IPHC staff work plan for MSAB related activities from May 2016 to May 2018

Introduction

This work plan is a description of activities related to the Management Strategy Advisory Board (MSAB) that IPHC staff will engage in for the next two years starting May 2016. It describes each of the priority tasks, lists some of the resources needed for each task, and provides a timeline for each task. However, this work plan is flexible and may be changed throughout this period with the guidance of the MSAB and Science Review Board (SRB) members. The order of the tasks in this work plan represents the sequential development of each task, and many subsequent tasks are dependent on the previous tasks. A set of working definitions are provided in Appendix A.

Management Strategy Evaluation (MSE)

Management Strategy Evaluation (MSE) is a process to evaluate alternative management strategies. This process involves the following

1. defining fishery goals and objectives with the involvement of stakeholders and managers,
2. identifying management procedures to evaluate,
3. simulating a halibut population using those management procedures,
4. evaluating and presenting the results in a way that examines trade-offs,
5. applying a chosen set of management procedures,
6. and repeating this process in the future in case of changes in objectives, assumptions, or expectations.

Figure 1 shows these different components and that the process is not necessarily a sequential process, but there may be movement back and forth between components as learning progresses. The involvement of stakeholders and managers in every component of the process is extremely important to guide the MSE and evaluate the outcomes.

Background

Many important tasks have been completed or started and much of the work proposed will use past accomplishments to further the Management Strategy Evaluation (MSE) process. The past accomplishments include:

1. Familiarization with the MSE process.
2. Defining goals for the halibut fishery and management.
3. Developing objectives from those goals.
4. Development of an interactive tool (the Shiny application).
5. Discussions about coast-wide (single-area) and spatial (multiple-area) models.

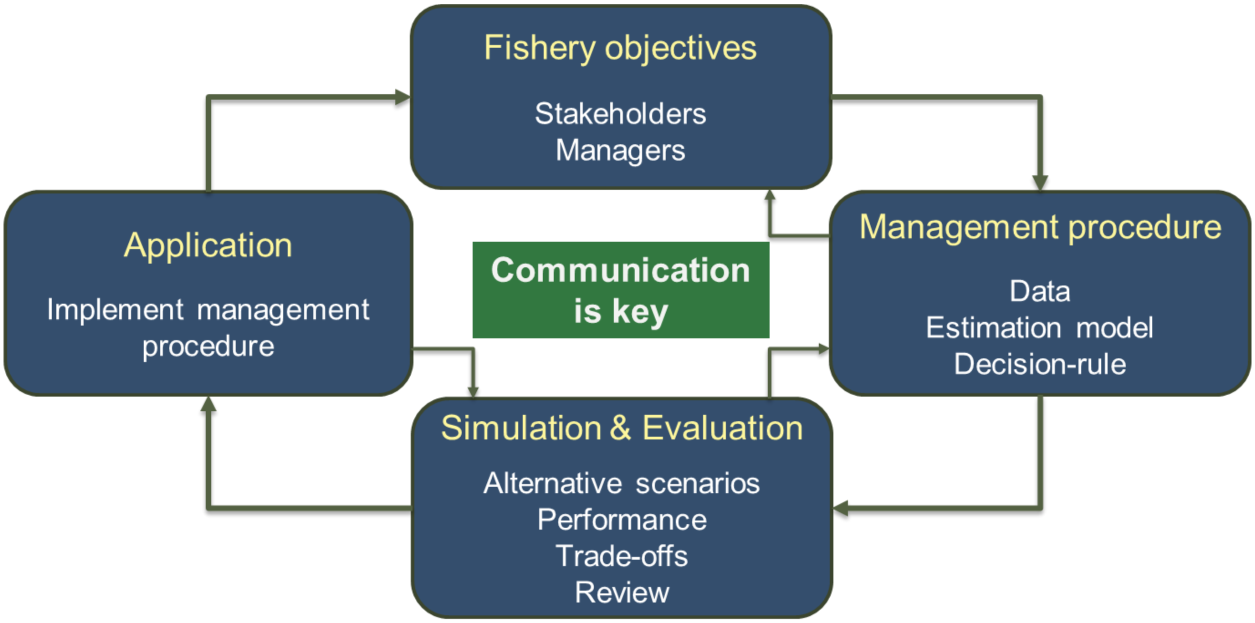

Figure 1: A depiction of the Management Strategy Evaluation (MSE) process showing the iterative nature of the process with the possibility of moving either direction between most components.

The new tasks described in this work plan expand upon all of the work that has already been done since the MSAB was formed. Dr. Allan Hicks will be responsible for much of the upcoming work, and comes to the IPHC with experience working with harvest policy and in conducting management strategy evaluations for other fisheries. He has worked with stocks of orange roughy (*Hoplostethus atlanticus*) in New Zealand and observed the development of harvest strategies by the New Zealand Ministry of Fisheries. More recently, he has been the lead for the assessment of Pacific hake (*Merluccius productus*) in U.S. and Canada, and started a MSE for Pacific hake in 2012. Progress on the hake MSE was made in the three years that he worked on it, and stakeholders and managers found the analyses to be useful.

