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

By

Robin Cook

Prepared for
The Center for Independent Experts

Contents

Executive Summary 3

Background 4

Findings 4

ToR 1: Review the Biomass Augmented Catch-MSY model: 4

ToR 2: Evaluate the model configuration 6

a) Choice of r range 6

b) Choice of K range 7

c) Choice of depletion levels 7

d) Constraints on biomass trajectories 7

e) NMFS biomass estimates 7

f) Catch data 8

g) Biomass process error 8

ToR 3:Comment on the estimates of MSY 8

ToR 4:Suggest alternative models 10

ToR 5:Suggest research priorities to improve our understanding 10

Conclusions and Recommendations 11

Appendix 1: Bibliography 13

Appendix 2: Statement of Work 15

Executive Summary

i. A review of the Augmented Catch-MSY model was conducted by three CIE reviewers in Honolulu, Hawaii from the 30th June to the 3rd July 2014. Materials for the review included a report on the new model, a description of survey biomass estimates and papers describing the framework for managing reef fishes in the Western Pacific.

ii. The new model incorporates biomass estimates into a catch only model developed by Martell and Froese (2012). The inclusion of biomass data is likely to lead to substantially improved estimates of MSY and this should provide a better basis for determining ACLs compared with the use of average catches.

iii. A number of assumptions are required for the model to produce credible results. These include estimates of resilience in order to bound the intrinsic rate of increase (r), relative biomass depletion at the start and end of the time series, range of carrying capacity (K) and limits on biomass. These assumptions are subject to significant uncertainty and it is desirable to undertake further sensitivity testing to help understand the performance of the model.

iv. There is a lack of documentation around the revision process to update the prior ranges of r and K that are implemented in the original Martell and Froese paper. Not only does the revision affect the MSY estimates but there are two variants of the revision that give different estimates of MSY. This problem requires further investigation to establish the need and basis for the revision.

v. Care is required in the interpretation of the distribution of MSY estimates. The distribution describes the frequency of occurrence of MSY estimates from permissible stock trajectories. It is does not characterise the likelihood of the MSY estimates given the data. As a result the P* calculation does not have a clear statistical basis.

vi. The use of biomass estimates from surveys is a major advance in the estimation of MSY. At present the sampling strata for the surveys are limited and the CVs associated with the estimates appear unrealistic. There are potentially large gains to be made by improving survey techniques and obtaining more reliable estimates of sampling errors.

vii. It should be possible to improve model performance by considering a more formal statistical treatment of the biomass data. At present the bounds on the biomass appear somewhat arbitrary. Suggestions on how this might be approached are discussed.

Background

1. Current catch limits (ACLs) for reef fish in the Western Pacific are based on mean observed historical catches. Because the limits discount the mean by 25% the more recent catches will be restricted and will not reflect prevailing biomass. This has the potential to lead to a downward ratchet in future catch limits if these more recent catches are included into the calculation of the mean since the repeated application of a 25% discount factor will steadily erode the catch limit. In an effort to avoid this problem the Western Pacific Regional Fishery Management Council funded the development of a new approach based on the model of Martell and Froese (2012) which uses the catch stream in a Schaefer production model. The original Martell and Froese model uses only catch data and makes assumptions about the biomass trend as well as the r and K parameters in the model. This model has been developed further by introducing observations of biomass from visual surveys (Sabater and Kleiber, 2014). The survey data are limited to a few years but help by adding information on K and depletion level. The purpose of the review was to assess the new model and advise on the reliability of the estimated MSY values.

2. The review was held at the NOAA Fisheries office at Pier 38, Honolulu, Hawaii from the 30th June to 3rd July. Prior to the meeting five background documents were provided and reviewed. They consisted of the report of the new model and its application, a description of the biomass survey data, a summary of the P* process and a report of the SEEM workshop. During the first two days of the meeting, presentations were made describing the management arrangements for Pacific reef fish by the Western Pacific Regional Fishery Management Council, the development and analysis of the new model and the P* report. The reviewers were able to ask question of the Council and NMFS Center staff to clarify points in the presentations and reports. On day 3 the panel members discussed their findings in closed session and began drafting their reports. On the final day the panel met with Gerard DiNardo, Marlowe Sabater and Jared Makaiau to provide a preliminary summary of the panel's conclusions on the terms of reference.

