaska Fisheries Science Center NOAA - NMFS
Category: Fishes and Invertebrates
Abstract: The Pacific halibut (Hippoglossus stenolepis) are distributed throughout the North Pacific Ocean and its fishery is one of the most important commercial fisheries in this region. The International Pacific Halibut Commission has been managing the Pacific halibut fishery since 1923 and throughout its history it has recorded changes in the size-at-age (SAA) of fish caught in the commercial fishery as well as in its own survey research efforts. Importantly, a consistent decrease in SAA has been observed since the late 1990s that has led to steady declines in the exploitable biomass of the Pacific halibut stocks. Although the decrease in SAA has been attributed to several potential causes, including environmental effects, such as temperature or food availability, as well as ecological or fishery effects, our knowledge on the actual factors that influence SAA of Pacific halibut is still scarce. This proposal aims at elucidating the potential contribution of somatic growth in driving changes in SAA by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. In order to evaluate growth physiological responses in response to factors that could participate in the observed decrease in size-at-age in Pacific halibut, we will investigate the effects of temperature, density, social structure and stress manipulations on biochemical and molecular indicators of growth. Emphasis will be placed on the physiological responses to temperature, given the demonstrated importance of this environmental parameter in determining growth patterns in the Pacific halibut. This study will lead to a significant improvement in our understanding of the physiological mechanisms regulating growth in the Pacific halibut in response to environmental and ecological influences but also, importantly, to the identification of molecular and biochemical growth signatures characteristic of growth patterns that will be used to monitor growth patterns in the Pacific halibut population.
Links to Prior NPRB Projects: The present project is linked to the recently completed NPRB Project 1309 entitled “Fishery, Climate and Ecological Effects on Pacific Halibut Size-at-Age” (2013-2016). NPRB Project 1309 developed bioenergetic and integrated growth models to evaluate the effects of environmental, ecological and fishery effects on Pacific halibut growth. The results obtained led to the conclusion that changes in SAA in Pacific halibut may be the result of ecological and fishery effects and that, although the data analyzed did not allow to separate the contributions of the various effects, these effects may act in concert to affect SAA. Importantly, this project gave support to the possibility that environmental temperature changes may have influenced halibut growth and, as a consequence, SAA. The present project builds on the initial conclusions of NPRB Project 1309 and will demonstrate the basis of the temperature-, density- and stress-regulated growth by investigating separately and systematically the effects of these various variables on growth of juvenile Pacific halibut in captivity.
Total Funding Requested From NPRB: $230,127

1. International Pacific Halibut Commission: $131,891
2. Alaska Fisheries Science Center: $98,236

Total Other Support: $132,606

1. International Pacific Halibut Commission: $68,945
2. Alaska Fisheries Science Center: $63,661

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IV. MAIN RESEARCH AREAS (KEYWORDS)

FISH PHYSIOLOGY, FISH REPRODUCTIVE BIOLOGY, FISH GENOMICS

Selected Publications (last 5 years)

Palstra, A.P., Chiba, H., Dirks, R., **Planas, J.V**., Ueda, H. The olfactory transcriptome and progression of sexual maturation in homing chum salmon *Oncorhynchus keta*. PLoS ONE. 2015 10(9): e0137404.

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Palstra AP, Rovira M, Rizo, D, Burgerhout E, Torrella JR, Spaink HP, **Planas JV**. Exercise-induced growth and vascularization of fast skeletal muscle through activation of myogenic and angiogenic transcriptional programs in adult zebrafish. BMC Genomics. 2014. 15: 1136.

Benzekri H, Cousin X, Armesto P, Rovira M, Crespo D, Merlo MA, Mazurais D, Bautista R, Guerrero-Fernández D, Ponce M, Infante C, Zambonino JL, Nidelet S, Gut M, Rebordinos L, **Planas JV**, Begóut ML, Claros MG, Manchado M. De novo assembly, characterization and functional annotation of Senegalese sole (*Solea senegalensis*) and common sole (*Solea solea*) transcriptomes. Integration in a database and design of a microarray. BMC Genomics. 2014. 15: 952.

Magnoni LJ, Palstra AP, **Planas JV**. Fueling the engine: induction of AMP-activated protein kinase in trout skeletal muscle by swimming. J. Exp. Biol. 2014. 217: 1649-1652.

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Manchado, M., **Planas, J.V**., Cousin, X., Rebordinos, L., Gonzalo Claros, M. Current Status in other Fish Species: Description of current genomic resources for the gilthead seabream (Sparus aurata) and soles (Solea senegalensis and Solea solea). In: “Genomics in Aquaculture”. MacKenzie, S., Jentoft, S., eds. Academic Press. ISBN: 978-0-12-8014189. 2016, in press.

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Magnoni, L.J.; Felip, O.; Blasco, J.; **Planas, J.V**. Metabolic Fuel Utilization During Swimming: Optimizing Nutritional Requirements for Enhanced Performance. In: “Swimming Physiology of Fish: Towards Using Exercise to Farm a Fit Fish in Sustainable Aquaculture” Palstra A.P.; Planas, J.V.; eds. Springer, Berlin. ISBN: 978-3-642-31048-5. 2013, pp. 203-236.

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Other scientific and academic activities

Academic advisory roles:

- PhD supervisor: 8 PhD theses.
- MSc supervisor: 9 MSc theses

Member of the *Editorial Board* of the following journals:

- *Reproductive Biology and Endocrinology* (since 2002).
- *PLoS* One (Academic Editor since 2011).
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- *Research Journal of Endocrinology and Metabolism (since 2013).*
- *Fishes (since 2015).*

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Current research projects:
1. Temperature effects on growth of Bering Sea flatfishes
2. Impacts of ocean acidification in Alaskan fishes.
3. Use of shallow-water nursery areas by Bering Sea flatfishes and gadids.

Recent Funding:
2015-2017. Effects of ocean acidification on Alaskan groundfishes, II. NOAA-OAP
2014-2015. Effects of ocean acidification on behavior of flatfishes. NOAA-LMRCSC
2012-2013. Shallow-water nursery areas in the Bering Sea. NOAA-AK Region
2009-2014. Effects of ocean acidification on Alaskan groundfishes. NOAA-OAP
2008-2011. Patterns of SE Bering Sea Pacific cod recruits. NPRB
2007-2009. Potential trawl impacts upon flatfish nurseries. NPRB (co-PI).

Relevant Publications (of 47 peer-reviewed publications; * NPRB Supported)

Hurst, T.P. 2016. Shallow-water habitat use of Bering Sea flatfishes along the central Alaska Peninsula. Journal of Sea Research 111:37-46. Special Issue-Proceedings of International Flatfish Symposium. doi: 10.1016/j.seares.2015.11.009

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Resubmission

no

Descriptors

Category

Fishes and Invertebrates

Issue

- Ecology and physiology of forage species

Species

Pacific halibut (Hippoglossus stenolepis)

Large Marine Ecosystem(s)

Gulf of Alaska

Research Approach

Monitoring, Process Studies

Keywords

density, growth, gulf of alaska, liver, muscle, Pacific halibut, physiology, size-at-age, stress, temperature

Background

The Pacific halibut (*Hippoglossus stenolepis*) is a flatfish species that is distributed throughout the North Pacific Ocean and its fishery is one of the most important commercial fisheries in the Northeast Pacific Ocean region. The International Pacific Halibut Commission has been managing the Pacific halibut fishery in the Northeast Pacific Ocean off the United States and Canada since 1923 (Fig. 1) and throughout its history it has recorded changes in the size-at-age (SAA) of fish caught in the commercial fishery as well as in its own survey research efforts. Existing data shows that SAA steadily increased from the 1920s until historical highs in the 1990s, and that it subsequently declined in a consistent fashion until recently to levels comparable to the first recorded SAA values in the 1920s. From a fishery perspective, changes in SAA have important consequences on the yields of the Pacific halibut fishery due to the changes in the amount of exploitable biomass, although the historical record indicates that changes in SAA occur at a relatively slow rate (Stewart et al., 2016). Therefore, the current low values of SAA combined with low recruitment of cohorts spawned at the time of the initial decrease in SAA in the 1990s have contributed to a decrease in exploitable Pacific halibut biomass. As an example, the estimated female average weight of a 12 yr-old Pacific halibut female has decreased from approximately 40 lb (net weight) in 1975 to less than 20 lb (net weight) in 2015 (Stewart and Monnahan, 2016; Fig. 2).

Despite the recognition of the marked decrease in SAA in the Pacific halibut population and its importance for fisheries management, our understanding of the potential causes for this decline in SAA (and the long-term variability) is still rather scarce. Changes in SAA in Pacific halibut have been hypothesized as being attributable to a variety of causes, including changes in population dynamics of the Pacific halibut stock due to a density effect, whereby high population densities would negatively affect growth, as well as changes in extrinsic factors (Loher, 2012). It is believed that extrinsic factors such as fishing can directly and indirectly impact SAA through size-selective harvest (as is the case in the Pacific halibut fishery), leading to the selective removal of faster growing individuals, and by its ability to alter ecological interactions, respectively. Importantly, environmental and ecological influences in the form of changes in ambient parameters (e.g. temperature) or in the competitive interaction with other species can have a direct impact on SAA by regulating somatic growth. Although other factors may be contributing, the results of a recently completed NPRB-funded study strongly suggest that environmental temperature changes may have influenced halibut growth (Kruse et al., 2016). However, we presently lack the tools required to evaluate the spatial, temporal, and age-specific growth patterns to fully evaluate this hypothesis. Further, it appears likely that other environmental and ecological factors are involved in the observed decline in SAA. Unfortunately, little is known regarding the underlying physiological basis of somatic growth in response to these other environmental factors in this species.

Fundamentally, growth in fish is the result of a complex set of biochemical processes that result in synthesis of new body tissues. These processes are regulated by the expression of key genes that control aspects of energy acquisition, metabolic rates, digestive activities, energy transfer and protein synthesis. The molecular and biochemical fine-tuning of growth responses to habitat changes is particularly relevant during periods of environmental variability or habitat shifts. During these changes, fish may undergo compensatory or catch-up growth following an earlier period of growth suppression induced by starvation, altered temperatures or oxygen availability (Ali et al., 2003) with the objective to restore growth patterns. Previous work by one of the Principal Investigators demonstrated that growth rates of juvenile Pacific halibut are more sensitive to environmental temperature than other co-occurring flatfish species (Ryer et al., 2012). In addition, juvenile Pacific halibut have the potential for compensatory growth following a period of reduced growth associated with low-temperature habitats (Hurst et al. 2005). Therefore, this study represented one of the first demonstrations of the direct effects of temperature on somatic growth in the Pacific halibut. In this species, compensatory growth was accomplished, at least in part, by a reduction in the deposition of storage lipids: halibut increase muscle growth at the expense of energy storage. The liver is the primary site of lipid energy storage in juvenile flatfishes (Haug et al., 1988) such that liver mass is frequently used as an indicator of fish energetic condition (expressed as Hepato-Somatic Index, HSI). Hurst (2004) has further shown that liver mass (reflecting lipid storage) changes with temperature and feeding history. Combined, these results demonstrate that an understanding of the biochemical processes occurring in the primary growth (muscle) and energy storage (liver) tissues could provide a much more comprehensive understanding of the physiological state of Pacific halibut in relation to its growth pattern and/or potential in response to environmental and ecological influences.

In view of this, the main goal of this study is to investigate the physiological basis of growth alterations in the Pacific halibut in order to improve our understanding of the contribution of growth changes in the observed decrease in size-at-age in the Pacific halibut population.In this study, the physiological growth responses to various influencing conditions will be evaluated at the biochemical and molecular levels, including at the gene expression and protein levels, in order to identify specific biochemical and molecular growth signatures that can be used to identify growth responses and monitor growth patterns in the Pacific halibut population (Fig. 3).

Objectives

1. To investigate the physiological effects of temperature on growth in juvenile Pacific halibut by describing specific biochemical, transcriptomic (gene expression) and proteomic (protein) responses to temperature in skeletal muscle and liver, two key tissues that participate in growth regulation.

2. To investigate the physiological effects of density and dominance hierarchies on growth potential in order to understand the influence of population density and social interactions may influence growth potential in the nursery areas.
3. To investigate the physiological effects of handling stress on growth in juvenile Pacific halibut in order to understand the potential effects of handling-related stress on growth potential

Design and Approach

In order to evaluate growth physiological responses in response to factors that could contribute to the observed decrease in size-at-age in Pacific halibut, we will investigate the effects of temperature, density, social structure and stress manipulations on biochemical and molecular indicators of growth. Emphasis will be placed on the physiological responses to temperature, given the demonstrated importance of this environmental parameter in determining growth patterns in the Pacific halibut (Hurst et al., 2005; Ryer et al., 2012; Kruse et al., 2016). The effects of temperature will be evaluated in part using state-of-the-art, high-throughput technologies that will allow us to identify novel specific patterns of growth responses at the gene expression and protein levels at an unprecedented depth. The transcriptomic and proteomic approaches proposed will allow us to identify thousands of genes and hundreds of proteins that are regulated by temperature. This will lead to a significant improvement in our understanding of the physiological mechanisms regulating growth in the Pacific halibut but also, importantly, to the identification of molecular and biochemical growth signatures characteristic of growth patterns that will be used to monitor growth trajectories in the Pacific halibut population. The effects of density, social hierarchies and handling stress on growth will be investigated by focusing on known growth regulators and stress factors at the molecular and biochemical levels. We will identify the responses that are common across the range of growth manipulations as well as those that are specific to a single type of influence on growth rate. Biochemical characterization of growth responses will involve quantification of the levels of energy reserves (e.g. glycogen, triglycerides) and substrates (e.g. ATP/AMP, phosphocreatine). Importantly, we will also measure the activity levels of AMP-dependent protein kinase (AMPK), a key energy-sensing enzyme that under conditions of increased energy use (i.e. energy consumption with the consequent generation of AMP from ATP) will increase catabolic pathways to restore ATP levels, under the different growth manipulation conditions.

Experimental approaches

This proposal takes advantage of the integration of the distinct research backgrounds and technical expertise at the AFSC and IPHC. Dr. Hurst in the Resource Assessment and Conservation Ecology Division of AFSC has extensive experience examining the environmental influences on growth and habitat use of flatfishes including Pacific halibut, focusing on the influences of temperature. Joining the Biological and Ecosystem Research Program at IPHC in 2016, Dr. Josep Planas brings his extensive experience in growth physiology and genomics to issues of fisheries ecology in the North Pacific.

All laboratory experiments will be conducted with wild juvenile Pacific halibut collected from nearshore nursery habitats in the Gulf of Alaska (in the vicinity of Kodiak Island). Fish will be collected with small-mesh trawls, held overnight in ambient seawater and transported by air to the AFSC laboratory in Newport, Oregon where the experiments will be conducted. The 20,000 ft^2 laboratory has extensive facilities for conducting physiological and behavioral studies of cold-water marine fishes including temperature control between 0 & 16°C. This laboratory has been the site of multiple previous experiments with juvenile and sub-adult Pacific halibut.

The studies to be conducted in this proposal are distributed among the following tasks that relate specifically to the three specified objectives:

Task 1. Effects of temperature variation on growth potential.

Temperature has a direct influence on all aspects of physiology and is generally considered a primary regulator of growth rates in fishes, as it sets the upper bounds of growth rates (e.g. “potential growth”). While the growth rates of all ectothermic species are sensitive to temperature, laboratory studies have demonstrated that Pacific halibut are more temperature sensitive than other North Pacific flatfishes (Hurst et al. 2005; Ryer et al. 2012). While they can express rapid growth rates at high temperatures, they actually grow slower than northern rock sole (*Lepidopsetta polyxystra)* at temperatures below 5°C. While most experimental studies of growth are focused on early juvenile stages, it is well recognized that temperature affects the growth rates of later life stages as well. Matta et al. (2010) demonstrated temperature-associated synchrony in annual growth rates of sub-adult and adults of 3 Bering Sea flatfish species (yellowfin sole *Limanda aspera*, northern rock sole, and Alaska plaice *Pleuronectes quadrituberculatus*). In addition, recent analyses have suggested that temperature variation has been a contributing factor to the observed changes in Pacific halibut size at age (Kruse et al. 2016). The proposed experiments will describe the thermal conditions leading to maximal growth and the temperature-induced molecular and biochemical differences between juvenile Pacific halibut growing at different rates. Furthermore, although Ryer et al. (2012) did not find a positive correlation between growth rates and risky behavior, the proposed experiments will specifically describe molecular and biochemical features of skeletal muscle performance under different growth rates. The results from these studies will provide insight into the possible effects of growth patterns on physiological mechanisms underlying swimming performance in relation to anti-predator behavior, given that in some species high growth has been linked with decreased swimming performance (Billerbeck et al., 2001).

Experiment 1. In order to investigate temperature-dependent growth over a wide range of temperatures to capture the temperature variation that juvenile Pacific halibut may experience throughout its distribution range, juvenile Pacific halibut (age 0, 5-7 cm length, N = 75) will be individually tagged (Biomark mini RFID PIT tags) and acclimated at 10°C for 4 weeks. After the acclimation period, fish will be divided into 5 groups (N=15 per group) and reared at 2°C, 5°C, 10°C, 15°C and 20°C in triplicate tanks (N=5 per tank) for 6 weeks. After 2 weeks at each of these temperatures, fish will be measured for weight and length (time 0) and growth monitored every 2 weeks, (at 4 and 6 weeks from the beginning of the temperature experiment). During the experiment fish will be fed ad-libitum daily rations. Growth parameterization will allow for calculation of the temperature at which growth is maximal (T_{max}). At the end of the experiment (week 6), fish will be sacrificed by an overdose of anesthetic (MS-222), and muscle and liver samples will be excised with one set of samples preserved for molecular analyses in RNAlater (Invitrogen) and stored at -20°C and a second set of samples frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses. Experiment 2. In order to describe the molecular and biochemical features of high growth under temperature-induced growth compensation, individually tagged juvenile Pacific halibut (age 0, 5-7 cm length, N = 60) after a period of acclimation at 10°C will be divided into two groups and reared at 2°C (N = 30and 10°C (N = 30) for 8 weeks, being fed ad-libitum daily rations. Under these temperature range and time conditions, previous studies in juvenile Pacific halibut showed marked differences in growth (Hurst et al. 2005; Ryer et al. 2012). After the 8-week temperature regime, 10 fish from each group will be removed from the tanks and sampled as described below and will provide information on temperature effects on growth. Subsequently, half of the fish reared at 2°C will then be acclimated to 10°C for an additional eight weeks of growth in order to induce compensatory growth (temperature compensation effects), as shown previously to occur in Pacific halibut following a period of temperature-induced growth suppression (Hurst et al. 2005). Each temperature treatment will be conducted with 10 fish in each of two experimental replicate tanks. Fish will be measured at 2-week intervals to determine the temperature-dependent growth potential. However, because the fish will be individually tagged, we will also be able to characterize the amount and size-based pattern of individual growth rate variation. At the end of the experiment, fish will be measured, sacrificed by an overdose of anesthetic (MS-222), muscle and liver samples will be excised and fish will be frozen for compositional analyses. Muscle and liver tissue samples will be preserved for molecular analyses in RNAlater (Invitrogen) and stored at -20°C until analysis. In addition, muscle and liver tissue samples will be frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses.

Task 2a. Effects of density on growth.

Density-dependence is an important component of population regulation at a range of spatial and temporal scales. This density-dependence is most commonly thought to be the result of competition for limited prey or habitats. Flatfishes are considered to be particularly sensitive to this type of regulation because they exist in a 2-dimensional habitat and can be concentrated in a smaller portion of the adults' distribution range (Beverton et al. 1995; Nash et al. 2007). In Pacific halibut, the potential importance of density-dependence is reflected in the association of growth rates to stock sizes observed by Clark and Hare (2002) with growth being negatively related to biomass or abundance. However, the direct effects of density on growth in Pacific halibut have not been examined to date. The proposed laboratory experiment will examine the effects of rearing density on growth and expression of growth marker genes in Pacific halibut.

Individually tagged juvenile Pacific halibut (age 0, 5-7 cm length; N = 30) will be reared at 10°C at three different densities (1, 4 and 10 fish/tank) for 12 weeks, being fed limited daily rations at 1% growth/day in order to mimic the effects of density-dependent competition in the wild. Two experimental replicate tanks will be used per density treatment. Fish will be measured at 2-week intervals, with daily rations adjusted based on increasing fish sizes. At the end of the experiment, fish will be measured and blood samples will be drawn from the caudal vein with the use of heparinized syringes and needles. Fish will be sacrificed by an overdose of anesthetic (MS-222), muscle and liver samples will be excised and the rest of the body will be frozen for compositional analyses. Muscle and liver tissue samples will be preserved for molecular analyses in RNAlater (Invitrogen) and stored at -20°C until analysis. In addition, muscle and liver tissue samples will be frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses. Blood samples will be centrifuged at 1,500 x g for 30 min at room temperature and plasma will be separated and stored at -80°C until assayed for metabolites and stress hormones (see below).

Task 2b. Effects of dominance hierarchies on growth potential.
Although not as generally recognized as those of birds and mammals, fish species such as the Pacific halibut engage in complex social interactions. While it is unknown if Pacific halibut establish persistent dominance hierarchies in the wild, they clearly engage in size-based interactions which impact foraging opportunities. When reared in pairs, the larger fish fed first and grew faster than the smaller fish, with the difference in growth dependent on the magnitude of the size difference (Hurst et al. 2005). Observations with older fish (2-3 year old) showed that when mixed-size groups were offered food, the food was usually consumed by the larger fish, even though most often located first by the smaller fish (Stoner and Ottmar, 2004). Similar patterns were observed among wild fish; larger fish were observed "guarding" baits from smaller fish and "stealing" baits from smaller fish (Stoner, unpublished observations). The proposed laboratory experiment will examine the impacts that these behavioral interactions and social dominance structures have on the growth and expression of growth marker genes in juvenile Pacific halibut.

