Independent Peer Review Report

Developing integrated assessments for data poor stocks

Pelagic meeting room, Western Pacific Regional Fisheries Management Council, 1164 Bishop Street, Suite 1400, Honolulu, Hawaii. 13-16 October 2015

Prepared for the Center for Independent Experts

By

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Executive Summary

A CIE Review of the development of an integrated catch-MSY method for assessing data poor stocks was held in Honolulu, Hawaii over the period 13-16 October 2015. The method is an extension of earlier versions that re-focusses estimation directly on management-oriented quantities and allows incorporation of additional data within a statistical framework. The review took the form of a study of background literature, and a series of interactive presentations on the coral reef fisheries of the Western Pacific Islands Region, available fishery-dependent and -independent data, an overview of the management process, and "hands-on" sessions on the integrated catch-MSY method itself. The main conclusion of the review was that, despite having a solid scientific foundation and moving in the right direction in terms of making best use of available, sparse data, the integrated catch-MSY method is not yet ready for frontline use. The main reason for this is that the method appears still to be in a development phase, and currently lacks the rigorous testing and wide application needed on the types of data sets available in the Western Pacific Islands Region, prior to rolling it out for serious application. Nevertheless, support for further development of the method is recommended, along with rigorous testing, and a more complete set of diagnostics and guidelines.

Background

This review concerns the development of an integrated catch-MSY method for assessing data poor stocks that could potentially be used for the derivation of Annual Catch Limits (ACLs) for these stocks. The method, described in Martell (2015), is an extension of that proposed by Martell and Froese (2013), and further developed by Sabater and Kleiber (2014), but re-focusses its estimation directly on management-oriented quantities (F_{MSY} and MSY) instead of on difficult-to-estimate and highly-confounded parameters (Schaeffer r and K). This management-oriented approach, originally proposed by Martell and Walters (2008), has not as-yet seen wide application, possibly because of entrenched approaches and lack of opportunity, but the current development and associated context (data poor fisheries in the Western Pacific Islands Region) offers up such an opportunity.

The review took place over the period 13-16 October 2015 at the West Pacific Fisheries Management Council Offices in Honolulu, Hawaii. The materials provided in support of the review are listed in Appendix 1, covering background literature provided prior to the meeting, presentations given during the meeting, and the package tools and other supporting material provided during the course of the meeting. The Statement of Work, which lays out the framework for, and context of, the review is provided in Appendix 2 and its Annexes, while Appendix 3 details participation in the review and the Agenda, as it developed.

Review activities

The review activities included preparation prior to the meeting by studying the background literature listed in Appendix 1, attending the four-day meeting at the West Pacific Fisheries Management Council Offices in Honolulu, Hawaii, and providing an independent Peer Review of the integrated catch-MSY model being proposed for use as a management tool for the data poor fisheries of the Western Pacific Islands Region. During the meeting, reviewers listened to the presentations, interrogated the presenters on details of their presentations, sometimes requesting further information (see Appendix 1), and interacted with the main developer (Steve Martell) during the example application of the method to Lutjanid (American Samoa). At the end of the meeting, each reviewer presented their summaries and findings, in brief, in a wrap-up session (see Appendix 3 for participation in this). This review report fleshes out these brief summaries and findings, from my perspective.

My role in the review was to participate fully in these review activities. In particular, I made a careful study of the main document that provided a scientific description of the integrated catch-MSY model (Martell 2015), and found several errors in the mathematical descriptions (detailed in Appendix 4). I also ensured that the catch-MSY R package could run on my computer (which uses a Windows-based operating system), and found some technical issues that were ironed out (through interaction with the developer, Steve Martell) prior to the training workshop held on the final two days of the meeting (which the reviewers did not participate in).

Findings with regard to the TORs

The reviewers were not provided a finished product, in the sense that the integrated catch-MSY method appears still to be in its development phase, and currently lacks the rigorous testing needed prior to its application for management purposes. A large part of the meeting was taken up trialling the new approach, cleaning up some technical issues with the code, and providing

some further development (e.g. to output annual size frequencies as a precursor to including size frequency data in the model fit). Apart from the case study used in development work (the non-data-poor Namibian hake example), the method was only applied to one of the "local" data sets (for Lutjanid in American Samoa). The reviewers therefore found it difficult to fully address all of the Terms of Reference in the Statement of Work. Nevertheless, I have made an attempt to do so below.