3. The review meeting was conducted in a constructive and helpful atmosphere and the panelists were extremely grateful for the assistance of all participants in facilitating their work.

Findings

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

4. The augmented catch-MSY model is a development of the method described by Martell and Froese (2012) to estimate MSY from catch data and prior knowledge. It is intended for data poor stocks where only a time series of catch data are available. The method is based on the well-known Schaefer model (Schaefer, 1954) that characterises population biomass dynamics in terms of the intrinsic rate of increase (r) and carrying capacity (K). For the method to work using catch information alone assumptions need to be made about r and K

as well as the level of biomass depletion at the start and end of the time series of catches. Martell and Froese suggest some simple rules to give a limited range of depletion levels based on the magnitude of the catch in relation to the maximum catch. Once limits have been set on r, K and the depletion levels, the method identifies values of r and K that give viable stock trajectories (i.e. those that do not result in stock collapse) given the observed time series of catches. Typically the range of r and K pairs that satisfy this condition is limited and can be used to derive a distribution for MSY using the formula MSY=rK/4. Martell and Froese used their method to estimate MSY from catch data of approximately 150 stocks worldwide for which there we detailed assessments and suggest that their method provides useful estimates of MSY.

5. Where additional data exist on stock biomass it is possible to restrict, further, the range of viable r and K values and hence obtain more reliable estimates of MSY. At the review meeting, an approach to incorporating biomass estimates into the Catch-MSY method was presented (Sabater and Kleiber, 2014). In this development, not only do viable stock trajectories have to contain non-zero population biomass but they also have to pass close to the observed biomass estimates for those years where these observations are available. The biomass estimates should provide information on the values of K and stock depletion given the catch. With these additional data it is in principle possible to relax some of the constraints in the original Catch-MSY method. Sabater and Kleiber, for example, did not place restrictions on the depletion level at the start and end of the time series. (Note that the depletion values in Tables 2 and 3 in Sabater and Kleiber, 2014 were not actually implemented in the model code).

6. Sabater and Kleiber constrain the allowable biomass stock trajectories to fall within a 95% interval of the observed biomass values where the interval is based on the sampling error (expressed as a CV) assuming a log-normal distribution. However, the specific implementation of the method allows for an inflation factor to be applied to the estimated CV when no trajectories fulfill all the necessary criteria. In these circumstances, the CV is inflated until at least some viable trajectories are accepted.

7. For the majority of stocks between 1-3 biomass estimates are available for the more recent years. These are probably too few to be able to estimate r and K with any useful precision using a conventional statistical approach and it is therefore appropriate to develop the Catch-MSY method to include the few biomass values available. However, the biomass constraint on the acceptable stock trajectories appears to be *ad hoc* as it is based on a pass/fail criterion where the width of the interval in which forecast biomass must fall is inflated until at least some trajectories “pass”. It raises the question about what the appropriate proximity to the observed value is acceptable. This is an issue that requires further investigation.

8. An important step in the model is a refinement of the prior r and K intervals. After an initial run of the model, where r and K intervals are predefined, an update step is applied where these intervals are revised so that some r and K values are excluded. This step is not described in the original Martell-Froese paper though the code used by these authors does include it. The documentation and rationale behind these revision rules are missing and

appear to improve the sampling of the viable parameter space but it is hard to evaluate whether they are appropriate. It is noteworthy that the application of these revisions can make a substantial difference to the estimated MSY (see Sabater and Kleiber Table 4). Moreover, two revision procedures are described that give differing results and it is unclear which is to be preferred. Further investigation of this issue is required.