Individually tagged juvenile Pacific halibut (age 0, 5-7 cm length; N = 20) will be reared in pairs (2 fish/tank) at 10°C for 12 weeks in 10 experimental replicate tanks, being fed ad-libitum daily rations. Subordinate and dominant fish will be identified by directly observing feeding responsiveness and by recording their PIT tag IDs. At the end of the experiment, fish will be measured and blood samples will be drawn from the caudal vein with the use of heparinized syringes and needles. Fish will be sacrificed by an overdose of anesthetic (MS-222), muscle and liver samples will be excised and the rest of the body will be frozen for compositional analyses. Muscle and liver tissue samples will be preserved for molecular analyses in RNAlater (Invitrogen) and stored at -20°C until analysis. In addition, muscle and liver tissue samples will be frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses. Blood samples will be centrifuged at 1,500 x g for 30 min at room temperature and plasma will be separated and stored at -80°C until assayed for metabolites and stress hormones (see below).

Task 3. Effects of stress manipulations on growth potential.
The directed fishery for Pacific halibut is prosecuted primarily with longlines, with additional harvest of incidental catches in trawl fisheries directed toward other species. Harvest limits and size-preferences in both

the recreational and commercial fisheries result in substantial numbers of halibut being captured and released. Much effort has been directed toward estimating the mortality rates of discard bycatch from fisheries (reviewed by Davis 2002). However, for fish that survive, there can be lingering effects from the stresses associated with capture and release that affect feeding and growth in the wild. For Pacific halibut, little is known how stress may alter the physiology of the fish. The only studies available to date indicate that increased handling time in Pacific halibut results in increased plasma levels of ions (i.e. potassium and sodium) and glucose and that exposure to air and high temperatures cause a rapid elevation of plasma cortisol, glucose, lactate and ion levels (Oddsson et al., 1994; Davis and Schreck, 2005). Therefore, cortisol and metabolites (glucose and lactate) measured in blood can be used as stress and disturbance indicators in this species. While not designed to specifically mimic the catch and release process, the proposed experiment will examine the effects of experimentally-induced handling stress on growth, blood stress indicators and gene expression in halibut with the goal of identifying biochemical and genetic markers of fish undergoing post-handling stress.

Individually tagged juvenile Pacific halibut (age 0, 5-7 cm length; N = 45) will be reared at 10°C at a density of 5 fish per tank for a total of 4 weeks, being fed ad-libitum daily rations except during the stress manipulation period. Fish will be subjected or not (control group) to two different stress manipulations: a) air exposure for 5 min, b) air exposure for 10 min once a week for duration of the 4-week experimental period. Three experimental replicate tanks will be used per stress treatment. Fish will be measured only at the termination of the experiment in order to avoid additional handling stress and feeding disturbance. At the end of the experiment, blood samples will be drawn from the caudal vein with the use of heparinized syringes and needles and fish will be sacrificed by an overdose of anesthetic (MS-222). Muscle and liver samples will be excised and the rest of the body will be frozen for compositional analyses. Muscle and liver tissue samples will be preserved for molecular analyses in RNA later (Invitrogen) and stored at -20°C until analysis. In addition, muscle and liver tissue samples will be frozen in liquid N_2 and stored at -80°C for biochemical and protein analyses. Blood samples will be centrifuged at 1,500 x g for 30 min at room temperature and plasma will be separated and stored at -80°C until assayed for metabolites and stress hormones (see below).

Methodological approaches

In order to identify molecular and biochemical signatures that are associated with high growth patterns in the Pacific halibut and that can be used to monitor growth patterns in the wild population, a high-throughput approach using state-of-the-art techniques will be used. First, we will aim at identifying genes that are expressed in skeletal muscle and liver, two important tissues involved in growth regulation, and at identifying the changes in their expression levels under temperature-regulated growth manipulation (Task 1). This transcriptomic approach (i.e. a qualitative and quantitative assessment of the entire collection of expressed genes or transcripts: the transcriptome) will be performed by RNA sequencing, a technical approach that provides an unprecedented view of the molecular mechanisms of physiological regulation, as performed in other teleost species (Scott and Johnston, 2012; Palstra et al., 2013), and that has never been previously conducted in the Pacific halibut. Through this approach we will be able to identify thousands of genes that respond to growth manipulation and the physiological processes or pathways that they participate in (e.g. metabolism, energy regulation, homeostasis, etc.). Second, we will aim at the mass identification of proteins (i.e. proteome: the collection of proteins expressed in an organism) that are expressed in skeletal muscle and liver and their regulation under temperature-induced growth manipulation in the Pacific halibut (Task 1). This approach will allow us to identify hundreds of proteins that respond to growth manipulation. The application of this proteomic approach will be an important validation to the transcriptomic approach, given that proteins are produced (i.e. translated) as a product of the expressed genes (i.e. transcripts or messenger RNAs). Since differential regulation can occur at the transcript and/or protein level, it is important that physiological responses at a molecular level are assessed both at the transcript and protein levels. Through the combination of these transcriptomic and proteomic approaches we will identify gene and protein markers for high growth patterns that can be used to monitor growth patterns in the wild.

Molecular assessment of growth changes under density (Task 2a), dominance hierarchies (Task 2b) and stress

(Task 3) manipulations will be performed using a "candidate gene" approach based on suitable growth markers identified by RNA sequencing in Task 1 or by existing information on genes expressed in adult skeletal muscle and liver currently available at IPHC (see below).

Biochemical indicators will also be measured in the proposed experiments to provide information on the levels of metabolites and other factors (e.g. the stress hormone cortisol) under the various growth-manipulating conditions (Tasks 1 to 3). These determinations will provide important information on the metabolic processes that are affected by the various growth-manipulating conditions and that will help interpret the transcriptomic and proteomic data generated. In addition, these studies will provide information on the validation of biochemical indicators for describing growth processes in field studies.

Transcriptomic and proteomic identification of molecular changes that take place under temperature-regulated growth and validation of potential growth molecular markers.
-*Transcriptomic (gene expression) analyses*. Total RNA will be extracted from skeletal muscle and liver samples from Pacific halibut subjected to the temperature acclimation (temperature effect) and compensatory growth (compensation effect) phases of the study and used for the transcriptomic analysis. Briefly, total RNA samples (N = 5/tissue/group) will be sequenced (RNA sequencing or RNA-seq) at Omega Bioservices (Atlanta, GA) using Illumina's HiSeq2500 at a sequencing depth of approximately 25-30 million reads per sample and the sequencing reads, after cleaning and processing, will be assembled using a de novo strategy at Omega Bioservices. Quantitative differences in gene expression in skeletal muscle and liver among treatment groups will be evaluated as described in Palstra et al. (2013). Specifically, analyses will involve comparison of patterns of gene expression in muscle and liver tissues among experimental temperature treatments: 2°C versus 10°C after temperature acclimation (N = 5 per group) and after compensatory growth (N = 5 per group). The results obtained will provide information on the sets of genes that are expressed at higher levels under conditions of high growth. - *Proteomic (protein) analyses*. Proteins extracts will be obtained from skeletal muscle and liver samples (N = 5/tissue/group) from Pacific halibut subjected to the temperature acclimation (temperature effect) and compensatory growth (compensation effect) phases of the study and subjected to proteomic analyses. These will consist in the separation and identification of expressed proteins by liquid chromatography - mass spectroscopy (LC/MS). Proteome comparisons among the different temperature groups (2°C versus 10°C after temperature acclimation (N = 5 per group) and after compensatory growth (N = 5 per group)) will be performed by label-free proteomics analysis. Proteomic analyses will be conducted and analyzed at the Mass Spectrometry Center at Oregon State University in Corvallis, OR. The results obtained will provide information on the sets of proteins that are expressed at higher levels under conditions of high growth.

Molecular characterization of density-, social hierarchy-, and stress -regulated growth using novel growth markers in the Pacific halibut.
Total RNA will be extracted from skeletal muscle and liver samples from Pacific halibut from the "density", (Task 2a), "hierarchy" (Task 2b), and "stress" (Task 3) experiments to characterize the physiology of growth under these varying environmental and anthropogenic influences. Expression levels of a set of 10 genes that show regulated expression in Task 1 will be evaluated by quantitative real time PCR (qPCR), as described in Magnoni et al. (2013). Sequence information required for developing qPCR assays for the selected genes will be derived from the results of Task 1 that can be complemented by a recent IPHC-generated collection of skeletal muscle and liver expressed gene sequences generated by RNA-seq that includes more than 13,000 well-annotated sequences. These analyses will provide quantitative information on the expression levels of the selected growth marker genes in Pacific halibut in response to density, social and stress conditions.

Biochemical characterization of temperature-, density-, social hierarchy-, and stress -regulated growth in skeletal muscle, liver and blood.
In skeletal muscle and liver samples from the various growth-manipulation experiments in Pacific halibut, we will determine the levels of energy reserves and energy substrates in order to understand the biochemical requirements of growth regulation. In particular, we will measure the levels of energy reserves in the form of carbohydrates (i.e. glycogen) and lipids (i.e. triglycerides) in skeletal muscle and liver using standard

methodologies, as described previously (Magnoni et al., 2015). Furthermore, we will measure the levels of energy substrates in skeletal muscle and liver in the form of ATP and AMP in order to calculate the ATP/AMP ratio (high ATP/AMP ratio being indicative of anabolic processes) and also of phosphocreatine, an ATP-containing molecule that can deliver ATP or incorporate ATP according to the cellular energetic requirements, by using commercially available assays. In addition, we will also measure the activity levels of the enzyme AMPK in skeletal muscle and liver samples of fish under the various growth experimental paradigms by a commercial specific enzyme-linked immunoabsorbent assay (ELISA; provider), as described previously (Magnoni et al., 2014). In addition to tissue energy reserves, we will also measure the levels of metabolites in the blood, including glucose and free fatty acids with the use of commercial assays, to provide information on carbohydrate and lipid mobilization under different growth conditions. The results obtained will provide information on the metabolic signature of high growth and how this may change under growth-manipulation conditions. In the growth manipulation experiments involving density, dominance hierarchies and stress (Tasks 2a, 2b and 3), the levels of the stress hormone cortisol, one of the most commonly used stress indicators in fish (Bertotto et al., 2010), will be measured by a commercial ELISA.

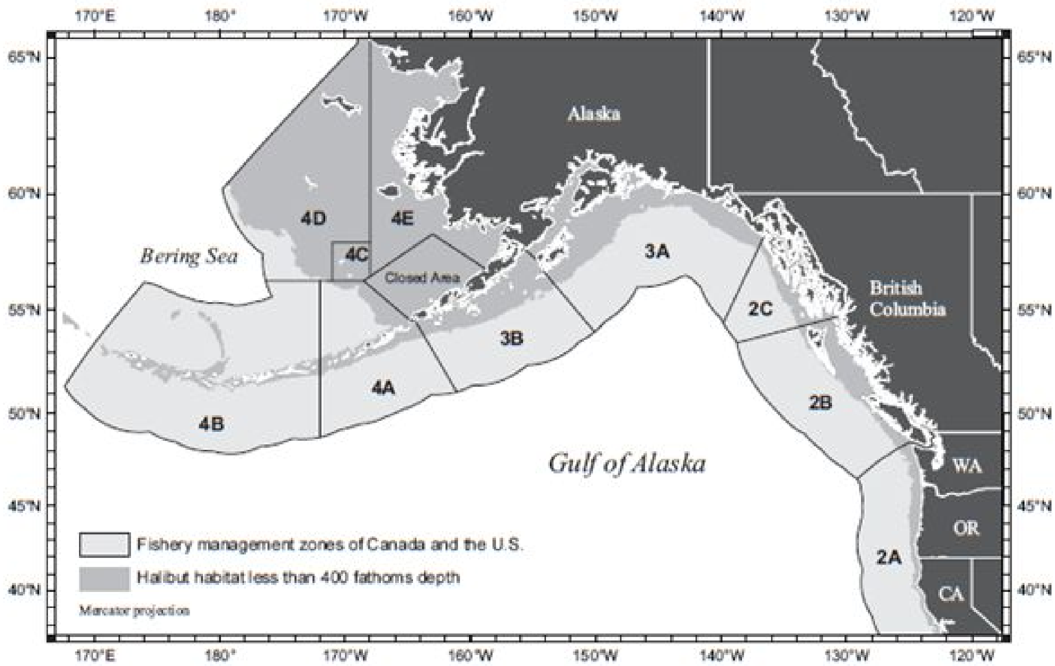

Figure 1. IPHC regulatory areas for the Pacific halibut fishery.

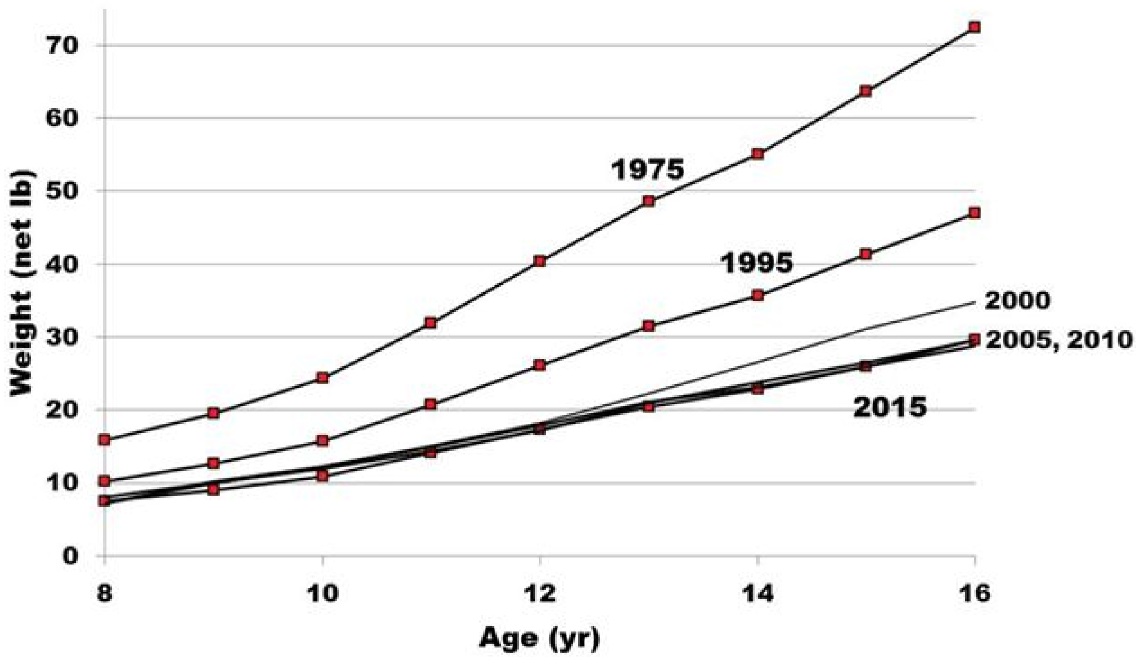

Figure 2. Coastwide aggregate estimated female average weight-at-age trends from setline survey and fishery data over the last four decades. Adapted from Stewart and Monnahan, 2016.

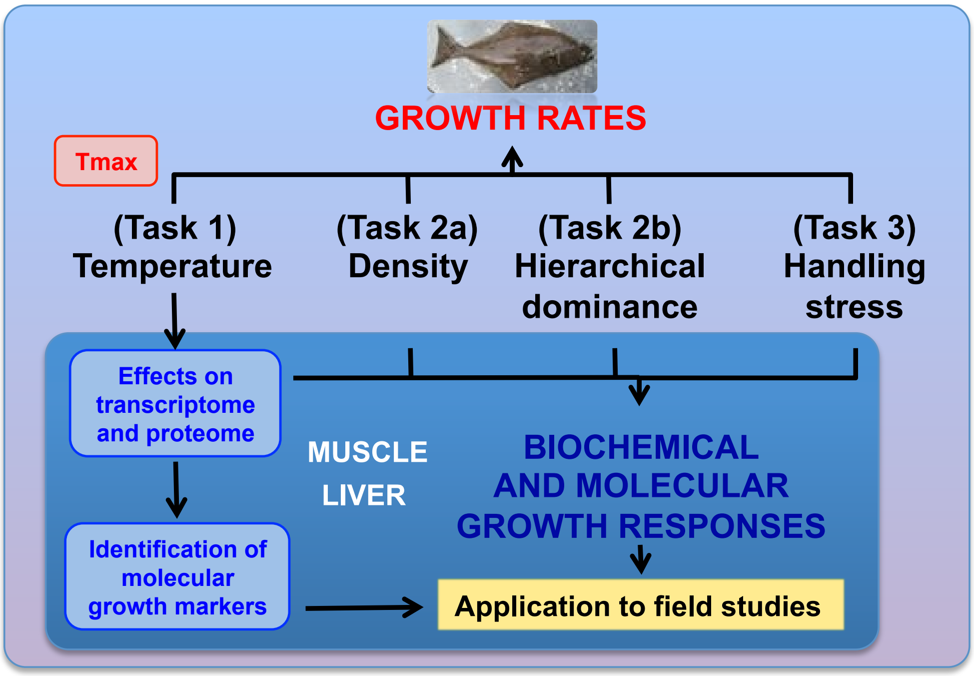

Figure 3. Schematic diagram of the objectives of the project with indication of the different tasks.

Management or Ecosystem Implication

The proposed research has important implications for our understanding of growth changes in the Pacific halibut population given that the decrease in biomass, as evidenced by the decrease in size-at-age during the last three decades, has been hypothesized to be the result of size-selective fishing, altered ecological interactions and, importantly, environmental influences leading to changes in somatic growth. Specifically, the proposed research will improve our understanding of the effects of nursery habitat conditions on growth in Pacific halibut, namely of the effects of temperature, population density and social interactions. Furthermore, our characterization of somatic growth regulation will lead to the development of molecular and biochemical growth markers that will be applied in field studies to describe ontogenetic and life history changes in growth as well as changes in growth trajectories in relation to geographic location.

Therefore, the proposed studies on the effects of temperature and density on growth will inform fishery managers and stock assessment scientists on how changing conditions in the Pacific halibut habitat may influence biomass through its effects on somatic growth. Furthermore, the results from these studies will have implications for harvest policy decisions and may be used to predict future changes in biomass under different climatic and population scenarios. The proposed studies are intended to provide information on the potential contribution of environmentally driven growth changes to the observed decrease in size-at-age in the Pacific halibut.

In addition, by investigating the effects of stress manipulation on growth the proposed research will inform on the potential growth-stunting effects of handling related events in the non-directed trawl fishery. These studies will contribute to further understand the medium- and long-term effects of fishery practices on bycatch survival that, in turn, will have important management implications.

Community & Stakeholder Involvement

Given the great economic and societal importance of the Pacific halibut fishery for Alaska, IPHC has a long history of working together with communities and stakeholders. On an annual basis, contacts between communities and stakeholders and the IPHC take place formally in the framework of advisory bodies to the IPHC that include the Conference Board, the Processors Advisory Group, the Management Strategy Advisory Board and the Research Advisory Board. In addition to these meetings where communities and stakeholders discuss with IPHC scientists key aspects of the Pacific halibut fishery and biology, IPHC locally interacts with communities and stakeholders during the fishing season in ports throughout Alaska that host IPHC staff. For the purpose of the proposed project, the research plans and results related to growth regulation in the Pacific halibut will be formally presented to IPHC's advisory bodies and feed-back and comment will be requested. Reports on the presentation and discussion of the proposed research to the community and stakeholders will be produced and made publically available in the IPHC website.

Links to Prior NPRB Projects Section

The present project is linked to the recently completed NPRB Project 1309 entitled “Fishery, Climate and Ecological Effects on Pacific Halibut Size-at-Age” (2013-2016). NPRB Project 1309 developed bioenergetic and integrated growth models to evaluate the effects of environmental, ecological and fishery effects on Pacific halibut growth. The results obtained led to the conclusion that changes in SAA in Pacific halibut may be the result of ecological and fishery effects and that, although the data analyzed did not allow to separate the contributions of the various effects, these effects may act in concert to affect SAA. Importantly, this project gave support to the possibility that environmental temperature changes may have influenced halibut growth and, as a consequence, SAA. The present project builds on the initial conclusions of NPRB Project 1309 and will demonstrate the basis of the temperature-, density- and stress-regulated growth by investigating separately and systematically the effects of these various variables on growth of juvenile Pacific halibut in captivity.

Had prior experience with NPRB

yes

Project Management

Dr. Josep Planas will lead the IPHC component. Dr. Planas has extensive expertise in the physiological regulation of growth in teleost fish. Relevant to this proposal, Dr. Planas also has experience in the application of transcriptomic and proteomic approaches to flatfish physiology as a tool to understand the molecular and biochemical basis of physiological processes in fish including growth. Dr. Planas has led and participated in a number of previous research projects and his experience, together with that of the other Principal Investigator, will ensure the success of this project. Ms. Dana Rudy will participate in the set-up, implementation and sampling of the different experiments proposed.

Dr. Thomas Hurst will lead the AFSC component. Dr. Hurst has extensive experience in flatfish ecology and has conducted seminal work on the temperature and feeding requirements for growth in Pacific halibut juveniles. Dr. Hurst also provides essential expertise on captive fish experimentation. Dr. Hurst has led and participated in a number of projects on the ecology and habitat distribution of flatfish species, including the Pacific halibut.

Dr. Planas and Dr. Hurst will communicate regularly to discuss progress of the project and to discuss specific issues related to the implementation of the project. Communication will take place by phone or Skype at prearranged times. In addition, a kick-off meeting between Dr. Planas and Dr. Hurst will take place in Seattle, WA during Month 1 of the project. Subsequently, Dr. Planas and Dr. Hurst will hold a second meeting in Newport, OR at Month 6 that will coincide with either the mid-point or the termination of the first experiment.