TOR 1: Review the assessment methods used: determine if they are reliable, properly applied, and adequate and appropriate for the species, fisheries, and available data considering that the data itself have been accepted for management purposes.

The integrated catch-MSY method has a strong scientific basis, and follows sound scientific principles. It is an extension of the work published by Martell and Froese (2013) and Sabater and Kleiber (2014), but, in contrast to these two papers, it re-focusses its estimation directly on management-oriented quantities (F_{MSY} and MSY) instead of on difficult-to-estimate and highly-confounded parameters (Schaeffer r and K) (see Martell et al. 2008). The significant development of the integrated approach is its extensions, where needed, to incorporate data other than catch data into the model (e.g. biomass and abundance indices, and size composition data) on a statistical basis (i.e. through the inclusion of likelihood formulations in the model appropriate to the data being fitted). This provides a highly flexible approach that makes best use of available data, an important development for data poor fisheries where data are scarce and sparse, and may provide much-needed information to narrow down the uncertainty in model estimates.

Despite these positive developments, and the fact that the method appears appropriate and highly suited to data poor fisheries, it is difficult to judge its reliability and adequacy for use for management purposes. This is because the method does not appear to have yet been rigorously tested and widely applied to data sets appropriate to the fisheries in the Western Pacific Islands Region (the latter making it impossible to judge its proper application). There are significant data issues in these fisheries (pertaining to the quality and reliability of catch data, and the lack of life history data for many species, these issues becoming clear during the presentations on data), and without rigorous testing (including comparisons with other candidate methods, such as that of Nadon et al. 2015), it is difficult to judge how reliable the method is for these data poor fisheries, particularly relative to other candidate methods (since these will likely have similar issues, and the eventual choice may be restricted to the best of available, limited approaches).

TOR 2: Evaluate the implementation of the assessment methods: determine if data in its current form are properly used, if choice of input parameters seems reasonable, if models are appropriately specified and configured, assumptions are reasonable and reasonably satisfied, and primary sources of uncertainty accounted for.

Based on the single example application of the integrated catch-MSY method to Lutjanid in American Samoa, which used catch data and three survey estimates of biomass (with associated CVs), the method appeared to work well, and the R scripts were easily constructed and relatively easy to follow. A major advantage of the current implementation is that the source code is available; although the R package facilitates help pages, these are still relatively sparsely documented, but the availability of the source code counter-balances this to some extent: useful for the more advanced users, but perhaps not as much for relatively inexperienced users.

However, the example application to Lutjanid did raise some concerns:

(i) A simple self-test, where simulated data based on the original model fit was used to test if the method could reproduce its "true" values (i.e. the F_{MSY} and *MSY* values of the original model fit) revealed a bias – the method requires further checking and testing to resolve this problem. This bullet raises questions about the performance of the model.

(ii) The model used the same selectivity parameters to calculate F_{MSY} as it did to calculate the vulnerable biomass used to fit the survey biomass index – this assumption does not necessarily hold (e.g. surveys may be surveying a different part of the population compared to the fishery), and careful thought needs to be given to data that is being fitted and what the appropriate selectivity assumptions should be. A further possible complication is that the overall composition of a fishery may change over time (e.g. the relative importance of gears changes over time, or the fishery shifts its operation to different areas/depths), potentially implying selectivity changes over time. This bullet raises questions about the appropriate use of data.

(iii) A simple sensitivity test, where the input prior range for *MSY* was changed (the upper bound was increased from the 95th quantile of the catch, to 1.5 times this value) did reveal the model was sensitive to this input prior (the MSY estimated increased substantially). This is not necessarily a concern for the method per se, since other methods would have similar problems, but it does reveal that careful consideration needs to be given to constructing priors for this method. This bullet raises questions about the reasonable choice of input parameters.

TOR 3: Comment on the scientific soundness of the estimated population benchmarks and management parameters (e.g. stock status estimates, MSY-based reference points or their proxies) and their potential efficacy in addressing the management goals stated in the relevant FEP or other documents provided to the review panel.

Since the method was not "seriously" applied to any data sets during the meeting (the Lutjanid application was just illustrative), it is not possible to answer this TOR.

TOR 4: Determine whether the results (such as MSY proxies, stock status) in their current form from the assessment methods can be used for management purposes without further analyses or changes considering that the data itself have been accepted for management purposes.

