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PEER REVIEW REPORT ON THE FUNCTION OF THE ISC STOCK ASSESSMENT REVIEW PROCESS

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International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

Peer Review Report on the Function of the ISC Stock Assessment Review Process

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Executive Summary

An international Peer Review Team (PRT) with no Committee affiliation conducted a rigorous comprehensive evaluation of the function of the ISC Stock Assessment Review Process. The review centered on mechanisms to determine the quality of ISC stock assessments that enable sound management decision-making based on best available scientific information. PRT deliberations considered appropriateness for particular species, fisheries, and available data. This was tempered by what was "seen and heard" at working group (WG) meetings at several locations and ISC scientists and membership. Nine terms of reference were considered by the PRT.

Twenty-three (23) species of tuna and tuna-like species (5 tunas, 7 billfishes, and 11 sharks) in the North Pacific Ocean have been identified by ISC for which stock assessments may ultimately be completed. To date, seven principal fisheries resources have actually been assessed by ISC. The ISC stock assessment process temporal sequence for a given species currently consists of two primary assessment functions: (1) a "Benchmark" conducted every four (4) years; and, (2) an "Update" that follows two years after the benchmark stock assessment. Benchmark stock assessments use two relatively concurrent working group (WG) meetings; here defined as DATA preparatory and MODEL workshops. DATA WG workshops are largely centered on understanding the population dynamics and ecology of the highly migratory species (HMS) and associated prey-species populations to accurately estimate, model and assess stock productivity and status relative to fishery exploitation rates and population reproductive conditions. A transition to the MODEL WG occurs near the end of the DATA workshop when candidate stock assessment models, given the data, are considered. These deliberations are tempered by the appropriateness of the "best available scientific information (BASI)". The MODEL WG conducts the formal stock benchmark stock assessment modeling and analysis efforts driven BASI assimilation inputs provided by the Species DATA WG Member scientists. Final choice of the appropriate stock assessment model is typically based on information provided by he DATA WG. To assist in the quality of regional resource manager decision making, stock projections and harvest policy analyses are usually conducted by the MODEL WG. The PRT believes that to be successful in this endeavor requires that the WGs have a solid handle on what projections are desired. Thus, we recommend that ISC should develop a standard set of projections as guidance for future WG efforts. WG findings, decision criteria, and conclusions normally will be be reached by consensus. However, there are likely to be situations where reasonable efforts are made, but ultimately the WG still fails to yield consensus. In these cases, findings may reflect varying opinions and the differing views and the WGs would be left with providing suggestions for

conflict resolution, or offer suggestions for a research plan that at some point could resolve or clarify the different views proposed. This dilemma might be ameliorated by the presence and dynamic interaction of an informed and involved external reviewer who had no stakes in the debate, but could provide much needed alternative views and advice. Overall, this emphasizes that the ISC stock assessment process should not be stagnant, but rather a dynamic entity as new (or controversial) information comes forward. Ultimately, the best and appropriate advice should arise from strategic synthesis of the two (DATA and MODEL) WG operations, as these form the fundamental basis of ISC scientific stock assessment function to member nations and regional fisheries management organizations (RFMOs).

The PRT noted that most of the appropriate actions and activities seemed to be taking place in the execution of both the species DATA and MODEL working groups. However, at these workshops, many important and high impact decisions that could ultimately strongly influence the types and depth of final analyses and decisions to be are made by ISC are rushed together in a relatively narrow time window. Some of these typical relevant issues and decisions involve: (1) parameters and indices selection; (2) reference points and status of overfishing; and, (3) unresolved issues with assessment model(s), etc. The workshop timelines are frankly too short to legitimately consider, analyze, synthesize and write in a logical fashion the WG findings that can be coherently communicated to decision-makers in the ISC Plenary. Addition of actively engaged independent reviewers with specialized mathematical and statistical stock assessment skills, dedicated to understanding, questioning and advising the process, could directly and substantially improve the quality of the stock assessment. Independent external reviewers actively engrossed in the discussions and analyses at workshops could be at liberty to ask specific questions, scrutinize assumptions and results recommend additional needed runs, or to clarify analyses. This would likely involve generation of external peer-review report(s) for each of the WG workshops.