Management Strategy Evaluation is a process that can develop over many years with many iterations. It is also a process that needs monitoring and adjustments to make sure that management procedures are performing adequately. Therefore, we expect that MSE work for Pacific halibut fisheries will take a number of years to set up before specific recommendations are approved. This time will involve consultation with stakeholders and managers, defining and refining goals and objectives, developing and coding models, running simulations, reporting results, and making decisions. Along the way, there will be useful outcomes that may be used to improve existing management, and will influence recommendations for future work. This work plan outlines the priority tasks of the MSE process for the next two years.

Overall, the plan is to use what has already been learned to continue making progress on the investigation of management strategies. Furthermore, more focus will be given to uncertainty and the achievement of objectives.

Main tasks for the next 1-2 years

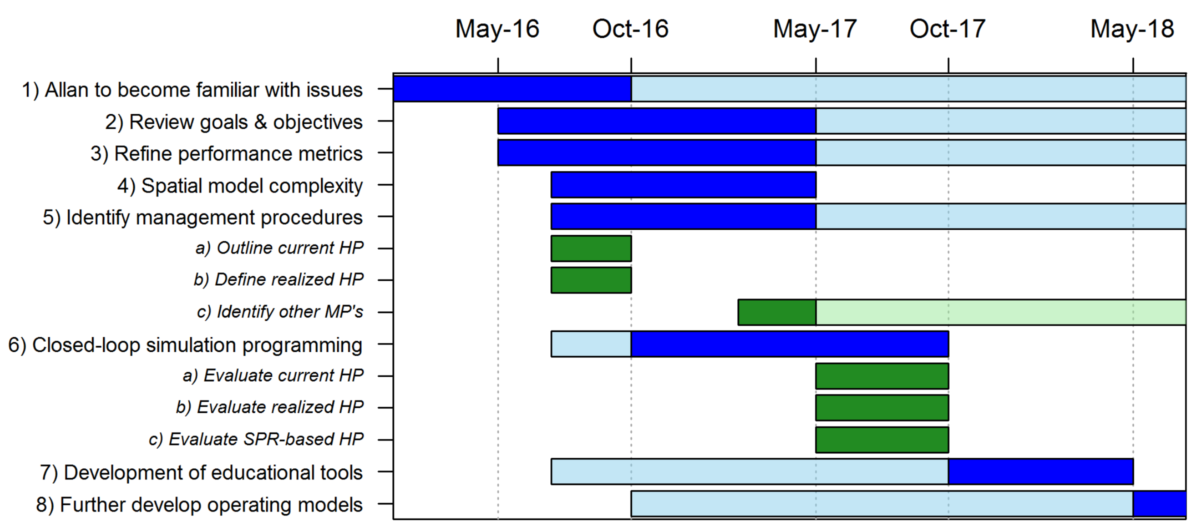

Figure 2: Gantt chart for the two-year work plan. Tasks are listed as rows. Dark blue indicates when the major portion of the main tasks work will be done. Light blue indicates when preliminary or continuing work on the main tasks will be done. Dark green indicates when the work on specific sub-topics will be done and light green shows when continuing work will be done. ~~t~~The end of the dark color shows when those results will be presented.

Description and timeline of tasks

1) Become familiar with halibut management, the MSAB and IPHC processes, and past activities

Timeline: October 2016, continual learning after then

Deliverables: Further develop a vision and path forward for the MSE. Develop a plan to involve the SRB and MSAB advisory bodies when proposing work and presenting progress.

Relevance: Being familiar with the process and having a smooth workflow will make the process much more efficient.

Resources: Time and access to literature.

Relation to other tasks: This task will inform all other tasks.

Description: Dr. Allan Hicks began working at IPHC in early April, and it will be useful to allow time for him to become familiar with the IPHC process, to learn more about the management of halibut, and to review past documents, meetings, and decisions before planning and embarking on new analyses. This will help to build from past experiences and maintain continuity in the MSAB process. Part of that learning experience was at the May MSAB meeting where Allan formally met many of the MSAB members and discussed his vision of the MSE.

When learning more about the IPHC process, Allan will also review how the different advisory bodies are integrated, especially the MSAB and SRB. More specifically, a plan will be developed for how and when proposed work will be approved by each advisory body, and how and when completed work will be reported to each advisory body. For example, are two meetings a year sufficient, should research be vetted by the SRB, and when should decisions be made by the MSAB to feed into the annual management process?

A final task will be to specify definitions of terms commonly used by the MSAB. Consultation with other MSE experts on the west coast will ensure a consistent use of terminology and encourage effective and clear communication.

2) Verify that goals are still relevant and further define objectives

Timeline: October 2016, and ongoing

Deliverables: A list of goals important to the management of the halibut fishery, and a set of measureable objectives associated with those goals.

Relevance: Relevant goals and measureable objectives are essential to the MSE process. They are necessary to determine what types of models are needed and how to evaluate the management strategies.

Resources: Time to review past meetings, MSAB members to confirm and verify intent of goals, MSAB members to assist with the development of measureable objectives.