9. Overall the model is suitable for the available data since it takes the important additional step of making use of biomass observations to augment the limited information in the catches. The model should therefore provide more reliable estimates of MSY than the basic Catch-MSY model described by Martell and Froese. There are perhaps two points to make in qualifying this statement. Firstly, the Sabater and Kleiber document makes reference to other data poor methods that were considered but not used which nevertheless might provide useful insights into model uncertainty if explored. Secondly, there is scope to do more detailed sensitivity analysis of the new model using simulated and real data to explore uncertainty around a number of the model assumptions. Without these additional analyses it is difficult to comment the absolute reliability of the method in relation to MSY estimates.

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.*

a) Choice of r range

10. The Catch-MSY model uses ranges for r based on the resilience of the species concerned where high resilience implies high values of r and vice versa. The Augmented model uses the same criteria with data being taken from Fishbase (www.fishbase.org). The complication that arises in the application to reef fish is that catch data represent a mixture of species that will have differing resilience and some judgment is required in order to arrive at a chosen resilience representative of the family grouping. Without sensitivity testing it is difficult to assess whether the values selected are optimal. It is also important to note that the values of resilience in Fishbase are unverified and their quality is uncertain. This does not mean they are inappropriate nor that they should not be used, but caution is required.

11. The resilience values from Fishbase refer to single species whereas the data available in the analysis here relates to catches of family groupings of fish species. Hence within a family there may be a range of resilience values for which only one can be applied in the model and this requires some judgment to select an appropriate value. Discussion with the assessment staff suggested that reasonable criteria, such as the abundance of species in the catch, were used to select suitable values.

b) Choice of K range

12. Martell and Froese report that they used the maximum observed catch and 100 times the maximum catch as the lower and upper bounds on K although their code appears to use a factor of only 50. In the Augmented model it is unclear what was used for the upper bound. Since biomass estimates are available in the augmented model, the bounds on K are likely to be less critical. They could be based on the observed biomass values rather than the catch since the largest observed biomass sets a lower bound on the value of K.

c) Choice of depletion levels

13. Tables 2 and 3 of Sabater and Kleiber give depletion levels for the start and end biomass that are taken from Martell and Froese (2012). However, these do not appear to have been implemented in the model code where the respective bounds are 0.01-0.99, effectively not constraining these values. The relaxation of the constraints may not matter given that the observed biomass values should provide information on K and the depletion level in the most recent years. However, it is an issue that needs to be checked especially in relation to initial depletion since for this point there are no biomass data to constrain the model. Where no observed biomass data are available, the choice of depletion level interval could have a major effect on the distribution of MSY estimates since the interval 0.01-0.99 accepts trajectories (and hence r and K pairs) that correspond to near stock collapse even though this seems unlikely for the stocks considered here.

d) Constraints on biomass trajectories

14. In the augmented model the biomass trajectories generated from the prior distributions have to pass through an interval centred on the observed biomass in the years where they are available. The interval is initially based on the estimated CV of the observation but this is widened if no trajectories pass the test. It is, of course, obvious that some trajectories must pass through an interval but it does raise the question about how far it is appropriate to inflate the interval. Clearly the wider the bounds, the more valid combinations of r and K will be selected.

e) NMFS biomass estimates

15. Biomass estimates are available for a few years (up to three) for many stocks with associated CVs. There are data from earlier years but the design of the surveys in these years is not regarded as satisfactory and were not used. Discussion with Center staff suggested this was an appropriate decision since there was no adequate sample station randomization or design for the survey in earlier years.

16. The biomass values are derived from visual surveys and follow a statistical design described in Williams (2010). They are limited to a single depth stratum and may therefore underestimate the overall biomass. Provided the fishery operates mainly in the

same depth stratum and fish do not move substantially between strata this should not be a major problem.

17. As well as point estimates of the biomass the survey data include estimates of the CV. Many of the CVs appear much lower than might be expected from the type of survey being undertaken. To some degree this is of minor importance since the Augmented Model inflates the CV until at least some generated trajectories are accepted. However, more work is required to obtain robust estimates of the CVs and a more soundly based method to define the biomass interval through which the stock trajectory must pass.

f) Catch data

18. The catch data used in the analysis are derived either from surveys or trip records. In the former case CPUE is estimated from a sample which is expanded using effort data. In some cases it is only possible to sample a portion of the fishery and this will mean that the estimated catch is a minimum estimate of the total catch. Where this occurs it is important to ensure that the associated biomass estimate is consistent in scale with the catch to avoid bias in estimating the exploitation rate.