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1.0   ISC Function and Background to this Peer Review

The International Scientific Committee (ISC), established in 1995 through an intergovernmental agreement, has the following goals and purpose: (1) strengthen the scientific framework for conservation, sustainability and rational utilization of highly-migratory tuna and tuna-like species in the North Pacific Ocean; (2) enhance scientific research cooperation on all life stages of tuna and tuna-like species in the region; and, (3) provide strategic scientific advice and leadership on ISC fisheries to Member governments and regional fisheries management organizations (c.f., ISC Operations Manual 2016). The "Committee" is comprised of Members (coastal states and fishing entities) and non-voting Members (relevant intergovernmental fishery and marine science organizations). The Committee regularly analyzes and models fishery data and other relevant information on species of concern, then prepares assessment reports on findings concerning species sustainability status from population abundance trends, developments in fisheries, and other relevant conservation needs. The Committee strives to adopt these reports by consensus, and then formulates proposals for international and national research programs addressing issues for the species of concern. In these deliberations, ISC uses the best available science taking into account the findings of other relevant technical and scientific organizations. ISC mandate requires that the Committee shall every five years organize a team of recognized peers with no Committee affiliation to review the function of the Committee's subsidiary bodies and offer recommendations for improvement. An international Peer Review Team (PRT) of experts with no Committee affiliation, Drs. Jerald Ault (USA, Chair) and Hiroyuki Matsuda (Japan), was formed to undertake a comprehensive review of the function of the ISC Stock Assessment Review Process that is appropriate for the particular species, fisheries, and available data.

1.1   Terms of Reference

The Terms of Reference (TOR) provided to the PRT contained nine question areas for careful consideration. In our deliberations, the review process was tempered by what we "saw and heard" at various working group (WG) meetings and this report attempts to summarize our impressions from the WG meetings. The following Section 2.0 provides a rigorous, transparent and independent evaluation of each TOR. Then in Section 3.0 we provide some recommendations for a path forward as a result of the nine TORs that were specified by ISC focused on improvement of the ISC stock assessment process.

1.2   PRT Travel & Background Discussion Required to Produce this Report

In the course of developing this report, the PRT conducted several sets of interactions at various locations with the ISC scientists and membership:

(1) March 5-12, 2018. Dr. Ault attended the ISC Pacific Bluefin Tuna Working Group (PBF WG) Workshop held at the Southwest Fisheries Science Center (SWFSC) in La Jolla, CA. The PRT member was careful not to participate or interfere in any way the Working Group's activities, but listened and gathered essential information for construction of this report.

(2) April 17-24, 2018. Dr. Matsuda attended the ISC intercessional workshop of the Billfish Working Group held at the National Research Institute of Far Seas Fisheries in Shimizu, Japan. The PRT member was careful not to participate or interfere in any way the WG's activities, but listened and gathered essential information.

(3) May 28-31, 2018. Drs. Ault, Matsuda, Hiroaki Okamoto and Gerard DiNardo organized and participated in several days of meetings, including the Pacific Bluefin tuna management strategy evaluation (PBF MSE) workshop held in Yokohama, Japan. They discussed essential elements of the peer review and began drafting the PRT's interim consensus report for presentation at the ISC Plenary.

(4) July 9-14, 2018. Dr. Matsuda attended the 18th meeting of the ISC Plenary (ISC18) in Yeosu, Korea, and presented and discussed the draft consensus report with the Plenary.

(5) October 15-18, 2018. Dr. Ault met with project sponsors in an end of project summary working meeting at the SWFSC in La Jolla, California.

2.0   Terms of Reference for Peer Review Team Evaluation

The Peer Review Team's (PRT) comprehensive, rigorous, and transparent review of the function of ISC stock assessment process centered on mechanisms to determine the quality of quantitative stock assessments, and methods to ensure that management decision-making for ISC fisheries is based on best available scientific information (BASI). The PRT focused their considerations on the following nine terms of reference (TOR):

2.1   Species/stocks/fisheries on which ISC conducts stock assessments. [TOR 1]

Twenty-three (23) species of tuna and tuna-like species (5 tunas, 7 billfishes, 11 sharks) in the North Pacific Ocean have been identified by ISC for which stock

assessments may ultimately be completed. To date, seven principal fisheries resources have actually been assessed by ISC (**Table 1**).

