Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources

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Executive Summary

The 2006 reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA) required that all regional management councils had to set annual catch limits (ACL) for all managed stocks. This mandate presents a challenge for the hundreds of reef-fish stocks managed by the Western Pacific Regional Fishery Management Council (WPRFMC) for American Samoa, Guam, the Commonwealth of the Northern Mariana Islands and Hawaii. Most of these fisheries are considered data poor and have not been managed under an MSY or its proxy. To effect management, the WPRFMC has grouped these species into family assemblages with especially vulnerable species considered separately. The WPFMC has a tier structure to set management control rules, with Tier 1 being data rich and Tier 5 as data poor. The majority of reef fish stocks have been managed under Tier 5. Data that are available include catch data from a combination of dealer reports, logbooks, and creel surveys depending on the area, but these data are incomplete and only provide a lower estimate of true catch. In addition species composition, average length and life history information are also available. Most recently, valid estimates of biomass are also available.

Because many of the world's fisheries are also considered data poor, models that can provide estimates of MSY or proxies have been a focus of stock assessment scientists. New models have been developed over the past decade (Rosenberg et al. 2014), and the catch-MSY model (Martell and Froese, 2013) has been a focus of worldwide interest. Tests of this model on temperate water fish species that have been subjected to significant harvest has shown that it provides a reliable estimate of MSY, with a tendency to overestimate stock biomass. The reef fish fisheries have the data needed to apply this model when they are aggregated to the family level. Thus the model provides a potential avenue to move reef fish from Tier 5 to Tier 3 management. NMFS has explored the value of this model by developing a Biomass-Augmented Catch-MSY model that has the option to include any reliable estimates of biomass that are available, thus tuning the model to observed biomass.

The meeting to review Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources had five terms of reference: 1) Review the Biomass Augmented Catch-MSY model: determine if the methods used to estimate MSY are reliable and adequate given available data; 2) Evaluate the model configuration, assumptions, and parameters, including NMFS biomass estimates: determine if input parameters seem reasonable, data are properly used, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty are accounted for; 3) Comment on the estimates of MSY and a clear statement on the soundness of MSY estimates for setting ACLs for stocks with, and without biomass data; if necessary, recommended values for alternative management benchmarks (or appropriate proxies); 4) Suggest alternative models and/or methods to reliably estimate MSY for coral reef ecosystem resources given the available data; 5) Suggest research priorities to improve our understanding of essential population and fishery dynamics necessary to formulate best management practices. The Review Team was able to discuss and evaluate all five terms of

reference and were in agreement on the value and limitations of this data-poor modeling approach.

We reviewed the modifications made by Pierre Klieber to the Catch-MSY model developed by Martell and Froese (2013). Modifications included incorporation of the available biomass estimates, randomization of the initially chosen categorical B_0 initial depletion starting value. In the Martell and Froese model specification, the categorical B_0 initial depletion starting value ranged from list of B_0 ordered from low to high, and they chose the first and therefore lowest value of B_0 as the beginning the simulated viable trajectory. Klieber's modification results in choosing the first B_0 that leads to a viable trajectory whether or not it is the lowest. Klieber achieved this by choosing the B_0 position in the list randomly without replacement. In both cases, the first viable trajectory is chosen, thus only one starting value is chosen. Klieber also expanded the possible range of K values by allowing K to range to a maximum of 500 times maximum catch. By building on the catch-MSY model, Klieber also incorporated the same R code including the method that Martell and Froese used in revision r and K values initially selected for a second pass of the model.

Overall, Klieber has improved the value of this model by greatly improving the code's documentation – it needs more documentation, by choosing parameters values more carefully, and by providing simulations specifically for reef fish fisheries. A singularly important addition was the use of available biomass estimate to eliminate r-K pairs that might otherwise have been accepted. Even with these improvements and as promising as the new Biomass-Augmented catch-MSY model appears, there are important issues to be addressed before the new model can be used to set MSY as the basis of reliable ACLs. The impact of the revision algorithm needs to be made explicit; the model needs more thorough documentation and justification for its revision algorithm; the impact of error in the catch time series needs to be modeled as does the efficacy of low harvest time series of uncertainty in the MSY calculations.

