Center for Independent Experts (CIE) Peer Review of the Biomass Augmented Catch-MSY Model for Pacific Island Coral Reef Ecosystem Resources

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Executive Summary

The BAC-MSY methodology, like almost all data-poor methods, invariably provides an output; in this case a mean estimate of MSY plus a range of possible values around that mean. The simpler Catch-MSY method, upon which it is based, has undergone extensive empirical comparisons with MSY estimates from fully quantitative stock assessments and the method appears to be at least as reliable as other data-poor catch-based methods. As such this method is suitable for the estimation of ACL values in the coral reef fisheries. However, it needs to be emphasized that all such data-poor methods will be inherently uncertain and so discretion and care is needed in the use of words such as 'reliable' and the expectations placed upon estimates deriving from such methods.

The addition of biomass estimates to the Catch-MSY method to form the Biomass Augmented Catch-MSY method should invariably improve any estimates of productivity and hence MSY. Eventually, given sufficient biomass estimates this data-poor method holds the potential of evolving into a more inclusive model that would be fitted to the data rather than finding parameter combinations that are simply consistent with the data.

To improve the defensibility of the method it is recommended that the robustness of the model outcomes be tested for sensitivity to uncertainty in the assumptions concerning data uncertainty, uncertainty in the initial and final depletion levels, some choices regarding constraints placed on the selection of acceptable parameters, some structural choices, and related details. This testing would require management strategy evaluation of some form to allow for the investigation of such details.

The data collection, the data processing, and the BAC-MSY methodology need detailed documentation. In addition, criteria need to be developed for deciding when a data set or particular data point is insufficiently representative of the fishery or in some other defensible way flawed to such an extent that it should not be included in the assessment analysis. Similarly, criteria are required for determining when an analysis using the BAC-MSY method would be inappropriate and a fall back methodology utilized to produce ACL values.

Recommendations

- It is recommended that before the next round of ACL setting in the coral reef fisheries a management strategy evaluation of the BAC-MSY method is made to explore its strengths, limitations, and robustness to uncertainty.
- It is recommended that the methodology for both the data collection and processing and the model implementation both require detailed documentation to improve the defensibility of the analytical strategy.
- It is recommended that a detailed review be undertaken of the data collection and processing to prepare the data for analysis in the assessment method. Criteria need to be developed for deciding when a dataset or data point is atypical, not representative of the fishery, or constitutes an outlier. In this way ad hoc decision during the analysis can be avoided and the outcomes would become more defensible.
- It is recommended that the model outcomes be tested for their sensitivity to the resilience value selected for a particular species complex. Intuitively the inclusion of biomass estimates should reduce the effect of a misclassification; nevertheless, the

potential errors introduced through a misclassification of resilience should be explored within the MSE simulation testing.
- It is recommended that while improving and testing the BAC-MSY methodology, the literature on data-poor methods be kept up to date so as to monitor published tests of currently available methods and to look for alternative methods that may prove simpler, cheaper, or more appropriate for the coral reef fisheries under consideration.

Research Priorities
- It is recommended that management strategy evaluation simulation testing be applied to the major assumptions behind the BAC-MSY and Catch-MSY methodology; including comparisons with the 0.75 Maximum Catch for completeness.
- It is recommended that the catch and survey data used in the BAC-MSY method be explored to develop criteria for determining their representativeness of the stock and fishery as a whole. This is necessary to remove doubts that derive from what appear to be exceptional values of precision and disparities between the catches and the biomass.
- It is recommended that the general need to improve the documentation of the methods used in both the data compilation and the assessment methods be addressed before the next round of ACL setting; especially to justify or explain the selection of the various assumptions and default values used in the selection process of r – K pairs.

Background

Statement and History of the Problem

The Magnuson-Stevens Fishery Conservation and Management Act (MSA: U.S. Department of Commerce, 2007) requires each fishery council to generate a fishery management plan for each fishery under its authority that requires conservation and management. Within that plan the councils also need to develop annual catch limits (ACLs) for each of its managed fisheries (MSA, p67 – 68). This was a serious challenge for the Western Pacific Regional Fishery Management Council which is responsible for the coral reef fisheries in the Western Pacific. These fisheries are comprised of thousands of species, many of which only experience relatively low levels of catch. The major difficulty for these fisheries is that there are only catch data available along with some survey estimates of biomass for some of the major fish families. Further, there are no marine protected areas on most of the coral reef fisheries, there are no size limits, and they are only loosely managed with no near time catch reporting.

To address the requirement of setting ACLs based primarily on previous catch data, the Council initially attempted to use a set proportion of the historical catch levels (the 75th percentile of the past catches). However, it is well recognized that fishing effort across the islands has greatly reduced in recent years and that local catches are correspondingly reduced. The Council quickly realized that using the 75th percentile of previous catches would lead to excessively conservative catch limits. In addition, it was pointed out that if the fisheries proceeded with ACL set at 75% of previous catches and those catches were added to the time series then the ACL would be ratcheted downwards as time progressed. Their objections included that only one data set was used, that the creel survey catch data were not the whole catch, that not all areas or fishing periods were covered, and finally that the catch data had been affected by recent improvements in data collection. Given these issues alternative approaches for setting the ACL were explored (WPRFMC, 2013a, 2013b, 2014).

After consideration of a number of alternatives, one of the simplest methods was selected for further investigation: the Biomass Augmented Catch-MSY method (Martel and Froese, 2013; Sabater and Kleiber, 2013). This method is well suited to the available data from the coral reef fisheries in that it requires only a time series of catch data plus a few assumptions about initial and final depletion levels. The strategy is to use a surplus production model and search for the model parameter combinations in addition to the catches to generate biomass trajectories that do not lead to extinction or run-away population growth. The resulting sub-set of possibilities is used to generate an estimate of maximum sustainable yield and this can be used to produce management advice. In addition, the assumptions concerning depletion can be relaxed to a large extent if there are any biomass estimates that can be used to constrain what constitute acceptable biomass trajectories.