Since the method was not "seriously" applied to any data sets during the meeting (the Lutjanid application was just illustrative), it is not possible to answer this TOR.

TOR 5: Suggest research priorities to improve our understanding of essential population and fishery dynamics necessary to formulate best management practices. Comment on alternative data sources and modeling.

The integrated catch-MSY method appears to be well-suited for data-poor applications. It can be applied where only catch data are available, with a focus on setting prior ranges directly for management quantities F_{MSY} and *MSY*, but more importantly, it allows other information to be

included, where these are available. However, the method does not appear yet to be ready for frontline use, and there are several areas that need further attention.

(a) Testing: The method lacks rigorous testing to ensure that it is appropriate for use on the types of data available for the Western Pacific Islands Region. Such testing could take the form of self-testing (as a basic check that the method is working), the use of simulated data of known properties (to check sensitivity and robustness to model assumptions and inputs for the kind of data that will be encountered), and the use of data-rich assessments (where available) in data poor mode (i.e. relevant data reduced to data poor status) for comparing the performance of the method against a benchmark. Wider application to actual data sets for the Western Pacific Islands Region (something that was not seen during this meeting) will no doubt highlight further issues that need to be considered, and enhance understanding of the strengths and weaknesses of the approach.

(b) Diagnostics: Diagnostic tools provide an important check for the analyst on model performance. Although the method currently produces useful diagnostics (e.g. the reasons for failure, shown as colour-coded plots, when scanning over prior ranges), more model diagnostics are needed (e.g. residual plots associated with the various likelihood components when fitting to additional data; estimates of precision; etc.).

(c) User Manual: The R-package [using library(catchMSY) in R] allows help pages to be accessed, which, if properly designed, can be used as a User Manual for application of the method. Furthermore, the availability of a github site (https://github.com/smartell/catchMSY) allows access to the source code, making the method transparent to the user. However, the help pages still contain the bare minimum of information, and some of the help examples don't appear currently to work [e.g. the runModel(hake) command in the Namibian hake vignette does not appear to work, at least not on a Windows computer]. The availability of good help pages with annotated examples, providing valuable guidelines to the user, both in terms of applying the method and understanding how to set up prior ranges and derive reasonable values for inputs, is essential for the proper use of the method.

(d) Further development: There were a few aspects of the code that were incomplete, in particular the modelling of the dynamic plusgroup to ensure that the mean weight of the plusgroup was appropriately handled (e.g. through the use of a discrete time delay-difference model formulation), and the inclusion of a size frequency likelihood component, so that this data could be fully fitted (instead of just fitting the mean size), opening up the possibility of being able to estimate selectivity parameters.

(e) Prioritising data: The simple example application to Lutjanid (American Samoa) during the meeting demonstrated the benefits of including additional data other than catch data (in this case, survey estimates of biomass with associated CVs), which helped narrow the uncertainty in model estimates. This provides a significant advantage compared to other similar methods that use catch only, such as the original catch-MSY method of Martell and Froese (2013). The statistical framework within which the additional data is introduced also provides an advantage over the augmented approach of Sabater and Kleiber (2014), because posterior distributions are actual statistical distributions rather than equally-weighted estimates that have simply passed certain criteria (pre-defined windows, specifying a range of acceptable values). The method can therefore be used to help prioritise the types of data that will be most useful for management. In this regard, the Reef Fish Visual Survey Program-based biomass estimates (as used in the Lutjanid example application, for instance) appears to offer tangible benefits, as does the potential availability of representative size-frequency data. [See also point (f) below.]

(f) Application to data: The integrated catch-MSY method is best suited for data at the stock level, but it was clear from presentations on data during the meeting, and subsequent information supplied, that gathering even species-level information posed a significant challenge (Bob Humphreys presentation, and Anon. 2015b in Appendix 1), and that the method may even be considered for application at the family level. However, species within a family can have quite widely varying life-history traits, and care needs to be taken to avoid applying the method at the family-level when such widely varying life-history traits within the family are present. Another possibility is applying the method to groups of species that have similar life-history traits (e.g. similar levels of productivity), if species-level assessments are not possible. Care should also be taken when assuming so-called life-history invariant ratios (e.g. $M/\kappa = 1.5$, as per Jensen 1996) when deriving values for input parameters to the integrated catch-MSY method, because recent work has shown that these life-history ratios were not actually "invariant", but can vary markedly across species (Prince et al. 2015; but see also Jardim et al. 2015 for examples). This suggests that some effort should be made, whenever possible, to gather life-history information, at least at the species level, in order to ensure the life history information used is appropriate. [The points raised in (ii) under TOR 2 about selectivity are also relevant here.]