Background

In 2006, reauthorization of the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA) required that the regional management councils had to set annual catch limits (ACL) for all managed stocks. Additionally, the MSFCMA required that scientific and management uncertainty be considered when setting the ACL. Moreover, the over fishing limit (OFL) was defined as the catch that results from fishing at F_{msy}. The subsequent approach to setting the ACL by the management councils has been to add a buffer that decreases allowable catch commensurate with the uncertainty of data available to assess the stocks. These requirements have placed demands on stock assessment scientists to develop new models and methods to provide ACL for stocks that lack sufficient information for an age-structured analysis.

For the hundreds of reef-fish stocks managed by the Western Pacific Regional Fishery Management Council (WPRFMC) for American Samoa, Guam, the Commonwealth of the Northern Mariana Islands and Hawaii, most are considered data poor and have not been managed under an MSY or its proxy. They have been grouped into family assemblages with especially vulnerable species considered separately. Thus, stock assessments are now being done for family groupings, not individual species unless the species are vulnerable. The WPRFMC has a 5 tier management scheme and data poor reef fish species have been managed as tier 5 that provide only a catch history. Using catch alone, the WPRFMC sets acceptable biological catch (ABC) at 75% of historic catches. There are several drawbacks to this strategy: it imposes greater precaution in setting the ACL; as effort has declined and subsequently catches, there is a "ratcheting down" of the 75% measure of catch that doesn't match a decline in stock status; it does not use the biological and survey data that are available.

Data that are available include catch data from a combination of dealer reports, logbooks, and creel surveys depending on the area, but these data are incomplete and only provide a lower estimate of true catch. In addition species composition, average length and life history information are also available. Recent efforts to improve sampling have resulted in more reliable estimates of biomass provided by a fixed station underwater visual survey. To improve data available for assessment of these stocks, fisheries scientists have assigned levels of resilience as defined by Musick (1999) using approaches initially shown by Kimura et al. (1984) and Kimura and Taggart (1982).

The catch-MSY estimator (Martell and Froese 2013) has recently been applied to these reef fish. This model requires a catch history, an estimate of resilience, estimates of initial and final depletion, and some idea of productivity usually derived from life history parameters. The model is based on the Schaefer equation: $\widehat{B_{t+1}} = B_t + rB_t\left(1 - \frac{B_t}{B_0}\right) - C_t$. The model uses this basic equation with the input parameters to provide a range of potential r and K values which are in turn used to calculate MSY, also based on the Schaefer model as $MSY = \frac{rK}{4}$ where r is the intrinsic rate of population growth and K is the population carrying capacity. The catch-MSY model assumes logistic population growth with peak productivity at 1/2K. A deviation from the underlying logistic growth assumption will change is point of maximum productivity and its relative positioning to K. Model input requires an initial range of B_0 to start the chain of calculations and the starting levels are categorized based on the relative ratio of the initial catch to the maximum catch. Similarly the final biomass, B_n, is used to accept or reject the simulated series and is based on the ratio of final catch to maximum catch. The bounds on r are set by its resilience level and, in the original model, the maximum bound for K is set at 100 times the maximum catch.

This new method has gotten a lot of attention for use in data-poor populations. Rosenberg et al. (2014) report a detailed evaluation of the catch-MSY model and three others to use in data-poor fisheries. They developed extensive simulations that mimicked temperate fisheries under no to

high levels of depletion and state that the catch-MSY model performed the best. They found they the model tended to overestimate B_{MSY}, but worked the best of the models on short time series. Their tests were confined to species-population level evaluation. They state that such tests of the model should be extended to tropical species and to species complexes. They also note that for the model to be reliable, there must be an informative catch history.

The original catch-MSY model was modified by Pierre Klieber for use in setting ACLs for the recently been applied as the Biomass-Augmented Catch-MSY estimator to western Pacific reef fishes fisheries to provide estimates of MSY, thereby offering the possibility of raising these stocks from tier 5 to tier 3. It was this modified model that the CIE panel was asked to review.

Description of the Individual Reviewer's Role in the Review Activities

My role as a CIE reviewer at was to participate in the review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources meeting held at the National Marine Fisheries Service (NMFS) Pier 38 office, in Honolulu, Hawaii during June 30-July 3, 2014 (see Appendix 3 for meeting agenda) and to participate in discussions and deliberations. Background documents were sent by email. To prepare, I read and became familiar with the relevant documents provided to the panel by the NMFS scientists (Appendix 1) and literature upon which these models were based. I also reviewed additional literature that was available to illuminate this data-poor approach (Appendix 1).