Because the catch statistics are often not to species level these approaches to generating estimates of the ACL were restricted to aggregations of species into family species complexes. Despite this aggregation there were still over 100 fisheries recognized for which ACLs were required. Another advantage of the Biomass Augmented Catch-MSY method was that it could be automated to deal with many species quickly once the methods had been developed.

The review objectives were:

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.

Review Activities

The documents listed in the first part of Appendix 1 were received on 19th June 2014. The other documents listed in Appendix 1 were obtained from a variety of sources. The review documents were limited in the detail in which the use of data-poor methods in general were being considered, but the other documents listed in Appendix 1 were of value in understanding the context in which the allocation of ACLs was being made.

The review itself was held at the NOAA Fisheries Honolulu Service Center at Pier 38, 1129 North Nimitz Hey, Suite 220, Honolulu, Hawaii over the period Monday 30th June – Thursday 3rd July 2014. Presentations and discussions were made over the Monday and Tuesday, then further questions and report writing occurred on the Wednesday and a final de-briefing and more report writing on Thursday 3rd July.

The review started with Gerard DiNardo leading formal introductions and providing a description of the review process. This was followed by presentations which were inter-mixed with discussion.

Five presentations were given, each of which engendered discussion:

Pierre Kleiber and Marlowe Sabater: Modified “Catch-MSY” method for setting ACLs for coral reef species. *Alternative to setting allowable catch to percentage of historical catch*. This was a description and explanation of how the Catch-MSY method had been modified and applied to the coral reef fishery.

Jarad Makaiau: A Clinical Presentation on the Anatomy of an ACL. This was a thorough explanation of the requirements and constraints under which Annual Catch Limits are to be set. A detailed example using the assessment for the Deep 7 Bottomfish fishery was provided (Brodzial *et al.,* 2011).

Marlowe Sabater: Initial ACL specification and the need to improve…. This was a detailed description of the initial attempts to tackle the data-poor situation. It included the establishment of the family level species complexes, the guidelines for using time series of data, the selection of the 75th percentile, and the subsequent requests for alternative methods to calculate the ACLs.

Marlowe Sabater: Report on the P* Working Group Meeting. This was a description of the Productivity and Susceptibility analysis required in the assessment process or the coral reef fisheries. This again used the assessment of the Deep 7 Bottomfish complex (Brodzial *et al.,* 2011) as a further detailed example.

Marlowe Sabater: Data preparations for the Back-Missy! Model. This was a description of the data sources and survey designs that when combined give rise to the commercial catch statistics and the biomass estimates used in the subsequent application of the Catch-MSY model.

List of People Attending:

Center for Independent Experts (CIE) Reviewers

Robin Cook,
Malcolm Haddon,
Cynthia Jones

National Marine Fisheries Service Staff

Gerard DiNardo
Pierre Kleiber
Jarad Makaiau
Marlowe Sabater

Observers

Martha Maciasz, Hawaii Pacific University
Merrill Rudd, University of Washington

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Summary of Findings

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

Because data-poor methods are so simple they will typically provide a result in most situations; the question that then arises is whether or not the result gained is both plausible and valid. The Biomass Augmented Catch-MSY method (BAC-MSY) is a variant on the Catch-MSY method described by Martell and Froese (2013). The Catch-MSY method requires only a time-series of catches to which it adds a number of assumptions that eventually leads to an estimate of MSY for the fishery being assessed. The assumptions are that the dynamics can be adequately described using a simple surplus production model and that inferences can be made about the possible range of initial and final biomass depletion levels from the initial and final catches relative to the maximum catch. The surplus production model used (see Haddon, 2011, Ch. 11) only has three parameters: an initial biomass level, B_1, a carrying capacity or unfished biomass, K, and a population growth rate, r. The initial biomass is expressed as a set of fixed values across the range of the chosen initial depletion levels; thus, if the initial range is from 0.3 – 0.6 the values selected might be p = {0.3, 0.333, 0.366, 0.4, 0.433, 0.466, 0.5, 0.533, 0.566, 0.6}; the B_1 are then calculated as $B_1 = p.K$. The r and K parameter combinations are selected N times at random, from pre-specified ranges, which were much wider than plausible (N is a large number, such as 30,000). When these parameters are combined with the observed catches using the surplus production model:

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t \tag{1.1}$$

where B_t is the biomass in year t and C_t is the catch taken in year t. Given combinations of r, K, and $p(=B_1)$, equ (1.1) produces a biomass trajectory describing the predicted biomass in each year defined by the time series of catch data, as well as for the immediately following year (finalyear + 1; as in t+1). Only those rK combinations are accepted that generate biomass trajectories that do not lead to extinction (predicted biomass of zero or negative biomass) or lead to run-away population growth (defined as a population size greater than K). These constraints generate a sub-set of the possible combinations of r and K. The method adds a further step of slightly expanding the ranges of the r and K obtained from the first selection process and then re-running the selection process so as to increase the number of example parameter combinations within the acceptable ranges. Using the simple surplus production model it is possible to estimate MSY, and other fishery statistics with simple formulations:

$$MSY = \frac{rK}{4} \qquad B_{MSY} = \frac{K}{2} \qquad F_{MSY} = \frac{r}{2} \tag{1.2}$$

Once the MSY estimate is produced, along with an uncertainty interval around it, management advice can be developed.