Results from the project will be disseminated at selected fishery and scientific conferences and, importantly, by submitting written reports in the form of scientific papers to peer-reviewed papers. Initially targeted conferences include ComFish 2019, the Western Groundfish Conference (unannounced location in California in 2018), the Wakefield Symposium 2018 and the Alaska Marine Science Symposium 2019. Journals that will be targeted for publication of our results include Journal of Fish Biology, Frontiers in Marine Science, PLoS One, Canadian Journal of Aquatic and Fishery Science. In addition, dissemination of the outcome of this project will also take place at meetings with the community and the stakeholders

ɔcesses in the Pacific halibut (Hippoglossus stenolepis) and their response to temperature, density and stress m

September, 2017 - August, 2019

	Responsible Party	2017		2018				2019	
		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Alaska Marine Science Symposyum	Josep Planas, Thomas Hurst			X				X	
Final Report	Josep Planas, Thomas Hurst								X
Data and Metadata Transfer	Josep Planas								X
Progress Report	Josep Planas, Thomas Hurst	X		X		X		X	
Objective# 1 To investigate the physiological effects of temperature on growth in juvenile Pacific halibut by describing specific biochemical, transcriptomic (gene expression) and proteomic (protein) responses to temperature in skeletal muscle and liver, two key tissues that participate in growth regulation.	Josep Planas, Thomas Hurst, Dana Rudy	X	X	X	X	X	X		
Objective# 2 To investigate the physiological effects of density and dominance hierarchies on growth potential in order to understand the influence of population density and social interactions may influence growth potential in the nursery areas.	Thomas Hurst, Josep Planas, Dana Rudy		X	X	X	X	X		
Objective# 3 To investigate the physiological effects of handling stress on growth in juvenile Pacific halibut in order to understand the potential effects of handling-related stress on growth potential	Josep Planas, Thomas Hurst, Dana Rudy				X	X	X	X	X

Budget

No	Institution	Requesting Funds	Other Support
1	International Pacific Halibut Commission 1. Dr. Josep V. Planas [PI, Lead-PI] International Pacific Halibut Commission 2. Mr. Michael Larsen [Grant Manager] International Pacific Halibut Commission	131,891	68,945
2	Alaska Fisheries Science Center 1. Dr. Thomas P. Hurst [PI] Alaska Fisheries Science Center NOAA - NMFS 2. Mrs. Jennifer Ferdinand [Grant Manager] Alaska Fisheries Science Center, NOAA - NMFS	98,236	63,661

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Josep V. Planas
ORGANIZATION	International Pacific Halibut Commission

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	DESCRIPTION Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**21,401**	**21,615**	**43,016**	**Unit effort and rate applied must be shown for each individual.**
Technical support	21,401	21,615		1 person, 6 months per year, 2 years (YR1 and YR2)
2. Fringe benfits	**4,280**	**4,323**	**8,603**	**Unit effort and rate applied must be shown for each individual.**
Technical support	4,280	4,323		1 person, 6 months per year, 2 years (YR1 and YR2)
3. Travel	**2,050**	**7,000**	**9,050**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
Domestic				
Rental car	500	0		PI Meeting in Newport 1 person
Hotel Newport	200	0		2 nights Newport, 1 person
Per diem	150	0		3 days Newport, 1 person
Rental car	500	0		Participation in experiments in Newport, 2 people, YR1
Hotel Newport	400	0		2 nights Newport, 2 people, YR1
Per diem	300	0		3 days Newport, 2 people, YR1
Rental car	0	500		Participation in experiments in Newport, 2 people, YR2
Hotel Newport	0	400		2 nights Newport, 2 people, YR2
Per diem	0	300		3 days Newport, 2 people, YR2
Airfare domestic conference	0	1,000		2 people, YR2
Hotel conference	0	800		4 nights, 2 people, YR2
Domestic conference registration		600		Registration fees, 2 people
Per diem	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Conference, YR2
Airfare Seattle-Anchorage Return	0	1,200		Alaska Marine Science Symposium, 2 people, YR2

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut			
PRINCIPAL INVESTIGATOR	Josep V. Planas			
ORGANIZATION	International Pacific Halibut Commission			
Hotel Anchorage	0	800		4 nights, 2 people, YR2
AMSS registration		200		Registration fees, 2 people
Per diem Anchorage	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**7,000**	**8,500**	**15,500**	
Laboratory supplies	7,000	8,500		Molecular biology reagents,qPCR reagents, general laboratory chemicals, protein determination kits, AMPK kits, antibodies
6. Contractual	**22,542**	**26,180**	**48,722**	
RNA sequencing costs	22,542	0		Sequencing, assembly and differential gene expression analyses for 25 muscle and 25 liver samples by Omega Bioservices, Norcross, GA
Proteomic analyses	0	26,180		Label-free mass spectrometry-based proteomic analyses on 10 muscle and 10 liver samples by Oregon State University Mass Spectrometry Center, Corvallis, OR
7. Other Expenses	**500**	**6,500**	**7,000**	
Shipping costs	500			Sample shipping to Omega Bioservices
Publication costs		4,000		2 papers at 2000 each
Outreach activities		2,500		Travel to Kodiak, Ak for ComFish meeting (1 person) and educational activities at the Kodiak Fisheries Research Center (1 person).
8. Modified Total Direct Costs	**0**	**0**	131,891	**Total amount to which indirect costs are applied.**
9. Indirect Costs	0	0	0	**NICRA must be included in proposal. 10% may be claimed for organizations without a NICRA.**
10. TOTAL FUNDING REQUESTED	**0**	**0**	**131,891**	

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

CATEGORIES	**NPRB Year 1**	**NPRB Year 2**	**NPRB TOTAL**	**DESCRIPTION** Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**3,100**	**3,100**	**6,200**	**Unit effort and rate applied must be shown for each individual.**
	3,100	3,100		Overtime during field collections
2. Fringe benfits	**248**	**248**	**496**	**Unit effort and rate applied must be shown for each individual.**
	248	248		Fringe benefit of 8% applied to overtime costs
3. Travel	**8,450**	**11,354**	**19,804**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
Domestic				
Airfare Portland-Kodiak Return	2,800	2,940		Fish collection - Kodiak, AK, 2 people
Rental car Kodiak	1,200	1,260		Rental car Kodiak
Hotel Kodiak	1,884	1,978		6 nights for 2 people YR1 and YR2
Per diem	1,134	1,190		7 days for 2 people YR1 and YR2
Miscellaneous travel	200	210		Newport, Portland, Kodiak
Rental car	500	0		PI Meeting in Seattle, 1 person
Hotel Seattle	410	0		2 nights Seattle
Per diem	222	0		3 days Seattle
Miscellaneous travel	100	0		Seattle
Airfare conference	0	500		Domestic conference, 1 person
Ground transportation Newport-Portland	0	150		1 person
Hotel conference	0	640		4 nights conference
Per diem conference	0	370		5 days, 1 person

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

Miscellaneous travel	0	100		Conference
Airfare Portland-Anchorage Return	0	900		Alaska Marine Science Symposium
Ground transportation Newport-Portland	0	150		1 person
Hotel Anchorage	0	396		4 nights, 1 person
Per diem Anchorage	0	570		5 days, 1 person
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**8,000**	**8,000**	**16,000**	
Laboratory supplies	8,000	8,000		Fish food, nets, plumbing supplies, dissecting equipment, fish shipping materials, boat fuel, moorage fees
6. Contractual	**23,195**	**24,804**	**47,999**	
Technical support	23,195	24,354		1 person, 3 months per year
Conference registration	0	450		PI Hurst for domestic conference and Alaska Marine Science Symposium
7. Other Expenses	**2,000**	**2,000**	**4,000**	
Shipping costs of live fish	2,000	2,000		Transport of live fish from Alaska collecting site to AFSC lab in Newport, OR
8. Modified Total Direct Costs	**44,993**	**49,506**	**94,499**	**Total amount to which indirect costs are applied.**
9. Indirect Costs	1,868	1,868	3,737	**Indirect rate of 60.27% applied only to overtime costs.**
10. TOTAL FUNDING REQUESTED	**46,861**	**51,374**	**98,236**	

MULTIPLE ORGANIZATION SUMMARY

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
ALL PRINCIPAL INVESTIGATORS	Dr. Josep V. Planas, Dr. Thomas P. Hurst
ALL ORGANIZATIONS	International Pacific Halibut Commission, Alaska Fisheries Science Center-Newport OR

Combine the total amounts for all organizations for each line item by year below.

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	Other Support TOTAL
1. Salaries	24,501	24,715	49,216	102,288
2. Fringe benefits	4,528	4,572	9,100	30,318
3. Travel	10,500	18,354	28,854	
4. Equipment	0	0	0	
5. Supplies	15,000	16,500	31,500	
6. Contractual	45,737	50,984	96,721	
7. Other Expenses	2,500	8,500	11,000	
8. Modified Total Direct Costs	**102,766**	**123,625**	226,391	**132,606**
9. Indirect Costs	1,868	1,868	3,736	
10. TOTAL FUNDING REQUEST	**104,634**	**125,493**	**230,127**	**132,606**

Each individual organization must also submit a **BUDGET DETAIL.**

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Josep V. Planas
ORGANIZATION	International Pacific Halibut Commission

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	DESCRIPTION Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**21,401**	**21,615**	**43,016**	**Unit effort and rate applied must be shown for each individual.**
Technical support	21,401	21,615		1 person, 6 months per year, 2 years (YR1 and YR2)
2. Fringe benfits	**4,280**	**4,323**	**8,603**	**Unit effort and rate applied must be shown for each individual.**
Technical support	4,280	4,323		1 person, 6 months per year, 2 years (YR1 and YR2)
3. Travel	**2,050**	**7,000**	**9,050**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
Domestic				
Rental car	500	0		PI Meeting in Newport 1 person
Hotel Newport	200	0		2 nights Newport, 1 person
Per diem	150	0		3 days Newport, 1 person
Rental car	500	0		Participation in experiments in Newport, 2 people, YR1
Hotel Newport	400	0		2 nights Newport, 2 people, YR1
Per diem	300	0		3 days Newport, 2 people, YR1
Rental car	0	500		Participation in experiments in Newport, 2 people, YR2
Hotel Newport	0	400		2 nights Newport, 2 people, YR2
Per diem	0	300		3 days Newport, 2 people, YR2
Airfare domestic conference	0	1,000		2 people, YR2
Hotel conference	0	800		4 nights, 2 people, YR2
Domestic conference registration		600		Registration fees, 2 people
Per diem	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Conference, YR2
Airfare Seattle-Anchorage Return	0	1,200		Alaska Marine Science Symposium, 2 people, YR2

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut			
PRINCIPAL INVESTIGATOR	Josep V. Planas			
ORGANIZATION	International Pacific Halibut Commission			
Hotel Anchorage	0	800		4 nights, 2 people, YR2
AMSS registration		200		Registration fees, 2 people
Per diem Anchorage	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**7,000**	**8,500**	**15,500**	
Laboratory supplies	7,000	8,500		Molecular biology reagents,qPCR reagents, general laboratory chemicals, protein determination kits, AMPK kits, antibodies
6. Contractual	**22,542**	**26,180**	**48,722**	
RNA sequencing costs	22,542	0		Sequencing, assembly and differential gene expression analyses for 25 muscle and 25 liver samples by Omega Bioservices, Norcross, GA
Proteomic analyses	0	26,180		Label-free mass spectrometry-based proteomic analyses on 10 muscle and 10 liver samples by Oregon State University Mass Spectrometry Center, Corvallis, OR
7. Other Expenses	**500**	**6,500**	**7,000**	
Shipping costs	500			Sample shipping to Omega Bioservices
Publication costs		4,000		2 papers at 2000 each
Outreach activities		2,500		Travel to Kodiak, Ak for ComFish meeting (1 person) and educational activities at the Kodiak Fisheries Research Center (1 person).
8. Modified Total Direct Costs	**0**	**0**	131,891	**Total amount to which indirect costs are applied.**
9. Indirect Costs	0	0	0	**NICRA must be included in proposal. 10% may be claimed for organizations without a NICRA.**
10. TOTAL FUNDING REQUESTED	**0**	**0**	**131,891**	

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	DESCRIPTION Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**3,100**	**3,100**	**6,200**	**Unit effort and rate applied must be shown for each individual.**
	3,100	3,100		Overtime during field collections
2. Fringe benfits	**248**	**248**	**496**	**Unit effort and rate applied must be shown for each individual.**
	248	248		Fringe benefit of 8% applied to overtime costs
3. Travel	**8,450**	**11,354**	**19,804**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
Domestic				
Airfare Portland-Kodiak Return	2,800	2,940		Fish collection - Kodiak, AK, 2 people
Rental car Kodiak	1,200	1,260		Rental car Kodiak
Hotel Kodiak	1,884	1,978		6 nights for 2 people YR1 and YR2
Per diem	1,134	1,190		7 days for 2 people YR1 and YR2
Miscellaneous travel	200	210		Newport, Portland, Kodiak
Rental car	500	0		PI Meeting in Seattle, 1 person
Hotel Seattle	410	0		2 nights Seattle
Per diem	222	0		3 days Seattle
Miscellaneous travel	100	0		Seattle
Airfare conference	0	500		Domestic conference, 1 person
Ground transportation Newport-Portland	0	150		1 person
Hotel conference	0	640		4 nights conference
Per diem conference	0	370		5 days, 1 person

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

Miscellaneous travel	0	100		Conference
Airfare Portland-Anchorage Return	0	900		Alaska Marine Science Symposium
Ground transportation Newport-Portland	0	150		1 person
Hotel Anchorage	0	396		4 nights, 1 person
Per diem Anchorage	0	570		5 days, 1 person
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**8,000**	**8,000**	**16,000**	
Laboratory supplies	8,000	8,000		Fish food, nets, plumbing supplies, dissecting equipment, fish shipping materials, boat fuel, moorage fees
6. Contractual	**23,195**	**24,804**	**47,999**	
Technical support	23,195	24,354		1 person, 3 months per year
Conference registration	0	450		PI Hurst for domestic conference and Alaska Marine Science Symposium
7. Other Expenses	**2,000**	**2,000**	**4,000**	
Shipping costs of live fish	2,000	2,000		Transport of live fish from Alaska collecting site to AFSC lab in Newport, OR
8. Modified Total Direct Costs	**44,993**	**49,506**	**94,499**	**Total amount to which indirect costs are applied.**
9. Indirect Costs	1,868	1,868	3,737	**Indirect rate of 60.27% applied only to overtime costs.**
10. TOTAL FUNDING REQUESTED	**46,861**	**51,374**	**98,236**	

MULTIPLE ORGANIZATION SUMMARY

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
ALL PRINCIPAL INVESTIGATORS	Dr. Josep V. Planas, Dr. Thomas P. Hurst
ALL ORGANIZATIONS	International Pacific Halibut Commission, Alaska Fisheries Science Center-Newport OR

Combine the total amounts for all organizations for each line item by year below.

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	Other Support TOTAL
1. Salaries	24,501	24,715	49,216	102,288
2. Fringe benefits	4,528	4,572	9,100	30,318
3. Travel	10,500	18,354	28,854	
4. Equipment	0	0	0	
5. Supplies	15,000	16,500	31,500	
6. Contractual	45,737	50,984	96,721	
7. Other Expenses	2,500	8,500	11,000	
8. Modified Total Direct Costs	**102,766**	**123,625**	226,391	**132,606**
9. Indirect Costs	1,868	1,868	3,736	
10. TOTAL FUNDING REQUEST	**104,634**	**125,493**	**230,127**	**132,606**

Each individual organization must also submit a **BUDGET DETAIL.**

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
7600 Sand Point Way N.E.
Seattle, Washington 98115-6349

The Alaska Fisheries Science Center (AFSC), as part of the federal government, does not have negotiated indirect rates, nor are there standard rates for all federal agencies.

The AFSC charges indirect fees only on labor costs. For fiscal year 2017, the AFSC's indirect rates are:

- National Oceanic Atmospheric Administration (NOAA) Management Fund 22.07%
- National Marine Fisheries Service (NMFS) Management Fund 12.2%
- Alaska Fisheries Science Center Management Fund 16%
- General Services Administration (GSA) Rent 9%

The NOAA, NMFS and AFSC Management Fund rates cover all overhead associated with the administration of non-appropriated funding agreements (e.g., legal reviews, invoicing, budgeting, accounting, etc...). The AFSC charges GSA rent for reimbursement of fees which are incurred while completing outside-funded projects. These include infrastructure costs such as phones, networks, vehicle leases, and utility charges.

Please accept this explanation of our indirect rates in lieu of a Negotiated Indirect Cost Rate Agreement.

INTERNATIONAL PACIFIC HALIBUT COMMISSION

ESTABLISHED BY A CONVENTION BETWEEN CANADA

AND THE UNITED STATES OF AMERICA

EXECUTIVE DIRECTOR
DAVID T. WILSON

2320 W. COMMODORE WY, STE 300
SEATTLE, WA 98199-1287

TELEPHONE:
(206) 634-1838

FAX:
(206) 632-2983

November 28, 2016

To whom it may concern:

The International Pacific Halibut Commission (IPHC) does not charge an indirect cost rate (NICRA) for federal, state or other grants and contracts that are awarded to the organization. The intent for waiving the indirect cost rate is to improve the competiveness of the application and the ensure that any funds received are used efficiently to further fisheries research and management. For further clarification or questions please email me at mike@iphc.int or via phone at 206-522-7671.

Sincerely,

Michael J Larsen
Administrative Officer
International Pacific Halibut Commission

MULTIPLE ORGANIZATION SUMMARY

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut	
ALL PRINCIPAL INVESTIGATORS	Dr. Josep V. Planas, Dr. Thomas P. Hurst	
ALL ORGANIZATIONS	International Pacific Halibut Commission, Alaska Fisheries Science Center-Newport OR	

Combine the total amounts for all organizations for each line item by year below.

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	Other Support TOTAL
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2. Fringe benefits	4,528	4,572	9,100	30,318
3. Travel	10,500	18,354	28,854	
4. Equipment	0	0	0	
5. Supplies	15,000	16,500	31,500	
6. Contractual	45,737	50,984	96,721	
7. Other Expenses	2,500	8,500	11,000	
8. Modified Total Direct Costs	**102,766**	**123,625**	226,391	**132,606**
9. Indirect Costs	1,868	1,868	3,736	
10. TOTAL FUNDING REQUEST	**104,634**	**125,493**	**230,127**	**132,606**

Each individual organization must also submit a **BUDGET DETAIL.**

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Josep V. Planas
ORGANIZATION	International Pacific Halibut Commission

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	DESCRIPTION Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**21,401**	**21,615**	**43,016**	**Unit effort and rate applied must be shown for each individual.**
Technical support	21,401	21,615		1 person, 6 months per year, 2 years (YR1 and YR2)
2. Fringe benfits	**4,280**	**4,323**	**8,603**	**Unit effort and rate applied must be shown for each individual.**
Technical support	4,280	4,323		1 person, 6 months per year, 2 years (YR1 and YR2)
3. Travel	**2,050**	**7,000**	**9,050**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
Domestic				
Rental car	500	0		PI Meeting in Newport 1 person
Hotel Newport	200	0		2 nights Newport, 1 person
Per diem	150	0		3 days Newport, 1 person
Rental car	500	0		Participation in experiments in Newport, 2 people, YR1
Hotel Newport	400	0		2 nights Newport, 2 people, YR1
Per diem	300	0		3 days Newport, 2 people, YR1
Rental car	0	500		Participation in experiments in Newport, 2 people, YR2
Hotel Newport	0	400		2 nights Newport, 2 people, YR2
Per diem	0	300		3 days Newport, 2 people, YR2
Airfare domestic conference	0	1,000		2 people, YR2
Hotel conference	0	800		4 nights, 2 people, YR2
Domestic conference registration		600		Registration fees, 2 people
Per diem	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Conference, YR2
Airfare Seattle-Anchorage Return	0	1,200		Alaska Marine Science Symposium, 2 people, YR2

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut			
PRINCIPAL INVESTIGATOR	Josep V. Planas			
ORGANIZATION	International Pacific Halibut Commission			
Hotel Anchorage	0	800		4 nights, 2 people, YR2
AMSS registration		200		Registration fees, 2 people
Per diem Anchorage	0	500		5 days conference 2 people, YR2
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**7,000**	**8,500**	**15,500**	
Laboratory supplies	7,000	8,500		Molecular biology reagents,qPCR reagents, general laboratory chemicals, protein determination kits, AMPK kits, antibodies
6. Contractual	**22,542**	**26,180**	**48,722**	
RNA sequencing costs	22,542	0		Sequencing, assembly and differential gene expression analyses for 25 muscle and 25 liver samples by Omega Bioservices, Norcross, GA
Proteomic analyses	0	26,180		Label-free mass spectrometry-based proteomic analyses on 10 muscle and 10 liver samples by Oregon State University Mass Spectrometry Center, Corvallis, OR
7. Other Expenses	**500**	**6,500**	**7,000**	
Shipping costs	500			Sample shipping to Omega Bioservices
Publication costs		4,000		2 papers at 2000 each
Outreach activities		2,500		Travel to Kodiak, Ak for ComFish meeting (1 person) and educational activities at the Kodiak Fisheries Research Center (1 person).
8. Modified Total Direct Costs	**0**	**0**	131,891	**Total amount to which indirect costs are applied.**
9. Indirect Costs	0	0	0	**NICRA must be included in proposal. 10% may be claimed for organizations without a NICRA.**
10. TOTAL FUNDING REQUESTED	**0**	**0**	**131,891**	