I attended the review meeting from 8:30 on 30 June until 15:00 3 July (Appendix 3; meeting agenda). On June 30 and July 1, NMFS scientists presented the results of their new approach to modeling data-poor complexes and stocks in PowerPoint or Pdf presentations (Appendix 1). During these presentations, the Review Panel members asked questions about the model specifications and received clarifications. We asked for additional model runs in regard to evaluating how the models fit various taxonomic groups, and eliminated certain combinations of r and K. Formal presentations were finished by Tuesday, and the reviewers met on Tuesday afternoon, all day Wednesday, and Thursday afternoon to evaluate the model. To do so Dr. Haddon revised the Biomass Augmented Catch-MSY model that he downloaded from the website in Martell and Froese (2013) and provided model runs to illustrate undocumented issues, issues apparent from studying the code, and discussion otherwise missing or undocumented in the 2013 paper. Some of these issues were addressed in the revised model by Klieber, who modified parameter restrictions on starting and end biomass values, but the main features of the revision algorithm had been retained.

Summary of Findings for each ToR

ToR 1 – Review the Biomass Augmented Catch-MSY model: determine if the methods used to estimate MSY are reliable and adequate given available data.

Most, if not almost all, of the reef fish populations in the Pacific Islands Reef Ecosystems under U.S. management are data poor and are currently classified into management at the Tier 5 level, a tier in which stocks are managed on the basis of catch time series alone. The WPRFMC uses 75% of average catch from the time series to establish the ABC and ACL. Use of the Biomass-Augmented Catch-MSY model would permit many to be managed under Tier 3, which has harvest control rules based on estimated MSY. The result of this change in tier designation would be to provide a smaller precautionary buffer because of the greater information on which decisions can be made.

There are hundreds or more species in the Pacific Islands Reef Ecosystem complex. Sheer numbers of species and stocks alone make it very difficult to obtain all but the most rudimentary of statistics; thus, the species are grouped by family and area to logistically manage them. Species that are thought to be particularly vulnerable can be evaluated separately, as is being done by the WPRFMC. For these families, some information is known about catch, relative resilience, maximum age and size, relative growth rates, among others. Recently, reliable estimates of biomass are also available for a few years.

The Biomass-Augmented Catch-MSY model relies on having valid biomass estimates and these serve to scale the magnitude of catch and MSY. For this new model, the r-K pairs must not only produced viable trajectories that neither exceed K or decline to 0, but must also pass within the confidence bands of the observed biomass. There has been a paucity of valid biomass estimates for these families based on proper survey sampling techniques, such as stratification and obtaining a representative sample through randomization within strata. Recent estimates of biomass appear to satisfy proper sampling and, even though few, provide a legitimate estimate of biomass in time and area. The use of biomass estimates provides an improvement for these data poor species.

The original Catch-MSY model was developed by Martell and Froese (2013) and was based on the availability of a removal (catch + discards) time series and some knowledge of life history sufficient to evaluate potential r and K values. Their model uses the removal time series to test which r and K pairs provide biomass estimates that persist in the face of these removals and which neither collapse nor exceed K. These r and K combinations can then be used to calculate MSY (MSY=(r*k)/4). Moreover, the r and K trajectories are tested through a set of initial and final biomass depletion levels. The method of doing so is not clear from the paper itself, but is made clearer in the R code that is available by download. Further from these initial levels of B_0, the lowest category of B_0 is chosen with each iterated r and K that produces a viable trajectory. The initially successful r and K pairs are also subjected to further manipulation in a second pass

or revision. The Martell and Froese (2013) paper doesn't show the algorithm that is used to produce the r and k pairs used to calculate MSY and doesn't explain why the revision is done or why the values that modify the initial set of viable r-K pairs has been chosen. Again, this is available for inspection in the downloaded R code. This is a drawback to implementing the model and may reflects hasty publication of the paper.

We spent several hours trying to discern what exactly the revision of r-K values was doing and what impact it had on the production of MSY values. Although Malcolm Haddon added code in the Martell-Froese model to provide us with plots of the intermediate values so as to clarify precisely what this component of the model was doing, I am afraid that what this section of code is providing is still unclear to me and no explanation is provided in the paper. When the reviewers are revising code to show intermediate plots, it reflects a significant lack of adequate documentation of the model. Inadequately documented and tested models may not provide reliable estimates of MSY.

