The IPHC MSE Explorer tool

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PURPOSE

This document provides a description and tutorial of the IPHC's web-based MSE Explorer tool (http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/MSE-Explorer/) used to examine current Management Strategy Evaluation (MSE) results.

BACKGROUND

To support the IPHC's MSE process, IPHC Secretariat developed an interactive tool that can be used to examine the MSE results (i.e. performance metrics) by comparing and ranking management procedures (MPs), plotting performance metrics, and investigating trade-offs. There are many different views in MSE Explorer with control over what is viewed. There is a table of performance metrics, a page with plots of performance metrics against the MPs, plots of trade-offs between performance metrics, plots of trade-offs between IPHC Regulatory Areas, and tables ranking the MPs against the primary objectives. Additionally, there are help pages defining commonly used terms and acronyms, describing the performance metrics, and explaining the MPs.

THE MSE EXPLORER

The MSE Explorer is a necessary tool to understand the outcomes of the IPHC MSE because it filters pre-calculated performance metrics and pre-defined MPs that resulted from simulations using the IPHC MSE framework. An MSE can simulate many MPs and have many performance metrics calculated for each MP. The table of results can become so large that it becomes onerous to interpret the results and compare MPs. The MSE Explorer assists with the evaluation by allowing the users to select exactly what they would like to focus on and make comparisons that are easier to interpret.

There are eleven general MPs defined by the MSAB and for each MP, different levels of fishing intensities (i.e. Spawning Potential Ratio, SPR) were included. Additional MPs were included to investigate additional components or specifications. Each management procedure has nearly 700 performance metrics calculated for it. The MSE explorer gives the user the freedom to view specified performance metrics for selected management procedures in tabular form or with various plots. The selected tables can be easily downloaded for further analysis and plots can be copied and pasted into a document.

There are eight pages in MSE Explorer:

1) **Description**: First page displayed by default showing a description, updates, and grids indicating available and chosen MPs.
2) **Table**: A table of the performance metrics for selected MPs. Useful to see the exact values of the performance metrics to make detailed comparisons.
3) **Plots**: Plots of each performance metric for all selected MPs. Useful to compare a lot of MPs for individual MPs.

4) **Trade-offs**: Two performance metrics plotted against each other for all selected MPs. Useful to examine trade-offs between two performance metrics.
5) **Regulatory Areas Trade-offs**: Plots of selected Regulatory Area performance metrics with all Regulatory Areas on each plot. Useful to examine trade-offs between IPHC Regulatory Areas.
6) **MPs Ranking**: Table ranking the MPs for performance metrics related to the primary objectives. Additional tables are provided that summarize over IPHC Regulatory Areas and measurable objectives. Useful to compare the performance of MPs and quickly identify MPs that perform well compared to others.
7) **MPs**: A description of all of the MPs that may be selected.
8) **Help**: Definitions of some terms and descriptions of the performance metrics.

The left portion of the MSE Explorer is where options are selected for the management procedures, time-period over which statistics are calculated, Biological Regions and IPHC Regulatory Areas to include, and performance metrics to display. Pages 2 to 6 show results based on these specific selections. The logo on the top right corner of each page will direct directly to the IPHC website. A tutorial on how to select options is provided first, followed by a brief description of each page. How to interpret outcomes is provided throughout.

SELECTING OPTIONS

The left portion of the MSE Explorer, with a black background, is where the page, the elements of the MP, the time-period, the Biological Regions, the IPHC Regulatory Areas, and the performance metrics to be displayed can be selected. This selection panel can be hidden or made visible by clicking on the three horizontal lines at the top, immediately to the right of the words "IPHC MSE Results". The performance metrics can be chosen by clicking on "Expert Mode".

Figure 1 shows the different sections of the selection panel. The current pages that can be displayed are discussed in detail below. The other components are described here.
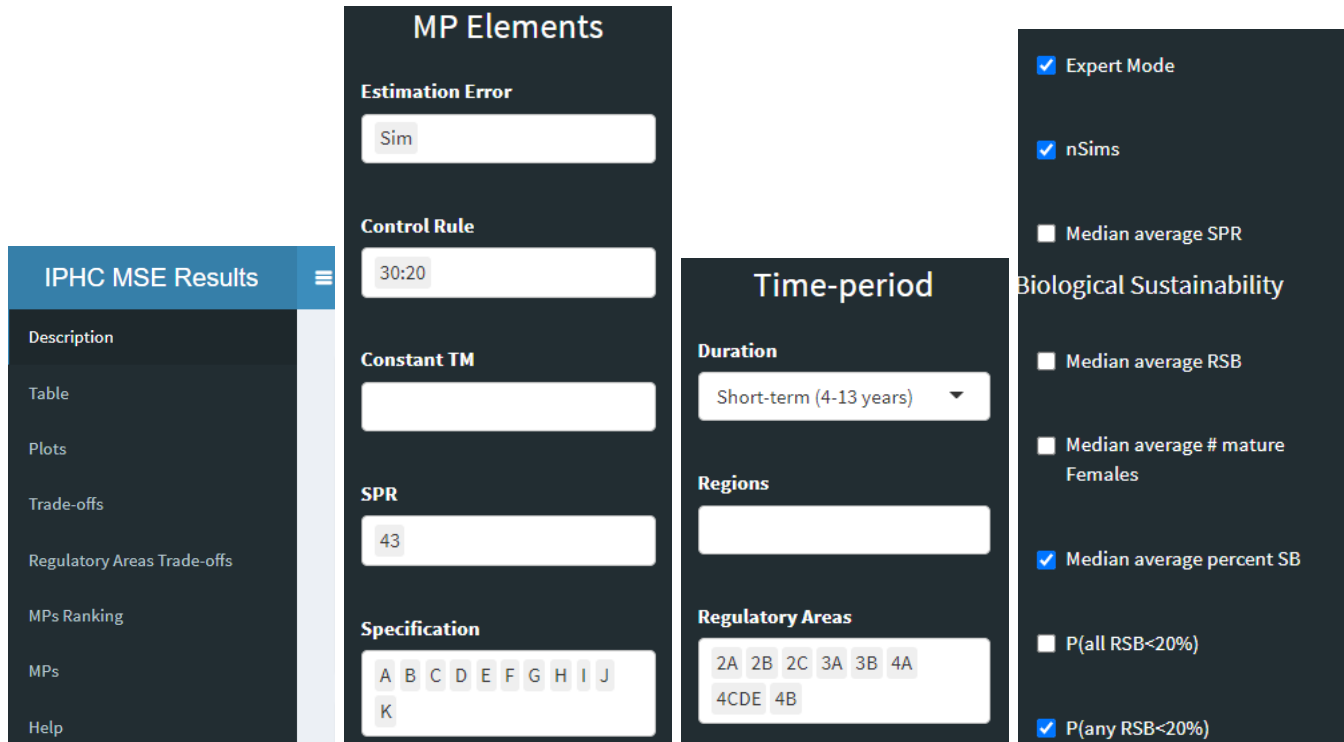
MP Elements

This section of the selection panel allows the user to select the elements of the MPs that in combination will be displayed in the results pages.

Estimation Error indicates the method used to simulate estimation error, and **"Sim" is the recommended option to use when evaluating MPs**. The three types of estimation error are:

None: No estimation error is simulated, thus the quantities needed to determine total mortality (e.g., population abundance and age-structure) and to distribute the TCEY to IPHC Regulatory Areas (e.g., O32 stock distribution) are known without error. This is useful to understand the underlying variability in outcomes due to the simulated population variability. However, it is an unrealistic simulation of the management process and is not to be used to evaluate MPs.

Sim: Estimation error for the stock assessment is simulated through a simple approximation using unbiased random number generation. Estimation error for the survey data is simulated realistically as determined from previous observations. This is the same method used for the IPHC coastwide MSE and is currently the most complete and trusted method to evaluate these MSE results.

SS: Estimation error for the stock assessment is simulated using a stock synthesis (SS) model similar to one of the models used in the current stock assessment ensemble. This approach is the most realistic method to use in MSE simulations, but is currently incomplete in these MSE results. Additional work is being done to improve this method for future use. However, it is currently not ready for evaluation of MPs, but is included as a comparison.