The ISC stock assessment process sequence for a given species currently consists of two primary functions: (1) a "Benchmark" assessment, conducted every four (4) years; and, (2) an "Update" assessment that follows two years after the benchmark stock assessment. The frequency and intensity of stock assessment activities (i.e., benchmark and update assessments) are determined by the species Working Groups and provided for consideration to the Committee for evaluation and recommendation of action(s).

Table 1.- Names and species acronyms of common highly migratory species of the North Pacific Ocean that currently undergo formal stock assessments by ISC.

Species Code	Common English name	Scientific name
PBF	Pacific bluefin tuna	*Thunnus orientalis*
ALB	North Pacific albacore tuna	*Thunnus alalunga*
BKS	Blue shark	*Prionace glauca*
SFM	Short-fin mako shark	*Isurus oxyrinchus*
SWD	North Pacific swordfish	*Xiphias gladius*
STM	Striped marlin	*Kajikia audax*
BUM	Blue marlin	*Makaira nigricans*

2.2   Selection of stock assessment and projection methods, including assessment and projection models, input parameters, model specifications, and inherent assumptions. HIGH Priority Topic [TOR 3]

The ISC stock assessment process has two overarching goals: (1) to provide scientific advice to resource managers on the current status and future trends in abundance and productivity of fishery resources of concern; and, (2) to establish the technical basis for fishery management measures (e.g., annual catch quotas) that will achieve optimum fishery yields while avoiding stock overfishing and ecosystem harm. To achieve these goals, every effort is made to ensure that species stock assessments are based on best available scientific information (BASI), and at a minimum, derived with the highest degree of integrity and independent peer-review possible. Benchmark stock assessments are conducted through use of two relatively concurrent working group (WG) meetings; broken into data preparatory (hereafter called "DATA") and MODEL

WGs. Each of these WG meetings, on average, consists of anywhere from 7 to 10 days of intense technical and scientific deliberations.

DATA Working Groups

The focus of species DATA Working Groups is largely to understand the population dynamics and ecology of the highly migratory species (HMS) and associated prey-species populations to accurately estimate, model and assess stock productivity and status relative to fishery exploitation rates and population reproductive conditions. The available data underlying these are carefully scrutinized by the DATA WG for accuracy, precision and reliability. The typical standard types of fishery and population-dynamic pieces of information that go into the stock assessments includes: (1) fishery catch, effort and fleet operational characteristics; (2) life history demography (age/growth probabilities, lifespan, maturity and fecundity); (3) unit stock population dynamic (spatial extent, environmental drivers); and, (4) fishery performance statistics (i.e., catch per unit effort (CPUE) and size-structured abundance).

Particularly needed from species DATA WG efforts are a reliable and statistically robust lifetime age-and-growth curve that has been derived from a relatively wide spatial extent, and that describes the full extent of age/growth probabilities. DATA WG outputs are assimilated via models and analyzed by ISC members in the species stock assessment and statistics working groups. The efforts of the Species DATA WG can often be greatly facilitated by the Statistical WG, whose function is to optimize the collection, exchange and archiving of fishery, biological and other data needed for ISC stock assessments, and for monitoring fishery developments, statistics and bycatch. Careful and thorough analyses and construction of the fundamental data components will ultimately contribute to giving the assessment modelers credence, and further, put management folks into the comfort zone. However, it is understood that sufficient information for understanding species' dynamics and appropriate for conducting a stock assessment may not accumulate on a regular, predictable schedule. Thus, species DATA WG findings may, at the WG's discretion, be relegated to interim progress reports until such time for sufficient data become available for a "current" stock assessment.

Near the end of the DATA preparatory meetings candidate stock assessment model(s) are discussed for appropriateness and potential reliability (see **Fig. 1**). These deliberations are strongly tempered by the appropriateness of the BASI. This particularly highlights the extreme importance of how BASI data have been assimilated and assembled. At this decision point some consideration must be given as to what

(multiple) model(s) will be run and why, with the specific purpose of comparing, calibrating and validating model outputs. Stock assessment models and projection methods need well established and clearly understood data criterion. The rationale and criteria for making mathematical or statistical assessment "model tweaks" must be clearly and unambiguously articulated at the DATA workshop. These choices and their rationale must be written in language that can be well-understood by management decision-makers. The participating scientists at the DATA WG meetings should be able to walk away from that meeting with a sense of what is appropriate and defensible. Competent external reviews must be part of this process to ensure the integrity and reliability of the very important group decisions.