The Biomass-Augmented Catch-MSY model that we reviewed improves on the Martell and Froese model. Pierre Kleiber modified the original code in several ways that address concerns with the original model. The addition of biomass estimates, when available, allows further and more realistic evaluation of the r-K pair trajectories. The r-K pairs which do not generate biomass estimates that pass through the confidence bands of the observed biomass can be eliminated as unrealistic. In this sense, the MSY calculated from the r-K pairs are also more realistic. The new model also used modified criteria to establish the initial and final B depletion values; had greater expansion of K values (500 times maximum catch), and randomly picked the starting B_0 category to begin the calculated trajectory. The new code also has greatly expanded documentation to help the user understand how the model is constructed. Such documentation is commendable and I encourage even more to make the code clearer, e.g. the values chosen for the revision algorithm. However, the new model maintained the revision code and its values with only minor modification. Hence the criticism that applies to the Martell-Froese model also applies to the new model. The impact of the revision of r-K values and the limits used in the revision algorithm are unclear and inadequately documented.

This ToR requests me to provide my opinion on whether the new model provides reliable estimates of MSY. This is a difficult task because more testing is needed to clarify the model output and without which I can't make this evaluation. There are two points in particular that give me pause: 1) I don't yet know what the revision code is actually doing, and 2) I am uncertain that the frequency of the MSY values from the r-K pairs is a true measure of likelihood as I will discuss below.

ToR 2 – Evaluate the model configuration, assumptions, and parameters, including NMFS biomass estimates: determine if input parameters seem reasonable, data are properly used,

models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty are accounted for.

Model configuration, assumptions, and parameters- The Biomass-Augmented catch-MSY model as configured by Pierre Kleiber improves on the Martell-Froese model because it restricts the r-K pairs to those that best conform to the limited but empirical estimates of reef fish biomass. Model assumptions include the level of resilience of a stock (to set the r values over which to search) and the assumed ranges of initial and final depletion for the catch time series (based on the ratios of initial and final catch to the time series maximum). An additional assumption underlying the Schaefer model and its calculation of MSY is that the population grows logistically. We have no information on whether these stocks grow logistically or not and cannot evaluate this assumption. There is potential to modify this method in the future to permit another formulation of population growth such as a Pella-Tomlinson, should that be warranted. The r-K parameter space from which the pairs are drawn are based on the resilience estimate which sets the r range from the resilience of the most abundant species in the catch. The resilience classification limits the range of values from which r is drawn, and thus the potential range of K values associated with the successful pairs. The resilience estimates are taken from FishBase, which are published and have been peer-reviewed. The level of initial and final depletion is more difficult to discern as it is thought that most of these species have not been heavily exploited and, most recently, effort has declined not because of decline in abundance but because of social changes. In the model, the initial and final catches are compared to the maximum in the catch time series. If the ratio (λ) is small, then it is assumed that there has been little depletion. In a heavily exploited fishery the maximum would be at or near t_0, indicating that the windfall biomass had been removed. Thus comparison to maximum catch provides an initial estimate of depletion in data-poor stocks. Given the paucity of data for these fisheries, the model assumptions are reasonable.

Biomass estimates – Biomass estimates are provided by the Rapid Assessment and Monitoring program using an underwater visual stationary point count method. Previously, the count method was not done at randomized locations (within appropriate habitat), nor were locations stratified. Recent changes to procedures have provided stratified random samples. Biomass estimates are summed to family level. These recent estimates have followed valid statistical survey techniques. Nonetheless, it was surprising to see biomass estimates with very low CVs and I wonder if the expansion of point counts was evaluated correctly. Often the use of stratification will decrease the total variance, but not usually by this much. I didn't have access to the estimation procedures, but would recommend that the CVs be reviewed for accuracy. Even though there are few years of reliable biomass data, the availability of these data are important, will increase with time, and will provide better tuning for the model.

Input parameters reasonable – The use of resilience in limiting the range of r values is justified and is founded on the best available data. Because the resilience at the family level is set from the resilience of the dominant species in the catch of that family, the model output better reflects a family with consistent resilience values and might over or under estimate species within the

family with differing resilience. The parameters σ and ρ seemed reasonable. Moreover, because Kleiber modified the R code to randomly chose the candidate B_0 and not just the lowest as in the Martell and Froese model, there is a better estimate of the frequency of r-K successful pairs and resultant MSY calculated from them.