In addition to catch data many of the coral reef fisheries have occasional abundance estimates derived from survey data. The addition of these biomass estimates have been used to articulate the Catch-MSY method somewhat further than expressed in Martell and Froese (2013); although their R-code included a framework for using a single biomass estimate but this was not documented in the publication. By including occasional biomass estimates the assumptions concerning initial and final depletion can be relaxed to a large extent as the biomass estimates can be used to constrain what constitute acceptable biomass trajectories. The novel aspect of the BAC-MSY method was the implementation of a method for including a small number of separate biomass estimates into the constraints imposed on the Catch-MSY model (Sabater and Kleiber, 2014).

Given catch data and a very limited number of biomass estimates, then, assuming that the catch estimates are representative of the fishery as a whole, and that the biomass estimates are un-biased, then the BAC-MSY approach will provide an estimate of MSY that can be used as the basis for recommending ACL values.

The only testing that has been applied to this method is to apply the method to data from stocks that have undergone full quantitative stock assessments to determine whether it is capable of generating MSY estimates that are similar to those from the formal stock assessments. Generally these tests were successful in that there was a good relationship between the two sources of MSY estimate. Nevertheless, before full confidence can be placed in this methodology it should really be formally tested using a Management Strategy Evaluation simulation framework. How the method would perform if any of the assumptions made were mistaken is unknown and simulation testing is effectively the only way this could be determined.

While the BAC-MSY method certainly needs to be MSE tested it remains the case that it provides a good match to available data in that the only data available are catches and occasional biomass estimates. It does provide an estimate of MSY and so the method is clearly adequate to the task but the reliability cannot be fully judged without the simulation testing.

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.*

The scale of the task of setting ACLs for over 100 family level species complexes was clearly difficult in the time available, which is reflected in the documentation of the model and project. It is true that the R code (R Core Team, 2014) was made available and that constitutes a form of complete documentation; nevertheless, in the next iteration of the process of setting ACL it is recommended that efforts be made to fully document exactly what was done and how things were done. The model configuration works and automates the process once the available data is codified into the correct format and such automation will be required for a task of this scale.

Assumptions

There are a number of important assumptions which need clarification, improved documentation, and formal testing. For example, the upper limit on biomass throughout each time series of predicted biomass levels is set at K. However, there are many fished species, especially those with more variable or even episodic recruitment dynamics that might frequently lead to their population rising above the theoretical unfished maximum. That maximum is an equilibrium, average concept. The net result is that this upper constraint is too restrictive for such species, which means it is prone to identification of false negatives. This effect may be ameliorated by the fact that species complexes are being used, which may smooth over such variations with the rise and fall of different species

If one calculates the harvest rate by dividing the observed catches in a year with the predicted biomass in the same year, leading to a predicted biomass in the following year by using equ (1.1), then it is possible for that harvest rate to be greater than 1.0 (an obvious impossibility). Such trajectories might occur where the biomass has declined to very low levels in the very last years but hasn't quite reached zero (Figure 1).

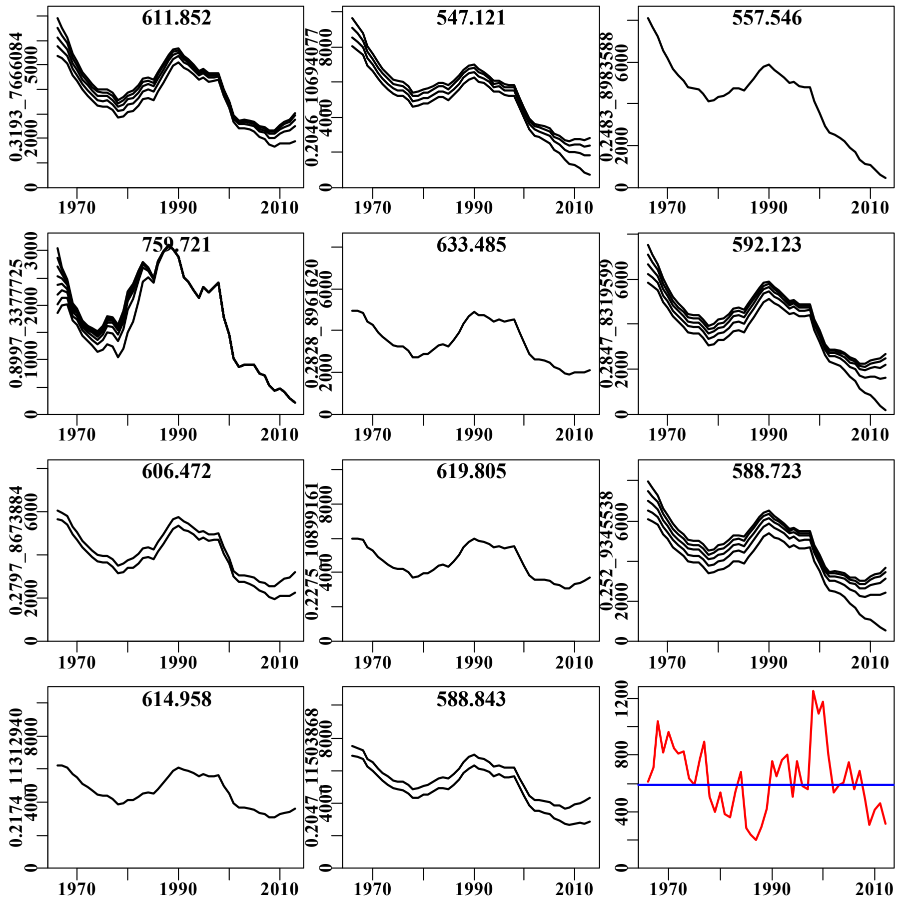

Figure 1. A selection of acceptable r-K combinations (the y-axis titles 'r_K') where the y-axes are in thousands of pounds, using data from the Atule fishery in the Hawaiian Islands (no biomass estimates are available for this species). Where there are multiple lines on a single graph implies that more than one of the *p* values led to a viable combination. The central title value in each graph is the MSY calculated for each r-K combination. The red line is the catch history (thousands of pounds). In this case, the mean catch is of the same order as the MSY estimates.