19. In the model the catch data are assumed to be exact which means that an important source of uncertainty is not explicitly accounted for, though such uncertainty may emerge in the posterior distributions of r, K and MSY. It would desirable to try to quantify the sampling error (and also possible bias) in the catch data since they are influential in determining model results and better understanding of the quality of the data would aid the interpretation of the output.

g) Biomass process error

20. Both the Catch-MSY model and the Augmented model make provision for process error in the biomass series. In the analysis this was assumed to be very small, i.e. that random effects such as growth rate, recruitment and natural mortality remain approximately constant. The robustness of this assumption will depend on the biology of the species concerned but in the absence of direct evidence assuming a low value appears sensible. Assuming a large process error would expand the range of r and k values that pass the validity tests and would lead to a broader range of MSY values. As currently implemented the errors in the catch data will effectively emerge as process error in the candidate biomass trajectories.

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).*

21. The output from the model provides frequency distributions of r, K and MSY. These distributions record the frequency with which combinations of r and K generated valid

stock trajectories and are not the same as conventional likelihood estimates where the mode and spread of the distributions are measures of the most likely value and uncertainty. In the case of the MSY the distribution records how frequently a particular value of MSY occurred, not how likely it is to occur. It may be that this distinction is unimportant in practice but it does mean that the MSY distribution should not be interpreted as a true measure of risk.

22. The MSY values generally provide an improved basis on which to set ACLs due to the inclusion of biomass estimates in the model. However, the currently tabulated values (Appendix 2 in Sabater and Kleiber 2014) should be regarded as preliminary and subject to revision based on a number of comments throughout this review. One reason for caution is that the precise basis for the values in these tables is not clearly documented in Sabater and Kleiber and it appears that the actual code used in model runs used configurations that differ in the document. While it is time consuming to do, it would be very useful to have for each stock a summary of the precise assumptions made (r and K ranges, depletion levels etc.), data input with summaries of model output, such as the standard output from the Martell-Froese paper (distributions of r, k and MSY) so that the reader can get a complete picture of the analysis.

23. The model output is used to propose ABCs where the OFL is assumed to be MSY and hence makes a steady state assumption about the fishery. Since the model can produce a distribution of estimated biomass in the final year (or indeed a year ahead) and an associated harvest rate, it should be possible to apply an approximation to the catch equation to derive an OFL geared to current biomass rather than relying on steady state conditions using the formula:

$$OFL = C_{MSY} * B_y / B_{MSY} ,$$

where C is the catch at MSY and B_y refers to the biomass in the current year and B_{MSY} is the biomass at MSY.

24. In the calculation of the ABC a value of P* is used based on a series of criteria related to the assessment and the data. In the scoring criteria for "model information and description" (WPRFMC, 2013b, page 3) a subset of criteria assigns the catch data a value of zero implying high quality. I thought this too optimistic in view of the fact that much of the catch data are derived from surveys and expanded by effort of unknown quality. I would expect some penalty to be applied to the catch data to reflect this uncertainty. I also felt that the additional discount factor of 5% applied to the ABC to obtain the ACL was arbitrary and simply another layer of caution added to an already cautious calculation. Why not just reflect all the uncertainty in the P* value by adjusting the scoring mechanism?

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

25. It is almost inevitable that data poor methods will suffer from a high degree of uncertainty for the very obvious reason that they are informed by few data. This makes the need to explore model uncertainty a high priority. While the Augmented model discussed at the review is a highly appropriate approach, it cannot alone illustrate model uncertainty. It would be desirable to explore the DCAC and DB-SRA methods discussed in Sabater and Kleiber (2103) in order to try to scope model uncertainty. These models require the user to make alternative assumptions and hence help to determine the robustness of MSY estimates to alternative beliefs about the natural system.