Data properly used – The statement of task stated that we were not to comment of the data quality. However, some issues of data quality affect whether the data were properly used. There was a disparity in the completeness of the available data. Reef fish are subjected to commercial and recreational harvest and to some extent an artisanal fishery. The catch time series should include all three. For Hawaii, only the commercial catch was used. It is generated from dealer reports that should be accurate. However, I observed anglers during my brief visit and would be concerned that there may be recreational harvest that could alter model estimates of MSY. Documents provided by NMFS stated that the Hawaiian recreational data will be undergoing reevaluation and should be included in future catch time series. For the other islands, both recreational and commercial landings were part of the catch time series and can be considered properly used.

Model appropriately configured – It is hard to say whether the model is properly configured because of the lack of documentation for the revision algorithm of r-K pairs. In the first pass of the model, 30,000 values of r and K are chosen from the r range determined by resilience and the K range chosen up to 500 times the maximum catch. For each r-K pair the abundance trajectory is calculated using the Schaffer equation and accepted if the abundance neither exceeds K nor drops to zero through the calculated trajectory. Of these pairs that pass, a further refinement of their ranges is done. The new r range is chosen as the lowest of the r values that passed to 1.2 times the maximum r value that passed. There is no documentation of why the value of 1.2 is chosen. There are two options for the revised K range, one that is based on the minimum passing K value given and r of less than 1.1 times the minimum of the first successful r range. Again, the choice of 1.1 is not documented, nor is the reason for the revision. We explored the effect of the revision algorithm through Malcolm Haddon's recoding of the Martell and Froese code, but had insufficient time to clarify the reason for these choices. These are important issues in the application of this model and need to be clarified before the model is used to set MSY.

Uncertainty accounted for - A standard approach in accounting for uncertainty is use of Bayesian analyses. In a Bayes analysis the observed data (in this case the catch time series) would be combined with a prior distribution of the parameters that underlie catch, to produced a posterior distribution wherein new and better estimates of the underlying parameters and their distributions would be generated to show likelihood profiles of the parameters. The posterior distribution is chosen from use of the Gibbs sampler, the Metropolis-Hastings algorithm, grid sampling and similar procedures. The approach that was done for the original and Biomass - Augmented modification did not strictly follow this approach, although they did use 30,000 iterations of randomly chosen combinations, from the priors for r and K chosen as stated above, to provide a frequency of those r-K values that could have generated population biomass

sufficient to render the observed catch time series. It was less clear if the frequency distribution was a full measure of uncertainty because the values of r-K produce a potential biomass, while the input data isn't biomass but rather the catch time series. There are too few biomass estimates to do this directly, but as more biomass estimates are accumulated the type of approach may be possible. However, these values depend on the information content of the observed catch time series. Within the limitation of the method and the data available, the Biomass-Augmented catch-MSY does produce a distribution that is the best representation of uncertainty available now.

ToR 3 - Comment on the estimates of MSY and a clear statement on the soundness of MSY estimates for setting ACLs for stocks with, and without biomass data; if necessary, recommended values for alternative management benchmarks (or appropriate proxies).

The development of the Biomass-Augmented catch-MSY model is an important effort in moving the reef fish assemblages from a data-poor to a higher tier status. The Martell and Froese model is a clever approach that they were able to show worked well with heavily exploited fish stocks of the Northeast Atlantic where catch has had a profound impact on stock abundance and biomass. This model was further tested by Rosenberg et al. (2014), but again on temperate species – not families or tropical species. Even though Martell and Froese original model did not use observed biomass data, the high ratio of catch to biomass drove the abundance trajectory and resulted in probable values of r-K and the subsequently calculated MSYs. Unlike the species that were used to validate the original model, the reef fish families are thought to be more lightly fished especially most recently as interest in being a fisherman has declined with economic and social changes on the islands. Hence, declines in catch may not reflect a decline in abundance in recent years and, if relatively lightly fished historically, fluctuations in catch may not have influence biomass. Under these circumstances, Martell and Froese (2012; page 507) state that the model may not provide reasonable measures of MSY in lightly exploited stocks.