Relation to other tasks: Defining goals and objectives is critical to developing useful performance metrics (Task 3), determining applicable management procedures (Task 5), and identifying the complexity needed in the operating model (Tasks 4 and 8).

Description: A very important part of the MSE process is to define goals (aspirational and realistic) and turn those into measureable objectives. The first step is to define a set of goals that are important to stakeholders and managers, which has been done at past MSAB meetings. It is important to verify that these aspirations are still of interest to all MSAB members, and to determine if additional goals should be added to the list. Currently, there are five overarching goals.

1. Biological sustainability
2. Fishery (all directed fisheries) sustainability and stability
3. Assurance of access – minimize probability of fishery closures
4. Minimize bycatch mortality
5. Serve consumer needs

Once a set of goals are verified, these can be used to define a set of measurable objectives, which are objectives that have

1. an *outcome* (a specific and measurable description of what is desired),
2. a *time frame* (over what period of time is this outcome desired), and
3. a *probability* (the tolerance for failure).

An example of defining a measureable objective may be to take the goal "assurance of access – minimize probability of fishery closures), and define the measureable objective as the predicted spawning biomass from the assessment is less than 20% of unfished equilibrium spawning biomass (*outcome*) over a ten-year period far in the future (*time frame*) no more than 5% of the time (*probability*).

Work has been done to translate the current goals into measurable objectives, as seen in Table 1, but additional work can be done to verify that these are still important, refine the details, and define them more clearly.

These measurable objectives are then used to evaluate alternative management strategies, and can be used to develop the specifics of a MSE simulation framework. For example, what spatial resolution is needed to evaluate the objectives (e.g., coast-wide single area vs. spatial operating model). The development of measureable objectives may be iterative, in that they may be revised as the MSE evolves and more is understood about the relative performance of various management procedures.

Table 1: Measureable objectives for some goals

Goals	Objective	Outcome	Probability	Time frame
Biological sustainability	Keep abundance above a certain level (**Limit**)	Maintain a minimum of number of mature female halibut coast-wide (e.g., one million)	0.99	Each year
		Maintain a minimum spawning stock biomass of 20% of the unfished biomass	0.95	Each year
	Reduce harvest rate when abundance is below a certain level (**Threshold**)	Maintain a minimum spawning stock biomass of 30% of the unfished biomass	0.75	Each year
	Risk tolerance and assessment uncertainty	When the estimated biomass is between the limit and threshold, reduce the probability of further declines	0.05-0.5	10 years
Fishery sustainability and stability **Assurance of access** **Serve consumer needs**	Maintain directed fishing opportunity (fish at the target harvest rate) Maintain a median catch within ±10% of 1993-2012 average Maintain average	Maintain directed fishery (*needs a quantifiable unit*)	0.95	Each year
	Catch at >70% of historical 1993-2012 average	Maximize yield in each regulatory area (*needs a quantifiable unit*)	0.5	Each year
			??	Within 5 years
	Harvest efficiency	Wastage in the longline fishery <10% of annual catch limit	0.75	5 year period
	Limit catch variability	Annual changes in TAC (coast-wide or by Regulatory Area) are less than 15%	1	Each year

3) Develop useful performance metrics to evaluate objectives

Timeline: October 2016, and ongoing

Deliverables: A list of performance metrics that would be informative to stakeholders, managers, and scientists to effectively judge the performance of different management strategies and the trade-offs between them. This list will likely include metrics derived by both the MSAB and the IPHC staff.

Relevance: The performance metrics are the key to evaluating management strategies and communicating outcomes to stakeholders. Determining important metrics and finding ways to present them effectively will help with the interpretation of the MSE results.

Resources: Time to review past meetings, MSAB members to confirm and verify current metrics, MSAB members to assist with the development of various performance metrics.

Relation to other tasks: Performance metrics are the key to presenting results from the management strategy evaluations and will be used in the outcomes from products generated from Tasks 4 (spatial model complexity) and 6 (Closed-loop simulation programming).

Description: Measurable objectives guide the development of the simulation framework for a MSE, and performance metrics are needed to gauge the performance of a management strategy relative to those objectives. For example, a measurable objective may be to keep the average catch above a specific amount (the *outcome*), in the long-term over a 10-year period (the *time frame*), at least 95% of the time (the *probability*). The performance metric, framed as a risk, could then be the probability that the average catch was less than that level in this time period (average here refers to the average over the 10-year period and the probability accounts for the many replicated simulations). Another example is that a potential aspirational goal would be to have stability in yield, which could be translated to a measurable objective as keeping the annual change in catch to less than 10% (*outcome*) over a 10-year period (*time frame*) at least 90% of the time (*probability*). The performance metric may then be, again framed as a risk, the average number of years that the absolute change in catch exceeded 10% over that 10-year period (the average number of years refers to average over simulations and is used because many replicate simulations would be done).