Some combinations respond to the catch history by a continual decline which in the final year doesn't quite reach zero but does decline to a level below the observed catch in the final year. Rather than set the lower limit to zero it should perhaps be set to at least the minimum catch taken in any one year. This assumption includes false positive combinations and hence is not sufficiently conservative.

Martell and Froese (2013, p505) state that "As no prior distributions of r and k are available for most fish stocks, we randomly draw r-k pairs from a uniform prior distribution". While the details are available in their Table A1, it was only noticed in the R-code, downloadable from one of the author's websites, that the random numbers are drawn from a log-normal distribution and then back-transformed, thus:

```
ri = exp(runif(N, log(r[1]), log(r[2])))    ## get N values between r[1] and r[2], assign to ri
ki = exp(runif(N, log(k[1]), log(k[2])))  ## get N values between k[1] and k[2], assign to ki
```

This will, of course, generate log-normal distributions for the r and K parameters (Figure 2). This is a perfectly acceptable strategy of sampling but why it was selected is not documented as such and is only identified here to emphasize that the methodology needs some detailed documentation for anyone to understand what it is doing and why it is being used without having to delve through the program code.

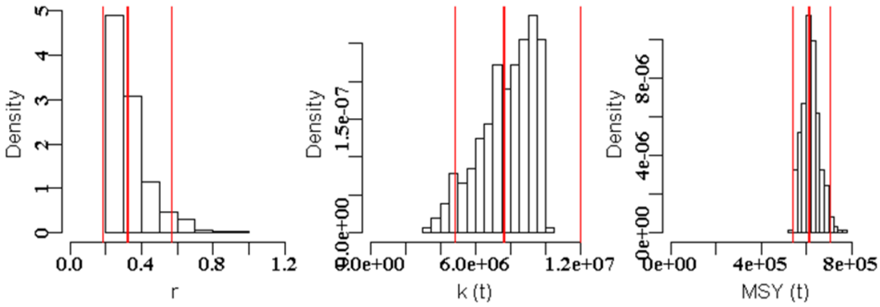

Figure 2. Plots of the second phase of identifying the acceptable r-K combinations for the Atule fishery from the Hawaiian Islands.

One major assumption is with the use of the Schaefer surplus production model; equ (1.1). This assumes a symmetric production curve, which is why the B_{MSY} can be estimated as $K/2$ as per equ (1.2). It may be seen as an advantage of the method that for most species a B_{MSY} target of 50%B_0 would be conservative. It is now accepted that many species will have a production curve skewed to the right so that B_{MSY} would be at a point less than 50%B_0. There are surplus production models (e.g. the Fox model; Fox, 1970, 1975) that are capable of producing such skewed production curves. Martell and Froese (2013) point this out in their methodological appendix. When the BAC-MSY model is MSE tested this structural assumption should be included in the aspects under test (if the underlying dynamics are from a skewed production curve, which model performs better?).

As Martell and Froese (2013) point out, the ability to define an acceptable initial range for the *r* and *K* parameters is important. However, their strategy of beginning with an implausibly wide range for each parameter, isolating approximately the acceptable range and then refining the identification of acceptable r – K combinations appears to be a good solution. The effectiveness of the second stage selection process should be examined with simulation testing. In the BAC-MSY (Sabater and Kleiber, 2013) rather than using 100 * maximum catch for the K value it is proposed to use 500 * maximum catch. This latter seems extreme and in the R-code seen during the review the value used was 50 * maximum catch, which was still well above any acceptable values (Figure 3).

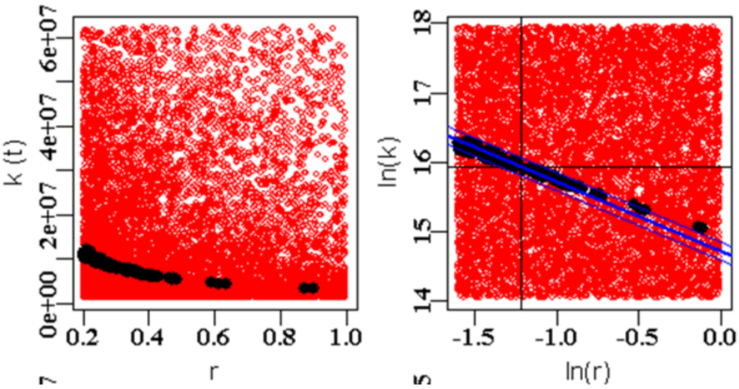

Figure 3. The initial selection of r – K combinations that match the constraints of the upper and lower bounds to biomass for the Atule fishery from the Hawaiian Islands. The red dots represent r – K combinations that failed to be acceptable given the constraints of the model whereas the black dots illustrate those that were accepted.

The second stage selection process, with the bounds on the initial parameter values limited to approximate slightly greater limits on *r*and slightly smaller upper limit on the *K* than those found in the first selection provide a more detailed sampling of the suitable parameter space (Figure 4).

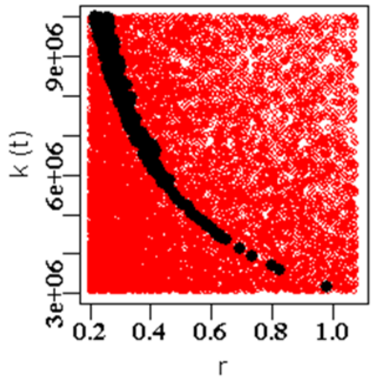

Figure 4. The outcome of the second stage selection process in terms of accepted (black) and rejected (red) r – K combinations, illustrating the improved detail in the array of acceptable combinations.