MODEL Working Groups

The MODEL WG's task is to conduct the formal stock benchmark stock assessments by assimilation of the BSIA inputs provided by the Species DATA WG to be used in modeling and analysis efforts by ISC Member scientists. Final choice of the appropriate stock assessment model should typically be based on the inputs of the DATA WG. Model reliability and flexibility will be tempered by the quality, complexity and resolution of the BASI. Stock status metrics and determinations should made and compared relative to common "sustainability reference points". These sustainability reference points need to be well established, well understood and easily conveyable to decision-makers.

To assist in the quality of regional resource manager decision making, stock projections and harvest policy analyses are usually conducted by the MODEL WG. But to be successful in this endeavor requires that the WG has a solid handle on what projections are desired. It would be useful for ISC to develop a standard set of projections as guidance for future WG efforts. However, this choice depends largely on the fishery, and how the data appear to fit together, both practically and theoretically. This would again suggest that the highest order of external peer-review is required to facilitate this task. We noted that, for example, in last spring's PBF update, that 2016 PBF recruitment $\bar{R}$ average appeared anomalously high, despite the fact that every other previous year was below the 2016 R estimate. Ultimately, projection methods will have to be based on empirical data, but the strategy to employ these data is of paramount importance. This makes shrewd data and model choices critical to accurate and reliable stock assessments!

WG findings, decision criteria, and conclusions should be reached by consensus. However, there are likely to be situations where reasonable efforts are made and the

WG still fails to yield consensus. In these cases findings may reflect varying opinions and the differing views and the WGs would be left with providing suggestions for conflict resolution, or offer suggestions for a research plan that at some point could resolve or clarify the different views proposed. This dilemma might be ameliorated by the presence and dynamic interaction of an informed and involved external reviewer who had no stakes in the debate, but could provide much needed alternative views and advice. Overall, this emphasizes that the ISC stock assessment process should not be stagnant, but rather a dynamic entity as new (or controversial) information comes forward. Ultimately, the best and appropriate advice should arise from strategic synthesis of the two (DATA and MODEL) WG operations, as these form the fundamental basis of ISC scientific stock assessment function to member nations and regional fisheries management organizations (RFMOs).

2.3 Selection of research priorities to improve the stock assessment including data analysis and gathering, life history, and modeling. HIGH Priority Topic [TOR 4]

ISC diligently promotes research cooperation and collaboration among member countries by developing proposals for conduct and coordination on international and national scales of research for the species of concern and interest. Because data remains an essential and critical component of ISC stock assessments, reliable and robust stock assessments will continue to require objective prioritization of data needs and requirements based on its precision and reliability. New directed research needs to specifically address uncertainties discovered in fisheries information, life history demographics, stock spatial dynamics, and fishery performance. Research priorities, recommendations and updated work plans for the next assessment cycle will likely arise from the consultations and analyses of the DATA and MODEL Working Groups. We suggest that the forward-looking ISC ecosystem-based research science framework should specifically accommodate data and models on climate, ocean, space, fish and fisheries.

A focused ISC research portfolio to achieve an integrated assessment framework will embody a large-scale fishery systems science approach. This perspective will allow efficient integration of spatial, biological-physical, and socio- economic assessment program along with technical and statistical refinements in fishery- dependent and fishery-independent surveys of fish catches, effort, and their biophysical and climate-environment relationships. Linking these processes in an ecosystem-based fishery management (EBFM) framework will also require more focused study of ecosystem

dynamics**.** What is the value of new data to achieve this perspective? With a hypothetical investment of $3 to $5 million over 5 years, what additional types of new data could be available, and what would be their value to stock assessment capabilities?

PBF migrations between western and eastern Pacific Ocean. Juveniles move between Japan and Mexico within the first two years of life. They stay in the eastern Pacific Ocean (EPO) for one to three years, and then migrate back to the western Pacific to spawn some years later. Thus, in this case, would the addition of spatial structure via a targeted tagging program advance stock assessment capabilities for PBF? What type of new science is needed?

For example, a new more directed tagging program is required (electronic and conventional) to facilitate the inclusion of much needed spatial structure in evolving stock assessment modeling approaches. Mexico has proposed to contribute to an EPO tagging program, where the only additional costs are those associated with Charters only. However, initiation of such a program focused on advancing understanding of the resource, particularly for more accurate stock assessments requires consensus approval from ISC member countries.

