Center for Independent Experts (CIE) Independent Peer Review Report of: Length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories

Graham Pilling
CIE reviewer

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1. Executive Summary

The Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories was held from the 8th to 11th September 2015 at the University of Hawaii Manoa Campus. I was contracted by the Center for Independent Experts (CIE) to act as a member of the Review panel. The purpose of the meeting was to provide an external peer review of a proposed length-based approach to evaluate reef fish stock status, in accordance with the requirements for CIE reviewers contained in the Statement of Work (Appendix 2).

Review activities
Documents were made available to the review panel through email in advance of the meeting. Prior to the review meeting I familiarized myself with these documents to gain an understanding of the methods used, their results, and to identify any issues requiring clarification or explanation. The review was carried out through a series of presentations (see Appendix 1). The review panel questioned the presenters and other members of the PIFSC team on any points requiring elaboration and/or clarification, and made a small number of requests for additional analyses to be undertaken and further information to be supplied. The additional requests were all addressed.

Main findings and recommendations
All Terms of Reference (ToR) were addressed fully. This report was agreed to meet the requirements of ToR 6.

The overall proposed assessment approach for coral reef fish stocks in Hawaii and other U.S. Pacific territories has two main elements:

1) deterministic length-based estimation of stock status (estimation of growth and estimation of M, SPR and F & F_{MSY}); and
2) estimation of abundance and OFLs.

I summarise findings under these two elements by ToR, and refer the reader to the main text for full information. Main observations and recommendations are highlighted in bold. Given the assessments are considered to be ‘data poor’, capturing uncertainty in estimates is key, and many of the comments and recommendations focus on this aspect.

Length-based estimation of stock status

ToR1
The length-based mortality estimation approach is based on known literature that has been peer reviewed, benchmark reviewed and simulation tested. The approach appears **generally appropriate for the coral reef species being assessed and for estimating SPR and F and F_{MSY} values, but expert judgment is required on a stock-by-stock basis when the approach is applied**.

Dependent upon the availability of data, the overall approach can be applied using three sub-approaches that incorporate uncertainty. Results from these approaches show the expected amplification of uncertainty through the process; e.g. CVs on results increase as the level of data poverty increases. However, the overall uncertainty is likely underestimated. The associated use of life-history parameter invariant relationships to estimate parameters within the most data-poor approach is based upon well-documented theory.

While the overall approach therefore appears appropriate and suitable for application, it does not appear to be robust (biases, variances and uncertainty are species-specific) and cannot be applied without using expert judgment. That judgment needs to be applied at each of the steps, to ensure the appropriateness of assumptions being made and parameter values being used, based on an understanding of the quality of analyses that developed those parameters. As a result, a key recommendation is: **the development of a clear decision chart of meta-rules to increase transparency in the application of the approach (through to developing OFLs).** Noting that part of this review was to focus on the generality of the approach for application in other areas/fisheries, **this decision tree would help guide the types of decision a user would need to make or consider during its application, and for managers would clearly indicate how the approach was applied.** Related to this, a further key recommendation is: **simulation testing of the approach, to examine its robustness to potential uncertainties and biases**.

ToR 2
Although the first methodological element and its application are considered appropriate, there are areas where alternative approaches or wider consideration of uncertainty is warranted. These are detailed within recommendations under ToR 2, in particular:

- As an alternative to calculating mean length across islands and applying that in the remainder of the process, **use the sectoral mean lengths (the primary index of exploitation) through to the estimate of fishing mortality, and weight resulting estimates to calculate overall fishing mortality;**
- The estimation approach for Lc is currently subjective. **Examine the sensitivity of estimated stock status and OFL to uncertainty in the value of Lc used. If results are sensitive, investigate the use of potentially less subjective approaches such as a length-converted catch curves to estimate Lc;**
- **Within the estimation of natural mortality, examine the sensitivity of results to using the actual estimate of survivorship at the oldest age (4.3% rather than 5%)**, and given that M is perhaps the most uncertain parameter within the analysis, **more fully capture uncertainty in natural mortality estimates**, for example by using the variability around the maximum age/Z relationship developed for the Northwest Hawaiian Islands. This would also influence the development of uncertainty in the M-K relationship derived in the stepwise data poor approach;
- When incorporating uncertainty in parameter estimates:
    - **Evaluate the data underlying the CVs derived from Kritzer et al. (2001), and compare them to those derived for species around the Main Hawaiian Islands and U.S. Pacific territories that can be estimated using e.g. the length-at-age bootstrapping approach for Linf and K**;
    - When applying the stepwise data poor approach, **develop a distribution of Lmax, e.g. by bootstrapping available data for related species, from which draws can be taken to capture this element of uncertainty.**
- For some Main Hawaiian Island stocks the available Lmax values extended beyond the range of estimates from which the life history parameter relationships were developed for the corresponding family. Therefore, **consider the efficacy of estimates and uncertainty developed where input parameters for a species require extrapolation outside the range of data on which the relationships were based, and note those within the development of the guidelines recommended above.**

ToR 3

The length-based approach allows the calculation of SPR, fishing mortality and F_{MSY} values, as well as optimum sizes at capture. **While the estimation of SPR and both F and F_{MSY} are scientifically sound for use within the management framework, expert judgment is required on a stock-by-stock basis when the approach is applied.** Specific issues with SPR estimation are detailed under ToR4.