26. The Augmented model develops the idea in the Catch-MSY model of setting boundaries on r and K pairs that lead to plausible stock trajectories consistent with the observed catch stream. In so doing the new model sets bounds on the observed biomass interval. Given very limited biomass data this may prove to be the appropriate way forward but it causes problems when trying to establish credible bounds for the biomass through which candidate stock trajectories must pass. It would be desirable to place the model on a more formal statistical footing where, rather than trajectories passing or failing, they assumed a likelihood based on their proximity to the observed value. Clearly if a full time series of biomass observations were available the Schaefer model could be fit using conventional statistical approaches without recourse to the Martell-Froese procedure. However, with more limited data an adequate fit is unlikely. One option would be to use the Martell-Froese procedure (without biomass data) to create a joint prior distribution for r and K that could then be used in a true Bayesian model that included the biomass data with a specified error distribution (such as lognormal). It would then be possible to obtain posterior distributions for MSY and ending biomass that could form true probability distributions for use in management.

27. A further extension of the above would be to model the catches so that the observed catches were included as data with errors. One approach would be to model the harvest rate, H, as a time series such that $\mathrm{logit}(H_{t+1})=\mathrm{logit}(H_t)\exp(e_t)$ where e_t is a normally distributed process error and then derive fitted catches from $C_t=H_tB_t$. The use of logits constrains the values of H to the interval (0,1). Such a model could be fitted using OpenBUGS, INLA or ADModel Builder. It would have the advantage of explicitly accounting for errors in the catches.

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

28. Critical information that is required for the model is an estimate of the resilience of the various species included in the analysis since this will determine the range of r and K values explored by the model. At present the analysis has relied on Fishbase as the source of this information. However, the quality of these estimates is unknown and they may well be dated or derived from populations in other areas where biological characteristics may differ. A high priority should be to assemble as much relevant biological information

as possible on the principal species of interest. Depending on the amount of information already available it may be necessary to initiate a programme of biological sampling in order to determine growth rates, age of maturity, fecundity etc. so that good estimates of resilience can be derived.

29. Biomass surveys are the most important data source other than the catches that are used in the model. It is important to improve the quality of these surveys both to increase coverage (for example by surveying deeper strata) and reduce the variance of the estimates. Current surveys are reliant on divers which limits depth coverage and is susceptible to individual diver effects. It should be possible to use cameras that are more cost-effective, can be used more widely and which reduce exposure to observer error.

30. Although some testing of the Martell-Froese procedure and the Augmented model has been done it remains rather limited. A comprehensive sensitivity test using simulated data is highly desirable. This will need to investigate, in particular the sensitivity of MSY estimates to the assumptions about depletion which are typically the least known quantities and on which strong assumptions have to be made when biomass data are few or absent.

31. In the current implementation of the method the range of valid r and K pairs is determined by drawing values of the parameters at random and testing whether the subsequent stock trajectory is permissible. An *ad hoc* procedure seems to have been implemented to increase the efficiency of the search algorithm by doing a preliminary search and then refining the range of r and K distributions for a second search. This requires a large number of draws. A possible alternative approach is to use the FAST method (Cukier et al 1978) to draw parameters. This method systematically searches the parameter space and reduces redundancy. An R package is available to implement the method (www.cran.r-project.org/web/packages/fast/fast.pdf).

Conclusions and Recommendations

32. The Augmented Catch-MSY model is an important advance in the estimation of MSY for management purposes because it makes use of biomass data. These data should provide substantially better estimates of MSY that the use of catch data alone. Catch limits based on estimates of MSY from the new method are likely to be a major improvement over the current procedure of setting catch limits based on average catches.

33. Risk tables generated using the new method given in Annex 2 if Sabater and Kleiber (2014) should be regarded as preliminary and subject to revision. There remains a great deal of uncertainty about the choice of priors for depletion levels, the biomass interval to eliminate invalid trajectories and the r and K interval revision procedure. I would recommend that a comprehensive sensitivity test is undertaken using both real and simulated data to investigate these issues.