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

CATEGORIES	NPRB Year 1	NPRB Year 2	NPRB TOTAL	DESCRIPTION Provide sufficient description for each line item to reconcile the amount shown. Add/remove lines as necessary. Ensure all formula cells are correct.
1. Salaries	**3,100**	**3,100**	**6,200**	**Unit effort and rate applied must be shown for each individual.**
	3,100	3,100		Overtime during field collections
2. Fringe benfits	**248**	**248**	**496**	**Unit effort and rate applied must be shown for each individual.**
	248	248		Fringe benefit of 8% applied to overtime costs
3. Travel	**8,450**	**11,354**	**19,804**	**NOAA approval must be obtained through NPRB prior to foreign travel on funded projects. Allow minimum of 3 months.**
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Airfare Portland-Kodiak Return	2,800	2,940		Fish collection - Kodiak, AK, 2 people
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Per diem	1,134	1,190		7 days for 2 people YR1 and YR2
Miscellaneous travel	200	210		Newport, Portland, Kodiak
Rental car	500	0		PI Meeting in Seattle, 1 person
Hotel Seattle	410	0		2 nights Seattle
Per diem	222	0		3 days Seattle
Miscellaneous travel	100	0		Seattle
Airfare conference	0	500		Domestic conference, 1 person
Ground transportation Newport-Portland	0	150		1 person
Hotel conference	0	640		4 nights conference
Per diem conference	0	370		5 days, 1 person

BUDGET DETAIL

PROJECT SHORT TITLE	Somatic growth regulation in the Pacific halibut in the Pacific halibut
PRINCIPAL INVESTIGATOR	Thomas P. Hurst
ORGANIZATION	Alaska Fisheries Science Center

Miscellaneous travel	0	100		Conference
Airfare Portland-Anchorage Return	0	900		Alaska Marine Science Symposium
Ground transportation Newport-Portland	0	150		1 person
Hotel Anchorage	0	396		4 nights, 1 person
Per diem Anchorage	0	570		5 days, 1 person
Miscellaneous travel	0	100		Anchorage
4. Equipment (>$5,000)	**0**	**0**	**0**	
5. Supplies (<$5,000)	**8,000**	**8,000**	**16,000**	
Laboratory supplies	8,000	8,000		Fish food, nets, plumbing supplies, dissecting equipment, fish shipping materials, boat fuel, moorage fees
6. Contractual	**23,195**	**24,804**	**47,999**	
Technical support	23,195	24,354		1 person, 3 months per year
Conference registration	0	450		PI Hurst for domestic conference and Alaska Marine Science Symposium
7. Other Expenses	**2,000**	**2,000**	**4,000**	
Shipping costs of live fish	2,000	2,000		Transport of live fish from Alaska collecting site to AFSC lab in Newport, OR
8. Modified Total Direct Costs	**44,993**	**49,506**	**94,499**	**Total amount to which indirect costs are applied.**
9. Indirect Costs	1,868	1,868	3,737	**Indirect rate of 60.27% applied only to overtime costs.**
10. TOTAL FUNDING REQUESTED	**46,861**	**51,374**	**98,236**	

Signature Page

Proposal No:

Start Date: Sep 2017 **End Date:** Aug 2019

Title: Somatic growth processes in the Pacific halibut (Hippoglossus stenolepis) and their response to temperature, density and stress manipulation effects

Applicant:
Dr. David T. Wilson, International Pacific Halibut Commission

Principal Investigator(s):
Dr. Josep V. Planas (Lead) , josep@iphc.int, International Pacific Halibut Commission

Dr. Thomas P. Hurst, thomas.hurst@noaa.gov, Alaska Fisheries Science Center NOAA - NMFS

Category:
Fishes and Invertebrates

Abstract: The Pacific halibut (Hippoglossus stenolepis) are distributed throughout the North Pacific Ocean and its fishery is one of the most important commercial fisheries in this region. The International Pacific Halibut Commission has been managing the Pacific halibut fishery since 1923 and throughout its history it has recorded changes in the size-at-age (SAA) of fish caught in the commercial fishery as well as in its own survey research efforts. Importantly, a consistent decrease in SAA has been observed since the late 1990s that has led to steady declines in the exploitable biomass of the Pacific halibut stocks. Although the decrease in SAA has been attributed to several potential causes, including environmental effects, such as temperature or food availability, as well as ecological or fishery effects, our knowledge on the actual factors that influence SAA of Pacific halibut is still scarce. This proposal aims at elucidating the potential contribution of somatic growth in driving changes in SAA by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. In order to evaluate growth physiological responses in response to factors that could participate in the observed decrease in size-at-age in Pacific halibut, we will investigate the effects of temperature, density, social structure and stress manipulations on biochemical and molecular indicators of growth. Emphasis will be placed on the physiological responses to temperature, given the demonstrated importance of this environmental parameter in determining growth patterns in the Pacific halibut. This study will lead to a significant improvement in our understanding of the physiological mechanisms regulating growth in the Pacific halibut in response to environmental and ecological influences but also, importantly, to the identification of molecular and biochemical growth signatures characteristic of growth patterns that will be used to monitor growth patterns in the Pacific halibut population.

Links to Prior NPRB Projects: The present project is linked to the recently funded NPRB Project 1309 entitled “Fishery, Climate and Ecological Effects on Pacific Halibut Size-at-Age” (2013-2016). NPRB Project 1309 developed bioenergetic and integrated growth models to evaluate the effects of environmental, ecological and fishery effects on Pacific halibut growth. The results obtained led to the conclusion that changes in SAA in Pacific halibut may be the result of ecological and fishery effects and that, although the data analyzed did not allow to separate the contributions of the various effects, these effects may act in a concerted manner to affect SAA. Importantly, this project gave support to the possibility that environmental temperature changes may have influenced halibut growth and, as a consequence, SAA. The present project builds on the initial conclusions of NPRB Project 1309 and will demonstrate the basis of the temperature-, density- and stress-regulated growth by investigating separately and systematically the effects of these various variables on growth of juvenile Pacific halibut in captivity.

Total Funding Requested From NPRB: $230,127

1. Alaska Fisheries Science Center: $98,236

Total Other Support: $63,661

1. Alaska Fisheries Science Center: $63,661

Authorizing Signature: Douglas DeMaster

Signature	Science and Research Director Title
Douglas P. DeMaster, Ph.D. Printed Name	NOAA Fisheries Alaska Fisheries Science Center Organization

2017RFP

Signature Page

Proposal No:

Start Date: Sep 2017 **End Date:** Aug 2019

Title: Somatic growth processes in the Pacific halibut (Hippoglossus stenolepis) and their response to temperature, density and stress manipulation effects

Applicant:
Dr. David T. Wilson, International Pacific Halibut Commission

Principal Investigator(s):
Dr. Josep V. Planas (Lead) , josep@iphc.int, International Pacific Halibut Commission

Dr. Thomas P. Hurst, thomas.hurst@noaa.gov, Alaska Fisheries Science Center NOAA - NMFS

Category:
Fishes and Invertebrates

Abstract: The Pacific halibut (Hippoglossus stenolepis) are distributed throughout the North Pacific Ocean and its fishery is one of the most important commercial fisheries in this region. The International Pacific Halibut Commission has been managing the Pacific halibut fishery since 1923 and throughout its history it has recorded changes in the size-at-age (SAA) of fish caught in the commercial fishery as well as in its own survey research efforts. Importantly, a consistent decrease in SAA has been observed since the late 1990s that has led to steady declines in the exploitable biomass of the Pacific halibut stocks. Although the decrease in SAA has been attributed to several potential causes, including environmental effects, such as temperature or food availability, as well as ecological or fishery effects, our knowledge on the actual factors that influence SAA of Pacific halibut is still scarce. This proposal aims at elucidating the potential contribution of somatic growth in driving changes in SAA by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. In order to evaluate growth physiological responses in response to factors that could participate in the observed decrease in size-at-age in Pacific halibut, we will investigate the effects of temperature, density, social structure and stress manipulations on biochemical and molecular indicators of growth. Emphasis will be placed on the physiological responses to temperature, given the demonstrated importance of this environmental parameter in determining growth patterns in the Pacific halibut. This study will lead to a significant improvement in our understanding of the physiological mechanisms regulating growth in the Pacific halibut in response to environmental and ecological influences but also, importantly, to the identification of molecular and biochemical growth signatures characteristic of growth patterns that will be used to monitor growth patterns in the Pacific halibut population.

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Total Funding Requested From NPRB: $230,127

2017RFP

1. International Pacific Halibut Commission: $131,891

Total Other Support: $68,945

1. International Pacific Halibut Commission: $68,945

Authorizing Signature:

Signature	Executive Director Title
David T. Wilson Printed Name	International Pacific Halibut Commission Organization

Signature Page

Proposal No:

Start Date: Sep 2017 **End Date:** Aug 2019

Title: Somatic growth processes in the Pacific halibut (Hippoglossus stenolepis) and their response to temperature, density and stress manipulation effects

Applicant:
Dr. David T. Wilson, International Pacific Halibut Commission

Principal Investigator(s):
Dr. Josep V. Planas (Lead) , josep@iphc.int, International Pacific Halibut Commission

Dr. Thomas P. Hurst, thomas.hurst@noaa.gov, Alaska Fisheries Science Center NOAA - NMFS

Category:
Fishes and Invertebrates

Abstract: The Pacific halibut (Hippoglossus stenolepis) are distributed throughout the North Pacific Ocean and its fishery is one of the most important commercial fisheries in this region. The International Pacific Halibut Commission has been managing the Pacific halibut fishery since 1923 and throughout its history it has recorded changes in the size-at-age (SAA) of fish caught in the commercial fishery as well as in its own survey research efforts. Importantly, a consistent decrease in SAA has been observed since the late 1990s that has led to steady declines in the exploitable biomass of the Pacific halibut stocks. Although the decrease in SAA has been attributed to several potential causes, including environmental effects, such as temperature or food availability, as well as ecological or fishery effects, our knowledge on the actual factors that influence SAA of Pacific halibut is still scarce. This proposal aims at elucidating the potential contribution of somatic growth in driving changes in SAA by investigating the physiological mechanisms that contribute to growth changes in the Pacific halibut. In order to evaluate growth physiological responses in response to factors that could participate in the observed decrease in size-at-age in Pacific halibut, we will investigate the effects of temperature, density, social structure and stress manipulations on biochemical and molecular indicators of growth. Emphasis will be placed on the physiological responses to temperature, given the demonstrated importance of this environmental parameter in determining growth patterns in the Pacific halibut. This study will lead to a significant improvement in our understanding of the physiological mechanisms regulating growth in the Pacific halibut in response to environmental and ecological influences but also, importantly, to the identification of molecular and biochemical growth signatures characteristic of growth patterns that will be used to monitor growth patterns in the Pacific halibut population.

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Total Funding Requested From NPRB: $230,127

2017RFP

1. International Pacific Halibut Commission: $131,891
2. Alaska Fisheries Science Center: $98,236

Total Other Support: $132,606

1. International Pacific Halibut Commission: $68,945
2. Alaska Fisheries Science Center: $63,661

Authorizing Signature:

[signature]	Executive Director
Signature	Title
David T. Wilson	International Pacific Halibut Commission
Printed Name	Organization

Budget Narrative – <u>Organization 1 – International Pacific Halibut Commission</u>

Total Amount requested by Organization 1 for this project is: $131,891

<u>1. Personnel/Salaries:</u>
- No salary expenses are requested for IPHC Staff.
- T<u>echnical support</u>. We request $21,401 in year 1 and $21,615 in year 2 to cover the costs of hiring temporary technical support for 6 months per year.

Total Personnel/Salaries request: $43,016

<u>2. Personnel/Fringe Benefits:</u>
No fringe benefits expenses are requested for IPHC Staff.
- T<u>echnical support</u>. We request $4,280 in year 1 and $4,323 in year 2 to cover the costs of benefits and contract service fees.

Total Personnel/Fringe request: $8,603

<u>3. Travel:</u>
Domestic:
Year 1: PI meeting, Newport OR (1 person)

Rental car	$500
Hotel 2 days	$200
Per diem 3 days/person	$150

Participation in growth experiments, Newport OR (2 people)

Rental car	$500
Hotel 2 days	$400
Per diem 3 days/person	$300
Total travel request in Year 1	**$2,050**

Year 2: Participation in growth experiments, Newport OR (2 people)

Rental car	$500
Hotel 2 days	$400
Per diem 3 days/person	$300

2018 Western Groundfish Conference, undisclosed CA (2 people)

Airfare	$1,000
Hotel 4 days	$800
Conference Registration	$600
Per diem 5 days	$500
Misc travel	$100

2018 Alaska Marine Science Symposium, Anchorage AK (2 people)

Airfare Seattle - Anchorage	$1200
Hotel Anchorage 4 days	$800

Conference Registration	$200
Per diem 5 days Anchorage	$500
Misc travel	$100
Total travel request in Year 2	**$7,000**

Total travel request: $9,050

4. Equipment:

No equipment is requested for this project.

5. Supplies:

Year 1: Laboratory supplies - molecular biology reagents, qPCR reagents, general laboratory chemicals - $7,000

Year 2: Laboratory supplies - molecular biology reagents, qPCR reagents, general laboratory chemicals, protein determination kits, AMPK kits, antibodies $8,500

Total supplies: $15,500

6. Contractual/Consultants:

- RNA sequencing costs (Omega Bioservices, Norcross GA):
  - Muscle samples. Sequencing, assembly and differential gene expression analyses for 25 samples: $15,028.
  - Liver samples. Sequencing, assembly and differential gene expression analyses for 25 samples: $7,514.

Proteomic analyses costs (Oregon State University, Corvallis OR). Label-free mass spectrometry-based quantitative proteomic analyses on 10 muscle and 10 liver samples: $26,180.

Total Contractual funds: $48,722.

7. Other expenses:

- Shipping costs. We request $500 in year 1 to cover the costs of shipping samples to Omega Bioservices.
- Publication costs. We request $4,000 in year 2 to cover the costs of publication of two scientific papers resulting from the work conducted in this proposal ($2000/paper).
- Outreach activities. We request $2,500 in year 2 to cover the costs travel to Kodiak, AK for the ComFish meeting for presentation and discussion of project activities with stakeholders (2 people) as well as educational activities at the Kodiak Fisheries Research Center Aquarium (2 people).

Total Other funds requested is $7,000.

8. Indirect Costs:

Total indirect funds requested is $0 in Year 1 and $0 in Year 2

Other Support/In kind Contributions for Organization 1 – International Pacific Halibut Commission:

Personnel/Salaries:
Principal investigator Josep Planas will dedicate 4 months of time (2 months each year) during the course of this project (total cost $38,986). Dana Rudy will dedicate 4 months of time (2 months each year) during the course of this project (total cost $13,567).

Personnel/Fringe Benefits:
Fringe benefits of 20% of salary will be contributed by the International Pacific Halibut Commission for PI-Planas (total amount of contribution is $13,255 over two years) and D. Rudy (total amount of contribution is $3,137 over two years).

Total Other Support provided by International Pacific Halibut Commission for this project is: $68,945

Budget Narrative – <u>Organization 2 – Alaska Fisheries Science Center</u>

Total Amount requested by Organization A for this project is: $98,236

<u>1. Personnel/Salaries:</u>
No salary expenses are requested for AFSC Staff.
Overtime expenses associated with fish collecting trips are requested in the amount of $3,100 in each year of the project.

Total Personnel/Salaries request: $6,200

<u>2. Personnel/Fringe Benefits:</u>
Fringe benefits of 8% are applied to overtime expenses.

Total Personnel/Fringe request: $496

<u>3. Travel:</u>
Domestic:

Year 1: Fish collection – Kodiak, AK (2 people)		
	Airfare Portland - Kodiak	$2800
	Rental car	$1200
	Hotel 6 days/person	$1884
	Per diem 7 days/person	$1134
	Misc travel	$200
PI meeting, Seattle WA (1 person)		
	Rental car	$500
	Hotel 2 days	$410
	Per diem 3 days/person	$222
	Misc travel	$100
Total travel request in Year 1		**$8450**
Year 2: Fish collection – Kodiak, AK (2 people)		
	Airfare Portland - Kodiak	$2940
	Rental car	$1260
	Hotel 6 days/person	$1978
	Per diem 7 days/person	$1190
	Misc travel	$210
Domestic conference presentation		
	Airfare	$500
	Ground Newport - Portland	$150
	Hotel 4 days	$640
	Per diem 5 days	$370
	Misc travel	$100
Alaska Marine Science Symposium		
	Airfare Portland - Anchorage	$900
	Ground Newport - Portland	$150
	Hotel 4 days	$396

Per diem 5 days Anchorage	$570
Misc travel	$100

Total travel request in Year 2 **$11,455**

Total travel request $19,804

4. Equipment:

No equiptment is requested for this project.

5. Supplies:

Year 1:	Laboratory supplies - fish food, nets, plumbing supplies, dissecting equipment, fish shipping materials, boat fuel, moorage fees	$8,000
Year 2:	Laboratory supplies - fish food, nets, plumbing supplies, dissecting equipment, fish shipping materials, boat fuel, moorage fees	$8,000
	Total supplies	**$16,000**

6. Contractual/Consultants:

We request $23,195 in year 1 and $24,354 in year 2 to cover the costs of hiring temporary technical support for 3 months per year. This includes hourly wages benefits and contract servive fees.

We request $450 in year 2 for conference registration for PI Hurst to attend the Alaska Marine Science Symposium and one other domestic scientific conference.

Total Contractual funds requested is $47,999.

7. Other:

We request $2,000 in each year to cover costs of shipping live fish from Alaska collecting site to the laboratory in Newport, OR.

Total Other funds requested is $4,000.

8. Indirect Costs:

The Alaska Fisheries Science Center's approved indirect cost rate of 60.27% is applied only to overtime.

Total Indirect Costs requested is $3,737

Other Support/In kind Contributions for Organization 1 – Alaska Fisheries Science Center:

Personnel/Salaries:

Principal investigator Thomas Hurst will dedicate 3 months of time (1.5 months each year) during the course of this project (total cost $30,525). We will also dedicate 4 months of technician time (2 months in each year) to assist with fish collections and laboratory experiments (total cost $19,210).

Personnel/Fringe Benefits:

Fringe benefits of 28% of salary will be contributed by the Alaska Fisheries Science Center for PI-Hurst and the fisheries technician. (Total amount of contribution is $13,926 over two years).

In addition to the specified staffing expenses, AFSC will provide the laboratory facilities where the experimental work will take place and the utilites costs of conducting the experiments. These expenses are not independently calculated.

Total Other Support provided by Alaska Fisheries Science Center for this project is: $63,661

Criteria

- Fields of Expertise
    - Biological Science
        - Biochemistry
        - Ecology
        - Genetics
        - Bioenergetics
        - Population Biology
    - Socio/Economic
        - Resource Management
        - Community Involvement
- Professional Activity
    - Field Research & Data Collection
    - Fishery Management
    - Laboratory Research
- Ecosystems
    - Marine – Benthic
    - Marine – Pelagic
- Ecosystem Components
    - Fish
        - Species Groups
            - Halibut
        - Specific Research Issues
            - Habitat
            - Climate Change
            - Physiology
- Geographic Regions
    - Gulf of Alaska
    - Kodiak Island
- Technological Expertise/Lab Methods
    - Laboratory Methods
        - Spectrometry
        - Tissue Sampling/Biopsy
        - Genetic Analysis
        - Fatty Acid Analysis
        - Physiology
- Modeling
    - Modeling type(s)
        - Bioenergetics
        - Stock Assessment
        - Management Strategy Evaluation
        - Climate
- Physical Science Specialty Areas
    - Climate/Atmosphere
        - Climate Variability
- Management/Policy/Social
    - Harvest Strategies
    - International Fisheries
    - Essential Fish Habitat (EFH)

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Outreach Plan

Outreach Option

COMMUNITY

Coastal Community

no

A. <u>Project Summary</u>

Applicant Organization: International Pacific Halibut Commission (IPHC).
Project Title: Improving discard mortality rate estimates in the Pacific halibut by integrating handling practices, physiological condition and post-release survival

S-K Research Priority: The proposed research addresses Priority #3 – "Techniques for Reducing Bycatch and other Adverse Impacts" by investigating discard mortality in the Pacific halibut fishery through studies designed to understand the influence of handling practices and physiological condition of the fish on post-release survival.

Project Location: Gulf of Alaska. IPHC Regulatory Area 3B.

Requested Project Period: September 1, 2017 – August 31, 2019

Funding Requested: $286,121

Name and Title of Principal Investigators: [1] Dr. Josep V. Planas, Biological and Ecosystem Science Program Head, IPHC (Lead PI); [2] Dr. Nathan Wolf, Assistant Professor, Alaska Pacific University; [3] Claude Dykstra, Research Biologist, IPHC; [4] Dr. Tim Loher, Research Scientist, IPHC; [5] Dr. Bradley Harris, Assistant Professor, Alaska Pacific University.

Collaborating partners: [1] Dr. Ian Stewart, Quantitative Scientist, IPHC; [2] Dr. Allan Hicks, Quantitative Scientist, IPHC.

Species/Resources Addressed: This project addresses the directed Pacific halibut (*Hippoglossus stenolepis*) fishery in the Gulf of Alaska. The results of this project will assist in revising estimates of discard mortalities and will consequently influence the catch levels of the directed fishery.

Description of Proposed Activities
The main objectives of this project are to address the important issue of discard mortality rates (DMRs) of Pacific halibut in the directed and non-directed longline fisheries and to refine current estimates of post-release survival in incidentally caught Pacific halibut. In order to accomplish these objectives, the relationship between fish handling practices and fish physical and physiological condition and survival post-capture as assessed by tagging will be investigated.