ToR 4

It was noted that the calculation of SPR was inconsistent with the calculation of benchmark proxies such as 30% SPR developed using female biomass only. In turn, there was concern over the potential impact of sex-change within reef fish on the calculation outputs. Recommendations therefore included: **that SPR be calculated using female biomass only; that the approach used by Ault et al. (2008) be applied to take into account the ratio of females within the calculation;** and **where the male proportion is considered important (e.g. in the case of protogyny), calculate male and female SPRs separately**.

There was an inconsistent treatment of assessment outputs where negative fishing mortality estimates were derived. It is recommended that **runs with a negative fishing mortality estimates be included within all calculations and representations to managers**, and approaches to do so are suggested.

Finally, although the length-based approach used is viewed as appropriate to estimate stock status, I would recommend: **a 'weight of evidence' approach whereby multiple methods are used to assess the status of the stock and drive management considerations.** For example, estimates of CPUE from the dive survey should already be standardized, and hence where the species biology imply these CPUE estimates may reflect population abundance, this could be used as another stock signal for management advice.

Estimation of OFLs

To estimate Federally-required OFLs, an estimate of abundance is required to scale up a relative measure (e.g. SPR) to an OFL. Two sources of data were used to do this: diver survey abundance estimates, and commercial/recreational catch data time series. The data collection approaches behind these values were explicitly outside the TOR for this review, and I will make no assumption on the efficacy of the approaches used to gather these values.

ToR 1

The alternative sources of abundance estimates represent the biggest source of uncertainty when calculating the OFL. Dependent upon the stock in question, expert judgment will be required to define whether dive survey abundance data and/or catch data are appropriate to use for OFL calculation. There will be cases for stocks where the uncertainty is so great, no OFL should be calculated.

ToR 2

There were areas where additional consideration of uncertainty is warranted within the estimation of abundance, **in particular where the dive survey information is used**. This includes **the identification of the key issues contributing to overall uncertainty**, and areas for consideration are suggested in the main text.

ToRs 3 and 4

Given that the estimation of OFLs appears to represent the greatest area of uncertainty, and to ensure this is clearly represented within information presented to managers, it is recommended that **OFL distributions arising from all relevant data set combinations be presented separately to ensure levels of uncertainty are understood by managers**.

ToR 5

For future work, three key areas were identified, along with the recommendations above:

- To gain a systematic understanding of the performance of the approach through to the OFL calculation, and its robustness under particular conditions (e.g. when applied to species with different biological characteristics, subject to different levels of exploitation, etc.) **the approach should be simulation tested to better understand its performance under varying conditions of species biology and fishery exploitation**.
- If a key concern for managers is the development of OFLs, **the most important focus of further work would be to improve available abundance information to scale outputs from the life history approach**.
- If managers are focused on management compatible with estimates of SPR and F & F_{MSY}, **studies improving knowledge of local life history parameters that will improve the estimation of SPR and F should be prioritized based upon the potential stock status concern identified through the current study, the commercial or recreational importance of the stock, and/or the anticipated ability to obtain (for example) growth parameter estimates from validated ages**.

2. Background

In accordance with the CIE Statement of Work (SOW: Appendix 2), I was contracted to participate as a CIE independent review panelist for the 2015 CIE Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories. This document represents my findings and interpretation of the information provided, and is based on the panel meeting and discussions. However, some of the thoughts and conclusions were formulated in the process of writing this report, and while they were generally raised during the review meeting, they may not have been discussed in detail.

3. Description of Reviewers Role in the Review Activities

The Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories was held from the 8th to 11th September 2015 at the University of Hawaii Manoa Campus. The bibliography consulted is listed in Appendix 1, and the Terms of Reference for the CIE panel is given within the SOW (Appendix 2: Annex 2). A list of meeting participants including panel members and PIFSC staff are listed in Appendix 3. There was no independent chair for this meeting.

The focus of this review was on suitability of the approach and its outputs to meet management requirements under the Magnusson Stevens Act and on possible improvements, rather than specific stock status and OFLs for the coming year. For specific stocks, assessments through to the OFL estimation stage were presented at the meeting; details of this stage of the estimation process were not provided within the documentation received prior to the review meeting. It was agreed that these specific assessments would be used only as examples of the process during the review. Some additional requests were made by reviewers for additional work to clarify particular issues within the process, and these were performed and presented during the review meeting period.

The following report presents my personal evaluation of the review process together with more extended observations on the data and assessment models. The Panel achieved a general consensus view on the ToR which was presented on the last day of the meeting. However my more extended observations are not necessarily shared with the other Panel members. I accept all responsibility for any errors in my report due to misinterpretations of the data or analyses.

4. Summary of Findings

I summarise my findings from the review under each of the Terms of Reference. In discussion with PIFSC staff, it was agreed that ToRs 1 and 3 be generalisations of the assessment approaches and their suitability to generate information appropriate for management decisions, respectively. ToRs 2 and 4 were used to provide specific feedback on approach application as presented in the documents and at the review panel meeting.

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

The overall approach has two main elements that are considered here:

1) length-based estimation of stock status (estimation of growth and M); and
2) calculation of abundance (for OFLs).

Within the first element, there was a hierarchy of three data-dependent approaches to incorporating uncertainty:

1) estimation of length-based mortality where local data are available (bootstrapping method);
2) use of relevant/borrowed life history parameters and use of Kritzer et al. (2001) for CVs around parameters; and
3) the data poor 'stepwise' approach based upon estimates of Lmax.

Uncertainty within abundance estimates were also developed within the second element.