The Biomass-Augmented model adds reality to the catch-MSY model under the circumstances of more lightly exploited stocks where the catch time series is less informative. It acts to restrict the potentially successful r-K pairs to only those that go through the confidence intervals of those biomass points. It also acts to more properly scale the MSY calculation from the reef fish families that might be less reliable otherwise. By theory, these calculations of MSY should provide a good scope of coverage of true MSY, but without a clarification of why the revision algorithm has been parameterized as it has been, I am not confident that I can fully endorse the soundness of the MSY estimates for setting ACLs until more testing and documentation of the new model are completed. I can say that the method appears promising.

ToR 4. Suggest alternative models and/or methods to reliably estimate MSY for coral reef ecosystem resources given the available data.

In 2012, I participated in the NMFS Data-moderate and Data-poor Modeling Panel, held in Seattle. At that time, the panel reviewed inputs to the data-moderate and data-poor models including: B_{MSY}/B_0; F_{MSY}/M; M/k; DB-SRA; and a new modification of the SS to handle data poor species. I comment on the applicability of these methods to the reef fish families.

B_{MSY}/B_0; F_{MSY}/M; M/k – For that panel, the ratio of B_{MSY}/B_0 for U.S. west coast stocks was estimated from the shape parameter of the Pella-Thomlinson model and differed depending on family. I doubt that this method would provide better estimates than the Biomass-Augmented catch-MSY model. Although the fisheries literature historically suggested that F could be substituted for M to yield sustainable harvests, this view has been modified to reduce this ratio to 0.8 or less depending on the species. Moreover, fisheries scientists have used life-history invariants to search for general patterns across stock vulnerabilities. In 1992, Beverton published on the differences in M/k between different families of exploited fish, but these families were all temperate species. To my knowledge, there has been no detailed study for reef fish such as was done by Beverton and as was done by Dr. Thorson for West Coast stocks to provide posterior distributions of M and K, that could inform estimates for data-moderate species and permit measures of uncertainty. There appears to be insufficient information on the reef fish stocks to use this approach. It might be an alternative approach that NMFS could pursue. Such an approach might augment the new Biomass-Augmented catch-MSY model approach.

DCAC; DB-SRA- The DCAC and DB-SRA are models that are being used in stock assessments when only catch data are available for a species. During the 2012 panel, Dr. E. J. Dick used a Productivity-Susceptibility Analysis (PSA) to improve the delta priors in DB-SRA. He showed a negative linear relationship between vulnerability (from PSA) and depletion. This regression worked well in heavily exploited stocks but not with lightly exploited or stocks. Moreover, because the reef fish stocks are thought to be lightly exploited, these methods are not likely to provide reliable estimates to improve assessment.

In 2014, FAO published a review (Rosenberg et al. 2014) that included stock assessment approaches for data-poor stocks which included Modified panel regression (mPRM; Costello et al. 2012), modified catch-MSY (CMSY- the Martell and Froese model), catch-only model with sampling importance resampling (COM-SIR; Vasconcellos and Cochrane 2005), and state-space catch only model (SSCOM; Thorson et al. in draft). The code for these models can be downloaded from ftp.fao.org/FI/STAT/Rfiles/C1086.zip. Rosenberg et al. report that these four models were subjected to a simulation framework that allowed a cross platform comparison of their performance against a range of population characteristics of demersal fish, small and large pelagics. None of the models was tested for reef fish, but there may be a benefit is using one or two of these as an alternate approach to the Biomass-Augmented catch-MSY model. One that seemed interesting was the COM approach which uses estimates of catch and biomass which has very similar data requirements to the catch-MSY model. The COM relies on the catch equation

based on the Schaffler model also: $\widehat{C_{t+1}} = P_{t+1}\left[B_t + rB_t\left(1 - \frac{B_t}{K}\right) - \widehat{C_t}\right]$ (Rosenberg et al. 2014; p 11 eq 3).

ToR 5 -Suggest research priorities to improve our understanding of essential population and fishery dynamics necessary to formulate best management practices.