The IPHC accounts for all mortalities or removals of Pacific halibut in its assessment of the stock, including bycatch as well as the incidental mortality from the commercial halibut fisheries (also known as wastage). Estimates of incidental mortality influence the output of the stock assessment and, consequently, the catch levels of the directed fishery. Prohibited Species Catch limits set by the North Pacific Fishery Management Council (NPFMC) requires that all Pacific halibut caught in non-directed fisheries must be discarded at sea, and these fisheries may be closed when Pacific halibut catch limits are reached.

The NPFMC has identified DMRs in the Pacific halibut fishery as a research priority. The proposed project will directly address this recommendation by providing new scientific information to improve current estimates of DMRs.

The specific objectives of this project include (1) evaluation of the effects of fish handling practices on injury levels and their association with the physiological condition of captured Pacific halibut, (2) investigations on the effects of fish handling methods and associated injury level and physiological condition on post-release survival, (3) application of electronic monitoring in associating fish handling methods to survival in vessels without observer coverage and (4) development of non-invasive methods for quantifying measurable physiological factors indicative of stress and physiological disturbance.

Anticipated Benefits/Outcomes

This project will help refine current estimates of DMRs in the directed Pacific halibut fishery by investigating the relationship between hook release methods, injury levels, physiological condition and survival post-release. This project will develop and implement quantitative measurable factors that are linked to fish handling practices and to fish physiological condition and ultimately to survival in order to improve current DMR estimates. In addition, given the reliance of DMR estimates on observer coverage rates in the non-halibut fisheries, this project will pioneer the use and application of electronic monitoring to associate fish handling methods with survival. The proposed research may help control and reduce incidental mortality and, consequently, will decrease possibilities for non-halibut fishery closures due to exceeded discard limits.

B. <u>Project Description</u>

Background

1. Project Goals and Objectives

The proposed research falls within the scope of **Priority #3 – Techniques for Reducing Bycatch and other Adverse Impacts**. Specifically, the proposed research addresses discard mortality in the Pacific halibut fishery through studies designed to understand the influence of handling practices and physiological condition of the fish on post-release survival.

The IPHC has been responsible for the management of the Pacific halibut (*Hippoglossus stenolepis*) stocks within the Convention waters of the United States and Canada for nearly one hundred years. Information on all halibut removals is integrated by IPHC, providing annual estimates of total mortality from all sources for its stock assessment and related analyses. 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. Due to regulatory requirements, all Pacific halibut that are caught as bycatch or that are of sublegal size in the targeted fishery cannot be retained and must be returned to the sea without sustaining additional injury (Trumble et al., 1993). The entire discarding process involves: first, the capture of the fish (by hooking in case of the longline fishery); second, the handling of the fish by members of the fishing boat and; finally, the release of the fish back into the ocean. Along the discarding process, Pacific halibut will receive injuries and will be subjected to a variety of influencing factors that will affect their survival potential after release. Individual variability in terms of survival (or its opposite, mortality) after release to the sea will be expected depending on the level of injuries and stresses incurred during the discarding process as well as on the biological characteristics of the fish (e.g., physiological condition or status). Therefore, an accurate understanding of the types and relative levels of injuries and stresses that fish are exposed to during the discarding process in relation to the biological characteristics of the fish can be instrumental in helping better estimate the probability of survival (or mortality) during the entire discarding process (Davis, 2002).

Discard mortality rates (DMRs) are calculated from data that are collected by observers regarding the release viability or injury characteristics of Pacific halibut post-capture and are used to estimate the percentage of incidentally-caught fish that die after release. Currently, post-capture DMR estimates are based on qualitative assessments of the physical condition of the fish (e.g., minor/moderate/severe/dead for longline gear) and have a certain degree of uncertainty associated with them, which represents a source of uncertainty in the estimation of total mortality within current stock assessment models. In practice, assigned DMRs and their uncertainty translate into *a priori* adjustments to expected mortality in each upcoming year, and to the catch limits that are thereafter assigned to each harvest sector. Given current low halibut yields relative to long-term mean productivity, this potential to translate uncertainty into catch limit reductions can place undue hardship on some sector(s) relative to others. Therefore, there is an urgent need to improve our estimates of DMR as well as to provide strategies to improve survival of incidentally-caught Pacific halibut after release.

Following upon initial studies of post-release mortality of longline-caught Pacific halibut in relation to injury type (Peltonen, 1969), in the early 1990s the IPHC conducted studies designed to relate injuries associated with capture events with survival post-release in the Pacific halibut longline fishery. Kaimmer (1994) reported that the survival rates of fish caught and subjected to manual hook removal (i.e. careful shake) were higher than fish subjected to automatic hook removal (i.e. hook stripper), with the latter method producing more severe injuries and resulting in decreased growth rates in the surviving fish. In a subsequent study, Kaimmer and Trumble (1998) reported on the survival rate of fish released from the hook by various techniques and classified under different condition codes according to the extent of the hook removal injuries and other descriptors of condition (i.e. bleeding and gill color, evidence of predation and muscle tone). The results of that study revealed that condition codes closely followed the hook removal injuries observed in the fish and, importantly, that survival rates were higher in fish in excellent condition when compared to fish in the poor and dead conditions, setting the ground for the use of condition codes as predictors of survival (Kaimmer and Trumble, 1998). As a result of this research, current estimates of survival of discarded fish are based exclusively on visual assessment of the external condition of individual fish, as measured by injury levels, activity, responsiveness, etc.

It has been well recognized that fish condition assessments that incorporate additional levels of information on the physiological characteristics of captured fish have improved power of predictability of survival in discarded fish (Davis, 2010; ICES, 2014). It is important to indicate, on one hand, that the physiological condition of the captured fish may influence their susceptibility to the stress associated with capture and handling events and, hence, their potential for survival after release. On the other hand, different capture and handling procedures can elicit different physiological responses in the fish to cope with the ensuing stress, which may also influence their survival after release. These two aspects are important because they drive most of the variability that is observed in estimates of discard survival (ICES, 2014). Therefore, it is important to measure physiological indicators of stress and condition in a quantitative manner in relation to capture and handling events in order to understand their influence on survival after release. Full condition assessments incorporating physiological parameters can then be used as a predictive tool to estimate discard survival rates (or alternatively DMRs) if properly calibrated with the results of direct survival or behavioral studies (e.g., tagging and telemetry studies).

Typically, **fish condition** has been expressed as the relationship between fish weight (W) and length (L) under the assumption than heavier fish are in better condition (i.e. fitter) than lighter fish (Bolger and Connolly, 1989). The two most commonly used condition factor indexes are Fulton's condition index ($K = W/L^3$) and the relative condition index ($K_n = W/\widehat{W}$; that expresses measured W in relation to calculated $\widehat{W}$ from a population-derived W-L relationship), with both indexes based on weight and length characteristics. Condition factor indices offer the benefit of being calculated with measures that can be taken from live fish and, therefore, are compatible with subsequent survival studies. A recent study performed at IPHC showed that K_n is better correlated than K with the hepatosomatic index (HSI; used as an indirect estimate of energy levels in the liver but that requires sacrificing the fish for its measure) (IPHC report, in preparation). However, despite their use to infer the condition of fish, condition factors or HSI do not provide a direct nor accurate measure of the energy levels present in the fish, which are a determinant of fitness. The recent development and demonstrated use of a non-invasive device

("Fatmeter") to measure the fat or energy levels of the fish that is based on microwave technology and that can be used on live fish (Crossin and Hinch, 2005) has provided the means to incorporate energy level measurements in field studies involving capture, handling and release of fish. At IPHC, Fatmeter-derived energy levels in the flesh of live adult Pacific halibut have been positively correlated with K_n and HSI determinations (IPHC report, in preparation), validating its use in physiological condition determinations in this species. Therefore, physiological condition of captured and handled fish, incorporating stress and disturbance parameters in the blood, can be measured in a quantitative manner and used to associate capture and handling events with post-release survival.

It is fair to state that the qualitative tests used to assess the viability of bycatch and sublegal size Pacific halibut are limited in their ability to accurately assess physical and physiological disturbances in a manner that can predict post–release survival with a reasonable degree of precision; thereby adding significantly to the uncertainty of total mortality estimates within stock assessment models. Evaluation of physiological stress indicators, such as circulating levels of stress hormones (e.g., cortisol and catecholamines such as epinephrine and norepinephrine) or compounds associated with the secondary stress response (e.g., glucose, sodium, potassium, lactic acid), offers a potential method by which physical, physiological, and perceived disturbances associated with catch events can be assessed and quantified in individual fish in a manner that recognizes the systemic nature of disturbance (Barton 2002). In addition to providing this integrated quantitative metric, improvement of the current vitality assessment methods with measurements of stress indicators may provide more precise estimates of post-release survival than the current vitality assessment methods alone. Research into the relationships between the stress response, metabolism, osmoregulation, body condition, the immune response, growth, and reproductive success in a variety of marine and freshwater fish species (Barton 2002, Jentoft et al. 2005, Haukenes and Buck 2006, Hosoya et al. 2006, Hur et al. 2007, Fast et al. 2008) has allowed for increased understanding of the physiological mechanisms linking stress to decreased physiological and physical performance and, consequently, the utility of physiological indicators of the stress response in predicting survival.

Plasma cortisol is the most commonly used stress indicator in fish (Bertollo et al. 2010 and references therein). Presumably, this is due to the relative ease with which plasma samples can be obtained and the rapid time course of increase in plasma concentrations of cortisol following the induction of a stressor (Haukenes and Buck 2006). However, the blood sampling procedure itself can be a source of stress for subjects, thereby resulting in potential increases of plasma cortisol levels possibly as a result of sampling artifacts (Bertotto et al. 2010). Consequently, the use of stress indicators, such as cortisol, to evaluate probability of survival in bycatch and sublegal size halibut may benefit from the development of a non-invasive sampling matrix that a) can provide an accurate indication of the magnitude of the stress response, b) does not inherently influence the stress response, and c) can be applied quickly and easily in a field setting. In particular, skin mucus has great potential as a sampling matrix for stress indicators to evaluate survival probability in Pacific halibut. Mucus sampling can be conducted quickly and easily in field settings, and, unlike plasma samples, mucus samples can be collected in a relatively non-invasive fashion; thereby decreasing the likelihood of the sampling procedure influencing the stress response. In a recent study, Bertotto et al. (2010) examined cortisol levels in plasma and mucus from three different fish species (European sea bass (*Dicentrarchus labrax*), common carp (*Cyprinus carpio*), and rainbow trout (*Oncorhynchus mykiss*)) following the introduction of a physical stressor. The authors observed significant increases in cortisol levels in plasma and mucus, found a significant correlation in the cortisol levels in plasma and mucus, and concluded that mucus cortisol is a viable candidate for measuring stress in fish. To our knowledge, no previous studies have evaluated the potential use of skin mucus for stress indicator measurements in Pacific halibut in field or controlled experimental settings.

In Pacific halibut, limited information is available regarding the measurement of physiological stress indicators in relation to stressful events. In one of the first reported studies, increased handling time in Pacific halibut was characterized by elevated plasma levels of potassium, sodium and glucose (Oddsson et al., 1994). In a later study, exposure to air and high temperatures in 1- and 2-yr-old Pacific halibut was reported to result in a rapid (within the first 30 min of exposure) elevation of cortisol, glucose, lactate, sodium and potassium levels in plasma (Davis and Schreck, 2005). However, these authors failed to observe a correspondence between the primary and secondary indicators measured and mortality rates in captive experiments (Davis and Schreck, 2005). Importantly, no studies have investigated to date the effects of capture and handling techniques on physiological stress indicators and physiological condition and their relationship with post-release survival in the field.

The rationale of the proposed research is based on the notion that by understanding the relationship between handling practices, injury levels and physiological condition, on one hand, and between these and post-release survival, on the other hand, estimates of DMR could be improved. An important underlying topic in this proposal is to better understand how a detailed assessment of physiological condition prior to release can improve our estimates of survival after release. This research will attempt to develop and introduce quantitative measurable factors that are linked to fish handling practices, physiological condition and ultimately survival in order to improve current DMR estimates.

For the above-stated reasons, the **main goal** of the proposed research is to *understand the relationship between fish handling practices and fish physical and physiological condition and survival post-capture as assessed by tagging in order to better estimate post-release survival in incidentally-caught Pacific halibut in directed and bycatch longline fisheries*.
Specific Objectives

1. Evaluation of the effects of hook release techniques (careful shaking, hook straightening, gangion cutting and automatic hook stripping) on injury levels and association with the physiological condition of captured Pacific halibut.
2. Investigations on the effects of hook release techniques and associated injury levels and physiological condition on post-release survival.
3. Application of electronic monitoring in associating hook release techniques to survival in vessels without observer coverage.
4. Development of non-invasive methods for measuring the levels of physiological factors indicative of stress and physiological disturbance.

Deliverables
1. Injury profile for different hook release techniques.

2. Physiological assessment of hook release techniques: fish condition index at post-capture.
3. Assessment of post-release survival in relation to hook release techniques, associated injury levels and physiological condition of halibut released in excellent condition.
4. Assessment of post-release survival in relation to size.
5. Electronic monitoring of hook release techniques and associated injury levels and projected survival.
6. Information on stress and physiological disturbance indicators in the mucus, a non-invasive sample that is easy to collect.
7. Establish the basis of a rapid assay for measurement of stress and physiological disturbance indicators in the mucus for its use in the field.

2. Project Impacts

The proposed research, by investigating the relationship between hook release methods, injury levels, physiological condition and survival post-release, will help **refine current estimates of DMRs** in the directed Pacific halibut fishery. Given that the incidental mortality from the commercial halibut fisheries (also known as wastage) and bycatch fisheries is included as part of the total removals that are accounted for in the IPHC's stock assessment, changes in the estimates of incidental mortality will influence the output of the stock assessment and, consequently, the catch levels of the directed fishery. Therefore, the proposed research can have a direct impact in improving the socio-economic aspect of the directed Pacific halibut fisheries by directly benefiting fishers. Importantly, the results of this project will inform on the handling techniques that, in relation to the physiological condition and size of the fish, will be associated with the **highest survival rates**. Therefore, **best practices** for the reduction or control of discard mortality rates will be able to be developed and implemented. The proposed research may help control and reduce incidental mortality and, consequently, will reduce possibilities for fishery closures due to exceeded discard limits.

3. Evaluation of the Project

The progress and success of the project will be evaluated continuously against the deliverables that were described above (Section 1: Project Goals and Objectives) at the bi-annual project meetings (see Section 7). Importantly, the project will be externally monitored and evaluated by scientific and stakeholder groups that currently evaluate research and management activities of IPHC: the Scientific Review Board, the Research Advisory Board and the Management and Strategy Advisory Board. Meetings with IPHC advisory bodies will take place annually. In addition, evaluation of the progress and success of the project will also be conducted by annual meetings (to coincide with project meetings) with other stakeholder groups that represent fishers and fishing communities that directly or indirectly depend on the Pacific halibut fishery (e.g., Alaska Longline Fishermen's Association, North Pacific Fisheries Association, Pacific States Marine Fisheries Commission; see Letters of Support). Evaluation of the scientific merit and success of the proposed research will also take place through the publication of the results in reputed peer-review journals and in the presentation of the results in scientific and fisheries-related conferences as well as the Electronic Monitoring Workshop.

Evaluation steps: a) Project confirmation of deliverables; b) Presentation of progress and results to IPHC advisory bodies; c) Presentation of progress and results to stakeholder groups; d)

Submission of research articles to peer-reviewed publications; e) Presentation of results in scientific and fisheries-related conferences.

4. Need for Government Financial Assistance

Although the project provides substantial non-federal contributions (matching funds), financial assistance is specifically requested for research activities and personnel needs that cannot be funded otherwise by the participating institutions in this project. Specifically, federal funding requested is for survival assessment by tagging, electronic monitoring, hiring of necessary additional personnel to conduct field and land-based research, and also for conducting the fish holding studies and physiological determinations. No additional funding has been requested from other sources. The successful completion of this project is dependent on the provision of funding from federal and non-federal (matching) sources as this project falls directly within one of the priorities of the current Saltonstall-Kennedy Research Program as well as within the research priorities of the NPFMC.

5. Federal, State, and Local Government Activities and Permits.

IPHC conducts extensive field studies in Alaska annually, abiding by all state, federal, and Coast Guard requirements. Additionally, all operations will carry a Letter of Acknowledgement from NMFS's Alaska Fisheries Science Center specific to the work, and incidental bird take permits from the USFWS. All standard post cruise reporting requirements (research fish landing tickets etc.) will be observed.

6. Statement of Work.

a) <u>Project Design</u>:

As stated above, the main overarching goal of this research proposal is to understand the relationship between hook release techniques and fish physical and physiological condition with survival post-capture as assessed by tagging (Objectives 1 and 2; Tasks 1 and 2) in order to better estimate post-release survival of discarded fish in the directed Pacific halibut longline fishery (wastage) and other longline fisheries that incidentally catch Pacific halibut. The earliest studies linking longline injury post-release survival employed "J" hooks (Peltonen, 1969) and studies linking release methods with post-release survival of Pacific halibut were conducted using small (13/0) circle hooks (Kaimmer and Trumble, 1998), both of which are unlike the large (16/0) circle hooks that comprise roughly 75% of the fishing effort applied in the directed Pacific halibut longline fisheries. Furthermore, physiological stress and disturbance indicators have not been measured and quantified previously in relation to release methods, hook injury levels, and post-release survival in the Pacific halibut. Therefore, the proposed studies aim at providing quantifiable measurable factors that are linked to fish handling practices and to fish physiological condition and ultimately to survival in the Pacific halibut. In addition, electronic monitoring will be investigated as a means to obtain information on release methods employed by commercial fishers and to facilitate the association of release methods with injury levels, physiological condition, and post release survival in vessels without observer coverage (Objective 3; Task 3). Furthermore, exploration of non-invasive detection methods of physiological stress and disturbance indicators will be conducted to develop fast, simple, and accurate physiological monitoring to be used in the field (Objective 4; Task 4). Finally, the implication of revised DMRs for estimating removals of Pacific halibut in longline fisheries, for stock assessment and the harvest policy will be assessed.

Description of tasks:

Task 1. Evaluation of the effects of hook release techniques on injury levels and association with the physiological condition of captured Pacific halibut. The work proposed involves evaluating the effects of different release techniques on injury levels and associated physiological condition levels using the large (16/0) circle hooks used in the Pacific halibut longline fishery.

- *Fish capture*. One vessel chartered to operate in Alaskan waters (within IPHC´s Regulatory Area 3B) will be used for the study. The fishing location will be selected based on the potential to catch adult fish of both legal (82 cm and above in length) and sub-legal (under 82 cm in length) sizes at rates that facilitate efficient completion of project goals. Functionally, however, the fleet has a tendency to discard fish under 84 cm to avoid landing fish that would appear to be sublegal (owing to shrinkage) post icing. Therefore, discard fish are considered to be all fish under 84 cm in length. The vessel will operate following the standard practices of the commercial Pacific halibut fleet; namely, in terms of the procedures and times of setting, soaking, and hauling baited longline gear. Average line soaking times used in the commercial fleet will be adopted. Two (2) fishing trips consisting of six (6) fishing days per trip will be targeted. On each day, three (3) hauls of eight (8) standard skates (i.e., 100 hooks) each will be targeted for a total of two hundred and eighty eight (288) skates of gear. Vessel will need to have a secondary roller with automatic hook-removal setup inboard of the outboard roller. Based on IPHC's survey data from 2016 in Regulatory Area 3B and the proposed effort, we estimate to catch a total of 1,864 fish, with 1,229 fish at or under 84 cm and 635 fish over 84 cm in length.
- *Hook release techniques*. Pacific halibut will be released from the hook using three different careful release methods as well as by the use of automated hook-stripping devices (i.e. hook stripper), yielding a total of four (4) treatments. The careful release methods used will be: careful shaking, hook straightening, and gangion cutting (approved under IPHC regulation and described in detail in Kaimmer and Trumble, 1998). Hook release with the use of automated hook-stripping devices will also be evaluated given that, although this is not an accepted hook release method, it occurs nevertheless whenever fish fail to be manually unhooked. The rate at which this occurs in both directed and non-directed longline fisheries is currently unknown, but patterns associated with the occurrence of prior-hooking injuries (Dykstra 2016) suggests that hook-stripping may be more prevalent than is currently assumed and may also vary spatially. Given that hook-stripping is likely to induce the highest DMRs in longline fisheries and that its occurrence might be easy to quantify via electronic monitoring, obtaining baseline data for this release method is important. In order to evenly distribute the release treatments throughout the course of the experiment, release methods will be randomly assigned by skate, within each set of gear, so that each haul will consist of two skates of each release method.
- *Hook injury assessment*. All landed fish corresponding to each of the hook release techniques or treatments will be measured for length and weight, examined to record the extent of the hook injury, sampled for blood and their physiological condition will be assessed. We will follow the hook injury classification scheme initially outlined by Kaimmer (1994) and expanded by Kaimmer and Trumble (1998) into 14 different categories (i.e. injury codes) corresponding to four major severity levels (e.g., minor, moderate, severe, and dead). Only fish that are 84 cm or less in length will be tagged.
- *Blood sampling*. After assessing injury levels of Pacific halibut released using each of the four above-mentioned treatments, a blood sample (approximately 1-2 ml) will be taken for each fish from the caudal vein with the use of heparinized hypodermic needles and syringes and stored

on ice until centrifugation. At regular intervals, blood samples from several fish will be centrifuged on board in microcentrifuge tubes at 1,500 x g for 30 min at room temperature using a small field centrifuge (Eppendorf). Plasma samples will be separated from the cellular component of the blood with the use of a Pasteur pipette, transferred to new pre-labeled microcentrifuge tubes and kept frozen in dry ice until they can be stored at -80 C. The procedure to retrieve blood samples and the amount of blood extracted are routine and will not impinge any negative effects on the condition of the fish nor on their survival. Prior to centrifugation, extracted blood samples will be used for hematocrit (i.e. percentage of red blood cells in the blood relative to the volume) determinations by filling glass capillary tubes with blood and centrifuging them in a field capillary centrifuge.