In addition to the assumption relating to the r – K parameters there are assumptions relating to identifying the initial and final depletion levels based on the initial and final catches relative to the maximum catch. An advantage of the BAC-MSY relative to the simple Catch-MSY is that the addition of biomass estimates effectively adds another constraint to the acceptable biomass trajectories. This has allowed Sabater and Kleiber (2013) to greatly relax these constraints so that almost the whole range of depletion levels from 0.01 to 0.99 can be covered in the first selection process.

An assumption relating to r-K pair selection, which is only identifiable from inspection of the R-code, is that in the identification of acceptable r-K pairs the routines step sequentially through the different *p* values (used to generate the B_1 values; = p.K) but stops if a successful trajectory is found. Thus there only needs to be a single successful trajectory for a particular r-K combination to be assumed a valid choice. In the code used by Marlowe and Kleiber (2013) they randomize the order in which the *p* values are explored, but because they also stop when the first successful trajectory is found, this randomization may not be improving effectiveness to any great extent. When considering some of the selected Hawaiian Atule fishery trajectories (Figure 1) it is clear that some combinations are more robust to differences in initial and final depletion levels than others (those with multiple trajectories can be considered to be more robust; in one instance a number of initial trajectories eventually become indistinguishable).

A fundamental assumption is that the BAC-MSY is a Bayesian methodology (Martell and Froese, 2013, do not make this assumption explicitly) and this leads to a flawed view of how the method operates. While the method operates in a manner that appears like a Bayesian strategy, in fact a simple grid search across the potential parameter space would provide the same identification of the r-K combinations that would give rise to acceptable biomass trajectories. By randomly sampling enough times across the pre-set parameter ranges it is possible to mostly fill the parameter space rather than using a grid (see the red dots in Figure 3);however, this gives the impression that the relative frequency of successful combinations is a measure of the relative likelihood of those combinations. The success of an r-K pair is not a measure of the likelihood that it represents the true MSY, and it merely measures how often the successful combination within the grid of successful values was sampled by the random numbers. The count of occurrence is not directly related to the likelihood of a particular MSY value or related r – K combinations being the true MSY of the stock under consideration.

A further issue of concern with the coral reef fisheries is the combination of arrays of different species into family species complexes. On examination of the resilience of some of these combinations of species it is apparent that the relative resilience within a particular species complex is not uniform. What this means is that some species within each complex will be more susceptible to fishing pressure than others but this would be obscured by the application of any assessment method to the species complexes. It would be sensible to explore the sensitivity of the outcome of the analyses to varying the assumed average resilience for different species groups.

All of these concerns do not mean that the method as it stands is ineffective; they only mean that it is in need of further testing, preferably Management Strategy Evaluation (MSE) testing, to make it the outcomes more defensible. The method generally provides an estimate of MSY and puts bounds around that figure.

The addition of the biomass estimates is a very influential inclusion to this data-poor model. By including such an informative constraint on which r-K combinations can generate acceptable biomass trajectories the MSY estimates should be improved. The current method implemented in Marlowe and Kleiber (2014) is to use either the CV or the CV expanded by some constant to describe bounds between which acceptable biomass trajectories must pass through. This retains the yes or no acceptance of each r-K pair rather than ascribing a relative likelihood to each pair. An alternative approach might be to estimate the relative likelihood of each trajectory relative to the biomass estimate so that those trajectories that pass very close to the biomass estimate would be considered more likely than those that remain between 0 – K but are distant from the biomass estimate in the given year. Once again this approach should be tested carefully using an MSE simulation framework. Such an approach, based on so few biomass estimates, would be considering the relative plausibility of different parameter combinations. Literally fitting the biomass trajectory through modifying the parameters to maximize the likelihood of the biomass estimate given the model and available data is currently overly ambitious because the model would effectively be over-parameterized for the amount of informative data. In modelling terms the BAC-MSY model is being conditioned on the data rather than being fitted to it.

Some of the biomass estimates have strangely small values for their coefficient of variation, which raises the suspicion that errors of some kind have entered the system. Dr Jones suggested that one possibility might be that either totals were summed across strata or averaged across strata thereby losing a great deal of the inherent variation. Whatever the case may be, these instances of low CVs need to be re-examined to alleviate suspicions of such remarkable precision and to make the biomass estimates more defensible.

More comments on the influence of the data used on the MSY estimates are given in section 3 below.

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 usefulness of using the 0.75 Average Catch as a strategy for setting the ACL certainly has limitations. Such an approach is one of the default methods used in New Zealand to set total allowable catches for many of its data-poor fisheries (MPI, 2014). Of course, such a method will always provide an estimate given a time series of catches but the Western Pacific Regional Fishery Management Council's objections that this approach leads to ACLs which are overly conservative appear well founded (WPRFMC, 2013a, 2013b, 2014). If the constant times the average catch ($\overline{Y}$) method:

$$ACL = 0.75\overline{Y} \tag{1.3}$$

is used, and this would presumably be the fallback position if there are species complexes for which the BAC-MSY appears inappropriate, then once it were applied there should be no further inclusions of catch data as time progresses otherwise the ratcheting down effect on catches would certainly occur. If the regulations on 'best available information' required the inclusion of catches taken under these new ACL then some other means of setting ACL would be required.