1. Expand documentation, simulation and testing. As much as I value the potential that the Biomass-Augmented catch-MSY approach and the work that Pierre Klieber has done to document the R code, there needs to be more documentation, and simulation and testing before it should be used to set ACL. The first priority is to document the revision algorithm, provide a full explanation as to the parameters chose to revise the r and K ranges, and to provide simulations that document how the revision changes the frequency of final r-K values as these are used directly to calculate MSY. A change in the r-K distribution will lead to a change in the MSY distribution. Although Dr. Malcolm Haddon revised the Martell and Froese R code to print out some of the changes in frequency distributions, we did not have the time to investigate these differences in any but a cursory way. In their evaluation of the catch-MSY method, Rosenberg et al. (2014) also state that the model needed more testing on tropical species.
2. Compare the model's projections with those of an alternate modeling approach where possible. This was a recommendation of NRC in 1998 when new models are being considered and that is especially important in this situation where the original model has not been thoroughly tested. One model to consider is the catch-only model (COM-SIR; Vasconcellos and Cohran, 2005) for example.
3. The input catch in these data poor models are assumed to be measured without error. It would be useful to test this assumption especially in those families that have moderate-to heavy levels of exploitation.
4. In several instances, the catch time series is incomplete lacking one or more of the harvest sectors. For example, the Hawaii catch time series does not use recreational catch. These data should be available through the new NMFS MRIP procedures and, should be included in that time series. A management strategy evaluation might help to assess if this causes unreliable model output.
5. There was no management strategy evaluation for this data-poor assessment model, and this should be part of further work with the model.
6. The WPRFMC is using a P*=.4, but simulations using other levels would be informative. This P* level is widely used, but a more thorough investigation would be advisable. Weidenmann and his colleagues used such simulations to investigate P* on other models for data-poor species (Final Progress Report to the Mid-Atlantic Fishery Management Council, August 31, 2011); I found that report enlightening and think that such approaches are invaluable in understanding performance of new models.

Appendix 1: Bibliography of materials provided by NMFS for review

Bibliography of materials provided by and presentations used for review

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Presentations during the review

Report on P* Working Meeting	Sabater
A Clinical Presentation of the Anatomy of an ACL	Klieber &
Modified "Catch-MSY" method for setting ACLs for coral reef species	Sabater
Data preparations for the Back-Missy! model	Sabater
Initial ACL specification and the need to improve.....	Sabater

Appendix 2: A copy of the CIE Statement of Work

Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources

Scope of Work: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract that provides external independent experts 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 Representative (COR), and reviewed by the contractor for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. The reviewers are selected by the contractor's Steering Committee and Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each reviewer is contracted to deliver an independent peer review report to be approved by the contractor's 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 reviewers for conducting an independent peer review of the following NMFS project.

Project Description: In October 2013, the Western Pacific Fishery Management Council hired a contractor to develop a modified Bayesian modeling approach to generate maximum sustainable yield (MSY) estimates for coral reef family groups by using available catch time series, a measure of population growth (*r*), carrying capacity (*k*), and biomass from NMFS underwater fish census surveys. This model, termed the Biomass Augmented Catch-MSY model, is based on the Catch-MSY model developed by Martell and Froese (2012), but differs in that it incorporates biomass data. The resulting MSY estimates generated from the Biomasss Augmented Catch-MSY model is the foundation upon which the Council and NMFS will base management decisions for Pacific Island coral reef fisheries, including establishment of annual catch limits (ACL) starting in 2015. An independent peer-review of the Biomass Augmented Catch-MSY modeling approach will provide valuable feedback to the Council and NMFS in setting ACLs. The ToRs of the peer review are attached in **Annex 2**.

Requirements for the Reviewers: Three external reviewers shall have the necessary qualifications to complete an impartial and independent peer review in accordance with the SoW tasks and ToRs specified herein. The reviewers shall have expertise in population modeling and stock assessment, as well as Bayesian statistics to complete the tasks of the peer-review described herein. Each reviewer shall attend the independent peer review in person, Therefore, travel is required, and will be paid for by the contractor.

Location of Peer Review: The CIE reviewers shall participate during a panel review meeting during June 30 through July 3, 2014 in Honolulu, Hawaii.

Statement of Tasks: Each reviewer 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 reviewer selection by the contractor's Steering Committee, the contractor shall provide the reviewer contact information to the COR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The contractor is responsible for providing the SoW and ToRs to the reviewers. The NMFS Project Contact for the review is responsible for providing the reviewers with the Biomass Augmented Catch-MSY report and other pertinent background documents for the peer review. Any changes to the SoW or ToRs must be made through the COR prior to the commencement of the peer review.

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 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 contractor's Lead Coordinator on where to send documents. The 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 reviewers shall read all documents in preparation for the peer review.