Figure 1: Four sections of the portion of MSE Explorer that allows you to select options. The four sections are located on the left of the screen and allow you to (from left to right) select the page, select the elements of the MPs, select the time-period, Biological Regions, and IPHC Regulatory Areas, and select the performance metrics once "Export Mode" is checked. The three horizontal bars next to the words "IPHC MSE Results" will hide or display the panel for these options.

Control Rule is the specification of the trigger and limit in a control rule, indicating the stock status at which the fishing intensity would begin to be reduced and where it would be theoretically set to zero, respectively. Currently, only a 30:20 control rule is available, thus is the only option.

Constant TM is a placeholder for results that project into the future under a constant total mortality. For example, a total mortality of zero (no fishing) or a specified value may be useful to understand the population and fishery dynamics. Currently, there are not simulations available for this element, but may be added in the future.

SPR is the spawning potential ratio which determines the fishing intensity. Lower SPR values correspond to higher fishing intensity and '43%' is the SPR currently used in the interim harvest strategy policy. The stock assessment (simulated in the MSE) uses the SPR to determine the coastwide total mortality. Most MPs have been tested for different SPR values.

Specification indicates the specifications of the MP as defined at MSAB015. Specifications were provided for eleven MPs and are described in Appendix V of IPHC-2020-MSAB015-R. Additional specifications, identified as 'Extra MPs' in the dropdown menu and prefixed with the number '16', were supplied to supplement the evaluation of the original eleven MPs. Descriptions of all specifications are available on the "MPs" page in MSE Explorer.

Results for an MP combining the selected elements for estimation error, SPR, and specification may not be available. In that case, that MP will not appear on any pages. For example, there are no results for an SPR of 36 and MP-I, but there is for an SPR of 36 and MP-A. The grids at the bottom of the Description page are useful to determine what combinations are available for evaluation.

Time-period

There are three time-periods to choose from in the drop-down box labeled "Duration". These are short-term (4-13 year projection), medium-term (14-23 year projection), and long-term (51-60 year projection). All three options cover ten-year periods so that statistics are comparable. Typically, sustainability objectives are evaluated in the long-term, representing equilibrium values, which is a common concept used in fisheries management. Any of the time-period may be considered for fishery objectives, and are useful to compare. Despite being provided, the MSE simulations are not purposefully designed for short-term predictions. MSE is, however, designed to represent long-term variability useful for strategic decision making.

Biological Regions and IPHC Regulatory Areas

Some performance metrics are calculated for Biological Regions and/or IPHC Regulatory Areas (Figure 2), but they are only displayed when a region or area is chosen in the drop-down boxes. Therefore, to view a performance metric for a region or area, a performance metric must be selected and the IPHC Regulatory Area or Biological Region must also be chosen.

Performance Metrics

When the box labeled "Expert Mode" is checked, the list of all available performance metrics is displayed with a check box next to each one. A set of default performance metrics associated with the current primary objectives are selected when the MSE Explorer is first visited or reloaded. Selecting the check box will display that performance metric along with other ones that are checked, although some performance metrics will also need to have an IPHC Regulatory Area or Biological Region chosen. The performance metrics are defined on the "Help" page and only those related to the primary objectives are defined in Appendix I.
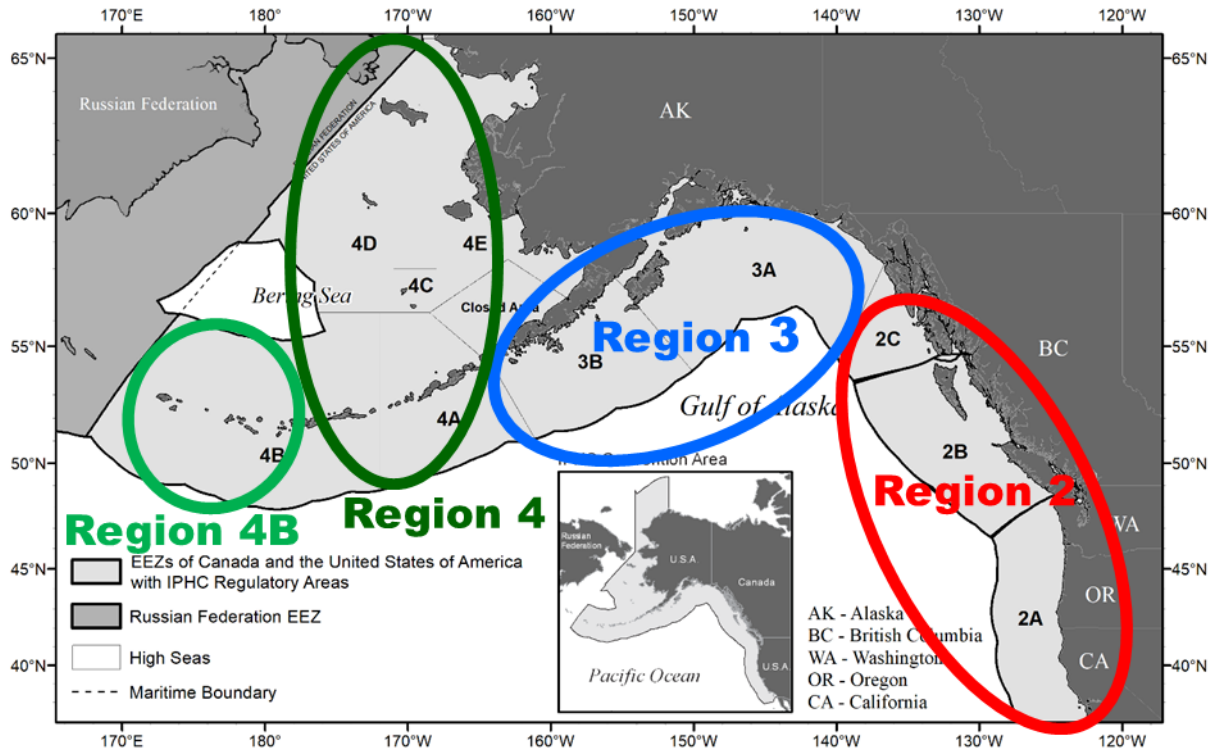
Figure 2: IPHC Regulatory Areas and Biological Regions. The Biological Region boundaries match IPHC Regulatory Area boundaries for practical purposes.

Pages of the MSE Explorer

Description

The Description page is the general landing page for the MSE Explorer and provides a description of the tool, a list of updates, and a display (grids) of the available and selected MPs. This page is displayed by default when first visiting the MSE Explorer or when refreshing the webpage. It is always a good idea to refresh the webpage (e.g., press the reload button on your browser or press F5) when you visit to make sure that you are viewing the most recent version.

The grids are presented separately for each type of estimation error. Each grid shows the SPR values on the vertical axis and the selected specification (i.e. Distribution Procedure) on the horizontal axis. Blue colored cells indicate that results are available for the combination of estimation error, SPR, and specification. Light-blue indicates that the elements are not selected and dark-blue indicates that they are selected and that results are displayed on other pages.