I provide general comments on the two main elements, and within each include discussion of approaches for capturing uncertainty.

Length-based estimation of stock status

The overall approach utilises the documented method of Ehrhardt and Ault (1992) which estimates total mortality (Z) from mean length and life history parameters. Estimates of natural mortality (M) were derived based upon species' longevity information and combined to estimate fishing mortality (F). In turn, life history parameters were used to develop estimates of SPR and F_{MSY} and identify theoretical optimum size-at-capture.

The approach to estimating total mortality is based on known literature that has already been peer reviewed, benchmark reviewed and simulation tested (robustness of mean length to equilibrium assumption; comparing the use of alternative Beverton and Holt and truncated methods). The approach appears generally appropriate for the coral reef species being assessed. In turn, the estimation of natural mortality is also well documented and appropriate. Specific issues with the application are discussed under ToR2. Issues with subsequent estimation of population benchmarks are discussed under ToRs 3 and 4.

The approach assumes equilibrium conditions, which has been evaluated within the stocks and fisheries of interest based on the stability of mean length over time, combined with knowledge of potential changes in fishing pressure/catch. Implementation of, for example, minimum size regulations would influence the equilibrium assumption. However, I note that non-equilibrium approaches are available for application in those situations.

The application of each of the three approaches to incorporate uncertainty based upon available data shows the expected amplification of uncertainty; for example, CVs on results increase with increasing data poverty. However, overall uncertainty is likely underestimated (see below). The associated use of life-history parameter invariant relationships at level 3 (stepwise approach) to estimate parameters is based upon well documented theory (e.g. Beverton and Holt, 1957; Hoeing, 1983; Froese and Binohlan, 2000).

While the behavior of the CVs appears as expected, as a package, however, the overall approach through to estimating SPR and F/F_{MSY} values does not appear robust (e.g. the biases, variances and uncertainty are species-specific. I note that this is not uncommon in data poor situations), and cannot be applied automatically/generically. Its use requires a case-by-case application using expert judgment. That judgment needs to be applied in each of the steps, to ensure the appropriateness of the assumptions being made, parameter values being used, and the quality of analyses and data that developed those parameters.

As a result, when developing and using the approach I recommend: **the development of a clear decision chart of meta-rules to increase transparency for stakeholders.** Noting that part of this review was to focus on the generality of the approach for application in other areas/fisheries, **this decision tree would help guide decision a user would need to make or consider during its application, and for managers would clearly indicate how the approach was applied when developing stock status estimates (and OFLs).**

In turn, a recommendation for future work is simulation testing of the approach, to examine its robustness to potential uncertainties and biases. I discuss this further under ToR 5.

Calculation of abundance
The second element is driven by the Federal requirement to develop OFLs. The reviewed approach required a relative measure estimated through the length-based approach (e.g. SPR) to be scaled up to the OFL through a measure of abundance. Two alternative sources of data were used to do this: diver survey abundance estimates, and commercial/recreational catch data time series. The data collection approaches behind these values were explicitly outside the ToR for this review, and I will make no assumption on the efficacy of the absolute values. However, during the review, there was considerable discussion on the sources of uncertainty within those estimates, as appropriate for a data poor assessment method.

The alternative sources of abundance estimates appear to represent the biggest source of uncertainty when calculating the OFL. This will also likely be an issue with alternative catch-based assessment methods that require an absolute scalar. By comparison, the SPR values calculated within the first element appear more robust to the inherent uncertainties.

Again, expert judgment is required when applying the approach to a stock to define whether dive survey abundance data or catch data are (the most, or at all) appropriate to use for OFL calculation. There will be cases for stocks where the uncertainty is so great that no OFL should be calculated.

Finally, although the length-based approach used is viewed as appropriate to estimate stock status, I would recommend: **a 'weight of evidence' approach whereby multiple methods are used to assess the status of the stock and drive management considerations.** For example, estimates of CPUE from the dive survey should already be standardized, and hence where the species biology might mean that these CPUE estimates may reflect population abundance, this could be used as another stock signal for management advice. I note that the relatively short time series of these data and a potential lack of trend may ultimately prevent the use of this time series in particular areas.

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

As for ToR1, I review details of the application of the method in its two main elements (length-based estimation of stock status; estimation of abundance and hence OFLs), and within each, the approaches used to evaluate uncertainty.

Length-based estimation of stock status
Each of the key stages is discussed separately.

Estimation of total mortality
As noted under ToR1, the estimation of Z using the approach of Ehrhardt and Ault (1992) has been well documented in the peer reviewed literature, and has been the subject of robustness testing. It uses estimates of the mean length in the catch length structure as a primary input. Within the current study, this estimate can be developed from two alternative data sets; the underwater visual census (diver survey) and data submitted by fishers to the Hawaii Division of Aquatic Resources (DAR). As noted in the TOR, review of the data collection approaches was outside the review scope. I therefore concentrate on how the data were developed for this analysis.

Commercial mean size estimates were developed from trip reports, using weight-length relationships and the mean catch weight, itself calculated from reported total catch weight and the corresponding number of fish caught in that trip. This introduces two sources of uncertainty that are not carried through within the analysis. Analyses presented suggested that this approach did not produce biased estimates at low sample sizes, which reflected a high proportion of the trips made. However, it was difficult to identify whether this lack of bias held for catches of greater numbers of individuals. In turn, the process of averaging an average will reduce the variability seen (also seen in other stages of the analysis). While the uncertainty may not be large, it is an area where further analysis should be considered within simulation testing (see ToR 5).