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

Specific Tasks for the Reviewers: The following chronological list of tasks shall be completed by each 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) Conduct an impartial and independent peer review in accordance with the tasks and ToRs specified herein, and each ToRs must be addressed (**Annex 2**).
3) No later than July 17, 2014, each reviewer shall submit an independent peer review report addressed to the contractor's Lead Coordinator. Each report shall be written using the format and content requirements specified in **Annex 1**, addressing each ToR in **Annex 2**.

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

May 12, 2014	The contractor sends the reviewer contact information to the COR, who then sends this to the NMFS Project Contact of the review.
May 26, 2014	NMFS Project Contact sends the reviewers background documents, including the Biomass Augmented Catch-MSY report.

June 30 – July 3, 2014	The reviewers attend the panel review meeting in Honolulu, Hawaii
July 17, 2014	The reviewers submit their draft independent peer review reports to the contractor's Lead Coordinator and Regional Coordinator
July 31, 2014	The contractor submits the independent peer review reports to the COR
August 7, 2014	The COR distributes the final reports to the NMFS Project Contact and NMFS Pacific Islands Fisheries Science 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 ToRs, or schedule of milestones resulting from the fishery management decision process of NMFS Leadership and the Council. 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 COR within 10 working days after receipt of all required information of the decision on changes. The COR 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 reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The ToRs shall not be changed once the peer review has begun.

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

Applicable Performance Standards: The contract is successfully completed when the COR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:

(1) Each report shall completed with the format and content in accordance with **Annex 1**,

(2) Each report shall address each ToR as specified in **Annex 2**,

(3) Each 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 COR, the contractor's Lead Coordinator shall send via e-mail the final reports in *.PDF format to the COR. The COR will distribute the reports to the NMFS Project Contact and Science Center Director.

Support Personnel:

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Annex 1: Format and Contents of Independent Peer Review Report

1. Each independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of each 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.

   Each independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. Each independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review

   Appendix 2: A copy of the Statement of Work

Annex 2 – Tentative Terms of Reference

Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources

1. Review the Biomass Augmented Catch-MSY model: determine if the methods used to estimate MSY are reliable and adequate given available data.
2. Evaluate the model configuration, assumptions, and parameters, including NMFS biomass estimates: determine if input parameters seem reasonable, data are properly used, models are appropriately configured, assumptions are reasonably satisfied, and primary sources of uncertainty are accounted for.
3. Comment on the estimates of MSY and a clear statement on the soundness of MSY estimates for setting ACLs for stocks with, and without biomass data; if necessary, recommended values for alternative management benchmarks (or appropriate proxies).
4. Suggest alternative models and/or methods to reliably estimate MSY for coral reef ecosystem resources given the available data.
5. Suggest research priorities to improve our understanding of essential population and fishery dynamics necessary to formulate best management practices.

Appendix 3. Meeting Agenda

Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources

June 30-July 3, 2014

NOAA Fisheries Service Center, Pier 38
Honolulu, Hawaii

AGENDA

Monday – June 30 (9:00 am to 5:00 pm):

1. Opening remarks and introductions — Robert Skillman
2. Overview of the review process — Gerard DiNardo
    a. Review of Scope of Work
    b. Review process mechanics
3. Background presentations
    a. MSRA requirements for Annual Catch Limits — Jarad Makaiau
    b. Initial ACL specification and the need to improve — Marlowe Sabater
4. Presentation on the data preparation for the model-based approach — Marlowe Sabater
5. Presentation on the Biomass Augmented Catch-MSY model — Pierre Kleiber
6. Discussion and questions to presenters — Review Panel
7. Public comment — Robert Skillman

Tuesday – July 1(9:00 am to 5:00 pm):

8. Presentation on the P* Analysis — Marlowe Sabater
9. Discussion and questions for presenters — Review Panel
10. Review panel deliberations and report writing (closed) — Review Panel

Wednesday – July 2 (9:00 am to 5:00 pm):

11. Review panel deliberations and report writing (closed)

Thursday – July 3 (9:00 am to 12:00 pm):

12. Review panel reports on findings and recommendations — Review Panel Chair
13. Adjourn

Review Panel:

Dr. Cynthia Jones:	Director for Center for Quantitative Fish Ecology, Old Dominion University, Norfolk Virginia
Dr. Malcolm Haddon:	Senior Fisheries Modeller, CSIRO Marine and Atmospheric Research, Hobart, Australia
Dr. Robin Cook:	Senior Research Fellow, LT802 Livingstone Tower, Scotland