Simulated Estimation Error
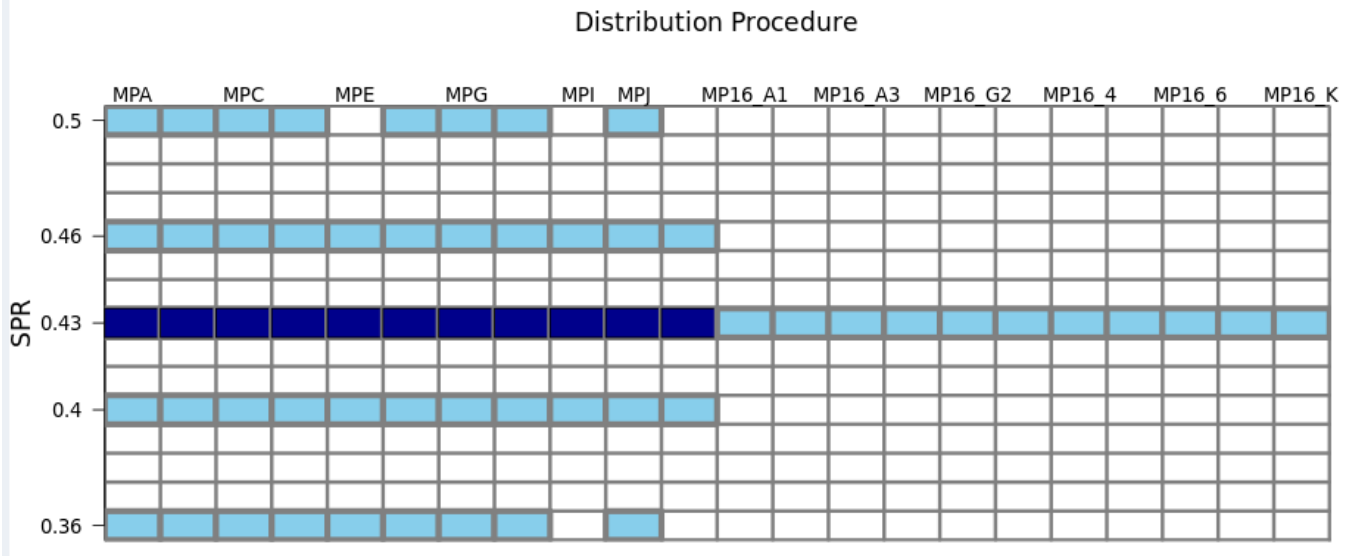
Figure 3: The grid for simulated estimation error showing the MPs available for combinations of SPR (vertical axis) and Specification (labeled Distribution Procedure) on the horizontal axis. The light-blue indicates that the combination is not selected for display and dark-blue indicates that the combination is displayed for evaluation on results pages. The grid is interactive and changes immediately upon a change in selection.

Table

The Table page presents the selected performance metrics as rows for the selected MPs across columns. The performance metrics are grouped by those related to the population and those related to the fisheries. The table expands based on the selections made and can be scrolled left and right as well as up and down. The values can be copied to a different program, such as a word processor or spreadsheet, by selecting rows and using copy commands. Alternatively, the table based on the selections can be downloaded as a csv file (comma delimited) with the "Download Table" button, making it easy to import into a spreadsheet for further analysis.

The Table page is useful because it reports the numeric values of each selected performance metrics. This allows the user to assess the actual difference between MPs, that could be difficult to determine in the pages with plots or ranks. In the plots, the difference between MPs might appear larger due to the scale used in the y axis, but looking at the Table page will allow one to evaluate if the difference is actually meaningful.

Plots

The Plots page is an extremely useful page to investigate the value of a single performance metric across all the selected MPs. This page shows an individual plot for each selected performance metric with the specification along the horizontal axis and the metric as the vertical axis. If multiple SPR values and/or estimation error types are chosen, they will be displayed as different colors in each plot (Figure 4).
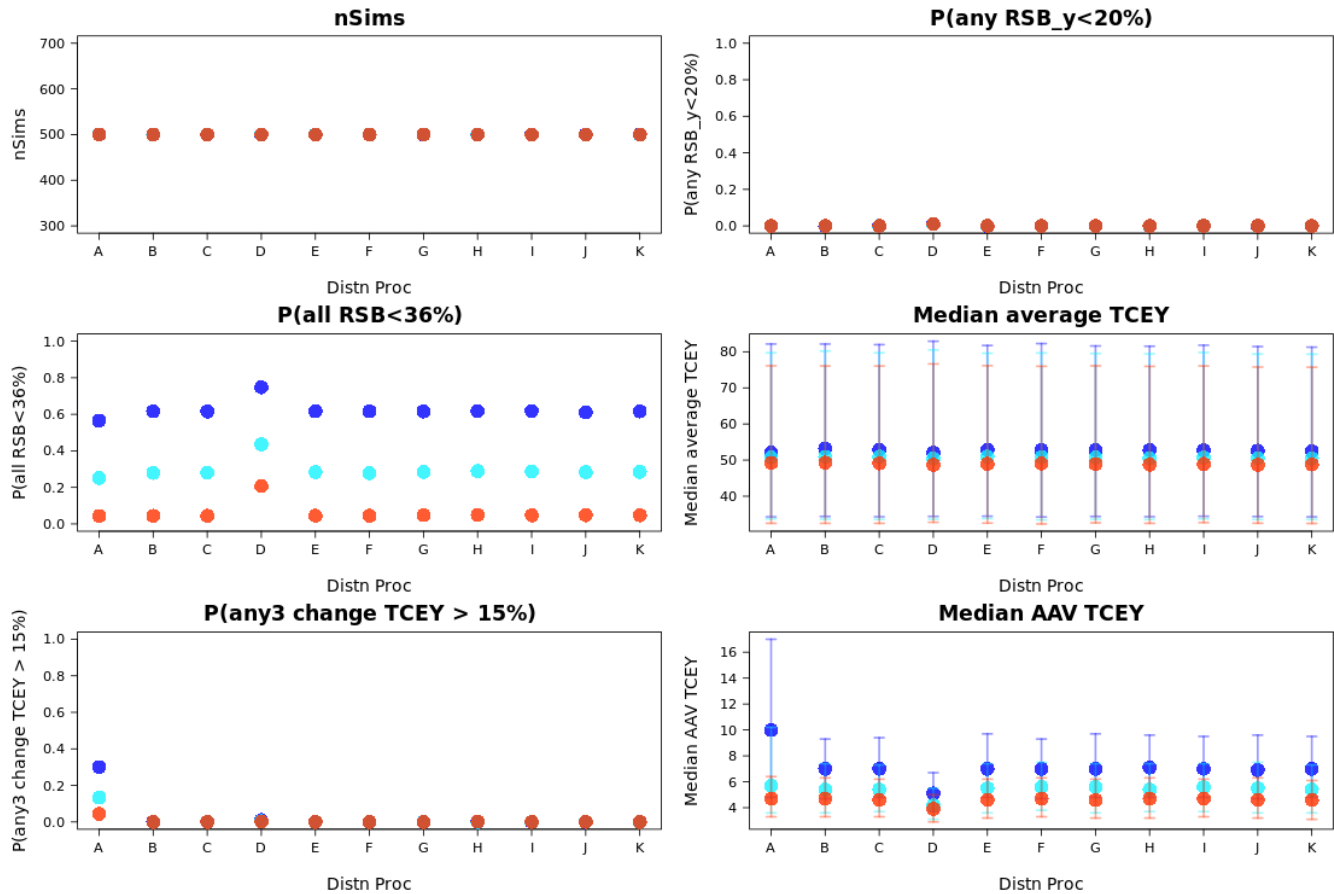
Figure 4: Plots of single performance metrics from the Plots page for the eleven MPs and three levels of SPR (40% in dark blue, 43% in light blue, and 46% in red). The 25th and 75th percentiles are shown for the median average TCEY and the median AAV of the TCEY. "nSims" is not a performance metric but is the number of simulations which is informative about the precision of performance metrics.

Some additional options are available on the Plots page. The height of the plot can be resized and the size of the plotting character (circle) can be changed. Performance metrics that are not probabilities are summarized by the median value average over a 10-year period. These also have the 5th, 25th, 75th, and 95th percentiles calculated and can be plotted by checking the appropriate box in the upper right. A percentile indicates that the defined percentage of simulations were less than that percentile value. For example, a 25th percentile means that 25% of the simulations were less than that value. Note that the median is the 50th percentile.

The plots are useful to examine a single performance metric for a range of MPs. In Figure 4, the median AAV (average annual variability) of the coastwide TCEY is shown in the lower right, and highlights some important results. First, the dark blue circles for an SPR of 40% (i.e., higher fishing intensity) show more variability in the TCEY that higher SPR values (i.e., lower fishing intensities). Furthermore, the variability tends to be highest for MP-A and lowest for MP-D.