For both dive survey and commercial data estimates, size data collected at the island level were merged to the level of the Main Hawaiian Islands. This is because the following: geographic scale is the focus for the Federal management approach; the level of connectivity between islands is uncertain; and data are frequently too sparse to allow a local assessment to take place. As islands are subject to different levels of exploitation, which will affect mean size, the mean lengths from each island were weighted by the hard-bottom habitat area around each island. While this weighting approach appears reasonable, care needs to be taken in case the assumption of comparable selectivity between islands is not maintained, or if State management interventions influence mean size, for example through minimum size limits that would affect the assumption that size is primarily influenced by exploitation relative to habitat area.

The weighting assumption introduces uncertainty into the process that is not currently captured (a point estimate being used within subsequent calculations). In turn, there is a conceptual issue of taking the mean of the mean length, which would reduce any CV for the combined region. While the approach could be bootstrapped to develop a CV on average length for use in subsequent calculations, an alternative recommendation is: **to take the sectoral mean lengths (the primary index of exploitation) through to the estimate of fishing mortality within the calculation and weight those sectoral estimates by hard bottom area or some other metric (e.g. current density from the dive survey data, if appropriate)**.

A further step to the estimation of total mortality through mean length is the development of an estimate of the length at first capture (Lc), being the first length fully selected by the gear. Currently the approach used to identify Lc is somewhat subjective, being based on visual identification of discontinuities within the length frequency, and taking knowledge of minimum size regulations into account. Bias in the estimation of this length would lead biased estimates of fishing mortality; however, the sensitivity of results to the Lc selected was unclear. A recommendation is to: **examine the sensitivity of stock status and OFL estimates to uncertainty in the value of Lc used. If results are sensitive, investigate the use of potentially (but I note not necessarily!) less subjective approaches such as a length-converted catch curves**.

Finally, in the approach as presented to the review, the 'best' length frequency was selected for use within the analysis, based upon expert knowledge. For example, for highly mobile species, the length data from dive surveys might be considered less appropriate than that from the commercial data, while in the U.S. Pacific territories the dive survey data might be considered more appropriate than that from commercial sampling. However, unless there is a clear basis for excluding one data set, the use of both data sets separately within the analyses is appropriate to capture this source of uncertainty and present it to managers. This is discussed further in recommendations under ToR 4 below.

Estimation of M

To calculate fishing mortality from the derived total mortality estimate, an estimate of natural mortality is required. The approach used is based on the largest estimate of a species' longevity from the worldwide literature, and an estimate of the fraction of a cohort that remains at the maximum longevity. This relationship is well described in peer reviewed literature. While that literature suggests 1.5% survivorship or less, a new fraction was developed using estimates of total mortality from the Northwest Hawaiian Islands where the population is considered unexploited, and hence Z=M. The resulting estimate of 5% is higher than reported in other studies, although that might be influenced by the inclusion of long lived species within literature analyses. The 5% used represents a rounding of the actual estimate of 4.3%. A recommendation is: **to examine the sensitivity of results to the use of a survivor fraction of 4.3% rather than 5%.** While this may have a minimal effect on M estimates (of approximately 5%), it is not clear what impact this could have when taken through to the stage of estimating OFLs.

During the review, it was noted that for some longer-lived reef fish species the estimate of M was potentially too low (results were inconsistent with the known biology of the species around Hawaii), and a lower survivorship fraction was considered more consistent. This again illustrates how the approach relies on expert opinion throughout.

While I note that the maximum age may be affected by the environment, level of fishing pressure, sample size and other factors, the approach used to estimate M is pragmatic. However, give that M is perhaps the most uncertain parameter within the analysis, a recommendation is **to more fully capture the uncertainty in natural mortality estimates**, for example by using the variability around the maximum age/Z relationship developed for the Northwest Hawaiian Islands (Figure 6 of the PLOS_{ONE} paper) or perhaps incorporating the approaches in Kenchington (2013).

Capturing uncertainty

It is highly appropriate to include estimates of uncertainty within the estimation of stock status through data poor approaches. In the length-based estimation of stock status, three alternative approaches through which CVs were estimated within population parameters were applied, dependent upon the level of data available:

1) deterministic estimation of length-based mortality where local data are available (bootstrapping method);
2) use of relevant/borrowed life history parameters and application of Kritzer et al. (2001) for CVs around parameters; and
3) the data poor 'stepwise' approach based upon estimates of Lmax.

As a general comment on the approaches presented, it was reassuring to see that the level of uncertainty in outputs propagates and multiplies through the process as it moved from relatively data rich (1; local data available) to data poor (3; data poor stepwise).

- ***Method 1 – local data available***

Where actual data (length-at-age and/or maturity-at-length data) were available, a size-stratified bootstrap approach was used to estimate variability in growth, natural mortality and maturity-at-length parameters. That size-stratification attempted to mimic the sampling design commonly underlying estimation of those parameters. This approach appeared reasonable, noting that issues of fully capturing uncertainty within the process have already been detailed when discussing the overall approach above.

I note that there were some differences between the results presented during the review process, and those in the documentation provided prior to the review meeting. For example, the version of Figure 7 of the PLOS_{ONE} paper was different to that shown at the review. Given the nature of the review, which focused on methodology rather than outputs, this was not a serious problem, but the reasons behind those differences should be investigated.