- *Monitoring of environmental conditions*. In addition to recording the time elapsed between hook removal and return of tagged fish back into the ocean, sea bottom temperature will be recorded with the use of dataloggers (Star Oddi DST centi-TD), as well as ambient temperature, light intensity on deck and sea state (Beaufort scale).
- *Assessment of physiological condition*. The physiological condition of each selected fish from each of the four release techniques with associated injury levels will be determined in two different ways. First, we will calculate two different condition factor indices (i.e. Fulton's K, relative K) that express differently the relationship between length and weight and that have been recently used to evaluate the condition of landed Pacific halibut (IPHC report, in preparation). Second, we will calculate the energy (fat) levels by using a microwave-based device (Distell Fish Fatmeter, model 692, Distell, West Lothian, Scotland) that is applied directly onto the skin of the fish allowing energy determinations in the musculature without the need to sample tissue (Fig. 1). This is a direct, non-invasive and harmless measure of energy levels that can be taken from live fish (Donaldson et. al, 2010, Sang et. al, 2009) and that has also been recently used at IPHC to measure fish condition and shown to correlate well with relative K condition index as well as with the hepatosomatic index (IPHC report, in preparation). Surface body temperature will be recorded with the use of a hand-held infrared thermometer.

Fig. 1. Use of the Fish Fatmeter in field studies in Pacific halibut (Photo by B. Ortiz)

- *Blood plasma measures*. The levels of stress and physiological disturbance indicators (e.g., cortisol, catecholamines, lactate, glucose, sodium and potassium ions, osmolarity and pH, hematocrit) will be measured in the blood plasma samples of selected fish by release technique with associated injury levels and condition indexes. The plasma levels of cortisol and catecholamines, as endocrine indicators of stress responses, will be measured by enzyme linked immunoabsorbent assay (ELISA; 2-CAT Research Elisa Kit, Labor Diagnostika Nord, Germany) at IPHC. The levels of lactate and glucose, as biochemical indicators of catabolic responses to stress, will be measured directly in the plasma samples by standard commercial colorimetric assay kits at IPHC. The plasma levels of sodium and potassium ions, osmolarity and pH will be measured by blood gas analysis (to be done in collaboration with NMFS).

Task 2. Investigations on the effects of fish handling methods and associated injury level and physiological condition on post-release survival. In order to evaluate the survival of discarded fish, two types of tagging approaches will be used: 1) mark-and-recapture of released fish with wire tags and 2) biotelemetric monitoring of released fish with the use of satellite-transmitting electronic archival tags equipped with accelerometers.

- *Mark and recapture of released fish with wire tags*. All selected fish (84 cm or less) from each of the release techniques that have associated injury level and physiological condition will be tagged using wire tags, as previously described (Forsberg et al., 2016). In brief, wire tags are inserted between the opercular bones of the eyed side of the fish and the two ends of the tag are twisted together around the operculum. The use of wire tags will allow for the long-term assessment of survival in the ocean; however, it is worth-noting that we do not expect to recover enough wire tags within the study's stated period to formally estimate rates associated with various survival covariates, and that estimates of survival rates using this approach are confounded by natural mortality and unreported recaptures. A total of ~300 fish will be tagged per treatment.
- *Biotelemetric monitoring of released fish with the use of satellite-transmitting archival tags*. A group of 80 fish that are determined to be in excellent condition (e.g., minor injury category) will also be tagged with Wildlife Computers (Redmond, Washington) sPAT archival tags equipped with accelerometers in order to evaluate post-release mortality. Only a single viability category will be studied due to the high cost of these tags. Here, we have chosen the excellent category because it represents the vast majority of targeted-fishery discards and, hence, the bulk of assumed mortality. Additionally, uncertainty regarding the survivorship of halibut that are discarded in excellent condition has the greatest impact upon current estimates of survivorship in the remaining viability categories. This is because the latter estimates have been derived by comparing tag recovery rates from fish tagged within these categories to the rate of recovery of tags from excellent fish, assuming a "known" excellent-fish survival rate. Tagged fish will not be released in the presence of whales.

  The architecture and internal programming of sPAT tags was developed in 2015 in cooperation with the tag manufacturer for the explicit purpose of indexing post-release mortality of sublegal-size halibut captured in Bering Sea trawl fisheries (*see* S-K funded project 15AKR013); tag calibration and parameterization based on field data was accomplished in 2016. The halibut-dedicated version of the sPAT is an epoxy-cast electronic tag shaped much like a small microphone, containing accelerometers in three axes, wet-dry detection capabilities, an automatic release mechanism, and a satellite transmitter. The tag measures 124 mm in length and 38 mm in diameter, is slightly buoyant in seawater, and is attached to the host fish via a dart-and-tether system that has been successfully employed since 2002, on halibut as small as 51 cm in length. Sensor data are captured and stored at 15-second intervals and compiled into summary data via onboard processing. Upon reaching the surface – after either the tag's pre-specified attachment period or upon premature release – the sPAT's position is determined via satellite and 2-hour summaries of rapid increases in tag tilt ("knockdowns") and percentage of time that the tag was tilted beyond a pre-specified threshold are reported. If physically recovered, the full high-resolution data archive can be downloaded. The accelerometer data allow for determination of whether premature tag release was consistent with a mortality event or represented an attachment failure that would invoke removal from the study's effective sample size. For putative mortalities, the data may further provide information regarding the time-course and dynamics associated with mortality events (Fig. 2) that may be correlated to fish size, condition, or environmental parameters at time of capture.

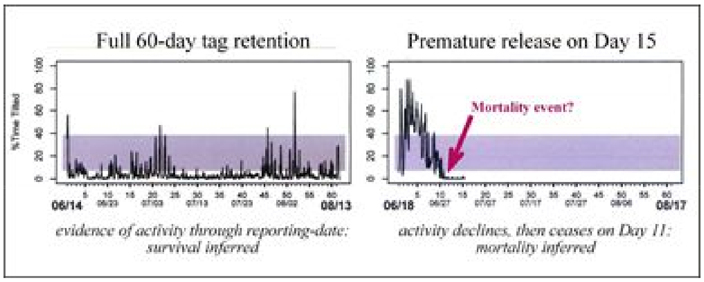

Figure 2. Satellite-broadcast accelerometer data from sPATs applied to two halibut incidentally captured and released from Bering Sea trawl vessels in 2016. The data are compiled over 2-hour periods and indicate the amount of time that the tags were tilted more than 50° past vertical. This threshold was established using field data from longline-captured halibut so as to indicate sustained swimming while rarely being triggered by tidal currents in the study area. Tags were programmed to detach after 60 days. The fish on the left retained its tag throughout the 60-day period and was therefore designated as having survived; note that the sustained activity throughout that period and immediately prior to tag detachment. The tag from the fish on the right detached prematurely and the fish was therefore assumed to have died; its data are consistent with the hypothesis that mortality occurred three days prior to tag release.

We will tag 80 halibut under 84 cm in length with sPATs programmed to detach and report after 150 days at liberty. Although this exceeds the 60-day survival period currently being used to study trawl DMR, current data indicate that shorter period survivorship can be accurately calculated using longer time-series data. The longer recording period will allow us to conduct standard DMR analysis while expanding the scope of the work to gain greater insight into time-course to recovery or normal behavior or delayed mortality in individuals whose records exceed 60 days. No field data currently exist with respect to these aspects of post-release physiology. Tags will be randomly distributed among individuals in the excellent category and the number of tags used (80) will allow us to be able to estimate survival with a confidence level of 95% and a margin of error of 8%. Sex of all tagged individuals will be determined using established ultrasonic techniques (Loher and Stephens 2011). As a visual summary, the workflow of activities between fish handling practices, fish physiological condition and survival as assessed by tagging is shown in Fig. 3.

Figure 3. Schematic diagram of the workflow of activities in Tasks 1 and 2.

<u>Task 3. Application of electronic monitoring (EM).</u> The North Pacific Fishery Management Council (NPFMC) is responsible for the collection of fisheries-dependent data used in catch

estimation for the fixed gear groundfish and halibut fisheries in Alaska. On vessels larger than 57’, fishery observers collect these data, which include counting, measuring, and assigning viability codes (i.e., categorize physical damage and responses to physical stimuli) to discarded halibut. The NPFMC has established its intention to integrate EM tools into the Observer Program (Al-Humaidhi, et. al., 2016) in order to collect data on the small vessel (<57’) component of the fixed gear fleets, and is on track for final implementation of camera systems into catch accounting in 2018. Pilot EM systems have been shown to be good at detecting release methods of fish, but are less effective in determining the condition of the fish (Al-Humaidhi et al, 2016) as EM does not always capture imagery from both sides of the fish, nor can EM be used to determine physical responses of the fish to stimuli. The work proposed under this project will develop a profile of injuries associated with different release methods, while at the same time quantifying the accuracy of EM in enumerating release methods, and fish conditions (Fig. 4). Both of these aspects are necessary to transform EM imagery into useable/actionable data.

- *Installation of EM System.* A standard 3-camera EM system used in the current pre-implementation trial by NMFS will be installed on the chartered vessel (Archipelago Marine Research Ltd).
- *Development of injury profile by release method.* Halibut caught on fixed gear will be evaluated for viability and subsequent survival for the three allowable release methods: a) hook straightening, b) cutting the gangion by the hook, c) careful shaking; as well as: d) removal via a hook stripper (crucifier) which occasionally happens when halibut make it past the gaffer.
- *Evaluation of EM data.* Reviewers will record release method and condition of released halibut. This data set will be compared to those collected by personnel at sea as part of their tagging efforts (equivalent to the human observer data).

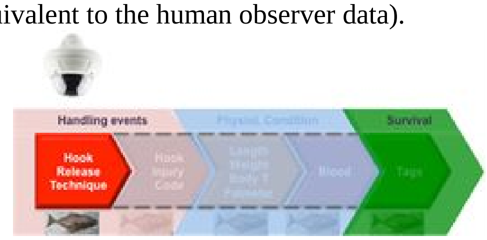

Figure 4. Schematic diagram of the workflow of activities in Task 3.

Task 4. Development of non-invasive methods for measuring the levels of physiological factors indicative of stress and physiological disturbance. The proposed work will involve a controlled experiment to explore the use of mucus cortisol concentration as a stress indicator in Pacific halibut with the potential for use in evaluating probability of survival in bycatch and sublegal size fish. Unlike plasma samples, mucus samples can be collected in a relatively non-invasive fashion, thereby decreasing the likelihood of the sampling procedure influencing the stress response. In addition, mucus sampling can be conducted quickly and easily in field settings.

- *Fish capture.* One vessel chartered to operate in Alaskan waters (within IPHC´s Regulatory Area 3A) will be used for fish capture. During September 2017, 16 – 24 adult Pacific halibut will be caught by jigging natural and artificial baits on the seafloor near Seward, AK. Only adult halibut between 20 and 31 inches will be brought onboard and kept for use in the experiment. This size range has been selected both to minimize the potential for variations in cortisol response in study subjects due to size (Barcellos et al. 2012) and as representative of fish of commercially-sublegal size. Once on board, fish will immediately be placed in onboard holding tanks for transfer to the UAF Seward Marine Center (Seward, AK) where all experimental work will be conducted. During holding, 50% of the water in the tanks will be replaced twice every hour to maintain dissolved oxygen concentrations and water temperature at levels resembling sea surface conditions (Haukenes and Buck 2006).

- *Animal housing and care.* Fish will be housed in 6 ft. x 3 ft. circular tanks (approximate filled volume = 580 US gallons) at the UAF Seward Marine Center (Seward, AK). Fish will be randomly assigned to tanks, and no more than 3 fish will occupy each tank. Water temperature and dissolved oxygen level will be kept constant and waste will be removed using an open flow through seawater system that will draw water from Resurrection Bay. Photoperiod will be standardized on a 12:12 light:dark regime. During the entire course of the experiment, the fish will be fed a fishmeal-based pellet diet once daily at a rate of 1 kg feed/kg fish. Haukenes and Buck (2007) observed elevated plasma cortisol levels in Pacific halibut sampled 10 days after the introduction of a stressor. In order to allow increased cortisol levels caused by the capture, transport, and acclimation to the experimental housing to return to baseline levels, the fish will be left undisturbed (except for feeding) for a period of no less than 30 days. Fish will also be left undisturbed (except for feeding) between experiment subcomponents.
- *Magnitude and rate of cortisol absorption and elimination in mucus.* Captive halibut will be randomly divided into three groups. Individuals from two of the groups will receive intraperitoneal injections of different doses of cortisol (0.1 μg/g of fish and 0.01 μg/g of fish). Individuals from the third group will act as a control, receiving intraperitoneal injections of sterile phosphate buffered saline (Espelid et al. 1996). Blood and mucus will be sampled from three parallel fish in the three groups at 0, 0.5, 2, 5, 24, 36, 48, and 72 hours after injection. In order to reduce handling stress, the individuals exposed to cortisol or control injections for 72 hours will be housed in the same tank and injected first. In the same fashion, the 48, 36, 24, 5, 2, 0.5, and 0 hour groups will be housed in separate tanks, each of which will be injected at successive pertinent times. Blood and mucus sampling for plasma and mucus cortisol levels will occur at the same time for all fish. For each tissue and treatment group, changes in cortisol concentration over time will be examined using repeated measures analysis of variance. Mann-Whitney U tests will be used to compare of the magnitudes of maximum cortisol levels between tissues and treatment groups, and Pearson's linear regression will be used to correlate cortisol values between tissues. Plasma and mucus cortisol values from the control group will be used to ensure the validity of results from both these experimental studies and the field studies described in Task 1.
- *Stress induction experiments.* Adrenocorticotrophic hormone (ACTH) is secreted rapidly in response to stress and acts on the adrenal cortex to stimulate the release of cortisol (Belanger et al. 2001). *In vivo* ACTH administration can be used as a tool to artificially stimulate cortisol release; thereby allowing for comparison between resting and stimulated cortisol levels and examinations of the cortisol rates of increase in unique tissues. While *in vivo* ACTH administration has been used to elicit cortisol responses in yellow perch (*Perca flavescens;* Girard et al. 1998) and white sturgeon (*Acipenser transmontanus*; Belanger et al. 2001), there is no information on the effect of ACTH on plasma cortisol in Pacific halibut and very little information on the ACTH dose–response relationship in any fish species. To examine cortisol rates of increase in plasma and mucus in response to ACTH administration, captive halibut will be randomly divided into three groups. Individuals from two of the groups will receive intraperitoneal injections of 1ml of Ringers solution containing 0.5 μM or 5 μM ACTH (Belagner et al. 2001). Individuals from the third group will act as a control, receiving intraperitoneal injections of 1ml of Ringers solution. Blood and mucus will be sampled from

three parallel fish in the three groups at 0, 0.5, 2, 5, 24, 36, 48, and 72 hours after injection. In order to reduce handling stress, the individuals exposed to ACTH or control injections for 72 hours will be housed in the same tank and injected first. In the same fashion, the 48, 36, 24, 5, 2, 0.5, and 0 hour groups will be housed in separate tanks, each of which will be injected at successive pertinent times. Blood and mucus sampling for plasma and mucus cortisol levels will occur at the same time for all fish. For each tissue and treatment group, changes in cortisol concentration over time will be examined using repeated measures analysis of variance, and Mann-Whitney U tests will be used to compare of the magnitudes of maximum cortisol levels between tissues and treatment groups. Pearson's linear regression will be used to correlate cortisol values between tissues. Post-injection plasma concentrations of ACTH will not be measured in this study. Plasma and mucus cortisol values from the control group will be used to ensure the validity of results from both these experimental studies and the field studies described in Task 1.

- *Blood and mucus sampling and sample processing*. Blood samples (approximately 1-2 ml) will be collected from the caudal vein using heparinized hypodermic needles and syringes and centrifuged immediately in microcentrifuge tubes at 1,500 x g for 30 min at room temperature. Plasma samples will be separated from the cellular component of the blood using a Pasteur pipette, transferred to new pre-labeled microcentrifuge tubes and stored at -80 C for analysis. Samples of skin mucus (approximately 1-2 ml) will be collected by gently scraping the side of the fish with a cotton swab or small plastic rod (Fig. 5) and stored at -80 C for analysis
- *Cortisol extraction and analysis*. Plasma cortisol levels will be measured by enzyme linked immunoabsorbent assay (ELISA; 2-CAT Research Elisa Kit, Labor Diagnostika Nord, Germany) at Alaska Pacific University. Mucus cortisol levels will be measured following Bertotto et al. (2010). Following Bertotto et al. (2010) and Mercado et al. (2016), mucus samples will be thawed and diluted with phosphate buffered saline (1:2). Mucus cortisol levels will also be measured by enzyme linked immunoabsorbent assay (ELISA; Demeditec Diagnostics, GmbH, Kiel, Germany) at Alaska Pacific University.

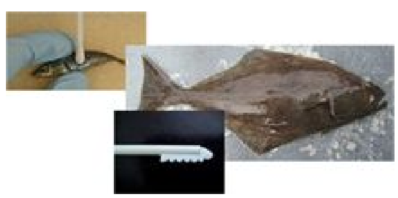

Figure 5. Gentle mucus extraction by swabs. Top left, example of a mucus sample taken from a stickleback with the use of a cotton swab. Bottom, example of small plastic mucus collector that will be used to extract skin mucus samples in Pacific halibut.

b) Description of personnel responsibilities:
The IPHC will represent the lead organization for this project. IPHC is an international organization that is responsible for the management of the Pacific halibut (*Hippoglossus stenolepis*) stocks within the Convention waters of the United States and Canada. IPHC has had a long history of conducting research on biological aspects of the Pacific halibut that impact stock assessment and is perfectly suited for undertaking the task of leading this project. The administrative and financial aspects of the project will be managed by IPHC. The project is composed of several principal investigators, two project collaborators and hired personnel to conduct specific technical-oriented tasks in the project.

Principal investigators (PIs)
[1] *Dr. Josep Planas* is the lead PI and will take responsibility for project coordination, administration and reporting. Dr. Planas will work with other PIs and project collaborators on all the tasks that will be performed. Dr. Planas will work directly with PI Claude Dykstra in Task 1 on physiological condition and disturbance indicators, with PIs Dr. Tim Loher and Mr. Claude Dykstra in Task 2 on conventional tagging and survival estimation through electronic tagging, with PI Claude Dykstra in Task 3 on electronic monitoring and with PIs Dr. Nathan Wolf and Dr. Bradley Harris in Task 4 on physiological indicator assessment of stress in captive studies. [2] *Mr. Claude Dykstra* will share responsibility with PI Dr. Josep Planas in Task 1 and will take the main responsibility for Task 3 on electronic monitoring working together with PI Dr. Josep Planas. He will also participate in Task 2 working together with PIs Dr. Josep Planas and Dr. Tim Loher. [3] Dr. *Tim Loher* will take the main responsibility for Task 2 on deployment of electronic tags and subsequent survival estimation, working together with PIs Dr. Josep Planas and Mr. Claude Dykstra. [4] Dr. *Nathan Wolf* and [5] Dr. *Bradley Harris* will share the main responsibility for Task 4 on the development of non-invasive methods for measuring the levels of physiological factors indicative of stress and physiological disturbance and will work together with PI Dr. Josep Planas.

Project collaborators
[1] *Dr. Ian Stewart* and [2] *Dr. Allan Hicks* will assist in evaluating the implications of the study's results with respect to DMR-based estimation of removals in the Pacific halibut fishery, in the context of halibut stock assessment and the harvest policy.

Personnel funded through the proposal
Hired sea samplers will participate in the collection of biological data from fish captured and released by the different assessed methods and in tagging. An MSc student and a student technician will participate in setting up and conducting the captive experiments and in the collection and analysis of biological samples from these experiments.

Distribution of tasks among the participants (responsible person underlined)
- Task 1. <u>Josep Planas</u>/<u>Claude Dykstra</u>
- Task 2. <u>Tim Loher</u>/Josep Planas/Claude Dykstra
- Task 3. <u>Claude Dykstra</u>/Josep Planas
- Task 4. <u>Nathan Wolf</u>/<u>Bradley Harris</u>/Josep Planas
- Monitoring, assessment, and harvest policy implications. <u>Ian Stewart</u>/<u>Allan Hicks</u>.

c) <u>Results Dissemination Plan</u>:
Project outcome will be written initially in the form of internal IPHC technical reports and reports in the annual Reports of Assessment and Research Activities that are publically available upon publication in the IPHC website (<u>www.iphc.int/library/raras.html</u>). Subsequently, these reports will be revised and formatted for submission as peer-review publications targeted to the fisheries scientific community in journals such as the ICES Journal of Marine Science, Frontiers in Marine Science, Canadian Journal of Fisheries and Aquatic Science, or more broad-based journals such as PLoS ONE. In addition to these specialized publications, more accessible documents will be produced to inform the general public regarding the main outcome of this

project. News releases both internally from IPHC as well externally from news organizations will be produced to the same effect. An important outcome of the project will be a training manual that will incorporate recommendations and procedures related to minimizing DMRs and that will be targeted to the fishing community as well as to fishery observers. The produced results from the proposed task on electronic monitoring will be disseminated by the production of videos showing different release techniques with their associated injuries and physiological sampling and tagging procedures to assess survival post-release. These videos will be posted in the IPHC website and will be used to train observers and sea samplers.