(g) Management Strategy Evaluation: Developing and conducting a Management Strategy Evaluation (MSE) can appear to be a rather daunting and time-consuming task (Punt et al. 2015). However, it is possible to develop some rather basic MSEs, where the underlying age-structured population model of the integrated catch-MSY method, as fitted to whatever data is available, initially forms the basis for an operating model. Even such a basic MSE places the integrated catch-MSY method within a risk framework, and would at least be able to investigate the extent to which, under ideal conditions, the method is able to meet any existing management objectives. The operating model could then be further developed to take more realistic account of existing uncertainties, while remaining consistent with available data. The MSE framework could also be used to compare the performance of the integrated catch-MSY method to the method that has currently been applied for management (the augmented catch-MSY method as applied by Sabater and Kleiber 2014) and to other data poor methods (e.g. the method of Nadon et al. 2015).

Conclusions and recommendations

The main conclusion, for which there was general agreement amongst the CIE reviewers, was that, despite the method having a solid scientific foundation and moving in the right direction in terms of making best use of available, sparse data, the integrated catch-MSY method is not yet ready for frontline use. The main reason for this is that the method appears still to be in a development phase and currently lacks the rigorous testing and wide application needed on the types of data sets available in the Western Pacific Islands Region, prior to rolling it out for serious application. A set of recommendations follow.

1. The integrated catch-MSY method has a solid scientific foundation, attempts to make best use of available data, and offers substantial advantages over earlier versions (Martell and Froese 2013, and Sabater and Kleiber 2014), and its further development should therefore be supported.
2. The code should be checked to ensure it follows the specifications of Martell (2015) (but see Appendix 4 for corrections), and is further developed to appropriately model the plusgroup mean weight and enable full inclusion and fitting of size frequency data.

3. Rigorous testing of the method should be carried out at various levels: self-testing to ensure the method is able to return true values under a variety of scenarios (see Needle 2015 as an example); use of simulated data with known properties (preferably capturing some of the issues found in the Western Pacific Islands Region data sets) to investigate sensitivity and robustness to model assumptions and inputs (see Hordyk et al. 2015 as an example); use of a data-rich assessment for similar species and fisheries found in the Western Pacific Islands Region (if available) for "benchmark" testing of the model (where the data are stripped down to data poor status and results for the integrated catch-MSY data-poor assessment compared to the data-rich assessment).
4. A more complete set of diagnostics is needed to help the analyst better understand model performance (e.g. goodness of fit and levels of precision) and behaviour.
5. The open-source nature of the R package is hugely advantageous, making the model transparent to the user, but current help pages are sparsely documented and in need of more examples, and in particular guidance to help the user derive appropriate input values and ranges (i.e. the R package needs something that is closer to a User Manual).
6. Attention should be given to assembling data that is likely to have the greatest impact on management, and an approach such as the integrated catch-MSY method can be used to help prioritise such data collection (e.g. fishery-independent survey estimates of biomass/abundance, size frequency data, species-specific life-history information).
7. Management Strategy Evaluation (MSE) is a powerful tool for placing assessment models and harvest control rules used for management in a risk framework, and investigating the extent to which these are able to meet management objectives. Even a basic MSE can be useful and should be considered as a means for evaluating the performance of the integrated catch-MSY model as a management tool, and also as a means of comparing its performance relative to alternative approaches (such as the augmented catch-MSY approach of Sabeter and Kleiber 2014 that has already been used to set management targets, and the approach of Nadon et al. being proposed as an alternative approach).

Comments on Terms of Reference

The current set of TORs were clearly designed to evaluate a finished product that was already been used to provide estimates useful for management (e.g. stock status, MSY-based reference points). The current product is still being developed and is nowhere near to producing such outcomes, so there is a question mark over the suitability of the current set of TORs for a developing product – these were clearly "out of sync" (particularly TORs 3 and 4). Comments on the individual TORs are nevertheless provided above.