I also note that in some of the growth parameter estimates presented in that paper (Table 3; *Lutjanus kasmira*, *Cephalopholis argus* and *Myripristis berndti*), highly negative t_0 values were present, suggesting that estimates may have been biased by a lack of young individuals within the sample. The over-estimation of Linf and underestimation of K that likely results may well be 'precautionary' as slower growth should lead to a lower estimate of natural mortality, but the potential for calculations later in the chain to lead to compensatory biases within the estimation of stock status cannot be ruled out. This again raises the need to simulation test the process (see recommendation under ToR5).

- ***Method 2 – relevant life history parameters***

Where underlying data were absent, but relevant life history parameter estimates were available, uncertainty around those estimates was assumed based on the results of analyses by Kritzer et al. (2001). CVs were defined by the number of samples underlying those parameter estimates, and represented the average CV for that sample size across the four species examined in that paper.

I note that the four species examined in Kritzer et al. (representing groupers, snappers and emperors) do not directly reflect any of the species examined within the Hawaiian data sets, and indeed include one family absent from the Hawaiian region. The approach also assumes that the CV within parameter estimates for a given sample size from Kritzer et al. is comparable where the underlying pattern of data for the estimation of that parameter in Hawaii or U.S. territories may potentially be very different. For example, the growth curves presented within Kritzer et al. can lack samples from younger fish (e.g. the case of *Cephalopholis cyanostigma*) and hence may influence the CVs of parameters estimated (e.g. CVs on K might be lower than expected). I therefore recommend: **a further evaluation of the data underlying the CVs estimated in Kritzer et al., and a comparison between these CVs and those for parameters for the Main Hawaiian Islands that can be estimated using Method 1 above**.

- ***Method 3 – data poor 'stepwise' approach***

In cases where no relevant life history parameters are available for a species, but size data are available, a sequence of life history invariant relationships are proposed to estimate necessary parameters (see figure). Those relationships were developed using relevant parameter estimates from reef fish species around the world. To capture uncertainty, outputs from the relationships were bootstrapped to develop distributions of estimated parameters, and hence a distribution of stock status estimates and OFLs.

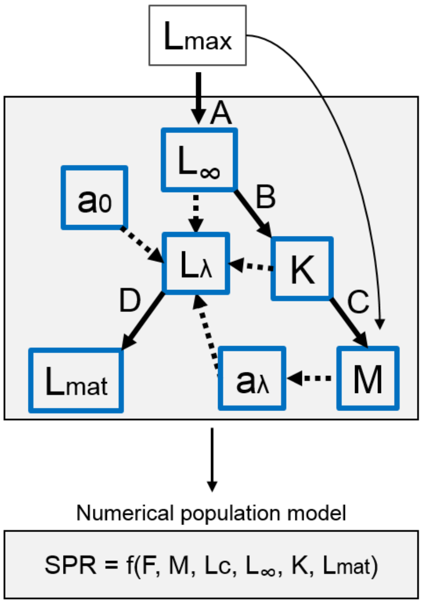

Figure reproduced from Nadon and Ault (2015b).

The relationships derived using biological parameters from the literature were developed within families, as life history invariants have been found to vary significantly between families. This is a pragmatic approach, and while environmental influences on life history will likely lead to within family variability, as seen within review presentations on life history estimates for species within U.S. Pacific territories, this cannot be readily captured but does suggest uncertainty may be underestimated.

A key input to the stepwise approach is Lmax, which is used to estimate Linf at the start of the process (see schematic above). In theory, if this 'stepwise' approach is applied using an Lmax from a more heavily exploited population than that from which the Lmax-Linf relationship was derived, lower Linf and higher K estimates would result, but the impact of this on the estimates of stock status may be compensated for to an extent through the Ehrhardt and Ault approach to estimating Z. It was not clear how the approach would react to such biases, and again I refer to the need to simulation test the approach to gain a better understanding (see ToR 5).

The value of Lmax is derived in different ways, dependent upon the data source. Where catch length samples were available, the actual maximum length was taken. Where length estimates from diver surveys were available, the 99th percentile of those length distributions was taken as Lmax. This percentile was selected based on relationships examined between Lmax values derived from the two data sets where both values were available, and where different percentiles of the maximum size were selected for the dive survey Lmax. The 99th percentile gave the 'closest' comparison to Lmax from catch length data, and reduced bias. Currently this value is used as a point estimate of Lmax to draw a random estimate of Linf, and hence K and M. This underestimates uncertainty, given that Lmax is influenced by other factors that are not captured here. Therefore I recommend: **that a distribution of Lmax be developed for each stock, e.g. by bootstrapping the available data, from which draws can then be taken to capture this element of uncertainty**.

Natural mortality is estimated based upon the relationship with K (where individual estimates of M derived through maximum longevity were used to develop the M-K relationship). As noted above, there is the potential to consider greater uncertainty within the estimate of M that goes into the M-K relationship, which would potentially better capture the uncertainty within that relationship. This is covered with the recommendation related to M above.

Finally, during the review it was noted that for some Main Hawaiian Island stocks the available Lmax values extended beyond the range of estimates from which the life history parameter estimates were developed for the corresponding family (e.g. in the cases of *Mullodichthys pfluegeri*, *Parupeneus cyclostomus* and *P. insularis*). Generally, extrapolating beyond the range of the data is not recommended due to the unknown form of a relationship outside that region. A recommendation is therefore: **to acknowledge and consider the efficacy of estimates and uncertainty developed where input parameters require extrapolation outside the range of data on which the relationships were based, and note those within the development of the guidelines recommended under ToR 1**.