The original Martell and Froese (2013) paper describes some circumstances where the Catch-MSY should not be used and generally these would also apply to the BAC-MSY method (although the presence of biomass estimates might alleviate this in some cases; see below). It seems clear that if catches have been so small relative to the stock size that they have no effect on the stock dynamics then the methods should not be used. The use of K values up to 100 * maximum catch would be an example where catches, being less than 1% in each year, would not be expected to affect the dynamics in any important way. They also point out that situations where catches steadily increase through time would also mean the method should not be applied, because such a time series would not be informative about maximum catches.

One thing omitted from the proposed ACL setting process using the BAC-MSY method is a demonstration that each family group species complex avoided these data criteria for application. For example, in the raw data table for Hawaii (Sabater and Kleiber, 2013, p50) the catches of Acan (Acanthuridae) are reported as being 108,401 pounds in 2010 whereas the biomass estimate was 14,276,986 pounds, so the catches were only 0.76% of the biomass. Even the maximum catches through the time series were only ever less than 1% of the biomass in 2010. This suggests that the method should not be applied to this species group. On the other hand, the addition of the biomass estimate means that the MSY estimate that derived from this data was presumably driven largely by that biomass estimate. It is uncertain how well the BAC-MSY method performs under these circumstances as the MSY estimates appear to be driven primarily by possibly a single biomass estimate. This aspect of the method also requires examination and testing using simulation testing.

Formal criteria for acceptance of data into each analysis should be developed. For example, in the Guam datasets (Sabater and Kleiber, 2013, p45) the Lethrinidae (denoted Leth) exhibit a clear disjunction between the catch time series and the biomass estimate in 2009, which is an order of magnitude less than the average catches; this particular biomass estimate also only has a CV of 0.03. Sabater and Kleiber (2013, p29) point out that this biomass estimate had to be omitted for the analysis to proceed successfully. It is recommended that such obvious disjunctions between the biomass estimates and the catch series be used as a basis for identifying outliers in the data to be used. As a minimum criterion the biomass estimates would need to be at least greater than the catch estimates. Such criteria, which should also be developed for the CV values, should be used to identify data estimates that at least require re-examination and then may need to be excluded from consideration.

In a number of species complexes the biomass estimates appear large relative to typical catches in a manner similar to the Acanthuridae. In review discussions about the scope of the surveys it seems that the biomass estimates relate to the whole island group concerned in the survey whereas in some cases the catch estimates may only apply to a part of the area and may underestimate the total for the fishery. In the next iteration of the ACL setting process improved documentation of the representativeness of the different data components used when applying the BAC-MSY or the Catch-MSY method for each species complex is required so that the validity of each estimate can be assessed.

When there are no biomass estimates the BAC-MSY defaults to the Catch-MSY and sometimes this appears to give an estimate which is close to the mean catch (Figure 1). However, explorations for some of the other species complexes without biomass estimates generally exhibit MSY estimates greater than the mean catch so the assessment process is doing more than simply averaging the catches. Once again, the defensibility of the method would benefit greatly from MSE testing.

Despite the issues above, the MSY estimates deriving from the BAC-MSY and Catch-MSY methods appear to be useful as a means of estimating acceptable and workable ACL values for many of the coral reef fisheries. The BAC-MSY estimates appear to be more robust than the straight Catch-MSY estimates, simply because they are including more information to focus the selection of plausible r-K parameter pairs (Carruthers et al, 2012). Once criteria for acceptance of the input data and better documentation are in place the ACL estimates obtained using these methods will be more defensible. It is recommended that such criteria and documentation be prepared for the next round of ACL setting for the coral reef fisheries.

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

The term 'reliably estimate' is of limited value when dealing with truly data-poor methodologies, as in the case of the coral reef fisheries. Fortunately, as the number of useable survey estimates of stock biomass increases at least some of these fisheries will become less data-poor. Eventually it should be possible to migrate away from truly data-poor methods and start to use more informative assessment methods that try to fit the stock dynamics to the available biomass estimates. Until that time while the use of a data-poor method might lead to elevated uncertainty around the estimates, there is little option but to review the state of these fisheries are regular intervals to ensure sustainability is maintained.

In fisheries where there is only catch information, however, the classical usage for the term 'reliable' when used with respect to MSY estimates seems likely to be misplaced. At very best Martell and Froese (2013) imply that estimates of MSY from the catch MSY method are only going to fall within 0.5 – 1.5 times the MSY's true value 95% of the time. That constitutes a wide range and it would be reasonable to encourage debate about how to handle such potential variation when providing management advice on suitable ACL values from such estimates. The data-poor methods are known to produce uncertain estimates of MSY, the solution is to select a harvest control rule that attempts to allow for that uncertainty when setting the ACL.

There are other data-poor catch-only methods available (e.g. DCAC, MacCall, 2009; DB-SRA, Dick and MacCall, 2011) although how applicable any of these methods are to species complexes is difficult to ascertain. The authors of the present work (Sabater and Kleiber, 2013) examined alternative methods and are aware of the main alternatives currently available. They selected the BAC-MSY method as being most applicable to the available data and the one that required fewest assumptions. This does not mean these alternative methods should not be examined again in more detail. Fortunately, there are already a number of analyses that make comparisons between these kinds of methods (Carruthers et al, 2014). The field of data-poor methods is currently attracting a great deal of attention so it would be sensible to keep monitoring the findings of other research groups as this work progresses. Generally this work entails the testing of the current array of data-poor methods so it is possible that the Catch-MSY method will be tested elsewhere before it is possible to organize in Hawaii.

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

There are three high priority research areas that need attention. The first is to apply MSE simulation testing to the major assumptions behind the BAC-MSY and Catch-MSY methodology; including comparisons with the 0.75 Maximum Catch for completeness. MSE testing of the method is required as the comparison of the method with methods that generate MSY estimates in relatively data rich fisheries, using more sophisticated methods explores the successes rather than examining the strengths and the weaknesses.