Trade-offs

The Trade-offs page produces a plot showing the relationship between two performance metrics. The user chooses a metric (near the top of the page) to be plotted on the horizontal axis and a metric to be plotted on the vertical axis. Only performance metrics selected by the user are present in the drop-down boxes. The resulting plot is color coded by specification and shows different SPR values with different shapes (Figure 5). There is a drop-down box for Factor, which currently contains only one choice. The plot height and point size can be adjusted as with the Plots page.
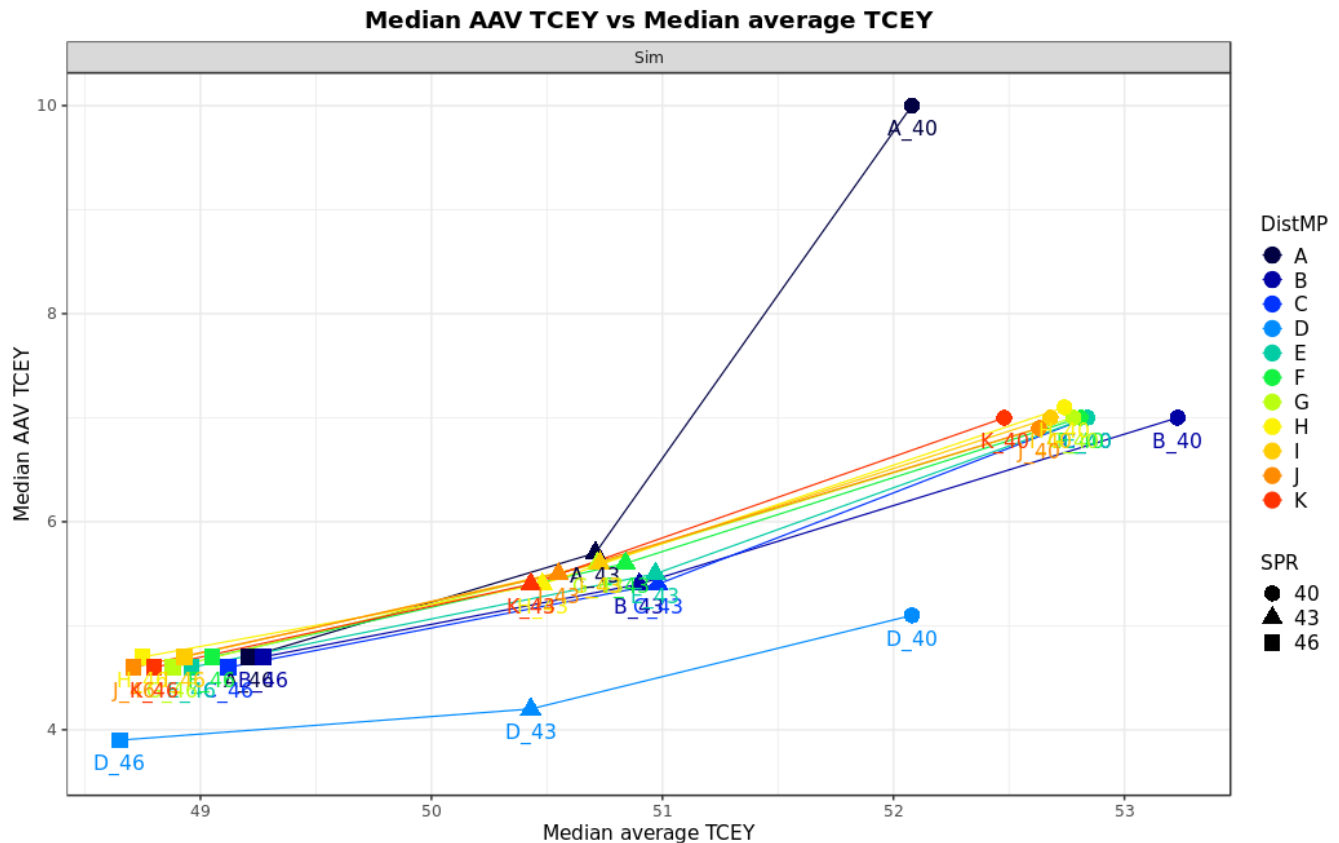
Figure 5: A trade-off plot from the Trade-offs page showing the relationship between the median AAV of the coastwide TCEY and the median average TCEY for the various specifications of the MPs (colors and letters) and three-levels of SPR (shapes connected by lines).

Trade-offs are an important concept to consider when evaluating MPs using MSE simulations. The performance metrics are typically related to objectives and it is important to determine the trade-offs between those objectives. For example, Figure 5 shows the trade-off between the median AAV of the coastwide TCEY and the median TCEY. As more fish are caught (horizontal axis) the variability also increases (vertical axis), indicating that two common objectives of reducing variability and increasing yield cannot be met simultaneously. Also in Figure 5, MP-A with an SPR of 40% stands out, and MP-D stands out as having lower variability, but also lower yield than the other specifications. Many insights can be gained from trade-off plots.

Regulatory Areas Trade-offs

The Regulatory Areas Trade-offs page contains plots for each performance metric showing the values organized by IPHC Regulatory Areas (Figure 6). The specification is shown along the horizontal axis and SPR levels are noted with different symbol shapes. Each IPHC Regulatory Area that is selected in the drop-down box on the selection panel is shown with a different color. The estimation error method selected is specified in the grey bar on top of each plot. Different plots are drawn for each of the estimation error methods, if desired. The user can use the dropdown menu for the 'Horizontal (x) Axis' to plot IPHC Regulatory Areas on the x-axis and display the different specification as different colors.
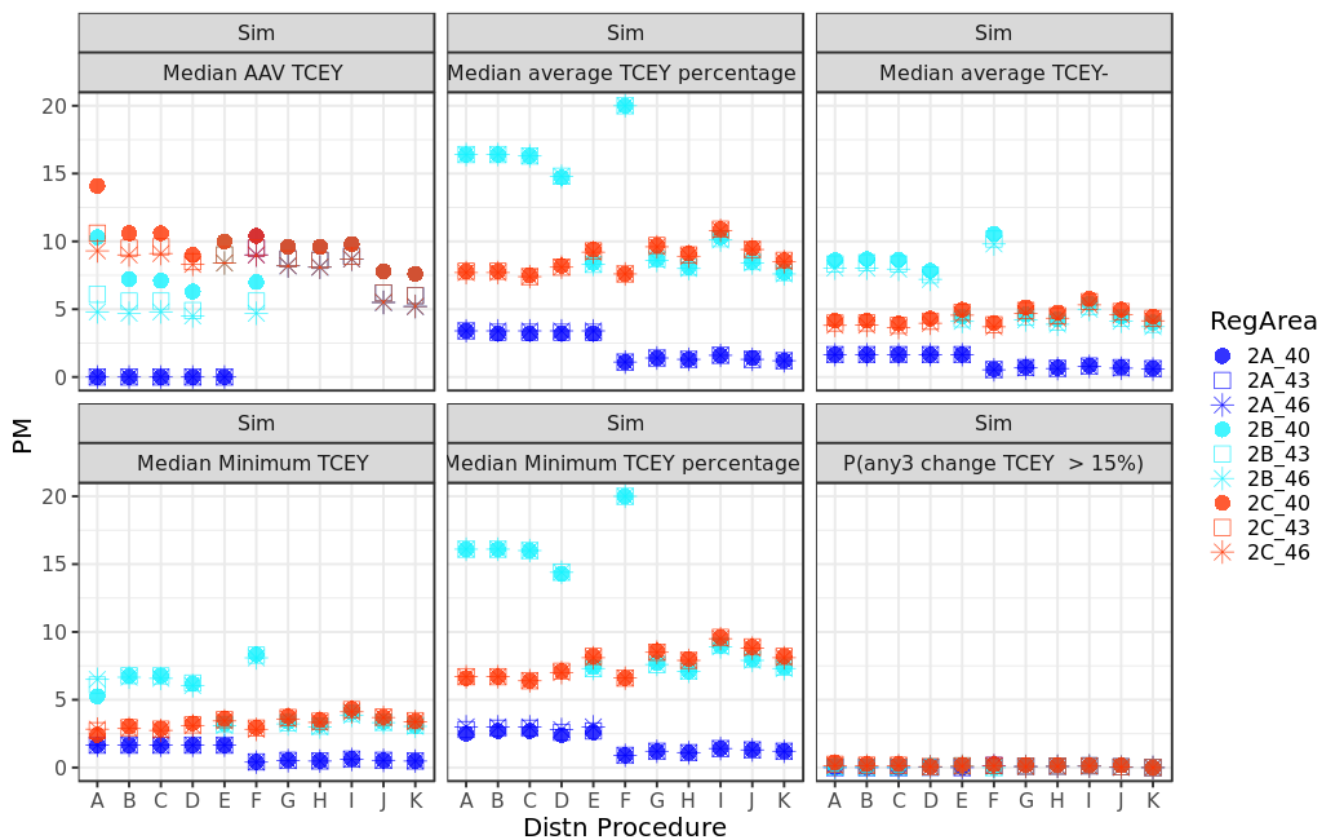
Figure 6: Plots from the Regulatory Areas Trade-offs page for simulated estimation error, various performance metrics, three SPR values, and IPHC Regulatory Areas 2A, 2B, and 2C.