Estimation of abundance

Estimates of abundance were required to estimate OFLs. This was identified as a key area of uncertainty driven by the abundance data inputs, which were derived from diver surveys or the combined catch records from recreational and commercial fisheries. These abundance estimates were calculated as ranges to capture uncertainty.

I note that the requirement for an island-chain-level (Main Hawaiian Islands) OFL does assume that the fish populations are 100% connected across islands. An unequal pattern of fishing across the islands may mean that one island could become heavily exploited (thereby affecting the equilibrium assumption), but 'averaging' the abundance (and hence OFL) across islands might mean the level of exploitation is assumed to be lower.

Dive survey abundance

Dive survey fish density estimates were bootstrapped by island survey sector/depth strata. Those sectors were developed from hard bottom habitat types (simple, coral, or complex) and also considerations of fishing intensity. However, this may not capture all key sources of uncertainty. For example:

- the physical area surveyed is relatively low compared to the habitat. While this is less of an issue when developing the relative abundance estimates that is the focus of the survey, it leads to large raising factors when estimating absolute abundance as required for OFLs;

- the area of habitat is considered a point estimate within calculations, so that uncertainty is underestimated;
- the length of fish estimated by the diver is assumed to be accurate, and the length-weight relationship used to calculate the resulting biomass-density at that site is deterministic, but variability around both the mean weight and length estimate may be estimable;
- there is uncertainty in the ability of the sampling design to capture all variability, which might be investigated through for example using alternative sampling strata for bootstrapping (or at the extreme, ignoring site-level data and sample from all data within a region);
- rather than bootstrapping the estimated site density estimates, consider using the raw length frequency data, for example by bootstrapping the abundance at size by strata;
- the current bootstrapping approach appears different to that used to develop the mean length information within the length-based estimation of stock status. Consider whether they should be consistent.

A recommendation is therefore: **to expand the estimation of uncertainty in dive-survey abundance estimates and identify the key uncertainties contributing to overall uncertainty**.

While the survey data were considered less likely to represent an accurate estimate of abundance for certain species, particularly highly mobile ones, it was potentially an improvement over the catch data for many species. In turn, it may represent better abundance information than catch data for U.S. Pacific territories, compared to the situation in the Main Hawaiian Islands.

Catch data

Under the assumption that the commercial and recreational catch data are correct, uncertainty was calculated from inter-annual variability within the data over the recent period, as the standard deviation of the mean annual catches. This likely underestimates the true uncertainty. Indeed, there appears to be a potentially unknown level of bias in the catch information; for most species, the recreational catch was the largest component, and that component was the most uncertain (being estimated through phone and intercept surveys) and the shortest time series. In turn for some families (e.g. parrotfish), catch has not been broken down by species which reduces the utility of catch data as a source of 'abundance' information for this family.

During the review meeting, the potential for a consistent underestimation of catches over time to lead to consistently precautionary OFL estimates was suggested. While the commercial catch data might indeed be underestimated for some species, there appeared to be relatively high inter-annual variability, and trends in some of the data sets in the recent period, which implies that such assumptions of constant bias would be difficult to make.

ToR 3. Comment on the scientific soundness of the estimated population benchmarks and management parameters (e.g., spawning potential ratio, F/F_{msy}, B/B_{msy}, stock status) and their potential efficacy in addressing the management goals stated in the relevant FEP or other documents provided to the review panel.

The approach develops the following management-relevant population benchmarks: SPR, F and F_{MSY}, and has been extended to estimate OFLs. During the review, examples of using the process to estimate OFLs were presented. While OFLs were a primary requirement for Federal management, it was also noted that other regulations could be implemented. I therefore acknowledge that the approach also allows minimum size of capture to be estimated to achieve population benchmarks for alternative management interventions.

Overall the estimation of SPR and both F and F_{MSY} appear scientifically sound for use within the management framework, but expert judgment is required on a stock-by-stock basis to understand the potential uncertainties and biases within the specific approach used. As noted above, uncertainty propagates through the overall hierarchical approach as anticipated (i.e. with increasing data poverty, uncertainty increases). However, I note that the resulting bias appears inconsistent between stocks and causes of that bias are not clear. Therefore, **while the estimation of SPR and both F and F_{MSY} are scientifically sound for use within the management framework, expert judgment is required on a stock-by-stock basis when the approach is applied**.

30% SPR is used as a proxy for MSY, consistent with the recommendations of Restrepo et al. (1998) for data limited situations. However, the percentage selected is a policy decision and alternative values can easily be calculated from the results of this approach.

However, the current implementation of SPR may be incorrect, particularly when applied to reef fish species that change sex over their lifespan. The 30% SPR from Restrepo et al. (1998) represents a female-only calculation. The current approach calculates SSB as male + female, although a female Lmat was used throughout. I recommend: **that SPR is calculated using female biomass only, consistent with the use of a female-only Lmat**; and **that the approach described in Ault et al. (2008), which attempts to takes the ratio of females into account within the SPR calculation, be used where practical. An alternative, if the male proportion is considered important (e.g. in the case of protogyny), is to calculate male and female SPR values separately.** There is also the potential to simulation test the implications of this assumption within the work recommended under ToR 5.