There are numerous assumptions whose origin and effect are at best uncertain. Even comparisons of ascribing different resilience values to particular species would have some value in illuminating the sensitivity of the methods to such potential errors.

An MSE can be used to ascertain the effects that might occur if mistakes are made with the resilience or the initial depletion levels and how robust the method is to such mistakes. It can also be used to compare alternative ways of sampling across the potential parameter space (a grid search rather than random sampling from a uniform distribution). Until the methodology is understood rather better, some doubt will remain on any of the management outputs that derive from this assessment approach.

The second high priority is an exploration of the limitations of the catch and the survey data used in the BAC-MSY method. The methods used to generate both the catch and the survey data sets need to be fully documented so that the representativeness of that data for the fisheries concerned can be assessed. By details is meant the process for extrapolating the biomass estimates from a single reef out to a complete set of islands needs to be clearly documented and the representativeness of the catch data needs to be understood. This is necessary so that the catches are compared to a biomass estimate that is directly comparable to the coverage of those catches.

How it is that some areas have tiny catches relative to the biomass or tiny biomasses relative to the catches also needs to be clarified and criteria developed and adopted to help decide when a data set can validly be used in the calculations required to set ACL.

The third high priority is the general need to improve the documentation of the methods used in both the data compilation and the assessment methods, especially to justify or explain the selection of the various assumptions and default values used in the selection process of r – K pairs.

Conclusions/Recommendation

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

The BAC-MSY method needs to be MSE tested to explore how sensitive its outputs are to its various assumptions. However, it provides a good match to available data in that the only data available are catches and occasional biomass estimates. The inclusion of a small number of biomass estimates enhances the methods capacity to select and reject parameter combinations that contribute to the estimates of MSY that it produces.

The only testing that has been applied to this method has been to apply it to data from stocks that have undergone full quantitative stock assessments to determine whether it is capable of generating MSY estimates that are similar to those from the formal stock assessments. Generally these tests have been successful in that there was a good relationship between the two sources of MSY estimate. How the method would perform if any of the assumptions made were mistaken is unknown and simulation testing is effectively the only way this could be determined.

The BAC-MSY method can provide an estimate of MSY and so the method is clearly adequate to the task required of it, but the reliability of those estimates cannot be fully judged without conducted detailed simulation testing of the methods robustness to faulty assumptions and uncertain data inputs.

It is recommended that before the next round of ACL setting in the coral reef fisheries a management strategy evaluation of the method be made to explore its strengths, limitations, and robustness to uncertainty.

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.*

The model documentation is currently inadequate, although the code itself is available, which constitutes the ultimate documentation. Nevertheless, even though how the method has been implemented can eventually be determined the reasons behind an array of choices regarding initial and final depletion levels, initial assumed ranges for the parameters, and the criteria used in the selection of those parameter combinations deemed acceptable cannot be determined from the code.

- It is recommended that the methodology for both the data collection and processing and the model implementation both require detailed documentation to improve the defensibility of the analytical strategy.

- A number of important assumptions in the BAC-MSY methodology require testing using simulation testing. These include:

  a) The influence of excluding those biomass trajectories in which any of the values becomes larger than the equilibrium unfished population size. (Trajectories exist that do rise above *K* but then come down into acceptable ranges again).
  b) The influence of retaining those trajectories whose predicted biomass in the final year is less than the average catch (this is merely a small change to the selection criteria, which should at least be that biomasses should always be greater than catches).
  c) The method treats the relative frequency of different MSY values, and their related *r* and *K* combinations are relative probabilities but in fact they simply relate to how common certain values are not how likely they are in actual fact.
  d) It may be useful to explore the possibility that a grid search across the available parameter space would be more efficient than randomly selecting values along each potential parameter vector.
  e) The use of log space when drawing random samples for the parameter pairs would appear to be advantageous simply because of the negative correlation between *r* and *K*. Nevertheless, it would be worth exploring the relative effectiveness of using uniform random numbers in a linear space.
  f) If the frequency of occurrence does have value then it needs to be explored why the method as implemented stops exploring *r* – *K* combinations if even one biomass trajectory from among the trial initial biomass depletion levels is accepted. There are combinations where only one trajectory is accepted and there are other combinations where 9 out of 9 are accepted. The latter would appear to be more robust to uncertainty in the initial depletion levels and hence should be given more weight.
  g) A large assumption is that the dynamics of the fishery and stock can be captured using a simple Schaefer surplus production model, which implies linear density dependence and asymmetric surplus production curve. In the simulation testing of the method a major test of the structural assumptions would be to include an alternative surplus production curve, such as the Fox model, which has a skewed production curve.
  h) The inclusion of biomass estimates appears to add greatly to the discriminating power of the method. The authors found they could greatly relax the assumptions about initial and final depletion and yet still find constrained answers. It would be valuable to explore the impact of including biomass estimates or not on the final outcomes.

There were some potentially serious issues with some of the catch time series and biomass estimates. There were instances of catch series which were very much smaller than the estimated biomass levels from surveys. In these instances an MSY estimate was still possible, even where there was no biomass estimate, but the method should not really be valid if the catches have no influence on the stock dynamics. This would mean the catches had no information about productivity and so should not be used to estimate MSY. If there is a biomass estimate then this would be driving much of any estimate of MSY derived from the data. There was also an instance where there was a serious disjunction between the biomass estimate and the catch (which was an order of magnitude greater than the apparent biomass).

In addition to these circumstances there were also instances where the biomass estimates had what appeared to be implausible CVs (between 1 – 10%; which would be remarkably low for any visual survey, even a well stratified one).

- It is recommended that a detailed review be undertaken of the data collection and processing to prepare the data for analysis in the assessment method. Criteria need to be developed for deciding when a dataset or data point is atypical, not representative of the fishery, or constitutes an outlier. In this way ad hoc decision during the analysis can be avoided and the outcomes would become more defensible.