This page allows for easier examination of the trade-offs between IPHC Regulatory Areas by plotting the areas on the same plot. In Figure 6, the SPR has a small effect on the performance metric for each IPHC Regulatory Area, while the specification of the MP has a much larger effect. The median AAV of the TCEY in IPHC Regulatory Areas 2A, 2B, and 2C (upper left of Figure 6) increases significantly for 2A while decreasing for 2C in the MP specifications to the right, which do not contain specific agreements for 2A and 2B.

MPs Ranking

A useful method to discern between multiple management procedures is to rank each MP based on the values of the performance metrics related to defined objectives, such as those currently defined by the Commission. Currently specified biological objectives and one of the fishery objectives are defined in a way such that it can be determined if they are met or not. In particular, the Biological sustainability objectives are stated as a probability of staying above a defined level with a specified tolerance. For example, a coastwide sustainability objective is to maintain the female spawning biomass above a biomass limit reference point 95% of the time. Using the outcomes of the MSE simulations, it can be determined if this objective is met, or not, by an MP. Most of the fishery objectives, on the other hand, do not have a tolerance defined. In this case, the scoring of the related performance metrics will identify a set of the best performing MPs relative to each objective.

The MPs Ranking page incorporates both of these concepts and summarizes the outcomes in a succinct way to assist with identifying robust MPs that perform well against the defined objectives. The page has different sections in accordance with the general objectives:

> 1.1: Biological Sustainability: Keep female spawning biomass above a limit to avoid critical stock sizes and conserve spatial population structure.

> 2.1: Fishery: Maintain female spawning biomass around a level that optimises fishing activities.

> 2.2: Fishery: Limit catch variability.

> 2.3: Fishery: Provide directed fishing yield.

At the top of each rank table is an option for the time-period (short-, medium-, or long-term): the default is set to the time-period specified by the MSAB when objectives were defined. The tables that rank the MPs provide rounding options to be applied before ranking. Rounding to different levels implies different levels of significance. Additional tables summarize the results over IPHC Regulatory Areas and then again for the three fishery goals (general objectives 2.1, 2.2, and 2.3). The dash on the top right corner of each table minimize the table itself, so to reduce the length of the page. The search box on top of each table allows filtering of the rows in each table using simple keywords.

The table for general objective 1.1. provides the actual value for that performance metric (a probability) and a color code to indicate if the objective is met (green to indicate it is met, red it is not). This table can be determined using short-term, medium-term, or long-term results, although long-term is recommended since these are Biological Sustainability objectives. There is a check box labelled "Include in Summary" which will color code columns in summary tables in red if any Biological Sustainability objectives are not met. Excluding the biological sustainability objective from the summary tables, allows for trade-offs in fishery objectives to be evaluated for all MPs regardless if they pass the Biological Sustainability objectives.

The tables for the fishery objectives contain ranks for individual performance metrics determined across the selected MPs. Cells are color coded with higher (better) ranked MPs given a light color and lower (worse) ranked MPs getting a dark blue color. MPs with the same value for a performance metric (i.e., a tie) are given the same rank and subsequent ranks continue from the

total number of MPs ranked better than it. For example, if three MPs all tie for first rank, they are given a 1, and the fourth MP is given a rank of 4. There are alternative ranking methods, but they are not applied here.

The table for general objective 2.1. provides the ranks for a single performance metric: how close to 0.5 is the probability that the spawning biomass is less than a target of 36% of unfished spawning biomass. This ranking is done on the proximity to 0.5 because the objective is related to a target. The time-period defaults to long-term, but the user can select short- or medium-term. Additionally, the difference in the probability from 0.5 can be rounded to one or two decimals before ranking.

The ranks for many performance metrics are provided for the objective to limit catch variability (2.2). These include two coastwide metrics: the probability that the annual change is greater than 15% and the median AAV. Both performance metrics are also reported for each IPHC Regulatory Area, resulting in a total of 18 rows in the table. The probabilities can be rounded to one or two decimals and the AAV can be rounded to the nearest integer, 0.5, or one decimal. This table uses short-term by default but can also use medium- or long-term periods.

The final ranking table is for general objective 2.3: provide directed fishing yield. The median coastwide TCEY is the only coastwide performance metric used in this table. The median TCEY, minimum TCEY, median percentage of the coastwide TCEY, and the minimum % of the coastwide TCEY are ranked for each IPHC Regulatory Area. This results in 33 rows. The short-term time-period is the default with medium- and long-term options available. The TCEY metrics can be rounded to the nearest one million pound or the nearest 0.1 million pounds. The percentages can be rounded to the nearest integer, one decimal, or two decimals.

The three tables for the fishery objectives have a total of 52 rows due to performance metrics for each IPHC Regulatory Area, which can still be overwhelming to evaluate. Therefore, a summary table is provided that averages over the ranks for IPHC Regulatory Areas within each performance metric, with equal weighting by default, resulting in ten rows (Figure 7). Weights for each IPHC Regulatory Area can be entered for comparison purposes, but equal weighting is recommended because there is currently no reason to give more weight to objectives in any particular areas. The resulting averages are color coded with light colors indicating better performance and dark blues indicating worse performance.

The ranks are further summarized to the three primary general fishery objectives by averaging over the measurable objectives within each general objective (Figure 8). This results in three rows with an average rank for general objectives 2.1, 2.2, and 2.3, allowing the user to examine the overall ranking of a management procedure relative to the target spawning biomass, catch variability, and fishing yield. The table is color coded with shades of blue as with other tables. Different weights can be assigned to the measurable objectives within 2.2 and 2.3 if desired, but the current objectives definition doesn't prioritize any fishery objective over the others.

The ranking tables are presented as one method to quickly examine many MPs and how they perform relative to each other given the currently defined objectives. The evaluation may be different depending on the rounding choices and the MPs selected. The page defaults to the methods and MPs used at MSAB016 and presented in IPHC-2020-MSAB016-R.

MPs

The MPs page provides a description of each specification of a management procedure. Elements of the MP are described for coastwide components, regional components, and

components specific to IPHC Regulatory Area. A priority is provided to indicate the priority assigned at MSAB015 in IPHC-2020-MSAB015-R for initial analysis, but is less pertinent now that results are complete. The MPs with a label beginning with MP16 were created by IPHC secretariat staff based on elements of interest identified at MSAB015. They are meant to supplement the evaluation and examine additional elements such as a slow-up fast-down constraint on the coastwide TCEY.

Help

The Help page provides a brief overview of how to use MSE Explorer, various definitions, and a description of the performance metrics. Performance metrics related to the primary objectives are described in Appendix I.