Other performance metrics may not be directly associated with measureable objectives, but related to aspirational goals. These could be the average catch and the average annual variability in catch, and they do not have a probability associated with them. They do, however, provide a comparison between management procedures, but can be more ambiguous in interpretation (e.g., compare an average catch of 101 tons to 100 tons, as opposed to a defined probability threshold for achieving a particular catch). If the goal is to maximize average catch or minimize average annual variability, then these performance statistics could be used to measure achievement of those goals (or to examine the trade-offs between them), but it is more difficult to gauge the performance of a metric like average catch in light of uncertainty. An important component of performance metrics is the *distribution of outcomes* under different scenarios; some scenarios may confer much greater sensitivity of results than others and the understanding of this sensitivity is critical to the evaluation of the management procedures that are tested. This is also a key element in understanding the uncertainty associated with results.

Determining important and useful metrics, as well as how to present them, is key to communicating outcomes, interpreting MSE results, evaluating trade-offs, and making decisions on management procedures. Many performance metrics have already been defined, and this task will refine those, identify new metrics, and develop ways to present them. For example, Table 2 and Figure 3 show results from a MSE for Pacific hake (Hicks et al 2016). The probabilities and other details are apparent in Table 2, while the trade-offs are easily seen in Figure 3. Additionally, performance metrics can be related to past performance, such as the observed average catch over the last 2 decades, and advice will be solicited to determine if there is a historical period for comparison.

Table 2: A table presenting performance metrics (rows) and management scenarios (columns) for a MSE on Pacific hake (from Hicks et al 2016).

	Long-term (2033-2042)				
	Perfect	F_{40}	F_{40}:0-500	F_{40}:0-375	F_{40}:180-375
Conservation					
Median average relative spawning biomass	26%	39%	42%	45%	35%
$Pr(B < B_{10\%})$	2%	6%	5%	5%	19%
$Pr(B_{10\%} \leq B \leq B_{40\%})$	77%	48%	47%	44%	41%
$Pr(B > B_{40\%})$	21%	45%	49%	51%	41%
Yield					
Median average catch	242	199	203	216	233
Median AAV	32%	52%	41%	34%	19%
Pr(catch = 0)	1%	13%	12%	10%	0%
Pr(catch < 180)	44%	52%	50%	44%	21%
Pr(180 ≤ catch ≤ 375)	31%	27%	25%	56%	79%
Pr(catch > 375)	25%	21%	26%	0%	0%

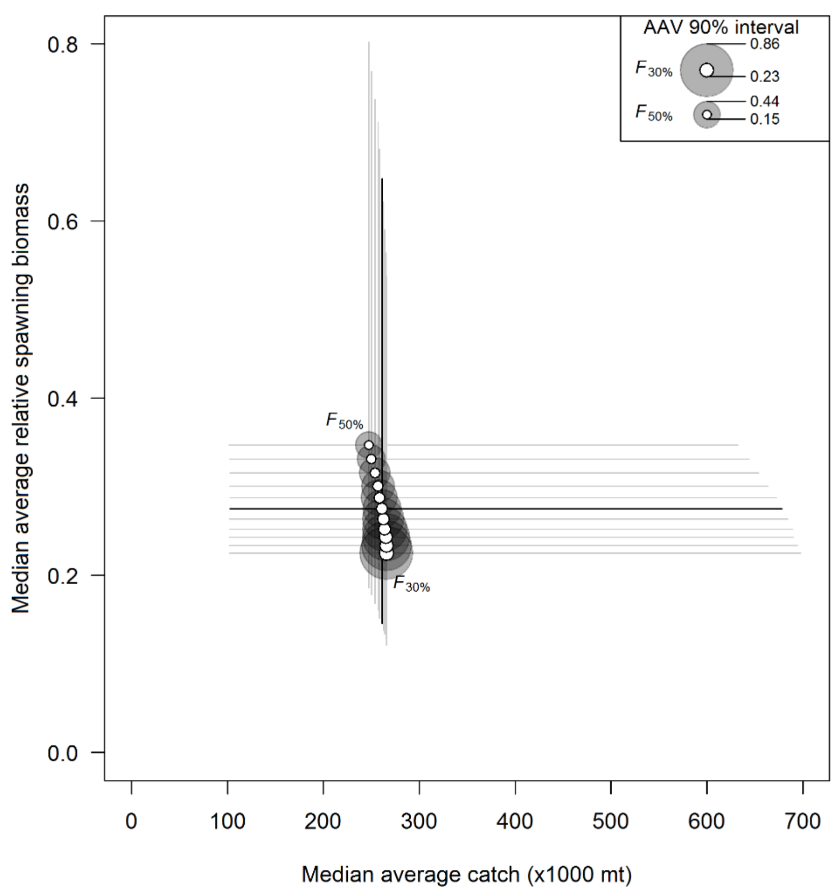

Figure 3: A figure showing the trade-offs between catch (x-axis), conservation (y-axis), and stability in catch (circle size). Quantiles representing 5% and 95% are shown as lines and shaded areas of the circles.