Comments on the review process

The review process itself was well organised, with clear presentations and helpful interactions. All involved were helpful, particularly with providing the information needed and getting the code working on a Windows machine, which was useful for viewing the package "in action" (and ironing out some technical issues in the process). My one concern is that this review process may have come too soon for the development stage at which the integrated catch-MSY package finds itself currently, although I hope that the CIE reviewers were still able to provide useful inputs at this stage.

References

Jardim, E., Azevedo, M., and Brites, N.M. 2015. Harvest control rules for data limited stocks using length-based reference points and survey biomass indices. Fisheries Research 171: 12–19.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53: 820-822.

Hordyk, A., Ono, K., Valencia, S., Loneragan, N., and Prince, J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. ICES Journal of Marine Science, 72: 217–231.

Martell, S. 2015. An integrated Catch-MSY model for data poor stocks. 30 September 2015

Martell, S, and Froese, R. 2013. A simple method for estimating MSY from catch and resilience. Fish. Fish. 14: 504-514.

Martell, S.J.D., Pine III, W.E., Walters, C.J. 2008. Parameterizing age-structured models from a fisheries management perspective. Can. J. Fish. Aquat. Sci. 65: 1586-1600.

Nadon, M.O., Ault, J.S., Williams, I.D., Smith, S.G., DiNardo, G.T. 2015. Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwestern Hawaiian Islands. PLoS ONE 10(8): e0133960. doi:10.1371/journal.pone.0133960.

Needle, C.L. 2015. Using self-testing to validate the SURBAR survey-based assessment model. Fisheries Research 171: 78–86.

Prince, J., Hordyk, A., Valencia, S. R., Loneragan, N., and Sainsbury, K. 2015. Revisiting the concept of Beverton–Holt life-history invariants with the aim of informing data-poor fisheries assessment. ICES Journal of Marine Science, 72: 194–203.

Punt, A.E., Butterworth, D.S., de Moor, C.L., De Oliveira, J.A.A. and M. Haddon. 2015. Management Strategy Evaluation: Best Practices. Fish and Fisheries, doi: 10.1111/faf.12104.

Sabater, M. and Kleiber. P. 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. S.A. Bortone (Ed.), Interrelationships between Corals and Fisheries, CRC Press, Boca Raton, FL (2014), pp. 199–218. 321 pgs.

Appendix 1

Bibliography of materials provided for review

Background literature provided prior to the meeting

Kimura, D. and Tagart, J. 1982. Stock reduction analysis, another solution to the catch equations. Canadian Journal of Fisheries and Aquatic Sciences, 39, 1467–1472.

Martell, S. 2015. An integrated Catch-MSY model for data poor stocks. 30 September 2015.

Martell, S, and Froese, R. 2013. A simple method for estimating MSY from catch and resilience. Fish. Fish. 14: 504-514.

Martell, S.J.D., Pine III, W.E., Walters, C.J. 2008. Parameterizing age-structured models from a fisheries management perspective. Can. J. Fish. Aquat. Sci. 65: 1586-1600.

Sabater, M. and Kleiber. P. 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. S.A. Bortone (Ed.), Interrelationships between Corals and Fisheries, CRC Press, Boca Raton, FL (2014), pp. 199–218. 321 pgs.

Presentations made during the meeting

The following presentations were made during the meeting (listed in order of presentation):

Beth Lumsden: “Introduction: CIE review of an integrated catch-MSY model for data poor stocks”.

Kimberley Lowe: “Hawaii commercial fishery-dependent data: overview” [later supplemented with Anon. 2014 and Anon. 2015a below].

Bob Humphreys: “Life history information” [later supplemented with Anon. 2015b below].

Ivor Williams: “Reef fish visual survey program: data gathering overview”.

Matt Dunlop: “The anatomy of an ACL: a brief overview of the management process”.

Marlowe Sabater; “Coral reef fisheries in the Western Pacific region”.

Steven Martell: “An integrated catch-MSY model for data poor stocks” [later supplemented with Jensen 1996 below].

R-package (information and installation assistance provided during the meeting)

Source code is fully available at: https://github.com/smartell/catchMSY

The R-packages can be installed with the following R scripts:

```
install.packages("devtools")
library(devtools)
devtools::install_github("smartell/catchMSY",build_vignettes=TRUE)
library(catchMSY)
```

An example application of the integrated catchMSY method for Lutjanid (American Samoa), was developed during the meeting, with the R-scripts made fully accessible at the above github site.