Dissemination items:

- IPHC technical and RARA reports available through the IPHC website.
- Peer-reviewed publications for the scientific fisheries community.
- Non-technical documentation of the outcome of the project for the general public.
- News releases on the outcome of the project.
- Communication of results from the project to scientific and fisheries conferences.
- Training manual.
- Videos describing procedures developed in the project available through the IPHC website.

d) Project Milestones and Timelines:
The project milestones are related to the completion of the various tasks and include the reporting and preparation for dissemination as well as the outreach activities planned throughout the 2 years of the project, as detailed by quarters and beginning in Sept. 2017. Tasks include, when required, the names of the individuals responsible (Josep Planas: JP; Claude Dykstra: CD; Tim Loher: TL; Nathan Wolf: NW; Bradley Harris: BH; Ian Stewart: IS; Allan Hicks: AH).

Task	**Year 1 Q1**	**Year 1 Q2**	**Year 1 Q3**	**Year 1 Q4**	**Year 2 Q1**	**Year 2 Q2**	**Year 2 Q3**	**Year 2 Q4**
Project meetings (PIs/collab.)								
Task 1 PIs: JP/CD								
Task 2 PI: TL								
Task 3 PI: CD								
Task 4 PIs:NW/BH								
Assessment and Harvest Policy Col.:IS/ AH								
Advisory Body Meetings								

Stakeholder Meetings								
Report prep.								
Publication								
Outreach								

The expected *deliverables* from the outcome of the project are the following:

- Injury profiles for different hook release techniques.
- Physiological assessment of hook release methods: fish condition index at post-capture.
- Assessment of post-release survival in relation to hook release methods and physiological condition as well as in relation to fish size.
- Information on electronic monitoring of hook release techniques and associated survival estimates.
- Information on stress and physiological disturbance indicators in the mucus and establishment of a rapid assay for its use in the field.
- Assessment of the impact of results on stock monitoring assessment and harvest policy.
- Dissemination products (reports, publications, conference presentations, news releases).
- Training (training manual, MSc and technician student training)

7. Project Management.

IPHC will represent the lead organization for this project. IPHC has had a long history of conducting research on biological aspects of the Pacific halibut that impact stock assessment and is perfectly suited for undertaking the task of leading this project. IPHC has actively and successfully participated previously in federal and non-federal funded research projects. The administrative and financial aspects of the project will be managed by IPHC. PIs from two different institutions, IPHC and Alaska Pacific University (Anchorage, AK), participate in this collaborative project and the knowledge and expertise of their respective PIs is complementary and, as a result, a synergistic outcome is expected from this research interaction. The curriculum vitae of PIs and collaborators that participate in this project are attached to this application under Support. Document.

Principal investigators (PIs)

The project will be led by [1] *Dr. Josep V. Planas* from IPHC and will take responsibility for project coordination, administration and reporting. Dr. Planas is currently Program Head of the Biological and Ecosystems Science Program at IPHC. Prior to his recent post at IPHC, Dr. Planas developed his career in fish physiology in the Academic field and has had extensive experience leading and managing research projects, both at national and international levels. In this project, Dr. Planas will work directly with other PIs in Tasks 1 to 4. [2] *Dr. Tim Loher* is a Research Scientist at IPHC. Dr. Loher has extensive experience with the tagging of halibut, both *in situ* and in captive holding. He has been responsible for the tagging of ~700 wild halibut using archival tags, has worked to refine deployment protocols for both external and surgically-implanted tags and to develop methods for non-invasive sex and maturity determination, and the parameterization and interpretation of accelerometry data in the context of halibut survival and behavior. Dr. Loher and will be responsible mostly for Task 2. [3] *Mr. Claude Dykstra* is a Research Biologist at IPHC. Mr. Dykstra is a biologist with extensive experience in field research with Pacific halibut and specifically in the application and development of condition indices for Pacific halibut. Mr. Dykstra also has extensive experience with contracting and working with fishing vessels on research projects. Mr. Dykstra will be responsible mostly for Task 3. [4] *Dr. Nathan Wolf* is Assistant Professor of Marine and Environmental Science and Principal Researcher at the Fisheries, Aquatic Science & Technology (FAST) Laboratory at Alaska Pacific University. Dr. Wolf has extensive experience conducting controlled experiments with captive animals to examine physiological processes. Dr. Wolf will be responsible for Task 4, together with Dr. Harris. [5] *Dr. Bradley Harris* is Associate Professor and Director of the Fisheries, Aquatic Science & Technology (FAST) Laboratory at Alaska Pacific University. Dr. Harris has abundant experience managing and participating in research studies on the ecology of Pacific halibut and other fish species. Dr. Harris will share responsibility for Task 4 with Dr. Wolf.

Project collaborators
[1] *Dr. Ian Stewart* is a Quantitative Scientist at IPHC and will work together with [2] *Dr. Allan Hicks*, also a Quantitative Scientist at IPHC, on the implications of the results generated by this project on mortality estimate inputs into stock assessment as well as on harvest policy.

8. Participation by Persons or Groups other than the Applicant.
The stakeholder groups that have expressed interest in the project (Section 3; see Letters of Support), as well as others that may join prior to or during the progress of this project, will participate in the project through annual meetings that will coincide with the project's meetings (see timeline of activities, Section 6).

9. Outreach and Education.
The following outreach and education activities are intended to fulfill NOAA's mission to protect the Nation's natural resources:
- To inform the fishing industry on the progress and outcome of the project through the stakeholder and advisory boards. Summary documents by project team members will be prepared for this purpose.
- To inform user groups (i.e. NPFMC, EM group) on the progress and outcome of the project through reports and in person presentations at their meetings.
- To inform the fisheries community through publication of documents (either technical documents or peer-review publications in journals) and also through presentations at relevant venues and conferences.
- To send news releases at the beginning and end of the project to broadly advertise the objectives of the project in a first instance and to, once available, publicize the results of the project to the media.
- To prepare a Story Map Journal (https://storymaps.arcgis.com/en/app-list/) that pictures the entire collection of components of the project, from capture and handling events in the fisheries, to assessing physiological condition of the fish, to its survival at sea after release and impacts of estimates of survival on stock assessment and harvest policy. This presentation could be made publically available through media outlets currently in place at IPHC and APU (webpage, Twitter, Facebook) and also sent specifically to schools and centers to be informed about the research conducted and its importance for the fisheries, with the supporting presence of one of the PIs.

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OMB Approval

Number:0648-

0538 Expiration

Date: 11/30/2018

Environmental Compliance Questionnaire for National Oceanic and Atmospheric Administration Federal Financial Assistance Applicants

This form is to be used in conjunction with Funding Opportunity Announcements (FOA) from the National Oceanic and Atmospheric Administration (NOAA). You must refer to the specific FOA for complete eligibility and application requirements. This form addresses information requirements specific to compliance with the National Environmental Policy Act ("NEPA"; 42 U.S.C. §§4321- 4370).

NEPA requires federal agencies to complete an environmental analysis for all major federal actions, including funding non-federal projects through federal financial assistance awards where Federal participation in the funded activity is expected to be significant. This *Environmental Compliance Questionnaire for National Oceanic and Atmospheric Administration Federal Financial Assistance Applicants* (Questionnaire) is used by NOAA to collect information about proposed activities for NEPA and other environmental compliance requirements associated with the proposed project, such as federal consultations.

You are only required to provide the information from this Questionnaire that is specified in the FOA to which you are applying. The FOA may present these questions in one of two ways:

1) The applicable questions are inserted directly into the FOA with reference to the OMB Approval Number (0648-0538) for this form; or
2) The FOA will specify which questions (e.g. 1, 2) an applicant must answer, with the entire OMB-approved Questionnaire attached to the FOA.

Submit the information according to the instructions in the FOA. If you do not answer in sufficient detail, NOAA may consider the application to be incomplete. If a question is not applicable to your proposed activity, answer "N/A" or explain why the requested information is not relevant.

Project Information

1. Describe the proposed activity, including:
    - its purpose, objectives, and goals;
    - graphics (i.e. figures, photographs), site plans, plan diagrams, models, etc.;
    - sampling, collection, or observation protocols and operational procedures;
    - any proposed mitigation or monitoring measures and protocols;
    - a description and plan diagram of the proposed impact area, if the proposed activity involves construction, restoration, dredging, excavation, and/or fill;
    - a description (i.e. specifications) of the equipment or structures (e.g. scientific monitoring equipment, deployment platforms, etc.) that would need to be temporarily or permanently placed in the environment.

Purpose, objectives and goals
The main objectives of this project are to address the important issue of discard mortality rates (DMRs) of Pacific halibut in the directed and non-directed longline fisheries and to refine current estimates of post-release survival in incidentally caught Pacific halibut. In order to accomplish these objectives, the relationship between fish handling practices and fish physical and physiological condition and survival post-capture as assessed by tagging will be investigated.

The IPHC accounts for all mortalities or removals of Pacific halibut in its assessment of the stock, including bycatch as well as the incidental mortality from the commercial halibut fisheries (also known as wastage). Estimates of incidental mortality influence the output of the stock assessment and, consequently, the catch levels of the directed fishery. Prohibited Species Catch limits set by the North Pacific Fishery Management Council (NPFMC) requires that all Pacific halibut caught in non-directed fisheries must be discarded at sea, and these fisheries may be closed when Pacific halibut catch limits are reached.

The NPFMC has identified DMRs in the Pacific halibut fishery as a research priority. The proposed project will directly address this recommendation by providing new scientific information to improve current estimates of DMRs.

The specific objectives of this project include (1) evaluation of the effects of fish handling practices on injury levels and their association with the physiological condition of captured Pacific halibut, (2) investigations on the effects of fish handling methods and associated injury level and physiological condition on post-release survival, (3) application of electronic monitoring in associating fish handling methods to survival in vessels without observer coverage and (4) development of non-invasive methods for quantifying measurable physiological factors indicative of stress and physiological disturbance.

Sampling, collection, or observation protocols and operational procedures
For Task 1 ("Evaluation of the effects of hook release techniques on injury levels and association with the physiological condition of captured Pacific halibut"), all captured Pacific halibut caught by each of the four hook release techniques or treatments will be measured for length and weight, examined to

record the extent of the hook injury, sampled for blood and their physiological condition will be assessed by length/weight relationships and by non-invasive indirect fat analysis using a Fish Fatmeter device. In Task 2 ("Investigations on the effects of fish handling methods and associated injury level and physiological condition on post-release survival"), a subset of the captured Pacific halibut (fish of 84 cm in length or less) will be selected for tagging with wire tags and 80 of these fish with sPAT archival tags to assess survival. In Task 3 ("Application of electronic monitoring"), EM will be used to record release methods and condition of released halibut. In Task 4 ("Development of non-invasive methods for measuring the levels of physiological factors indicative of stress and physiological disturbance"), adult Pacific halibut will be captured and acclimated to captive conditions in tanks at the UAF Seward Marine Center (Seward, AK), subjected to stress and blood and mucus samples will be collected for analysis.

Tagged fish from Task 2 will be monitored with the use of satellite-transmitting electronic archival tags equipped with accelerometers upon detachment and surfacing. Fish in Task 4 will be monitored continuously throughout the experiment.

2. List the species of plants and animals that are the subjects of the proposed activity, and describe the numbers (by species, age, sex, stock, location, etc.) to be targeted.
   The subject species of the proposed activity is the Pacific halibut (Hippoglossus stenolepis). The proposal involves targeting approximately 1,900 fish Pacific halibut of mixed sexes (50% females) captured by a charter vessel in the central-Western portion of the Gulf of Alaska (IPHC Regulatory Area 3B) as part of Task 1. In addition, the proposal also involves capturing 16 – 24 adult Pacific halibut near Seward, AK for captive experiments to be conducted at the Seward Marine Center.

3. List species that would be transplanted or introduced at the site or in its immediate vicinity, and specify whether any would be non-native. Specify which non-native species could be introduced incidentally and how.
   No species will be transplanted or introduced.

4. List hazardous substances (as defined by [29 CFR 1910.120(a)(3)]) that may be released into the environment or used during the proposed activity.
   No hazardous substances will be used or released.

5. List hazardous wastes (as defined by [40 CFR 261.3]) that may be generated during the proposed activity.
   No hazardous wastes will be generated.

6. List unique or unknown risks to human health or the environment from the proposed activity.
   No risks to human health will originate from the proposed activity.

7. List any individuals, groups, or organizations that may disapprove of or oppose the proposed activity, and describe the circumstances of their disapproval or opposition.
   None.

8. If the proposed activity is a continuation of an on-going project, describe any changes to the proposed activity since it was initiated, including progress toward achieving its objectives/goals. Include information and attach reports from previous years.
   This proposed activity is new.

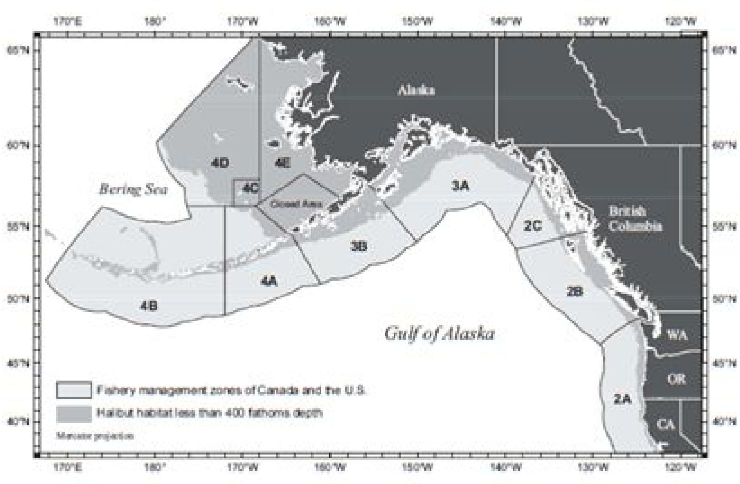
9. If the applicant does not receive funding from NOAA, would the applicant conduct the proposed activity anyways?
The applicant would be able to fund some of the work but without the requested funding from NOAA the work would be incomplete and the results inconclusive.

<u>**Project Location**</u>

10. Describe the proposed activity's location, including geographic coordinates, river mile markers, etc. and indicate whether it includes unique geographic areas of notable recreational, ecological, scientific, cultural, historical, scenic, or aesthetic importance (Examples include, but are not limited to: coral reefs; marine protected areas; national marine sanctuaries; essential fish habitat; habitat area of particular concern; critical habitat designated under the Endangered Species Act; park or refuge lands; wild or scenic rivers; wetlands; prime or unique farmland; sites listed on the National Register of Natural Landmarks; sites listed or eligible for the National Register of Historic Places; sites that are ecologically significant or critical areas including areas that are normally inundated by water or areas within the 100-year flood plain).
One vessel chartered to operate in Alaskan waters (within IPHC´s Regulatory Area 3B; see figure below) will be used for the study. The fishing location will be selected based on the potential to catch adult fish of both legal (32 inches and above in length) and sub-legal (under 32 inches in length) sizes at rates that facilitate efficient completion of project goals.

11. Would the proposed activity degrade or disturb previously undisturbed areas?
No.

12. Provide maps and graphics of the project location, if available.
Figure illustrating the IPHC Regulatory Areas, including Regulatory Area 3B in Alaska, where most of the project will be conducted:



13. If there are previous or ongoing uses of the proposed activity's site, or other issues, that make it likely that contaminants may be uncovered and/or disturbed by the proposed activity, describe

the previous or ongoing uses or other issues of the site, potential contaminant, and the circumstances that may uncover and/or disturb the contaminants.
No contaminants may be uncovered and/or disturbed by the proposed activity.

Project Timeframe

14. Specify the proposed start date and duration of the proposed activity.
September 1, 2017 – August 31, 2019. 24 months.

15. Provide proposed activity schedules, including:

- implementation dates of major elements of the proposed activity;
- frequency of activities within the project schedule (e.g. once per week, 10 days per month, daily);
- deployment and recovery schedules of equipment or structures that would be temporarily or permanently placed in the environment.

The temporal distribution of tasks is shown below, with the first quarter (Q1) of year 1 starting in September, 2017:

Task	Year 1 Q1	Year 1 Q2	Year 1 Q3	Year 1 Q4	Year 2 Q1	Year 2 Q2	Year 2 Q3
Task 1							
Task 2							
Task 3							
Task 4							

Fish capture and sample and observation collection related to Tasks 1 and 3 will take place during the two proposed chartered trips. Sample processing and analysis as well as EM and satellite transmission data will take place on a daily basis. Fish collection related to Task 4 will likely take place during a single chartered trip and experimentation, monitorization and sample collection and analysis of captive fish will take place on a daily basis.

No equipment or structures will be temporarily or permanently placed in the environment.

Project Partners, Permits, and Consultations

16. If the proposed activity would be conducted in partnership with NOAA or require NOAA' s direct involvement, activity, or oversight, describe NOAA' s involvement, activity, or oversight, including the name of the office or program that is involved.
Not applicable.

17. List all other interested or affected Federal, state, and local agencies; Tribal governments, nongovernmental organizations; minority or economically disadvantaged communities; and individuals. Describe listed entities involvement, activity, or oversight regarding the proposed activity.
As stated in the project narrative, we count on the support of various organizations with direct interest and participation in the Pacific halibut fisheries (e.g., Alaska Longline Fishermen's

Association, North Pacific Fisheries Association, Pacific States Marine Fisheries Commission, Alaska Fisheries Science Center - National Marine Fisheries Service; see Letters of Support in Supporting Documentation). These organizations will provide guidance towards evaluating the progress of the project and ensuring its success by meeting annually with the project consortium.

18. List all federal, state, or local permits, authorizations, waivers, determinations, or ongoing consultations that would be required for the proposed activity to comply with all applicable environmental laws and regulations. Provide the date the permit, authorization, waiver, or determination was obtained or would be obtained. Provide copies of the permits, authorizations, waivers, or determinations you have secured.
All operations will carry a Letter of Acknowledgement from NMFS's Alaska Fisheries Science Center specific to the work, and incidental bird take permits from the USFWS (see current permit as Appendix I to this document). All standard post cruise reporting requirements (research fish landing tickets etc.) will be observed.

19. Identify the lead Federal agency, if applicable, and whether any NEPA document has been completed or is in process for the proposed activity.
Not applicable.

Project Details

National Marine Fisheries Service

20. If the proposed activity is a continuation of an on-going project, provide information/reports for previous years addressing the following:

- The number of fish and other species that were collected for the activity/monitoring needs;
- any impacts to protected species, including takes (as defined by 50 CFR 216.3, 50 CFR 222.102, and 1
- any impacts to sensitive or protected habitats, including critical habitat that has been identified under the Endangered Species Act or essential fish habitat that has been identified under the Magnuson-Stevens Fishery Conservation Management Act (Magnuson-Stevens Act);
- and the number of non-target fish/invertebrates/protected species (listed by species) that were incidentally captured.

The proposed activity is new and is not a continuation of an on-going project.

21. What amount (total numbers and/or weight) of fish or invertebrates are proposed to be caught? What is the size (weight, length, and age class) of each species?
In Tasks 1 to 3, we estimate to catch a total of 1,864 fish, with 1,229 fish at or under 84 cm and 635 fish over 84 cm in length. These numbers are based on IPHC's survey data from 2016 in Regulatory Area 3B and the effort proposed for this particular project. The ages of fish captured will likely range from 7 to 15 yrs and weights will likely range from 7-8 lbs to 10-15 lbs in males and from 10 to 25-30 lbs in females based on trends in weight-at-age for male and female Pacific halibut captured in Area

3B by the IPHC setline survey (http://iphc.int/publications/rara/2015/RARA2015_11Assessmenddatasources.pdf).

In Task 4, we will aim at catching 16 – 24 adult Pacific halibut between 20 and 31 inches in length in order to minimize the potential for variations in stress response in study subjects due to size.

22. If targeted fish would be under the minimum size limit or is the applicant applying for an exemption to the minimum size limit, explain why an exemption is necessary to conduct the proposed activity.
Targeted fish in Task 2 will be 84 cm of less in length because the objective of this task is to investigate post-release survival of fish discarded at sea because of their sublegal size.

23. If any organisms would be released alive, how many of each species would be tagged, measured, or sampled? What is the probability of individuals surviving after being handled (e.g., tagged, measured) and released (e.g., percent of live or dead fish)?
Targeted fish in Task 2 will be released after tagging in order to investigate post-release survival and we estimate that approximately 1,230 fish at or under 84 cm will be tagged and released. Of note, 80 of these fish will be tagged with sPAT archival tags equipped with accelerometers. To determine the probability of survival capture and handling events is precisely one of the objectives of this project.

24. If the proposed activity involves commercial fishing, would the proposed activity be for research purposes only? If fish would be retained for sale or personal consumption, quantify the amount of each species that would be sold or used for personal consumption.
Although performed in a chartered commercial vessel, the proposed activity is designed for research purposes. For all fish captured, the relationship between hook release techniques, injury classification and physiological condition will be assessed. Fish at or under 84 cm will be subsequently tagged and released to investigate survival and approximately 1,230 fish are expected to fall within this category. Fish over 84 cm in length will be retained for sale by IPHC and approximately 635 fish are expected to fall within this category.

25. What type and size of gear would be used? Describe any differences between proposed research gear and currently regulated gear.
The gear used will be similar to the gear used in the IPHC survey: fixed gear with standard 1,800 ft skates, each with 100 16/0 circle hooks and with 18 ft spacing between gangions.

26. If using fixed fishing gear, how many traps, pots, gillnets, or other fixed gear would be used during the course of the study? Would new gear be added to the water or would existing, permitted fishing gear be used? If new gear would be added to the water, how many extra vertical lines would be associated with any fixed gear such as traps, pots, or gillnets? What lengths of gillnet would be used (e.g. number of nets per string, gillnet panel lengths, etc.)?
A total of two hundred and eighty eight (288) skates of fixed gear will be used.

27. Would the fishing gear being used conform to appropriate take reduction plan regulations under the Marine Mammal Protection Act (e.g. Atlantic Large Whale Take Reduction Plan, Harbor Porpoise Take Reduction Plan, Bottlenose Dolphin Take Reduction Plan, etc.) and other

appropriate fishery regulations (e.g. sea turtle gear requirements)? If not, explain the differences and the reason for the discrepancy.
Not applicable.