2.4   Timing, duration and frequency of ISC working group meetings and their role in completing stock assessments. HIGH Priority Topic [TOR 5]

The species WGs primary focus is driven by the need to conduct quantitative assessments of ISC priority HMS stocks (i.e., **Table 1**) on a regular and predictable schedule. WGs are guided in their mission by multi-year work plans and by the demands of the Committee. Spatial boundaries for ISC stock assessments encompass the entire range of the unit stock, and are conducted using an evolving cadre of best available scientific information (BASI). This information base must demonstrate superior knowledge of the population and spatial dynamics of the concerned species and the stock responses to exploitation and environmental changes.

The general HMS species stock assessment cycle for ISC is shown (**Fig. 1**). The DATA and MODEL workshops are usually several months apart.
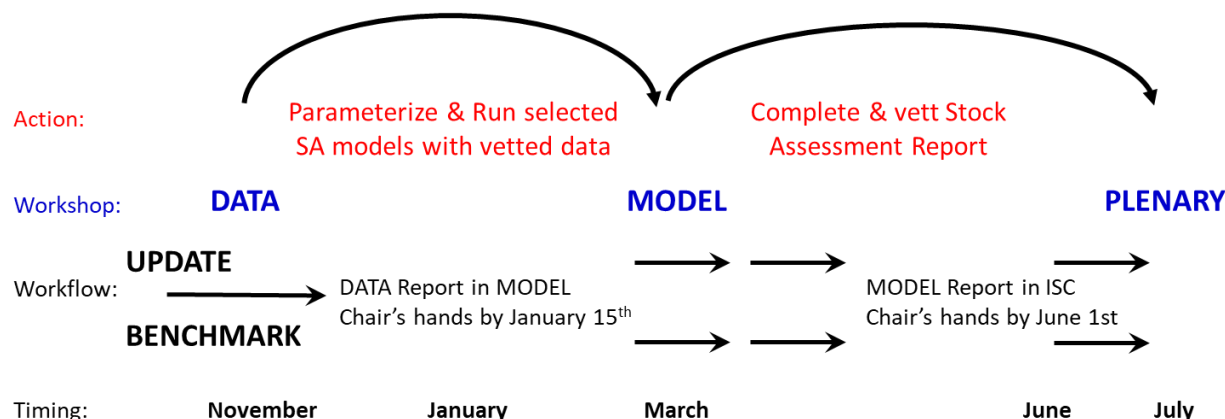
Figure 1. Envisaged ISC stock assessment preparation cycle with DATA and MODEL workshop assimilation, analyses, assessment and rigorous internal/external review process.

In the stock assessment process, a critical task for the members of the species DATA and MODEL WGs is the generation of working papers associated with each major area of the stock assessment. Of particular concern is the delivery timeline of the WG reports. Working papers for both major areas of the stock assessment (i.e., DATA and MODEL) must be completed and available to ISC scientists at least one month prior to the species workshops so that scientists have sufficient time to inspect and understand the analyses, and so that after the respective workshops they can walk away with clarity about what is appropriate and defensible. After a specific WG workshop (or major meeting) during either benchmark or update assessment cycle, the WG concentrates on providing a clean report to the ISC Chairman within one month after the Workshop. The Working Group and the ISC Chairman will work with an editor to revise each report to ensure that the writing is grammatically correct and understandable to outside audiences. With respect to the final stock assessment, what is required is a clean, well-written, and fully-vetted finalized reports authored by the MODEL Working Group prior to it being sent on to the Plenary in early June.

2.5   Availability of data to ISC members for stock assessment purposes. Medium Priority [TOR 2]

Data remains a critically-important enterprise for ISC. Ensuring the highest level of accuracy, precision and reliability of data is perhaps the most fundamental and crucial component of the ISC operation to meet their goals. Data that form the basis of stock assessments must absolutely be supported by scientific documentation of substance. ISC Operations Manual provides basic guidelines to help ensure that ISC technical

products are scientifically credible. The Operations Manual provides clear guidance for ISC WG scientists developing WG working papers and stock assessment reports.