4) Identify the strengths and weaknesses of single-area and multiple-area models from a MSE perspective

Timeline: October 2016 with a follow-up in May 2017

Deliverables: Describe what is needed to develop single-area and multiple-area operating models for use in closed-loop simulations, the resources needed to do so, and how much time it may take. Provide a table showing what measureable objectives a coast-wide or a spatial operating model would address. Present the strength and weaknesses of the coast-wide and spatial operating models in relation to each measurable objective.

Relevance: Identifying the strengths and weaknesses of these two models will help to determine what questions can only be answered by a multi-area model and what can be accomplished with a single-area model.

Resources: Time, a set of working objectives

Relation to other tasks: The spatial complexity with be determined from and related to the goals and objectives (Task 1) and feed into the closed-loop simulation programming (Task 2). What is learned from the spatial model and complexity task will be directly used in the further development of operating models (Task 8).

Description: The complexity of an operating model (simulating the population) is an important factor to consider in a MSE. A more complex operating model may be able to answer more specific questions, but is also more challenging to parameterize such that it represents reality, is more difficult to code, and typically increases the run time of the simulations. Due to these challenges, it may not always be optimal to simply try to create a complex operating model, especially if a less complex operating will answer many of the questions being asked. Therefore, it is useful to identify the strengths and weaknesses of simple and complex models from the perspective of being able to address the goals and objectives of the MSE when deciding on the complexity of the operating model.

The goals defined for the management of a fishery and the measurable objectives defined from these goals often have an operational component. These operational components can guide the development of the operating model. For example, an aspirational goal may be to have a sustainable fishery and a measureable objective may be to keep the long-term biomass above 20% of B_0 at least 95% of the time over a 10-year period. This goal and objective could be addressed with a coast-wide, single-area operating model since that defines the overall fishery. On the other hand, a different aspirational goal may be to maintain viable fishing opportunities across communities, and a measurable objective could be to keep average catch in each management area above a historical average at least 90% of the time over a 5-year period. The aspirational goal is vague in its guidance of the complexity of an operating model, but addressing the objective would require a model with spatial complexity (multiple areas) that at least includes each management area (or some type of apportionment approach in addition to the coast-wide, single-area operating model).

This task will also outline what is needed to develop a more complex operating model as well as the data needed to condition that model (make sure that it represents how we believe the population behaves).

The development of a spatial model, the investigation of that model, and its approval for use in a MSE will likely take longer than two years to complete. This is described in Task 8.

5) Identify realistic management procedures of interest to evaluate with a closed-loop simulation framework

Timeline: May 2017, and ongoing. Some results presented in October 2016.

Deliverables: A list of management procedures making up various harvest policies to be tested using closed-loop simulations. A description of the current harvest policy and how historical decisions departed from that policy.

Relevance: Identifying realistic management procedures that are of interest to stakeholders, managers, and scientists will ensure that the results of the MSE are pertinent and useful to managing the Pacific halibut stock.

Resources: IPHC staff and MSAB members.

Relation to other tasks: This task will rely on defined goals and objectives (Task 2) and will feed into the closed-loop simulation programming (Task 6).

Description: The purpose of MSE is to evaluate a set of management procedures by examining and comparing the performance and trade-offs of each one. A small enough set needs to be determined so that the simulations can be completed in a reasonable amount of time and be easily compared and contrasted. The first step is to accurately characterize what is intended from the current set of management procedures and what has actually been implemented. Then, alternative management procedures can be identified by modifying the current ones, consulting with stakeholders, or examining other fisheries. Initially, a large set will be identified, and then reduced to a manageable size, which can occur through further consultation and investigation with simpler models such as the equilibrium model.

Management procedures are specific components of a management strategy (i.e., harvest policy). Some management procedures that have been proposed by the MSAB are:

- **Total mortality**: Direct accounting by area for all sources of mortality in that area, including sub-legals.
- **Size limits**: No size limit, current minimum size limit, 26 inches instead of 32, slot limits.
- **Harvest strategies**: 30:20 control rule, reference removal rate 21.5%/16.125%, coast-wide and by area.
- **National shares**: catch limits by areas allocated rather than based on apportionment.
- **Bycatch mitigation**: Impacts among areas for bycatch in a particular area.

The management strategy that would be evaluated as part of the MSE process would contain all of the necessary components to set catch levels for the stock. An example management strategy may be

- Coast-wide F_{SPR} with a 30:20 control rule to determine coast-wide total removals
- Coast-wide directed fishery catch levels apportioned to regulatory areas based on proportion of survey biomass
- Size limit of 32 inches
- Status quo recreational, subsistence, and bycatch allocation
- Annual survey to inform the stock assessment
- Status quo fishery data collected
- Annual assessment to determine total catch

The MSAB has agreed at the May 2016 MSAB meeting that the best way forward would be to first outline the current management strategy and compare that with the historical decisions that were made (realized management strategy). Then, alternative management procedures of interest to MSAB members can be identified. These two management strategies can later be evaluated against the objectives defined by Task 2 and also lead to the testing of alternative management strategies.