Further background material provided during the meeting

The following background material was provided during the meeting, but was for information only (following requests/queries by panel members) and was not extensively discussed during the meeting:

Anon. 2014. Western Pacific Regional Creel Survey Data. Historical summary and analysis: 1982-2012. Guam, the Commonwealth of Northern Mariana Islands, and Western Samoa. Sun Bak Hospital, 1/3/2014.

Anon. 2015a. Summary of creel survey data: raw vs. expanded data and data quality. [This document was accompanied by six single-page pdfs with survey maps (two each) for American Samoa, Guam and Saipan.]

Anon. 2015b. Life history parameter table for coral reef fish. [This was supplied as an EXCEL spreadsheet.]

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53: 820-822.

Nadon, M.O., Ault, J.S., Williams, I.D., Smith, S.G., DiNardo, G.T. 2015. Length-Based Assessment of Coral Reef Fish Populations in the Main and Northwestern Hawaiian Islands. PLoS ONE 10(8): e0133960. doi:10.1371/journal.pone.0133960.

WPFMC. 2015. Contract Deliverables for the project “Developing an Integrated Assessment Model for Data Poor Stocks”.

Appendix 2

Copy of CIE Statement of Work

Statement of Work

External Independent Peer Review by the Center for Independent Experts

Developing Integrated Assessments for Data Poor Stocks

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description:

A large number of fish and invertebrate species listed in fisheries management plans have insufficient data to conduct routine stock assessments and determine stock status to inform managers' selection of Annual Catch Limits (ACLs). The current practice for setting ACLs for many data-poor species is based solely on: (a) the historical catch information, or (b) use of ratios such as change in mean size or spawning potential ratio (SPR) to infer depletion, or (c) comparative studies on local density in heavily depleted versus near pristine habitats using underwater visual census.

Nearly all of the assessment methods for data-poor stocks rely solely on catch data, or one source of data for directly estimating population density. A modified integrated assessment model has been developed, focusing on developing extensions for the Catch-MSY method, or stock reduction analysis proposed by Martell and Froese (2012) and Taggart and Kimura (1982) and modified by Sabater & Kleiber (2014), by incorporating data other than catch times series that directly inform total mortality rates (e.g. changes in mean size), relative and absolute abundance estimates, and other life history information. This modified model is being applied to data-poor coral reef fish stocks throughout the Pacific Islands Region, including Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. However these scientific analyses have not previously been applied for management purposes in the Pacific Islands Region, so there is a need to conduct an independent peer review of the analyses to improve the scientific basis for management.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have working knowledge and recent experience in the application of: General fisheries stock assessment methods, specifically numerical methods for constructing posterior distributions (e.g. Monte Carlo methods), and data-poor approaches to conducting stock assessments.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Honolulu, HI during October 13-16, 2015.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/
http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read the following documents (and others to be provided) in preparation for the peer review.

Document describing the newly-extended Catch-MSY method which incorporates data other than catch times series.
M. Sabater, P. Kleiber. 2014. Augmented catch-MSY approach to fishery management in coral-associated fisheries. S.A. Bortone (Ed.), Interrelationships between Corals and Fisheries, CRC Press, Boca Raton, FL (2014), pp. 199–218 321 pgs
Martell S, Froese R. 2013. A simple method for estimating MSY from catch and resilience. Fish. Fish. 14: 504-514.
Kimura, D. and Tagart, J. 1982. Stock reduction analysis, another solution to the catch equations. Canadian Journal of Fisheries and Aquatic Sciences, 39, 1467–1472.

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs cannot be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting at the *Honolulu, HI* during *October 13-16, 2015*, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than November 7, 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlani@ntvifederal.net, and Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

September 7, 2015	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
September 28, 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
October 13-16, 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
November 7, 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
November 16, 2015	CIE submits CIE independent peer review reports to the COTR
November 23, 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The CIE report shall address each ToR as specified in **Annex 2**,
(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations following Annex 2 Terms of Reference.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   d. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed. The CIE independent report shall be an independent peer review of each ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

Annex 2: Terms of Reference for the Peer Review

Developing Integrated Assessments for Data-Poor Stocks

1. Review the assessment methods used: determine if they are reliable, properly applied, and adequate and appropriate for the species, fisheries, and available data considering that the data itself have been accepted for management purposes.