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 alternatives of using a constant proportion of the average or of the maximum catch are variants on a common strategy of dealing with catch only data. If there are family species complexes to which the BAC-MSY method cannot be applied (for example, no biomass estimate and very low catches relative to biomass) then the 0.75 Average Catch will provide an ACL value. However, if this is used then the average catches should not be updated using more recent catches to avoid the downward ratchet effect of the lowered catches.

The addition of biomass estimates to the BAC-MSY method moves the method away from the equivalent to a grid search of possible outcomes to one where the model outcomes are being conditioned on real biomass estimates. As the number of valid biomass estimates increases the option of fitting the model to the biomass time series will begin to improve and the method will evolve from a data-poor assessment into one which makes fuller use of all available information; the criteria for data selection will be required for this to occur.

Even without biomass estimates it is the case that the Catch-MSY method was relatively successful in mimicking MSY estimates made by fully quantitative stock assessments across a wide range of stocks. Such an empirical demonstration does suggest that the method has merit although until it is formally tested in a simulation framework there would always be doubt and uncertainty when applying it to species with rather different life history characteristics (such as coral reef species).

One issue that would be hard to test is the impact of having to combine species into family species complexes. The BAC-MSY method requires a decision to be made regarding the relative resilience of a given fish stock. In the review it became clear that such complexes combined species having widely different resilience values (low to high).

- It is recommended that the model outcomes be tested for their sensitivity to the resilience value selected for a particular species complex. Intuitively the inclusion of biomass estimates should reduce the effect of a misclassification; nevertheless, the potential errors introduced through a misclassification of resilience should be explored within the MSE simulation testing.

Once criteria for acceptance of the input data and better documentation are in place for the data collection, processing, and the BAC-MSY methodology the ACL values obtained using these methods will be more defensible.

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

Given the analyses already presented and knowledge of alternative data-poor catch only methods the MSY estimates derived from the BAC-MSY and Catch-MSY methods appear to be at least as reliable and usable as could be achieved using a different method. The addition of the biomass estimates, especially if these continue to be added to the data sets, will act to improve the estimates and better focus the MSY estimates towards realistic values. It needs to be kept in mind, however, that no data-poor method can provide truly reliable estimates. However, as long as these estimates and the stock status is regularly monitored these ACL estimates should provide security against over-exploitation.

Alternative methods do exist and are known to the researchers in Hawaii. The development of data-poor assessment methods is currently an active research field and more methods are being developed in different countries around the world. While the focus of future work in the coral reef fisheries in Hawaii should be on improving and testing the BAC-MSY method, alternatives and the concurrent testing of those alternatives being carried out over the next few years may produce a data-poor assessment method that would be considered an improvement for the coral reef fisheries.

- It is recommended that while improving and testing the BAC-MSY methodology, the literature on data-poor methods be kept up to date so as to monitor published tests of currently available methods and to look for alternative methods that may prove simpler, cheaper, or more appropriate for the coral reef fisheries under consideration.

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

There are three high priority research areas that should be pursued.

- It is recommended that management strategy evaluation simulation testing be applied to the major assumptions behind the BAC-MSY and Catch-MSY methodology; including comparisons with the 0.75 Maximum Catch for completeness.
- It is recommended that the catch and survey data used in the BAC-MSY method be explored to develop criteria for determining their representativeness of the stock and fishery as a whole. This is necessary to remove doubts that derive from what appear to be exceptional values of precision and disparities between the catches and the biomass.
- The third high priority, is simply a general need to improve the documentation of the methods used in both the data compilation and the assessment methods, especially to

justify or explain the selection of the various assumptions and default values used in the selection process of r – K pairs.

Appendix 1: Bibliography of Materials Provided

Brodzial, J., Courtney, D., Wagatsuma, L., O'Malley, J., Lee, H-H., Walsh, W., Andrews, A., Humphreys, R., and G. DiNardo (2011) Stock Assessment of the Main Hawaiian Islands Deep 7 Bottomfish Complex Through 2010.

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Western Pacific Regional Fishery Management Council SEEM Working Group Meeting Report (2013a) May 28 2013, P* Working Group Meeting Draft Report 12p.

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Species level resilience assignment_AS NMI GU HI – Excel sheet containing the resilience assignments for the various species groups.

Other Material Examined or References

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Carruthers, T.R., Walters, C.J., and M.K. McAllister (2012) Evaluating methods that classify fisheries stock status using only fisheries catch data. *Fisheries Research* **119-120**: 66-79.

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Hilborn R., Branch, T.A., and D. Pauly. (2013) Does catch reflect abundance? *Nature* **494**: 303-304.

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Martell, S., and R. Froese (2013). A simple method for estimating MSY from catch and resilience. *Fish and Fisheries* **14**: 504-514. DOI: 10.1111/j.1467-2979.2012.00485.x

MPI (2014) Report from the Fishery Assessment Plenary, May 2014: stock assessments and stock status. Volume 1: Introductory Sections to Jack Mackerel. Compiles by the Fisheries Science Group, Ministry for Primary Industries, Wellington, New Zealand 464p. (http://fs.fish.govt.nz/Page.aspx?pk=61&tk=297)

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

U.S. Department of Commerce (2007) Magnuson-Stephens Fishery Conservation and Management Act. National Oceanic and Atmospheric Administration, National Marine Fisheries Service. 170 p.+

Presentations made by NMFS Staff

Copies of all these were given to the reviewers.

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

Appendix 2: Statement of Work

External Independent Peer Review

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.

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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: Terms of Reference for the Peer Review

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.

Annex 3 – 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