Furthermore, the MSAB decided at its October 2016 meeting to investigate a management approach based-on Spawning Potential Ratio (SPR), as well as other potential metrics, to account for all mortality. Spawning Potential Ratio is the long-term equilibrium spawning biomass per recruit with fishing divided by the long-term equilibrium spawning biomass per recruit without fishing. An SPR-based approach is defining a fishing level that results in a specific SPR (reduction in spawning potential) and noted as $F_{SPR=XX\%}$, where XX% is the SPR. This $F_{SPR=XX\%}$ will be treated as a management procedure and evaluated with closed-loop simulation to find a level that best satisfies the defined objectives.

6) Design a closed-loop simulation framework and computer program to extend the current equilibrium model approach

Timeline: October 2017, and ongoing

Deliverables: A design for a computer program that can perform closed-loop simulations for various operating models and management procedures. Once the design and framework are determined, the computer program will be written and tested.

Relevance: A computer program to perform closed-loop simulations is the engine for the MSE. It will perform the simulations and create the output needed to calculate performance metrics. A good design will ensure that the code is useful to address current questions and flexible to accommodate future questions.

Resources: IPHC staff, computer programmer, computing time

Relation to other tasks: This task will incorporate performance metrics (Task 3), spatial model complexity and operating models (Tasks 4 and 8), and management procedures (Task 5).

Description: To date, we have used an equilibrium model to introduce the concepts of a MSE. This model was used in a web-based application (the Shiny tool) because it produced results quickly and allowed MSAB members to change a few management options and see equilibrium outcomes related to biomass and yield. Those equilibrium outcomes are long-term averages of quantities that have natural variation (e.g., catches) if the fishery took place for an infinite amount of time.

Understanding the variability of the outcomes, such as yield and spawning biomass, is an important aspect of a MSE, but cannot be assessed with an equilibrium model. The equilibrium model is very useful because it produces results quickly and can be used to see the general patterns of various management strategies. However, this equilibrium model does not include the variability around the long-term equilibrium values, and does not incorporate a closed-loop simulation framework.

A closed-loop evaluation is the process of simulating the population dynamics, with an operating model, as well as the feedback from the management strategy and decision making process. The operating model consists of concepts that we cannot control, while the management process is what we can control. For example, the operating model will contain the population dynamics and some of the fishery dynamics that are not a part of the management process. The management process consists of data gathering, estimation models, and harvest strategies, as well as anything else that informs the decisions affecting the fishery and fish population. Figure 4 attempts to show the annual process of a closed-loop simulation.

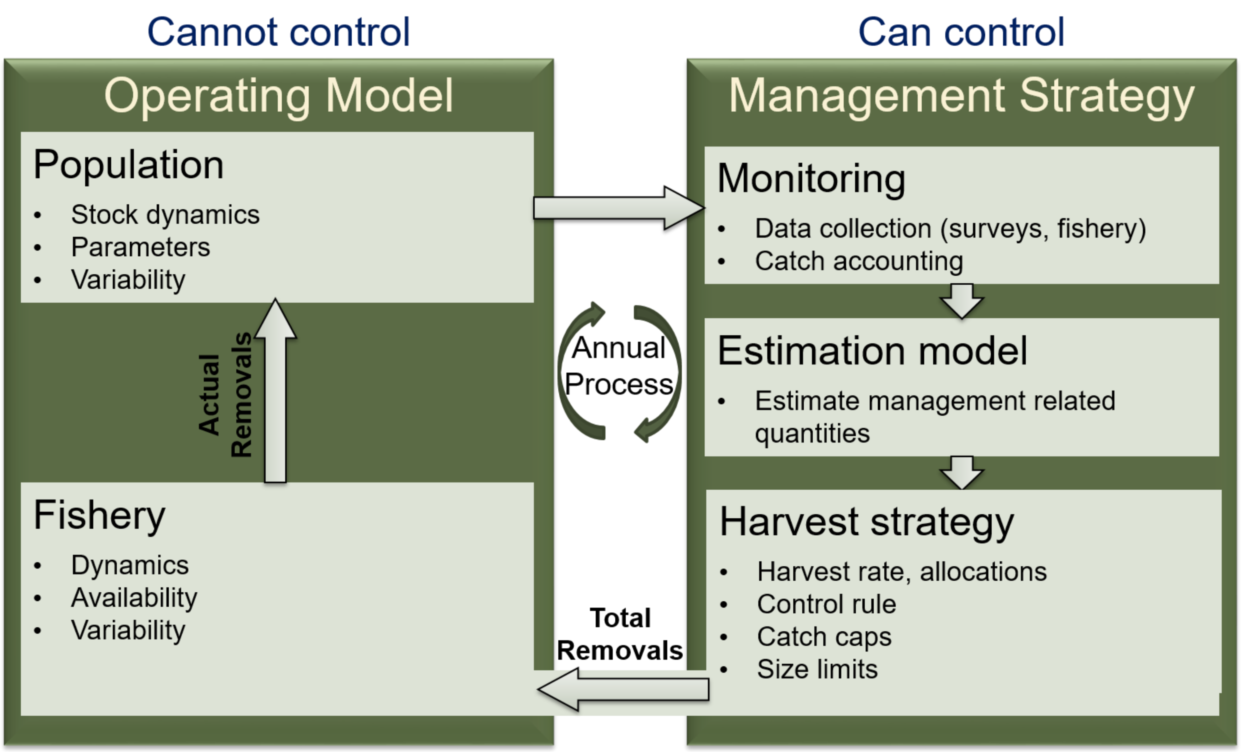

Figure 4: A flow chart of how the annual process is simulated in a closed-loop simulation.