2. Evaluate the implementation of the assessment methods: determine if data in its current form are properly used, if choice of input parameters seems reasonable, if models are appropriately specified and configured, assumptions are reasonable and reasonably satisfied, and primary sources of uncertainty accounted for.

3. Comment on the scientific soundness of the estimated population benchmarks and management parameters (e.g. stock status estimates, MSY-based reference points or their proxies) and their potential efficacy in addressing the management goals stated in the relevant FEP or other documents provided to the review panel.

4. Determine whether the results (such as MSY proxies, stock status) in their current form from the assessment methods can be used for management purposes without further analyses or changes considering that the data itself have been accepted for management purposes.

5. Suggest research priorities to improve our understanding of essential population and fishery dynamics necessary to formulate best management practices. Comment on alternative data sources and modeling.

Annex 3: Tentative Agenda

Review of Modified Integrated Assessments (based on Catch-MSY model) for Data-Poor Stocks

Honolulu, HI
October 13-16, 2015
8:30 AM – 5:00 PM

Tuesday October 13

1. Introduction
2. Background information - Objectives and Terms of Reference
3. Coral reef fisheries in the Pacific Islands Region
    - Operation (presented by PIFSC)
    - Management (Council and PIRO)
4. Data
    - State of Hawaii commercial system
    - Coral Reef Ecosystem Division surveys
    - Biological data
    - Other data
5. Discussion

Wednesday October 14

6. Review of modified integrated Catch-MSY stock assessment
7. Discussion

Thursday October 15

8. Continue Assessment Review (1/2 day)
9. Discussion
10. Panel discussions (Closed)

Friday October 16

11. Panel Discussions (1/2 day)
12. Present Results (afternoon)
13. Adjourn

Appendix 3

Panel membership and other pertinent information

CIE Review panel members:
Robin Cook (MASTS Population Modelling Group, United Kingdom)
John Nielsen (Department of Fisheries and Oceans, Canada)
José De Oliveira (CEFAS Lowestoft Laboratory, United Kingdom)

Presenters and other attendees:
Beth Lumsden (PIFSC)
Kimberley Lowe (PIFSC)
Bob Humphreys (PIFSC)
Ivor Williams (PIFSC)
Matt Dunlop (PIRO)
Marlowe Sabater (WPFMC)
Steve Martell (IPHC)
Rick Methot (casual attendee)

Attendees of final wrap-up session:
Beth Lumsden
Robin Cook
John Nielsen
José De Oliveira
Steve Martell
Marlowe Sabater
Chris Boggs (Director, Fisheries Research and Monitoring Division at the Pacific Islands Fisheries Science Center)

Modified Agenda, as presented by Beth Lumsden, and what actually transpired:

Tuesday:
Introductions, Objectives and Terms of Reference - Beth Lumsden (PIFSC)
Hawaii Commercial Fishery-Dependent Data: Overview - Kimberly Lowe (PIFSC)
Reef Fish Life History Information - Bob Humphreys (PIFSC)
Reef Fish Visual Survey Program Data Gathering Overview - Ivor Williams (PIFSC)
Management overview of Coral Reef ACL Processes – Matt Dunlop (PIRO)
Coral reef fisheries in the Pacific Islands Region - Marlowe Sabater (WPFMC)
Review of modified integrated Catch-MSY stock assessment – Steve Martell (IPHC)

Wednesday to Thursday morning:
Continued review of integrated catch-MSY method on an interactive basis, with the development of an example application of the method for Lutjanid (American Samoa)

Thursday afternoon:
Closed session for CIE reviewers with Beth Lumsden to discuss review issues, held concurrently with, but separately to, a catch-MSY training workshop given by Steve Martell.

Friday:
Wrap-up session for the CIE review (held prior to continued training workshop).

Appendix 4

Errors in Martell (2015)

The paper by Martell (2015) documents the integrated catch-MSY method in terms of its scientific justification and mathematical derivations (based on the earlier work of Martell et al. 2008, Martell and Froese 2013, and Sabater and Kleiber 2014). It is therefore an important scientific document that should accompany the use of the integrated catch-MSY method along with the tools for its application. However, the paper in its current form contains a number of mathematical errors; given its importance, these errors should be rectified in Martell (2015), and checks made to ensure these errors have not tracked through to the package code. Furthermore, some of the descriptions in Martell (2015) are written as they appear in the code (i.e. as pseudo-code); although this may be efficient from the point of view of running the code, it may not be the clearest and most efficient way to present the method mathematically. Suggestions for alternative presentations of some of the equations are therefore also included below.