34. At the heart of the new method is the use of biomass observations as constraints on the biomass trajectories. While this helps restrict the range of valid r and K pairs, the current implementation has no formal statistical basis and is open to subjectivity. I would recommend that a more formal statistical approach is developed based on likelihood or Bayesian approaches as discussed under ToR 4.

35. The catch data used in the model are assumed to be exact yet they are often based on CPUE survey information that is subject to both sampling error and bias resulting from incomplete coverage. I would recommend that studies are undertaken into these sources of uncertainty and consideration given to developing the model so that errors in the catch are explicitly taken into account (paragraphs 26 and 27).

36. The principal value of the new method lies in its use of biomass estimates and these are crucial. Every effort should be made to improve these surveys. I recommend that techniques to capture data underwater, such as the use of cameras, are developed to replace dependence on human observation, both to reduce variability and extend depth coverage. Attempts should be made to improve the estimates of the sample variance of the surveys.

37. The model configuration is reliant on resilience measures taken from Fishbase. While this is a useful source, effort should be made to obtain quality controlled information to replace this source. It may be necessary to initiate a sampling programme to collect the required biological information to calculate appropriate resilience measures.

38. It would be very useful to have for each stock a summary of the precise assumptions made (r and K ranges, depletion levels etc.), data input with summaries of model output, such as the standard output from the Martell-Froese paper (distributions of r, k and MSY) so that the reader can get a complete picture of the analysis.

Appendix 1: Bibliography

References

Cukier, R. I.; Levine, H. B. & Shuler, K. E. 1978. Non-Linear Sensitivity Analysis Of Multi-Parameter Model Systems Journal Of Computational Physics, 26 :1-42

Martell S, Froese R. 2012. A simple method for estimating MSY from catch and resilience. Fish and Fish. http://dk.doi.org/10.1111/j.1467-2979.2012.00485

Schaefer MB. 1954. Some aspects of the dynamics of populations, important for the management of the commercial fisheries. Inter-Am Trop Tuna Comm Bull. 1(2):23-56

Brodziak, J., Counrtney, 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.

Froese R, Pauly D. 2013. FishBase. [Internet]. World Wide Web electronic publication. [June, 2013] Available from: www.fishbase.org.

Sabater, Marlowe and Pierre Kleiber (2014) Improving Specifications of acceptable biological catches of data-poor reef fish stocks using a biomass-augmented catch-MSY approach. Western Pacific Regional Fishery Management Council, Honolulu, HI 96813 USA. NOAA Technical Memorandum NMFS-PIFSC-29 60p

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

Western Pacific Regional Fishery Management Council (2013b) December 11-12, 2013, P* Working Group Meeting Draft Report 6p.

Western Pacific Regional Fishery Management Council SEEM Working Group Meeting Draft Report (2014) February 26-28 2014, NOAA Technical Memorandum NMFS Series 16p.

Williams, I. (2010) US Pacific Reef Fish Biomass Estimates Based on Visual Survey Data. PIFSC Internal Report IR-10-024 243p.

Additional materials provided

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

Presentations

Report on P* Working Meeting

A Clinical Presentation of the Anatomy of an ACL
Modified "Catch-MSY" method for setting ACLs for coral reef species
Data preparations for the Back-Missy! model
Initial ACL specification and the need to improve.....

Appendix 2: 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:

Allen Shimada, COR Technical Assistant

NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
allen.shimada@noaa.gov Phone: 301-427-8174

William Michaels, COR
NMFS Office of Science and Technology
1315 East West Hwy, SSMC3, F/ST4, Silver Spring, MD 20910
William.Michaels@noaa.gov Phone: 301-427-8155

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc.
10600 SW 131st Court, Miami, FL 33186
shivlanim@bellsouth.net Phone: 305-383-4229

Key Personnel:

NMFS Project Contact:

Gerard DiNardo
2570 Dole Street
Honolulu, HI 96822-2396
gerard.dinardo@noaa.gov Phone: 808-983-5397

NMFS Pacific Islands Fisheries Science Center Director:

Samuel Pooley
2570 Dole Street
Honolulu, HI 96822-2396
Samuel.pooley@noaa.gov Phone: 808-983-5300

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.

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