There is no replacement for good (in the sense of accurate, precise and complete) data for enhancing overall stock assessment model performance. A driving property of this is the substantial need to develop an objective basis for inclusion of particular standard and "new" data streams into particular stock assessments. When generating this information, personal or institutional opinions will and should not constitute BASI. If the required data are insufficient, ISC must consider how to fill these gaps, and what types of additional or new data may be appropriate. For example, while statistically rigorous data on recruitment is desperately needed, projects will need to be designed and implemented over periods of 5-10 years, and thus some true vision and budgetary planning are needed.

The PRT felt that there is great intrinsic value in having ISC maintain a strategic and somewhat visionary perspective by continually asking WGs: "*What data are needed to implement the most appropriate next generation stock assessment model?*" Such a perspective will help to guide the necessary research science functions of ISC that will ultimately help to meet its goals. DATA and MODEL developments are imperative to help ISC provide the appropriate scientific advice in response to expected exploitation and environmental changes in the North Pacific Ocean.

2.6   Collaborations among member scientists and with other scientists. [TOR 6]
   Medium Priority
Collaborations are important and encouraged by ISC, but these must follow ISC rules. The goal of ISC in developing collaborations with regional fisheries organizations (RFOs) and RFMOs is to facilitate and coordinate scientific research and data acquisition concerning the abundance, biology and biometry of tuna and tuna-like species, and as necessary, of associated or dependent species, and the effects of natural processes and human activities on these stocks and species. The PRT felt that ISC interactions with other regional organizations (e.g. IATTC, PICES, etc.) have enabled ISC to fully function to meet its goals and objectives. However, ISC should establish transparent data sharing relationships with other RFMOs (i.e., IATTC, WCPFC) that include an environment that allows independent analysts access to data used in WG stock assessments.

2.7   Organizational structure of ISC and its membership. TOR [7] Low Priority

The PRT felt that the organizational structure of ISC and its membership was optimal to achieve its stated goals and purpose, as outlined above. If anything, the ISC stock assessment process could stand a boost by ensuring that additional rigorous peer review scrutiny is given to the DATA and MODEL WG process and products.

2.8   Availability of resources, including funding, ISC staff time, and member scientists' capabilities and time. TOR [8] Low Priority

The PRT was impressed by the fact that the WGs are doing their utmost to ensure that the appropriate data, models and analytical procedures are implemented in ISC stock assessments. It remains difficult to work out all the bugs in the system without some outside expert advice and guidance. Thus, the PRT strongly believes that a greater level of funding is required and must be identified to support and a higher level of external expert reviewer attendance and involvement in the WG review process.

2.9   ISC goals, objectives, and purpose (according to 2016 ISC Operations Manual. TOR [9] Low Priority

ISC goals, objectives and purpose are right on target. The very well thought-out and executed ISC Operations Manual provides an excellent overview of what each member country and WG scientists should provide to optimize the functionality of the ISC Stock Assessment process. The ISC Plenary Reports contain stoplight graphs by country that help to emphasize and improve this process.

3.0   PRT Recommendations: A Way Forward for ISC Stock Assessments

The PRT noted that most of the appropriate actions and activities seemed to be taking place in the execution of both the species DATA and MODEL working groups. However, at these workshops, many important and high impact decisions that could ultimately strongly influence the types and depth of final analyses and decisions to be are made by ISC are rushed together in a relatively narrow time window. Some of these typical relevant issues and decisions involve: (1) parameters and indices selection; (2) reference points and status of overfishing; and, (3) unresolved issues with assessment model(s), etc. The workshop timelines are frankly too short to legitimately

consider, analyze, synthesize and write in a logical fashion the WG findings that can be coherently communicated to decision-makers in the ISC Plenary.

At the WG meetings it is sometimes difficult for the WG to walk away with consensus on the model choice, particularly if the discussion was contentious, or even to complete the recommended model. Under these circumstances, an important consideration is how or in what way could the process be modified so that could ISC receive the appropriate and necessary feedback from reviewers? An important consideration is the strident evaluation of whether there are options beyond the confines of ISC which could enhance the function of the ISC stock assessment process. It is the PRT's belief that inconsistencies and discrepancies in this process could be ameliorated by greater external reviewer presence and involvement at both the DATA and MODEL WG meetings. Addition of actively engaged independent reviewers with specialized mathematical and statistical stock assessment skills, dedicated to understanding, questioning and advising the process, could directly and substantially improve the quality of the stock assessment. Independent external reviewers actively engrossed in the discussions and analyses at workshops could be at liberty to ask specific questions, scrutinize assumptions and results recommend additional needed runs, or to clarify analyses. This would likely involve generation of external peer-review report(s) for each of the WG workshops.