Summary table by Measurable Objectives

Weight for average

2A	2B	2C	3A	3B	4A	4CDE	4B
1	1	1	1	1	1	1	1

Ranking average

Search:

Objectives	PMs	Sim 30:20 43 MPA	Sim 30:20 43 MPB	Sim 30:20 43 MPC	Sim 30:20 43 MPD	Sim 30:20 43 MPE	Sim 30:20 43 MPF	Sim 30:20 43 MPG	Sim 30:20 43 MPH	Sim 30:20 43 MPI	Sim 30:20 43 MPJ	Sim 30:20 43 MPK
Maintain the coastwide female SB above a target at least 50% of the time	$P(SB < SB_{Targ})$	11	4	4	1	4	4	4	2	2	4	4
Limit AC in coastwide TCEY	$P(AC_3 > 15\%)$	11	1	1	10	1	1	1	1	1	1	1
Limit AC in coastwide TCEY	Median AAV TCEY	11	3	2	1	3	8	8	3	3	8	3
Limit AAV in Reg Areas TCEY	Median AAV TCEY RegAreas	9.75	7.25	6.75	1.75	7	5.62	6	5.88	5.75	2.5	3.5
Limit AC in Reg Areas TCEY	$P(AC_3 > 15\%)$ RegAreas	8.62	7	7.12	1.75	7.38	6.38	6	5.12	6.25	3.5	4
Optimize average coastwide TCEY	Median TCEY	1	3	3	1	3	3	3	3	3	3	3
Maintain minimum % TCEY by Reg Areas	Median Min(% TCEY) RegAreas	8.5	6.62	7.5	6.12	5.25	7.62	4.88	5.38	4.25	3.62	4.12
Maintain minimum TCEY by Reg Areas	Median Min(TCEY) RegAreas	6.38	4	3.75	1.75	2.62	4.5	3.25	3	2.88	2.5	3.12
Optimize Reg Areas TCEY	Median TCEY RegAreas	3.62	4.75	4.25	3.12	3.75	5.5	3.5	4.5	3.12	3.5	3.88
Optimize TCEY percentage among Reg Areas	Median % TCEY RegAreas	8.25	6.75	7.62	6.5	5	7.5	4.38	4.88	4	4.25	4.5

Showing 1 to 10 of 10 entries   Previous | 1 | Next

Figure 7: A screenshot of the summary table of ranks by measurable objectives. Columns are MPs and rows are coastwide measurable objectives or measurable objectives averaged over IPHC Regulatory Areas. The averaging is weighted by the assigned values at the top of this section, and equal weighting is the default and recommended. Lighter colors indicate higher ranks (i.e. better performance) and darker blues indicate lower ranks (i.e. worse performance).

Summary table by Primary Objectives

Weight for average

P(AC$_3$> 15%)	Median AAV TCEY	P(AC$_3$> 15%) RegAreas	Median TCEY	Median AAV TCEY RegAreas	Median TCEY RegAreas
1	1	1	1	1	1

Median % TCEY RegAreas	Median Min(TCEY) RegAreas	Median Min(% TCEY) RegAreas
1	1	1

Ranking average

Search: [   ]

Objectives	PMs	Sim 30:20 43 MPA	Sim 30:20 43 MPB	Sim 30:20 43 MPC	Sim 30:20 43 MPD	Sim 30:20 43 MPE	Sim 30:20 43 MPF	Sim 30:20 43 MPG	Sim 30:20 43 MPH	Sim 30:20 43 MPI	Sim 30:20 43 MPJ	Sim 30:20 43 MPK
Maintain the coastwide female SB above a target at least 50% of the time	P(SB < SB$_{Targ}$)	11	4	4	1	4	4	4	2	2	4	4
Limit catch variability	Limit annual change	10.09	4.56	4.22	3.62	4.59	5.25	5.25	3.75	4	3.75	2.88
Provide directed fishing yield	Optimize TCEY and maintain minimum TCEY in reg areas	5.55	5.02	5.22	3.7	3.92	5.62	3.8	4.15	3.45	3.37	3.72

Showing 1 to 3 of 3 entries   Previous [1] Next

Figure 8: A screenshot of the summary table of ranks by general objectives. Columns are MPs and rows are general objectives averaged over measurable objectives within a general objective. The averaging is weighted by the assigned values at the top of this section, and equal weighting is the default and recommended. Lighter colors indicate higher ranks (i.e. better performance) and darker blues indicate lower ranks (i.e. worse performance).

DISCUSSION

The MSE Explorer is a tool to assist in the evaluation of MPs, and other methods may be employed to further understand the simulation results. Performance metrics linked to the primary objectives are available along with many other performance metrics that may be useful. Additional metrics are being considered and may be added to the MSE Explorer in the future.

The MSE Explorer has evolved over time with different simulations, different performance metrics, and different pages. Archives of past MSE Explorers linked to MSAB meetings are available if desired. The following webpages refer to archives of the results used when writing reports for past MSAB meetings.

Coastwide MSE

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSAB012/

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSAB013/

Multi-Region MSE

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/IPHC-MSE-MSAB016/

The most recent version of MSE Explorer will also be at the following URL.

http://shiny.westus.cloudapp.azure.com/shiny/sample-apps/MSE-Explorer/

REFERENCES

IPHC-2020-IM096-11 Rev_1. Hicks A, Carpi P, Berukoff S, Stewart I. Management Strategy Evaluation results for distribution management procedures. 50 p. https://iphc.int/uploads/pdf/im/im096/iphc-2020-im096-11.pdf

IPHC-2020-MSAB015-R. Report of the 15th Session of the IPHC Management Strategy Advisory Board (MSAB015). 23 p. https://www.iphc.int/uploads/pdf/msab/msab015/iphc-2020-msab015-r.pdf

IPHC-2020-MSAB016-R. Report of the 16th Session of the IPHC Management Strategy Advisory Board (MSAB016). 25 p. https://iphc.int/uploads/pdf/msab/msab016/iphc-2020-msab016-r.pdf

APPENDICES

Appendix I: Performance metrics linked to primary objectives for the MSE

Appendix II: Description of management procedures proposed at MSAB015

APPENDIX I
PERFORMANCE METRICS LINKED TO PRIMARY OBJECTIVES FOR THE MSE

Below are descriptions of the performance metrics linked to the primary objectives. Additional performance metrics are available in the MSE Explorer with definitions provided on the Help page.

Metric	Description
BIOLOGICAL SUSTAINABILITY	
Median average RSB	The median dynamic relative spawning biomass (stock status), averaged over a ten-year period, that occurs over all simulations.
Median average percent SB	The median percentage of spawning biomass (averaged over a ten-year period) in each Biological Region. Available only when one or more Biological Regions are selected.
P(any RSB < 20%)	Probability that the dynamic relative spawning biomass (stock status) is less than 20% of the biomass if no fishing had occurred. 'Any' refers to the probability of this event occurring in a ten-year period (at least 1 of 10 years).
P(all RSB < 36%)	Probability that the dynamic relative spawning biomass (stock status) is less than 36% of the biomass if no fishing had occurred. 'All' refers to the chance that this event occurs in a given year.
P(all percSB<min)	Probability that the percent spawning biomass is less than a defined minimum for each Biological Region. Available only when one or more Biological Regions are selected. The defined minimums are 5%, 33%, 10%, and 2% for Biological Regions 2, 3, 4, and 4B, respectively.

Metric	Description
FISHERY SUSTAINABILITY	
Median Annual Change TCEY	Median annual change in TCEY (averaged over a ten-year period) that occurs over all simulations. The annual change in TCEY from year to year is greater than this value in half of the simulations. This metric is reported at a coastwide level and at an IPHC Regulatory Area level.
P(any3 change TCEY>15%)	Probability for any three years in a 10 year period that the change in TCEY limit is greater than 15%. This is one of the primary performance metrics for the stability objective. This metric is reported at a coastwide level and at a IPHC Regulatory Areas level. Also noted as $P(AC_3>15\%)$.
Median average TCEY	Median TCEY mortality limit (averaged over a ten-year period) that occurs over all simulations. The TCEY is greater than this value in half of the simulations. This metric is reported at a coastwide level and at the IPHC Regulatory Area level.
Median AAV TCEY	The Median Average Annual Variability (AAV) over a ten-year period for the TCEY, which can be thought of as the average change in the TCEY from year to year. The AAV is greater than this value in half of the simulations.
Median Minimum TCEY	Median minimum value of TCEY in each IPHC Regulatory Area over a ten-year period. Refers to the primary objective of maintain a minimum TCEY for each IPHC Regulatory Area. This metric is reported at the IPHC Regulatory Areas level.
Median Minimum TCEY percentage	Median minimum percentage of TCEY in each IPHC Regulatory Area over a ten-year period. Refers to the primary objective of maintain a percentage of the coastwide TCEY for each IPHC Regulatory Area. This metric is reported at the IPHC Regulatory Area level.
Median Average TCEY percentage	Median percentage of TCEY in each IPHC Regulatory Area (averaged over a ten-year period). Refers to the primary objective of optimize the percentage of the coastwide TCEY among Regulatory Areas. This metric is reported at the IPHC Regulatory Areas level.
PERCENTILES	
5th	the 5th percentile over a ten-year period. Five percent of the simulated metrics are lower than this metric.
25th	the 25th percentile over a ten-year period. Twenty-five percent of the simulated metrics are lower than this metric.
75th	the 75th percentile over a ten-year period. Twenty-five percent of the simulated metrics are greater than this metric.
95th	the 95th percentile over a ten-year period. Five percent of the simulated metrics are greater than this metric.