The operating model incorporates variability in the system and additional variability can be added to various parts of the management procedure (e.g., sampling error, assessment uncertainty, and implementation error). This variability is characterized by replicate simulations, resulting in a distribution of outcomes, which can be described with summary statistics (such as the mean) or by probabilities (such as the proportion of time the catch was below a certain level). It is important to note that closed-loop simulations are different than projections because they incorporate the management strategy instead of simply projecting with a specified catch.

The management strategy must be able to be coded in a computer program, although implementation error can be introduced to mimic a real process more closely (e.g., not consistently following the management strategy). The average of a long-term closed-loop simulation with a consistent management procedure should be very similar to the results of an equilibrium model. However, the closed-loop simulation will also provide an insight into the variability of the process.

The development of a closed-loop simulation framework will involve coding a program that will incorporate the following:

1. Operating models. These are meant to represent reality, including the uncertainty about it. Multiple operating models will allow for structural uncertainty and alternative hypotheses of reality. They will have to be selected, coded, and conditioned. Conditioning an operating model is to tune it such that it is the best representation of reality possible (as indicated by fits to data). Current assessment models used in the ensemble approach are good initial candidates for operating models.
2. Management Strategy
    a. Data collection. This represents the types of data that are collected (e.g., fishery age compositions, survey index), how often they are collected, and the processes that generate them.
    b. Estimation model. The method to assess the population can range from simple (e.g., an average of recent survey observations) to complex (e.g., an ensemble of age-structure stock assessment models using multiple sources of data), but its main purpose is to use the simulated data to provide an input for the harvest rule. The current assessment approach (ensemble modelling) is likely too time-consuming for a simulation framework, so simplifications will need to be made. The simplest approach to mimic the assessment process (but not as realistic) is to add bias and variability to the outcomes of the operating model.
    c. Harvest strategy. The harvest strategy is a common focus of a MSE and is the set of procedures that defines how the total removals are determined. The current halibut harvest rule is an aggregate harvest fraction for two areas (16.125% for Areas 3B-4 and 21.5% for Areas 2 and 3A) with a 30:20 biomass based control rule. However, this is not always exactly followed, so introducing implementation error will more closely mimic the current situation.

The framework will have to be flexible and compartmentalized to allow changes to be made for each component. Initial testing and running of the framework will be done on the current and realized harvest policies identified as part of Task 5, and presented in October 2017.

An equilibrium model still has a role in MSE and can be used, as it has been already, to quickly narrow the choices of prospective management procedures. Once the candidate management procedures are narrowed to a plausible number for simulation testing, the closed-loop simulations can be used to further investigate them and characterize the distribution of results.

7) Develop educational tools that will engage stakeholders and facilitate communication

Timeline: May 2018, and ongoing

Deliverables: Materials, programs (web-based or installed), examples, etc. that will allow users to understand the MSE process through reading or interaction.

Relevance: For a stakeholder driven process to be effective, an understanding of the process and how to interpret results is necessary. These educational tools will facilitate communication and allow users to understand trade-offs between performance metrics given alternative management procedures.

Resources: IPHC staff, computer programmer

Relation to other tasks: Effective understanding and communication is key to interpreting results and fostering communication between science, stakeholders, and management. Therefore, educational tools will be useful for all tasks.

Description: An interactive tool has been developed using the equilibrium model (called the Shiny tool) and has been useful for education and the investigation of some management procedures. This interactive tool will be further developed with additional options added and integrate a closed-loop simulation. Using a closed-loop simulation and introducing variability will necessitate the output to be changed to reflect the uncertainty in the results by reporting performance metrics, and results will be shown using various graphics and tables.

In addition, the development of materials that are useful to MSAB members and their constituents to assist with understanding the MSE process and facilitate communication will be done with the guidance of MSAB members.

8) Further the development of operating models

Timeline: Beyond May 2018

Deliverables: Initially, the specifications of additional operating models that will satisfy the objectives defined by MSAB members will be supplied. Once those are approved, model development will begin. In the end, computer models that read input files and produce simulated output will be provided.

Relevance: Alternative operating models are necessary to examine structural uncertainty and to answer specific management questions.

Resources: IPHC staff, computer programmer, computing time

Relation to other tasks: The further development of operating models will be guided by the analysis of spatial complexity (Task 4) and will be necessary to appropriately evaluate management procedures (Task 5) against the goals and objectives (Task 2). These operating models will be used within the closed-loop simulation framework (Task 6).

Description: Management advice for Pacific halibut is currently developed using an ensemble of four different models to account for structural uncertainty. This same concept extends to MSE, and using various operating models with different assumptions can help to properly characterize the overall uncertainty in the management of a fish stock.