The PRT considered the intrinsic and intellectual value of independent review, and three categories of reviews were identified:

(1) ISC Plenary: This is actually the ISC *status quo*, whereby completed assessments are reviewed and then approved by the individual participating countries in the course of the time at the ISC Plenary. This strongly suggests that the depth of evaluation and ensuing recommendations are somewhat superficial, since the stock assessment only receives a cursory review by member countries. The mode of review is probably the least desirable to the PRT.

(2) Desktop Review: These type of stock assessment reviews have been supervised by the Center for Independent Experts (CIE), and occur "at arm's length", and after the fact. Reviewers are tapped to evaluate stock assessment documents independent of the actual process, thus they are completely disconnected from the process and the thinking and analyses that went into them. This is likely the cheapest of the review types, but perhaps the most ineffectual. The PRT feels that since the reviewers "don't have a dog in the fight", and further, conduct the review at arm's length with minimal knowledge of the issues or how or of they were resolved, that their contributions to a robust process are perhaps questionable.

(3) Active/Interactive Review: – This PRT proposed structure will feature up to two peer reviewers at both the benchmark DATA & MODEL workshop meetings. The reviewers will be thoroughly engaged in the WG process, pushing ISC stock assessment scientists, being fully immersed in the discussions and analyses, asking penetrating questions. It is expected that the external independent reviewers will generate written reports after each workshop, which could influence the intervals between meetings (e.g., see **Fig. 1**). This type of active review inherently will have substantially deeper vetting, and greater rigor since the stock assessment WGs will obviously know that they are being closely watched, but in fact, are receiving an additional boost from collaboration. We expect that the process will very likely produce a much high quality, reliable and more defensible assessment work product.

Going forward, it would appear to the PRT, given the risks and consequences involved, that ISC must invest in a strategy that produces the highest quality stock assessments. But what would be the constraints and costs of implementing the aforementioned Active Review strategy? Below we outline some possible structures and costs associated with an "active" and independent stock assessment review in the context of several scenarios. We believe that the Active Review approach would only occur for "Benchmark" stock assessment.

As shown in **Table 2**, we suggest that there may be four alternative review modes or structures under the proposed Active Review rubric. Following is a summary of what we have proposed under the Active Review (AR) mode:

AR.3A: Calls for 1 reviewer attending just the MODEL workshop. The reviewer would actively participate in the discussions, analyses and recommendations, and further, write an opinion report. Approximate costs are $8,000 for travel, $15,000 to produce a written summary report for a total of $23,000 (**Table 3**). The clear benefit of having an active external reviewer immersed in the entire MODEL workshop process will be to provide insights and advice that enhance the WG capabilities.

AR.3B: Calls for 1 reviewer (preferably the same for continuity) to attend both the DATA and MODEL workshops. Approximate costs are $16,000 for travel, $20,000 to produce a written summary report for a total of $36,000. The benefit is to have an active external reviewer involved in the entire DATA and MODEL workshops and providing insights and advice across both components of the stock assessment.

AR.3C: Calls for 2 reviewers, each attending one of either the DATA or MODEL workshops (separate reviewer for each workshop). Approximate costs are $16,000 for travel, $25,000 to produce separate written summary reports for a total of $41,000. The benefit is to have active external reviewers involved in the DATA and MODEL workshops and providing insights and advice across both components of the stock assessment. The downside is maintaining the continuity between workshops.

AR.3D: Calls for a minimum 2 external reviewers, each attending both the DATA and MODEL workshops. Approximate costs are $32,000 for travel, $40,000 to produce separate written summary reports for a total of $72,000. The benefit is to have two very active external reviewers involved in both the DATA and MODEL workshops, and jointly providing insights and advice across both components of the stock assessment. This synergy could probably be maximized by having the reviewers collaborate on writing a single final summary report.

The AR strategy, implemented at whatever level deemed appropriate by ISC, could greatly increase the efficacy of subsequent updates by focusing needs from the benchmark reviews.

Table 2.- Categories and types of external reviews of ISC stock assessments.