APPENDIX II
DESCRIPTION OF MANAGEMENT PROCEDURES PROPOSED AT MSAB015

The proposed management procedures from the 15th Session of the Management Strategy Advisory Board (MSAB015) are described here. Each management procedure has a coastwide component and a distribution component. The distribution component can distribute directly to IPHC Regulatory Areas or distribute to Biological Regions first.

For all the MPs considered, the coastwide component sees the application of a coastwide SPR and of a 30:20 control rule. The 30:20 harvest control rule adjusts the reference SPR if the estimated stock status falls below the 30% trigger value. Specifically, the fishing intensity is reduced linearly if the stock status falls below 30% of unfished spawning stock biomass to a value of zero at and below an estimated status of 20% of unfished spawning stock biomass.

MP15-A: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0. Further adjustments are applied to the distributed TCEY, to assign a fixed 1.65 million pounds for IPHC Regulatory Area 2A (when possible) and a percentage allocation for IPHC Regulatory Area 2B calculated from a 30% weight on the current interim management procedure's target TCEY distribution (i.e., O32 stock distribution and relative harvest rates) and 70% weight to 20%.

MP15-B: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0. Further adjustments are applied to the distributed TCEY, to assign a fixed 1.65 million pounds for IPHC Regulatory Area 2A (when possible) and a percentage allocation for IPHC Regulatory Area 2B calculated from a 30% weight on the current interim management procedure's target TCEY distribution (i.e., O32 stock distribution and relative harvest rates) and 70% weight to 20%.

MP15-C: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to Biological Regions using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to Biological Regions such that the relative harvest rate in Biological Regions 4 and 4B is 0.75 and the relative harvest rate in Biological Regions 2 and 3 is 1.0. The regional TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. Further adjustments are applied to the distributed TCEY, to assign a fixed 1.65 million pounds for IPHC Regulatory Area 2A (when possible) and a percentage allocation for IPHC Regulatory Area 2B calculated from a 30% weight on the current interim management procedure's target TCEY distribution (i.e., O32 stock distribution and relative harvest rates) and 70% weight to 20%.

MP15-D this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0. Further adjustments are applied to the distributed TCEY, to assign a fixed 1.65 million pounds for IPHC Regulatory Area 2A (when possible) and a percentage allocation for IPHC Regulatory Area 2B calculated from a 30% weight on the current interim management procedure's target TCEY distribution (i.e., O32 stock distribution and relative harvest rates) and 70% weight to 20%. These 2A and 2B adjustments are made by adding to the total coastwide TCEY, rather than reallocating among IPHC Regulatory Areas (as in other MPs). Once this last step is complete, the sum of the distributed TCEY is compared with the TCEY corresponding to a SPR value of 36% (maximum fishing intensity). If the sum of the distributed TCEY is higher than the TCEY corresponding to the maximum fishing intensity, IPHC Regulatory Areas 2A and 2B are adjusted so that the sum of the distributed TCEY is equal to the TCEY corresponding to the maximum fishing intensity. If the sum of the distributed TCEY is lower than the TCEY corresponding to the maximum fishing intensity, no further adjustments are made.

MP15-E: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0. Further adjustments are applied to the distributed TCEY, to assign a fixed 1.65 million pounds for IPHC Regulatory Area 2A (when possible).

MP15-F: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. A National Share of 20% is then applied to IPHC Regulatory Area 2B and the remaining 80% is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0.

MP15-G: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0.

MP15-H: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in IPHC Regulatory Area 4B is 0.75 and the relative harvest rate in all other IPHC Regulatory Areas is 1.0.

MP15-I: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the 'all-sizes' stock distribution, which is determined from the biomass of all sizes of Pacific halibut caught in the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0.

MP15-J: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using a 5-year moving average of the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS. A proportional relative harvest rate is applied to IPHC Regulatory Areas such that the relative harvest rate in the western areas (i.e. 3B, 4A, 4CDE, and 4B) is 0.75 and the relative harvest rate in eastern areas (i.e. 2A, 2B, 2C, 3A) is 1.0.

MP15-K: this MP applies a coastwide SPR and the 30:20 harvest control rule to obtain a coastwide TCEY. A 15% constraint is then applied to not allow the coastwide TCEY to increase or decrease by more than 15% from the previous year's limit. The coastwide TCEY is then distributed to IPHC Regulatory Areas using the previous 5-year average of the O32 stock distribution (i.e. biomass of fish over 32 inches) from the FISS, calculated only every 5th year.

Table A.II.1: Identification of main elements incorporated in each of the management procedures (MP) proposed at MSAB015. Colors indicate groups of elements of similar concepts: in blue are coastwide fishing intensity options, in yellow are estimation methods for stock distribution from survey data, in red are relative harvest rates between IPHC Regulatory Areas, and in green are agreements for IPHC Regulatory Areas 2A and 2B.

Element	MP-A	MP-B	MP-C	MP-D	MP-E	MP-F	MP-G	MP-H	MP-I	MP-J	MP-K
TCEY constraint of 15%		■	■	■	■	■	■	■	■	■	■
Max Fishing Intensity buffer 36%				■							
O32 stock distribution	■	■	■	■	■	■	■	■			
O32 stock distribution (5-year moving average)										■	
All sizes stock distribution									■		
Fixed shares updated in 5th year from O32 stock distribution											■
Relative harvest rates of 1.0 for 2-3A, and 0.75 for 3B-4	■	■		■	■	■	■		■	■	
Relative harvest rates of 1.0 for 2-3, 4A, 4CDE, and 0.75 for 4B								■			
Relative harvest rates by Region: R2=1, R3=1, R4=0.75, R4B=0.75			■								
1.65 Mlbs fixed TCEY in 2A	■	■	■	■	■						
Formula percentage for 2B	■	■	■	■							
National Shares (2B=20%)							■				

APPENDIX III
LIST OF ACRONYMS USED IN THE IPHC MANAGEMENT STRATEGY EVALUATION

AAV	Average Annual Variation
AC	Annual Change
ADFG	Alaska Department of Fish and Game
CSP	Catch Sharing Plan
CR	Control Rule
DFO	Fisheries and Ocean Canada
$F_{xx\%}$	Fishing Intensity
FISS	Fishery-Independent Setline Survey
IPHC	International Pacific Halibut Commission
MP	Management Procedure
MSAB	Management Strategy Advisory Board
MSE	Management Strategy Evaluation
NMFS	National Marine Fisheries Service, NOAA
NPFMC	North Pacific Fishery Management Council
O26	Over 26 inches (66.0 cm)
O32	Over 32 inches (81.3 cm)
PMFC	Pacific Fishery Management Council
RSB	Relative Spawning Biomass
SB	Spawning Biomass
SRB	Scientific Review Board
SPR	Spawning Potential Ratio
SS	Stock Synthesis
TCEY	Total Constant Exploitation Yield
TM	Total Mortality

A set of working definitions are provided in the IPHC Glossary of Terms and abbreviations: https://www.iphc.int/the-commission/glossary-of-terms-and-abbreviations. Definitions and abbreviations are also provided on the help page of the MSE Explorer.

APPENDIX IV
DESCRIPTION OF PERFORMANCE METRICS USED IN THE IPHC MSE

Table A.IV.1: Table of performance metrics with descriptions and equations. Note that subscripts are as follows: *R* represents region, *A* represents IPHC Regulatory Area, *y* represents year, *yrs* represents all 10 years in the time period, *i* represents simulation, and *C* represents any type of fishery mortality limit (e.g., TCEY, directed commercial, recreational, etc.). A capital 'I' indicates an 'indicator' function which is given a value of 1 if the statement is true, or 0 if the statement is false.