With reference to levels of risk, again a management decision, the Magnuson-Stevens act describes a value of 50% risk, but no management decision on risk has been specifically taken in Hawaii for these species. While results at a risk level of 30% were presented during the review, these can also be re-calculated for alternative risk levels.

The scientific soundness of OFL estimates is less clear. As noted under ToR 2, the step from SPR and F_{MSY} to OFL introduces considerable uncertainty through the need to use catch/abundance data to scale up to the OFL estimate. From the examples presented, the OFL appeared appropriately estimated if a good estimate of that scalar was available, but not in the absence of an unbiased estimate of catch/abundance.

Within documentation provided to the review panel, there was a tendency to present results derived only from what was considered the 'best' length frequency distribution, or results as a weighted combination of data/models. However, a better practice is to provide the full representation of uncertainty to the managers, to ensure they are fully informed. Therefore, a recommendation is that: **alternative available data sets should be used through to the stage of estimating OFLs to better capture the uncertainty present, including both the population parameter value assumptions, and the abundance estimates for the OFL calculations**. Under this approach, multiple OFL distributions would therefore be presented to managers, representing different combinations of these input assumptions. One of these may represent a ‘base case’, while the others represent sensitivities. There may subsequently be an iterative process with managers to reduce the acceptable range of result options shown, but at this stage pre-selecting specific OFL distributions is not recommended.

The assumption of equilibrium conditions within the approach provides an advantage in that on a year-to-year basis monitoring the mean length estimate will identify any need to update population benchmark values. Monitoring and updating abundance/catch estimates would then be all that is required to update an OFL.

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

While the calculation of population benchmarks appeared appropriate - uncertainty in OFL calculation noted - the approach presented during the review was inconsistent in how it dealt with estimated negative fishing mortality estimates. These can arise through the calculations due to mis-matches between input parameter values and the length structure present. Within the calculation of risk of the stock being below population benchmarks these events were included and hence that calculation was considered appropriate. Within the graphical representation of the range of stock status (and hence also the OFL distribution), these runs were excluded. This has the potential to present an overly pessimistic picture to managers. I recommend: **that runs where a negative fishing mortality estimate was derived be included in all calculations and representations to managers**. Graphically, this may be presented through a ‘plus group’ for the distribution, or as a ‘zero’ F estimate (SPR=1) group which should be noted separately from ‘true’ zero F estimates.

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

Throughout the above TORs, recommendations are made for further work are listed within the Executive Summary and throughout the text above. Areas for research considered key, into which those earlier recommendations feed, are detailed below.

While a range of assessment runs were presented during the review, they did not allow identification of any consistent pattern in bias or uncertainty. Therefore, a key observation has been the need to gain a systematic understanding of the performance of the approach through to the OFL calculation, and its robustness under particular conditions (e.g. when applied to species with different biological characteristics, subject to different levels of exploitation, etc.) and what steps of the process lead to additive, or compensatory, biases. I recommend: **that the approach be simulation tested to better understand its performance under varying conditions of species biology and fishery exploitation**. This should mirror the processes through to the calculation of F, SPR and OFL. During this study, the occurrence of false positive and false negative stock status outcomes should be identified. Existing simulation testing of the approach of Ehrhardt and Ault (1992) should be consulted to avoid duplication. In turn, the design of the simulation should ensure that key assumptions in the assessment approaches are included. For example, where calculations assume knifeedge selectivity (e.g. in maximum yield-per-recruit), this assumption should be included in the calculations where modelling may include gears assumed to have, for example, asymptotic selectivity.

If a key concern for managers is the development of OFLs, I recommend that: **the most important focus of further work would be to improve available abundance information to scale the outputs from the life history approach**, be that catch (recreational and commercial reporting), or abundance from the dive survey, dependent upon which data set is considered 'best' for that stock.

If managers are focused on management compatible with estimates of SPR and F & F_{MSY}, improved local knowledge of growth parameters and other biological characteristics would clearly reduce uncertainty within the process, and avoid the use of the data poor 'stepwise' estimation approach. I recommend that: **studies improving knowledge of local life history parameters that will improve the estimation of SPR and F be prioritized based upon the potential stock status concern identified through the current study, the commercial or recreational importance of the stock, or the anticipated ability to obtain (for example) growth parameter estimates from validated ages**.

ToR 6. Draft a report of the WPSAR Panel conclusions and findings, addressing each Term of Reference.

On the first day of the meeting, it was agreed with the PIFSC staff that given the nature of the review and the format of the meeting (without an independent chair), the production of the individual reviewer reports would meet the requirements of this ToR.

5. Comments on the NMFS review process

The lead scientist (Marc Nadon) did a good job of presenting the information, was receptive to ideas, responsive to requests and helpful throughout. Thanks to him and the PIFSC team for the organization of the meeting logistics.

One area that could be improved would be the receipt of all documentation prior to the review meeting. As an example, we received information on the approach to estimating OFLs early in the review meeting, through PowerPoint, which did reduce the time available to review this key step in developing management advice.

6. Conclusions and Recommendations

The overall approach has two main elements that are considered here:

1) deterministic length-based estimation of stock status (estimation of growth and estimation of M, SPR and F & F_{MSY}); and
2) calculation of abundance and estimation of OFLs.

Length-based estimation of stock status

The length-based mortality estimation approach is based on known literature that has been peer reviewed, benchmark reviewed and simulation tested. The approach appears generally appropriate for the coral reef species being assessed and for estimating SPR and F/F_{MSY} values.