28. How long would the fishing gear be deployed? List average soak time for each gear type.
The fixed gear is deployed for a minimum of 5 hrs and a maximum of 24 hrs. Average soak time would be approximately 12 hrs.

29. What is the proposed number of gear hauls for each gear type (e.g., trawl gear, fixed gear, etc.)?
The number of gear hauls is three per day, with each haul consisting of eight standard skates. With 12 proposed days of fishing, a total of 36 hauls are targeted.

30. What is the proposed duration and speed of each tow for mobile gear, such as trawl gear?
Not applicable.

31. If trawls are proposed to be used, would a turtle exclusion device (TED) or marine mammal exclusion device be used?
No trawls will be used.

32. If the applicant is applying for an exemption to any of the following, please explain what the exemptions would be and why the exemption is necessary for the proposed activity:

- Fishing gear restrictions;
- Other regulatory requirements such as Days At Sea (DAS), Total Allowable Catch (TAC), and/or possession limits;
- Use areas closed to proposed activities (e.g., fishery management closed area, habitat closed area, etc.);
- Any closed or otherwise restricted fishing seasons.

Not applicable.

33. If the proposed activity would increase fishing effort, describe the extent of the increase.
Not applicable.

34. How many proposed fishing days are there within the year for each gear type?
The proposed activity involves 12 fishing days in two trips (six fishing days per trip).

35. Is the target species listed as endangered, threatened, or otherwise protected species (under Federal and/or state law; e.g. Endangered Species Act and/or Marine Mammal Protection Act, etc.)?
Not applicable.

36. If the proposed sampling involves the use of sonic tags, acoustic surveys, or any other specialized gear that may introduce sound, provide a description of the noise(s), including frequency (Hz), amplitude (dB), what angle (or degrees) radius the noise may travel from the source, and other relevant technical specifications.
Not applicable.

37. List non-target species that may occur in the proposed sampling area, and specify how many of each

non-targeted species are expected to be caught?

With the proposed effort, based on hook status calculated in IPHC Survey, the following non-target species and the number of fish caught would be expected to be caught:

- Pacific cod: 983
- Sablefish: 67
- Yellow Irish Lord: 115
- Big skate: 78
- Arrowtooth flounder: 112
- Longnose skate: 75

National Environmental Satellite Data and Information Systems

38. Would the proposed activity create high levels of noise for an extended period of time?

No.

39. Would the proposed activity require large amounts of water or electricity for an extended period of time?

No.

40. Would any fuel be used for the proposed activity during development or long term operation, including for powering small fuel cells?

Yes, for fueling the research vessel used for Task 1 (capture and handling events) and Task 4 (stress experiments in captivity).

41. Would the proposed activity, during development or long term operation, change the scenery or viewshed in the project vicinity, require large amounts of outdoor lighting, or create unusual odors?

No.

42. Would the proposed activity, during development or long term operation, change transportation infrastructure or increase local traffic?

No.

43. Would the proposed activity, during development or long term operation, change characteristics of the atmosphere or contribute to ozone-depletion?

No.

44. If the proposed activity involves installing equipment or antennas on buildings or property, has the owner of the property granted written approval for the use of their property? If yes, provide copies of the approvals.

Not applicable.

45. If the proposed activity involves installing equipment, how would the equipment get to its final location (i.e. would gasoline or diesel engine vehicles be used)?

Not applicable.

46. If biological agents would be used, specify how the proposed activity would meet all conditions of

the Biosafety Level 1 (BL1) standard from the most current version of the National Institutes of Health (NIH) and the Center for Disease Control and Prevention (CDC) Biosafety in Microbiological and Biomedical Laboratories (BMBL) guidelines.

Not applicable.

47. Does the proposed activity consist solely of software research and manipulation?
No

48. If the proposed activity requires airplane or balloon/sonde flights (e.g. investigations over Arctic Sea ice using satellite and aircraft altimetry), would the proposed activity use a previously scheduled flight or sea voyage, or would a special trip be required?

    Not applicable.

49. If the proposed activity involves installing equipment or antennas that would require structural support, describe the nature and extent of such support.

    Not applicable.

50. If the proposed activity has electromagnetic properties or creates electromagnetic fields, specify how those aspects would comply with the Institute of Electrical and Electronics Engineers (IEEE) standard C95.1-1991 (recognized by the American National Standards Institute (ANSI)), or newer guidance.

    Not applicable.

51. If the proposed activity involves ionizing radiation, specify:

    - whether the appropriate radiation safety authority has been consulted or when consultation would occur;
    - the results of the radiation safety authority's review;
    - how the proposed activity complies with NOAA's U.S. Nuclear Regulatory Commission (NRC) materials license #05-11997-01

    Not applicable.

52. If the proposed activity involves lasers, specify how the proposed activity would meet the American National Standards Institute (ANSI) safety standards Z136.1-2000 and Z136.6-2000, or newer

    Not applicable.

guidance.

53. If the proposed activity involves satellite sensors and experiments with radioactive materials, specify and include:

- whether NASA has evaluated the payload or when the evaluation would occur;
- the results of the evaluation (i.e. whether the proposed project is categorized as a Routine Payload On Expandable Launch Vehicles, as evaluated by the current version of NASA Routine Payload Environmental Checklist GSFC Form 23-78 and NASA Flight Projects Environmental Checklist GSFC Form 23-74);
- a copy of the evaluation, if available.

Paperwork Reduction Act Statement

Because this Questionnaire is intended for members of the public, NOAA must use the Questionnaire in accordance with the Paperwork Reduction Act ("PRA"; 44 U.S.C. §§ 3501– 3521). Congress passed the PRA to minimize the paperwork burden for non-federal entities and members of the public that can result from the collection of information by or for the federal government. The PRA is administered by the Office of Management and Budget (OMB), which has reviewed and approved the Questionnaire (OMB Approval No. 0648-0538).

Public reporting burden for this collection of information is estimated to be a maximum of 3 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to NOAA NEPA Coordinator, NOAA Office of Program Planning and Integration, SSMC 3, Room 15700, 1315 East West Highway, Silver Spring, MD 20910. The information collection does not request any proprietary or confidential information.
No confidentiality is provided.

Notwithstanding any other provisions of the law, no person is required to respond to, nor shall any person be subjected to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.

APPENDIX 1 (NEPA Questionnaire): USFW Permit

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
Migratory Bird Permit Office
1011 E. Tudor Rd (MS-201) - Anchorage, AK 99503
Tel: 907-786-3693 Fax: 907-786-3927
Email: permitsR7MB@fws.gov

FEDERAL FISH AND WILDLIFE PERMIT

1. PERMITTEE

INTERNATIONAL PACIFIC HALIBUT COMMISSION
ATTN: TRACEE GEERNAERT
2320 WEST COMMODORE WAY, SUITE 300
SEATTLE, WA 98199
U.S.A.

RECEIVED
MAY 18 2015
IPHC

2. AUTHORITY-STATUTES
16 USC 703-712

REGULATIONS
50 CFR PART 13
50 CFR 21.27
50 CFR 21.21

3. NUMBER
MB057716-0

4. RENEWABLE
☒ YES
☐ NO

5. MAY COPY
☒ YES
☐ NO

6. EFFECTIVE
05/13/2015

7. EXPIRES
03/31/2018

8. NAME AND TITLE OF PRINCIPAL OFFICER (If #1 is a business)
TRACY GEERNAERT
SURVEY COORDINATOR

9. TYPE OF PERMIT
SPECIAL PURPOSE - SALVAGE WITH IMPORT/EXPORT

10. LOCATION WHERE AUTHORIZED ACTIVITY MAY BE CONDUCTED

SALVAGE AUTHORITY: FEDERAL WATERS OFF ALASKA.
IMPORT AUTHORITY: ANY PORT DESIGNATED UNDER 50 CFR 14.12 and ALL NON-DESIGNATED PORTS IN

11. CONDITIONS AND AUTHORIZATIONS:

A. GENERAL CONDITIONS SET OUT IN SUBPART D OF 50 CFR 13, AND SPECIFIC CONDITIONS CONTAINED IN FEDERAL REGULATIONS CITED IN BLOCK #2 ABOVE, ARE HEREBY MADE A PART OF THIS PERMIT. ALL ACTIVITIES AUTHORIZED HEREIN MUST BE CARRIED OUT IN ACCORD WITH AND FOR THE PURPOSES DESCRIBED IN THE APPLICATION SUBMITTED. CONTINUED VALIDITY, OR RENEWAL, OF THIS PERMIT IS SUBJECT TO COMPLETE AND TIMELY COMPLIANCE WITH ALL APPLICABLE CONDITIONS, INCLUDING THE FILING OF ALL REQUIRED INFORMATION AND REPORTS.

B. THE VALIDITY OF THIS PERMIT IS ALSO CONDITIONED UPON STRICT OBSERVANCE OF ALL APPLICABLE FOREIGN, STATE, LOCAL, TRIBAL, OR OTHER FEDERAL LAW.

C. VALID FOR USE BY PERMITTEE NAMED ABOVE.

D. Authorized to salvage migratory birds found dead in which the permittee had no part in killing. Any endangered or threatened species must be turned over to the U.S. Fish and Wildlife Service within 48 hours of collection or return to port. Any dead bald eagle or golden eagle salvaged must be reported within 48 hours to the National Eagle Repository at (303) 287-2110 and to the issuing migratory bird permit office at 907-786-3693. The Repository will provide directions for shipment of these specimens.

For a list of threatened and endangered species in your state, visit the U.S. Fish and Wildlife Service's Threatened and Endangered Species System (TESS) at: http://www.fws.gov/endangered.

E. You may not salvage and must immediately report to the U.S. Fish and Wildlife Service Office of Law Enforcement any dead or injured migratory birds that you encounter that appear to have been poisoned, shot, electrocuted, have collided with industrial power generation equipment, or were otherwise injured as the result of potential criminal activity. See USFWS OLE contact information below.

F. You are also authorized to import and export migratory birds salvaged under this permit. Additional authorization is required to import and export bald eagles, golden eagles, threatened and endangered species, and species listed under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora).

G. All wildlife must be imported and exported through a wildlife designated port of entry/exit unless you have obtained a separate exception to designated port permit from the USFWS Office of Law Enforcement.

H. You must notify the USFWS Wildlife Inspector at the port of import or export **up to 3 days prior to import or export**. See the attached Standard Conditions for Migratory Bird Import/Export Permits for procedures specific to your activity.

I. You must declare your specimens to USFWS using USFWS Declaration for Importation or Exportation of Fish or Wildlife (Form 3-177;

☒ ADDITIONAL CONDITIONS AND AUTHORIZATIONS ALSO APPLY

12. REPORTING REQUIREMENTS

You must submit an annual to your Regional Migratory Bird Permit Office report each year, even if you had no activity.

ISSUED BY

TITLE
PERMIT SPECIALIST, MIGRATORY BIRD PERMIT OFFICE - REGION 7

DATE
05/13/2015

Data Sharing Plan

Data generated under this project will be made discoverable by and accessible to the general public in a timely fashion.

1. Types of information collected.
    a) Length and weight information on captured fish.
    b) Environmental data (bottom temperature, deck temperature, sea condition).
    c) Hook removal injury codes (14 different codes; Kaimmer and Trumble, 1998).
    d) Injury severity levels (4 different codes; minor, moderate, severe, dead; Kaimmer and Trumble, 1998).
    e) Electronic monitoring data.
    f) Blood samples and analyses (plasma levels of stress and physiological disturbance indicators: cortisol, catecholamines, lactate, glucose, sodium, potassium, osmolarity, pH).
    g) Physiological condition indicators: condition factor indices (Fulton's K, relative K) and lipid levels as derived from Fish Fatmeter readings.
    h) Wire tagged fish and information on returns.
    i) sPAT tagged fish and satellite data on accelerometer.

2. Data Management Plan

The IPHC Setline Survey has already in place a data management plan that involves the collection at sea of gear information, catch information and biological measures (e.g., length) that are recorded in paper data forms. Electronic data entry of data collected at sea with the use of electronic tablets is currently being developed and will likely be available for at sea data collection for this project. All collected data are then introduced into a dedicated database and metadata files are created to incorporate additional data such as aging data among other types of data. Additional fields will be created to incorporate the additional data indicated above. Biological data resulting from blood and physiological condition analyses will be introduced into the project's database and added to the metadata file with individual information on every fish.

Tag release data would be introduced in an already existing tagging database that would be linked to the metadata tables containing all other entries. In addition, broadcast data from sPATs, representing the raw data format, will be decoded into binned summary files that, upon analysis, will be incorporated into a dedicated database, the construction of which is currently underway at IPHC by our Technology Group.

Public access to the database will be through the IPHC webpage (http://www.iphc.int) and should be made available within six months from the completion of the project.

Budget Narrative – <u>Organization 1 – International Pacific Halibut Commission (IPHC)</u>

Personnel (Federal Share) - none
No salary expenses are requested for IPHC project participants (Josep V. Planas, Claude Dykstra, Tim Loher, Ian Stewart, Allan Hicks).

Fringe Benefits (Federal Share)- none

Travel (Federal), $4.220
Year 1:
Sample collection in captive experiment, Seward AK (2 people): $1.840

Airfare Seattle - Anchorage	$900
Rental car	$320
Hotel Seward 2 days	$320
Per diem 3 days Seward	$300

Year 2:
PI Meeting, Anchorage AK (3 people): $2.380

Airfare Seattle - Anchorage	$1350
Hotel Anchorage 2 days	$480
Per diem 3 days Anchorage	$450
Misc travel	$100

Equipment (Federal) - none

Supplies (Federal), $190.274

Wire tags. Total: $2.060
- Floy wire tags ($1 x 1.500) = $1.500
- Wire tag applicators ($16 x 35) = $560

Accelerometer tags. Total: $167.850
- Wildlife Computers sPAT tags ($2.000 x 80) = $160.000
- Givmar Tagging darts ($80 x 90) = $7.200
- VER Sales nicopress sleeves ($1,25 x 160) = $200
- Floy leaders, printed ($5 x 90) = $450

Assays for blood determinations. Total: $15.864
- Cortisol ELISA ($270 x 12): $3.240
- Catecholamine ELISA ($400 x 12): $4.800
- Lactate, Glucose Kits ($326 x 24): $7.824

General laboratory supplies. Total: $4.500.

Contractual (Federal), $24.886

Satellite transmissions of accelerometer tag data. Total: $14.000
- Argos testing ($35 x 80) = $2.800
- Argos platform and data transfer ($140 x 80) = $11.200

Blood gas analyses. Total: $2.500

Rental and installation of electronic monitoring system in chartered vessel. Total: $8.386
- Equipment rental ($999 x 1 month): $999
- Installation costs: $4.552
- Data review: $2.835.

Other (Federal), $3.840

Shipping costs. Total: $3.840
- sPAT tags: $2.240
- Samples: $1.600

Total Direct Charges IPHC: Federal: $223.220

Total Indirect Charges IPHC: Federal: None

Total Charges IPHC: Federal: $223.220

<u>Other Support/In kind Contributions for Organization 1 – International Pacific Halibut Commission:</u>

Personnel/Salaries, $86,799

Principal lead investigator Josep Planas will dedicate 4 months of time (2 months each fiscal year) during the course of this project (total cost $38,986). The other two principal investigators from IPHC (Claude Dykstra, Tim Loher) will dedicate each 2 months of time (1 month each fiscalyear) during the course of the project, (Claude Dykstra $15,802; Tim Loher: $18,8792; total cost combined $34,594).

A lead sampled will be hired for 15 days ($316 x 15 days = $4.736) and two second samplers will also be hired for 15 days ($283 x 15 days x 2 samplers = $8.482).

Personnel/Fringe Benefits, $27,897

The fringe benefit rate is 20% of salary, with $13,567 covering fringe benefits including employer portion of FICA/FICAMED for Josep Planas (PI) and $12,927 for Claude Dykstra and Tim Loher. Fringe benefit ratios vary based on employer-provided health care for spouse and dependents. Fringe benefits for lead sampler correspond to $503 ($34 x 15 days) and for the two second samplers correspond to $900 ($30 x 15 days x 2 samplers).

Supplies, $21.902

Bait: $21.902

Contractual, $87.808

Vessel charter:

- Vessel contract payments: $85.160
- P&I Insurance: $200
- Gear Maintenance: $2.448

Total Other Support provided by International Pacific Halibut Commission for this project is: $224,406

Budget Narrative – <u>Organization 2 – Fisheries, Aquatic Science and Technology (FAST) Laboratory at Alaska Pacific University (APU):</u>

Personnel (Federal Share) – Partial support for Nathan Wolf (NW) and Bradley Harris (BH), MSc student, and student technician: **$18,875**

Year 1:

NW **-** 0.5 months of support at $11,550/month: $5,775
BH **-** 0.5 months of support at $11,550/month: $5,775
MSc Student – 2.25 months of support at $2,500/month: $5,625
Student Technician – 2 months of support at $850/month: $1,700

Year 2:

No salary expenses are requested for APU project participants in year 2.

Fringe Benefits (Federal Share) - 10% fringe benefits on partial support for NW and BH: **$1,155**

Year 1:

NWolf **-** 10% Fringe Cost on 0.5 months of support at $11,550/month: $577
BHarris **-** 10% Fringe Cost on 0.5 months of support at $11,550/month: $577

Year 2:

No fringe benefits are requested for APU project participants in year 2.

Travel (Federal), $4.867

Year 1:

Sample collection and captive experiment, Seward AK (12 round trips for 2 people): $4.867

Mileage Anchorage **-** Seward (253 miles RT @ $ 0.54/mile): $1639
Per diem – Seward (12 days @ $269): $3,228

Year 2:

No travel funds are requested for APU project participants in year 2.

Equipment (Federal) - none

Supplies (Federal) - $3,799

Assays for blood determinations. Total: $2,700

- Cortisol ELISA ($270 x 10): $2,700

General laboratory supplies. Total: $1,099

Contractual (Federal), $26,000

Vessel charter for halibut capture (5 days @ $1,800/day): $9,000

Captive experimental, lab, and office facilities at the Seward Marine Center: $17,000

Other (Federal): none

Total Direct Charges APU: Federal: $54,697

Total Indirect Charges APU: Federal: $8,205

APU indirect charges (15% of $54,696.74): $8,205

Total Charges APU: Federal: $62,901

Other Support/In kind Contributions for – Organization 2 – Fisheries, Aquatic Science and Technology (FAST) Laboratory at Alaska Pacific University (APU):

Personnel/Salaries, $97,960

Nathan Wolf (NW) and Bradley Harris (BH) will each dedicate 3 months of time (1 month each in year 1 and 2 month each in year 2) during the course of this project (total cost $69,300).

The Fisheries Science and Aquatic Technologies Laboratory at Alaska Pacific University will dedicate 1 year of MSc student tuition (approximately $10,660) and stipend ($18,000) to a student working on this project (total $28,660).

Personnel/Fringe Benefits, $13,860

The fringe benefit rate is 10% of salary, with $13,860 covering fringe benefits for the 6 months (combined total) of salary time dedicated by NW and BH

Supplies, $1,500.00

General Laboratory supplies: $1,500

Indirect Charges APU, $2,735

APU indirect charges (5% of $54,696.74): $2,735

Total Other Support provided by the Fisheries Aquatic Science and Technology Laboratory at Alaska Pacific University for this project is: $116,055

Budget tables:

IPHC

BUDGET CATEGORIES	1st Year		2nd Year		1st + 2nd Year	
Object Class Categories	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**
a. Personnel	0	49826	0	36973	0	86799
b. Fringe Benefits	0	14584	0	13313	0	27897
c. Travel	1840	0	2380	0	4220	0
d. Equipment	0	0	0	0	0	0
e. Supplies	174410	21902	15864	0	190274	21902
f. Contractual	24886	87808	0	0	24886	87808
g. Construction	0	0	0	0	0	0
h. Other	3840	0	0	0	3840	0
i. Total Direct Charges	204976	174120	18244	50286	223220	224406
j. Indirect Charges	0	0	0	0	0	0
TOTALS	**204976**	**174120**	**18244**	**50286**	**223220**	**224406**

APU

BUDGET CATEGORIES	1st Year		2nd Year		1st + 2nd Year	
Object Class Categories	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**
a. Personnel	18875	51760	0	46200	18875	97960
b. Fringe Benefits	1155	4620	0	9240	1155	13860
c. Travel	4867	0	0	0	4867	0
d. Equipment	0	0	0	0	0	0
e. Supplies	3799	1500	0	0	3799	1500
f. Contractual	17500	0	8500	0	26000	0
g. Construction	0	0	0	0	0	0
h. Other	0	0	0	0	0	0
i. Total Direct Charges	46197	57880	8500	55440	54697	113320
j. Indirect Charges	6930	2310	1275	425	8205	2735
TOTALS	**53126**	**60190**	**9775**	**55865**	**62901**	**116055**

PROJECT TOTALS

BUDGET CATEGORIES	1st Year		2nd Year		1st + 2nd Year	
Object Class Categories	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**	**Federal**	**Non-Federal**
a. Personnel	18875	101586	0	83173	18875	184759
b. Fringe Benefits	1155	19204	0	22553	1155	41757
c. Travel	6707	0	2380	0	9087	0
d. Equipment	0	0	0	0	0	0
e. Supplies	178209	23402	15864	0	194073	23402
f. Contractual	42386	87808	8500	0	50886	87808
g. Construction	0	0	0	0	0	0
h. Other	3840	0	0	0	3840	0
i. Total Direct Charges	251173	232000	26744	105726	277917	337726
j. Indirect Charges	6930	2310	1275	425	8205	2735
TOTALS	**258102**	**234310**	**28019**	**106151**	**286121**	**340461**