Metric	Description	Equation
nSims	The number of simulated 60-year periods. More simulations result in better accuracy of the performance metrics and statistics of interest.	
Median realized SPR	The realized SPR over the time-period selected after application of the control rule and realized fishing mortality. The SPR will always be greater than or equal to the procedural (input) SPR. It is greater than this value in half of the simulations.	$\text{Median}_i(\overline{SPR})$
BIOLOGICAL SUSTAINABILITY		
Median average RSB	The median relative spawning biomass (averaged over a ten-year period) that occurs over all simulations.	$\text{Median}_i(\overline{RSB})$
Median # females	The median number of females expected for the defined period (short-, medium-, or long-term).	$\text{Median}_i(\overline{N_F})$
Median average percent SB	The median percentage of Spawning Biomass (averaged over a ten-year period) in each Biological Region.	$\text{Median}_i\left(\overline{SB_R/SB}\right)$
P(all RSB < *XX*%)	Probability that the relative spawning biomass (stock status) is less than 20% of the biomass if no fishing had occurred. 'All' refers to the chance that this event occurs in a given year across all simulations. Values available for comparison (XX) are 20%, 25%, 30%, 36%, and 40%.	$\dfrac{\sum_{i=1}^{nSims}\sum_y \text{I}\left(RSB_{i,y} < XX\%\right)}{nSims \times nYrs}$
P(any RSB < *XX*%)	Probability that the relative spawning biomass (stock status) is less than 20% of the biomass if no fishing had occurred. 'Any' refers to the probability of this event occurring in a ten-year period (at least 1 of 10 years).	$\dfrac{\sum_{i=1}^{nSims} \text{I}(\text{any } RSB_{i,yrs} < XX\%)}{nSims}$
P(increase SB|RSB 20-30%)	Probability that the spawning biomass increases when relative spawning biomass is between 20% and 30% of its dynamic unfished equilibrium value.	$\dfrac{\sum_{i=1}^{nSims}\sum_y \text{I}\left(SB_{i,y+1} > S\|20\% < RSB_{i,y} < 30\%\right)}{nSims \times nYrs\|20\% < RSB_{i,y} < 30\%}$

FISHERY SUSTAINABILITY

P(all AAV > *XX*%)	Probability that the average annual variability (AAV) of the TCEY over a ten-year period is greater than 15%. AAV can be thought of as the average change in the Total Mortality limit from year to year. Thresholds available (*XX*) are 15%, 20%, and 25%.	$$\frac{\sum_{i=1}^{nSims}\left[\left(\sum_y |TCEY_{i,y} - TCEY_{i,y-1}|\Big/\sum_y |TCEY_{i,y}|\right) > XX\%\right]}{nSims}$$
Median Annual Change (AC) TCEY/Commercial /Recreational	The median absolute annual change in TCEY, directed commercial, or recreational mortality limit (averaged over a ten-year period) that occurs over all simulations. This metric is reported at a coastwide level and at an IPHC Regulatory Area level.	$$\text{Median}_{i,y}\left(\frac{|C_y - C_{y-1}|}{C_{y-1}}\right)$$
P(any *Y* change TCEY>15%)	The probability for any *Y* years in a ten-year period that the change in the TCEY limit is greater than 15%. This metric is reported at a coastwide level and at a IPHC Regulatory Area level. The number of years in the calculation ranges from 1 to 5. Note that $AC_{i,y} = \frac{C_y - C_{y-1}}{C_{y-1}}$.	$$\frac{\sum_{i=1}^{nSims} \text{I}\big(|AC|_{i,yrs} > 15\% \text{ for } Y \text{ or more years}\big)}{nSims}$$
P(all TM < 34 Mlbs)	The probability that the Total Mortality limit (TM) would be set below a minimum value. The minimum TM has not been determined, and is currently an ad hoc value of 34 Mlbs, which is the minimum TM observed since 1906.	$$\frac{\sum_{i=1}^{nSims}\sum_y \text{I}\big(TM_{i,y} < 34 \text{ Mlbs}\big)}{nSims \times nYrs}$$
P(any TM < 34 Mlbs)	The probability that the Total Mortality limit (TM) would be set below a minimum value for at least one year of a ten-year period. The minimum TM has not been determined, and is currently an ad hoc value of 34 Mlbs, which is the minimum TM observed since 1906.	$$\frac{\sum_{i=1}^{nSims} \text{I}(\text{any } TM_{i,yrs} < 34 \text{ Mlbs})}{nSims}$$
Median average TCEY/Commercial /Recreational/ Discards	The median TCEY, directed commercial, or recreational mortality limit, or simulated discards (averaged over a ten-year period) that occurs over all simulations. This metric is reported at a coastwide level and at a IPHC Regulatory Area level.	$$\text{Median}_i(\bar{C})$$
P(all Comm=0)	The probability that the directed commercial fishery mortality limit would be zero. This can occur if there is not enough TCEY for the directed commercial fishery after allocation to other fisheries, or if the fishery limit in the control rule closes the directed fisheries.	$$\frac{\sum_{i=1}^{nSims}\sum_y \text{I}\big(Comm_{i,y} = 0\big)}{nSims \times nYrs}$$
P(any Comm=0)	The probability that the Commercial fishery limit would be zero in at least one year in a ten-year period. This can occur if there is not enough TCEY for the commercial fishery after allocation to other fisheries, or if the fishery limit in the control rule closes the directed fishery.	$$\frac{\sum_{i=1}^{nSims} \text{I}(\text{any } Comm_{i,yrs} = 0)}{nSims}$$
P(all decrease TCEY > 15%)	The probability that the TCEY decreases by more than 15% from one year to the next. Note that $AC_{i,y} = \frac{C_y - C_{y-1}}{C_{y-1}}$.	$$\frac{\sum_{i=1}^{nSims}\sum_y \text{I}\big(AC_{i,y} < -15\%\big)}{nSims \times nYrs}$$

P(any decrease TCEY > 15%)	The probability in at least one out of ten years the TCEY decreases by more than 15%. Note that $AC_{i,y} = \frac{C_y - C_{y-1}}{C_{y-1}}$.	$\frac{\sum_{i=1}^{nSims} \mathrm{I}(\text{any } AC_{i,y} < -15\%)}{nSims}$
P(all increase TCEY > 15%)	The probability in a given year that the TCEY increases by more than 15%. Note that $AC_{i,y} = \frac{C_y - C_{y-1}}{C_{y-1}}$.	$\frac{\sum_{i=1}^{nSims} \sum_y \mathrm{I}(AC_{i,y} > 15\%)}{nSims \times nYrs}$
P(any increase TCEY > 15%)	The probability in at one out of ten years the TCEY increases by more than 15%. Note that $AC_{i,y} = \frac{C_y - C_{y-1}}{C_{y-1}}$.	$\frac{\sum_{i=1}^{nSims} \mathrm{I}(\text{any } AC_{i,y} > 15\%)}{nSims}$
Median AAV TCEY/Commercial /Recreational	The Median Average Annual Variability (AAV) over a ten-year period for the TCEY, which can be thought of as the average change in the TCEY from year to year. The AAV is greater than this value in half of the simulations.	$\mathrm{Median}_i \left(\frac{\sum_y |TCEY_{i,y} - TCEY_{i,y-1}|}{\sum_y |TCEY_{i,y}|} \right)$
Median Minimum TCEY	The median minimum value of TCEY in each IPHC Regulatory Area over a ten-year period. Refers to the primary objective of maintain the TCEY above a minimum absolute level in each IPHC Regulatory Area. This metric is reported at the IPHC Regulatory Area level.	$\mathrm{Median}_i [\mathrm{Min}_y (TCEY_{A,i,y})]$
Median Minimum TCEY percentage	The median minimum percentage of TCEY in each IPHC Regulatory Area over a ten-year period. Refers to the primary objective of maintain the TCEY above a minimum absolute level in each IPHC Regulatory Area. This metric is reported at the IPHC Regulatory Area level.	$\mathrm{Median}_i \left[\mathrm{Min}_y \left(\frac{TCEY_{A,i,y}}{TCEY_{i,y}} \right) \right]$
Median Average TCEY percentage	The median percentage of TCEY in each IPHC Regulatory Area (averaged over a ten-year period). Refers to the primary objective of maximize the average TCEY in each IPHC Regulatory Area. This metric is reported at the IPHC Regulatory Area level.	$\mathrm{Median}_i \left(\frac{\overline{TCEY_{A,i,y}}}{TCEY_{i,y}} \right)$
QUANTILES		
Qth%	The Qth percentile over a ten-year period. Q percent of the simulated values are lower than this metric. Values presented include 5th, 25th, 75th, and 95th%. Note that the median is the 50th percentile.	