Additionally, some questions asked of the Pacific halibut MSE can only be answered with a spatial model. For example, investigating the yield in each regulatory area would require simulating the biomass and fishery in each regulatory area. The spatial complexity of the model depends on the questions being asked, thus before developing an operating model it is useful to determine the extent of the objectives. This will determine the structure of the operating model; for example, whether it needs to be flexible to incorporate different area specifications, or if it can have a fixed set of areas with simple movement between them. Once the level of complexity is decided, the next step is to determine how to best model space, movement, and time. After the design of the model is complete, programming can begin. Finally, the model will need to be conditioned to halibut data before being used in a MSE to ensure that it is a reasonable depiction of reality (or at least what we understand of it), and that we have enough data and knowledge to actually define the complexity of the operating model.

Taking the time to develop the specifications of an operating model is very important. The development of a multi-area model is ongoing as part of the annual assessment process, which will provide some of the framework for future operating model development. Therefore, a fully developed multi-area model is not likely to be completed in the next two years. However, there are many questions that can be answered with a single-area model before transitioning to a multi-area model. Additionally, using a single-area model to answer those questions will be much more efficient.

Appendix A: Definitions

It is important to have a set of working definitions, and this is especially true to the Management Strategy Evaluation (MSE) process since it involves many technical terms that may be interpreted or used differently by different people. Below are some definitions that will apply to this work plan. Additional definitions can be found at http://www.iphc.int/documents/glossary/Glossary_of_terms_IPHC_Dec_2015_change1.pdf.

These definitions are a work in progress and will likely be updated after discussions with other scientists implementing MSE on the west coast. A consistency among different fisheries and agencies would be useful to avoid confusion. For now, these definitions are pertinent to this document.

Closed-loop simulation: The process of simulating dynamics with a feedback loop. For example, simulating the feedback of the annual management process (i.e., setting catch levels) on a fish stock. The simulation framework incorporates an *operating model* and a *management strategy*, and all of the uncertainty that goes along with those.

Control Rule: Defined actions and reference points that provide an adjustment to the catch beyond the harvest rates. Often, the lower reference point is where catch is zero.

Estimation Model: A single model or multiple models that process data in a simple or complex way to provide outcomes to be considered by the *harvest strategy*.

Equilibrium Model: A model that provides the long-term average results for a population ~~under~~ given a set of ~~various~~ assumptions.

$F_{SPR=XX\%}$: A fishing level that results in a specific SPR (reduction in spawning potential). Also see *Spawning Potential Ratio*.

Goal: A high-level aim or desired result. These are typically broad and used to develop *Measureable Objectives*.

Harvest Policy: A set of *management procedures* that define how the fishery is managed (see *Management Strategy*).

Harvest Strategy: The specifics of how catch is determined and adjusted. For example, harvest rates and a *control rule*.

Management Procedure: A specific single procedure that can be modified as part of a larger *management strategy*. For example, a size limit or *control rule*.

Management Strategy: A set of *management procedures* that define how the fishery is managed (see *Harvest Policy*).

Management Strategy Evaluation: A process to evaluate *management strategies* against goals & objectives through simulation.

Measurable Objective: An objective that has an associated outcome, time-frame, and risk tolerance, and is typically developed from one of the goals. For example, if the goal is to have a healthy halibut stock, the measureable objective be to keep the population above 20% of unfished biomass (outcome), in the long-term measured over a 10 year period (time-frame), with a probability of 99% (risk tolerance of 1%).

Multi-Area Model: A coastwide model of the halibut population where the dynamics are modeled using more than one area. These areas are not necessarily Regulatory Areas, but assumptions of area-specific dynamics (e.g., migration, recruitment, growth, etc.) are necessary.

Operating Model: A model designed to represent the dynamics of a population and parts of the fisheries for which we cannot control. This is a representation of reality and the uncertainty about that reality.

Performance Metric: A single metric that can be used to evaluate an objective. These can be simply a probability associated with a measurable objective, or can be a measurement associated with an outcome of a measurable objective. For example, the probability that the spawning biomass is less than 20% of unfished biomass, or the average spawning biomass over a 10 year period.

Scenario: A specific set of assumptions for the operating model to determine how the halibut population and fishery are simulated. These assumptions are what we cannot (or choose not to) control and include three broad categories: 1) dynamics that are completely out of our control, such as size-at-age, recruitment patterns, acts of nature, etc., 2) aspects that may be under the control of others, but a management procedure would not apply to (e.g., some fishery dynamics such as where they choose to fish), and 3) management procedures that we choose not to control (e.g., bycatch).

Single-area Model: A coastwide model of the halibut population where the dynamics are modeled as one area (i.e., no migration).

Spawning Potential Ratio (SPR): The long-term equilibrium spawning biomass per recruit with fishing divided by the long-term equilibrium spawning biomass per recruit without fishing. This is a commonly used metric to define the effect of fishing on the spawning potential and used by many agencies to define a target fishing level.