Errors were found in Martell (2015):

Equation (6):
Errors in the second and third lines:

$$\iota_a = \begin{cases} 1 & , a = 1 \\ \iota_{a-1} \exp(-M_{a-1}) & , 1 < a < A \\ \dfrac{\iota_{a-1}}{1 - \exp(-M_a)} & , a = A \end{cases}$$

Equation (11):
Similar errors to equation (6) in the second and third lines:

$$\hat{\iota}_a = \begin{cases} 1 & , a = 1 \\ \hat{\iota}_{a-1} \exp(-z_{a-1}) & , 1 < a < A \\ \dfrac{\hat{\iota}_{a-1}}{o_a} & , a = A \end{cases}$$

Equation (16):
Errors in the second and third lines:

$$\frac{\partial \hat{\iota}_a}{\partial \dot{f}} = \begin{cases} 0 & , a = 1 \\ \dfrac{\partial \hat{\iota}_{a-1}}{\partial \dot{f}} s_{a-1} - \hat{\iota}_{a-1} s_{a-1} \upsilon_{a-1} & , 1 < a < A \\ \dfrac{\partial \hat{\iota}_{a-1}}{\partial \dot{f}} \dfrac{1}{o_a} - \dfrac{\hat{\iota}_{a-1} \upsilon_a s_a}{o_a^2} & , a = A \end{cases}$$

Equation (28):
Error in the third line:

$$N_{t,a} = \begin{cases} \dfrac{s_0 B_{t-1}}{1+\beta B_{t-1}} & , a = 1 \\ N_{t-1,a-1}\exp(-z_{t-1,a-1}) & , 1 < a < A \\ N_{t-1,a-1}\exp(-z_{t-1,a-1}) + N_{t-1,a}\exp(-z_{t-1,a}) & , a = A \end{cases}$$

Equation (30):
Observed catch in the numerator?

$$F_t = \frac{\hat{C}_t}{\sum_a N_{t,a}\exp(-0.5M_a)w_a\upsilon_a}$$

Equation (34)
ln(q) should be the mean difference between the log-index and its logged model equivalent (assuming there are *n* such differences):

$$\ln(q) = \frac{1}{n}\sum_{t\in I_t}\left(\ln(\hat{I}_t) - \ln(B_t)\right)$$

Equation (40):
I have difficulty in understanding this notation. Would the following be correct?

$$l_{t,l} = \sum_a p_{t,a}\upsilon_a P(l \mid a)$$

Equation (42):
$(l_l)_t$ has not been defined, the notation is difficult to follow, and this doesn't seem to be a weighted mean (isn't that the intention?). Is the following correct and what was intended?

$$\overline{L}_t = \sum_l \left[\frac{l \times l_{t,l}}{\sum_l l_{t,l}}\right]$$

Alternatives to Equations (6), (11) and (16) (the latter two parameterised only in terms of *s*, *o* and *υ*):

Equation (6):

$$\iota_a = \begin{cases} 1 & , a = 1 \\ \exp(-\sum_{i=1}^{a-1} M_i) & , 1 < a < A \\ \dfrac{\exp(-\sum_{i=1}^{A-1} M_i)}{1-\exp(-M_A)} & , a = A \end{cases}$$

Equation (11):

$$\hat{\iota}_a = \begin{cases} 1 & , a = 1 \\ \prod_{i=1}^{a-1} s_i & , 1 < a < A \\ \dfrac{\prod_{i=1}^{A-1} s_i}{o_A} & , a = A \end{cases}$$

Equation (16):

$$\frac{\partial \hat{\iota}_a}{\partial \dot{f}} = \begin{cases} 0 & , a = 1 \\ -\left(\prod_{i=1}^{a-1} s_i\right)\left(\sum_{i=1}^{a-1} \upsilon_i\right) & , 1 < a < A \\ -\dfrac{\left(\prod_{i=1}^{A-1} s_i\right)\left(\sum_{i=1}^{A-1} \upsilon_i\right)}{o_A} - \dfrac{\left(\prod_{i=1}^{A} s_i\right)\upsilon_A}{o_A^2} & , a = A \end{cases}$$