Review Type	Mode	Reviewers/WGs	Workshop Attendance	
1. ISC Plenary	In house	Members		
2. Desktop	CIE	3		
3. Active	3A	1/1		MODEL
	3B	1/2	DATA	MODEL
	3C	2/1	DATA	MODEL
	3D	2/2	DATA	MODEL

Table 3.- Estimated costs associated Active Review mode at ISC benchmark stock assessments. Trip cost is assumed to be $8,000 per external reviewer. Cost per workshop attendance: (1) data = $10,000; model = $15,000. Reviewers of type (3C) and (3D) are active trouble-shooters and have the greatest benefits to ISC.

	Active Review		Review Costs		
Mode	**Reviewers**	**Workshops**	**Travel**	**Report Writing**	**Total**
3A	1	1	$ 8,000	$ 15,000	**$ 23,000**
3B	1	2	$ 16,000	$ 20,000	**$ 36,000**
3C	2	1 ea	$ 16,000	$ 25,000	**$ 41,000**
3D	2	2 ea	$ 32,000	$ 40,000	**$ 72,000**

A hypothetical temporal sequence of ISC benchmark and update stock assessments is shown in **Table 4**. The working costs of such a strategy, by in large, the proposed follows the ISC current timeline for the sequence of assessments, and keeps the number of benchmark and update assessments in any year to a relatively manageable number. Finally, a reasonable question is can or should ISC consider coming up with a cheaper alternative than proposed by the PRT? We encourage out of the box thinking on this topic as it can lead to an improvement in the quality and impact of ISC stock assessments.

4.0   Summary Conclusions

ISC is an especially unique science organization due to its science-driven mission, apparent independence, and that it is not obligated to follow regional fisheries management organization's (RFMO) interests. ISC has built a special role that covers the gaps and helps to plan the necessary future science with a vision to support next-generation stock assessments.

Generally, ISC should continue to streamline the formal standardized framework for DATA and MODEL WG reports, with critical stock assessment information in the same formats, location and be of similar quality for each species considered. We are largely in agreement with the ISC guidelines for using BSIA for stock assessments: Reports would be comprised of three principal areas: (1) fishery catches and effort: (i) accurate species identification; (ii) spatio-temporal estimates of catch, fleet fishing effort, selectivity and catch size/age compositions by fishing fleet/gear; and, (iii) uncertainty characterization (catches, bycatch and discards). (2) CPUE standardizations: (i) history

of fishery; (ii) model selection and data sources, CPUE statistical standardization model, and CPUE estimates; (iii) model estimates, fit criteria and diagnostics; (iv) nominal and standardized CPUE comparisons; and, (v) model uncertainty. (3) stock assessment modeling: (i) model formulation, assumptions, and parameter estimates; (ii) model results including current stock status relative to sustainability reference points; (iii) model diagnostics; (iv) model uncertainties and sensitivity analysis relative to key parameters; and, (v) stock projections and uncertainty relative to proposed management alternative.

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References

Anonymous. 2016. Operations Manual. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean. 50 p.

Table 4.- Potential 2019-2027 sequence of ISC stock assessments for managed north Pacific Ocean pelagic tuna and billfish stocks. BM ≡ benchmark assessment; and, UP ≡ update assessment. PBF ≡ Pacific bluefin tuna; STM ≡ Striped marlin; ALB ≡ North Pacific albacore tuna; SWD ≡ North Pacific swordfish; BKS ≡ Blue shark; SFM ≡ Shortfin mako shark; BUM ≡ Blue marlin.

Rank	Overfishing	Issues	Stock	Last BM	2019	2020	2021	2022	2023	2024	2025	2026	2027
1	significant		PBF	2016		BM		UP		BM		UP	
2	significant	2 stocks	STM	2019	BM		UP		BM		UP		BM
3	ok/improving	1 stock	ALB	2016		BM		UP		BM		UP	
4	ok	2 stocks?	SWD	2018		UP		BM		UP		BM	
5	ok		BKS	2016			BM		UP		BM		UP
5	ok		SFM	2018		UP		BM		UP		BM	
6	ok	1 stock	BUM	2017			BM		UP		BM		UP
	Assessments				**1**	**4**	**3**	**4**	**3**	**4**	**3**	**4**	**3**
	AR.3D costs				**$72K**	**$144K**	**$144K**	**$144K**	**$72K**	**$144K**	**$144K**	**$144K**	**$72K**