Within the length-based approach, there was the option for three sub-approaches to incorporate uncertainty dependent upon the available data that shows the expected amplification of uncertainty through the process; for example, the CVs on results increase as the level of data poverty increases. However, the overall uncertainty is likely underestimated. The associated use of life-history parameter invariant relationships to estimate parameters is based upon well documented theory.

An issue raised is that while appropriate, the length-based approach does not appear robust (biases, variances and uncertainty are species-specific) and cannot be applied automatically/generically. It requires a case-by-case application using expert judgment, applied in each of the steps, to ensure the appropriateness of the assumptions being made and parameter values being used. As a result, a key recommendation is: **the development of a clear decision chart of meta-rules to increase transparency. Noting that part of this review was to focus on the generality of the approach for application in other areas/fisheries, this decision tree would help guide the types of decision a user would need to make or consider during its application, and for managers would clearly indicate how the approach was applied.**

In turn, a further key recommendation is: **the simulation testing of the approach, to examine the robustness of the approach to potential uncertainties and biases**.

Although the approach and its application are considered appropriate, there are areas where alternative approaches or additional consideration of uncertainty is warranted within this data poor approach. These are detailed within recommendations under ToR2, in particular: **in the calculation of mean length and length at first capture, estimation of natural mortality, where alternative approaches are suggested; the inclusion of uncertainty in the estimate of maximum length that drives the data poor stepwise approach; analysis of CVs from the literature around parameters; and caution where input values are outside the range of the data used to develop parameter estimation relationships.**

The length-based approach allows the calculation of SPR, fishing mortality and F_{MSY} values, as well as optimum sizes at capture. If managers are focused on management compatible with these population benchmarks, **improved local knowledge of growth parameters and other biological characteristics would clearly reduce uncertainty within the process, and avoid the use of the data poor 'stepwise' estimation approach**. It was noted that the calculation of SPR was inconsistent with the calculation of benchmark proxies such as 30%SPR that were developed using female biomass only. In turn, there was concern of the potential impact of sex-change within reef fish on the calculation outputs. Recommendations therefore included: **that SPR be calculated using female biomass only, consistent with the use of a female Lmat; that the approach used by Ault et al. (2008) that takes the ratio of females into account within the calculation be applied; and where the male proportion is considered important (e.g. in the case of protogyny), calculate male and female SPRs separately**.

Finally, although the length-based approach used is viewed as appropriate to estimate stock status, I would recommend: **a 'weight of evidence' approach whereby multiple methods are used to assess the status of the stock and drive management considerations.** For example, estimates of CPUE from the dive survey should be standardized, and hence where the species biology might mean that CPUE estimates reflect population abundance, this could be used as another stock signal for management advice.

Estimation of OFLs

To estimate Federally-required OFLs, an estimate of abundance is required to scale up a relative measure (e.g. SPR) to an OFL. Two sources of data were used to do this: diver survey abundance estimates, and commercial/recreational catch data time series. The data collection approaches behind these values were explicitly outside the TOR for this review, and I will make no assumption on the efficacy of the approaches used to gather these values.

The alternative sources of abundance estimates represent the biggest source of uncertainty when calculating the OFL. Again, **dependent upon the stock in question, expert judgment will be required to define whether dive survey abundance data or catch data are (the most, or at all) appropriate to use for OFL calculation. There will be cases for stocks where the uncertainty is so great, no OFL should be calculated**. However, it is also recommended that **OFL distributions arising from all relevant data set combinations be presented to managers to ensure levels of uncertainty are understood**. If OFLs are a key concern for managers, **the most important focus of further work would be to improve available abundance information to scale the outputs from the life history approach**. In turn, **approaches to more fully capture uncertainty in abundance estimates, particularly from diver surveys, are suggested**.

It was noted that there was an inconsistent treatment of assessment outputs where negative fishing mortality estimates were derived. It is recommended that **runs with a negative fishing mortality estimates be included within all calculations and representations to managers**, and approaches to do so are suggested.

7. Appendix 1. Bibliography of materials provided

Documents provided prior to the meeting:

- Ault, J. S., J. A. Bohnsack, and G. A. Meester. 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fishery Bulletin 96:395–414.
- Ault, J. S., S. G. Smith, and J. A. Bohnsack. 2005. Evaluation of average length as an estimator of exploitation status for the Florida coral-reef fish community. ICES Journal of Marine Science 62:417–423.
- Ault, J. S., S. G. Smith, J. Luo, M. E. Monaco, and R. S. Appeldoorn. 2008. Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation 35:221–231.
- Beverton, R. J. H., and S. J. Holt. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapports et proces-verbaux des reunions du Conseil International pour l'Exploration de la Mer 140:67–83.
- Ehrhardt, N. M., and J. S. Ault. 1992. Analysis of two length-based mortality models applied to bounded catch length frequencies. Transactions of the American Fisheries Society 121:115–122.
- Gedamke, T., and J. M. Hoenig. 2006. Estimating mortality from mean length data in nonequilibrium situations, with application to the assessment of goosefish. Transactions of the American Fisheries Society 135:476–487.
- Nadon, M. O., and J. S. Ault. 2015a. A stepwise stochastic simulation approach to obtain missing life history parameters for data-poor fisheries. Unpublished:1–34.
- Nadon, M. O., and J. S. Ault. 2015b. Assessment of data-poor Hawaiian coral reef fish populations using life history parameters obtained through a stepwise stochastic simulation approach. Unpublished: 1–31.
- Nadon, M. O., J. S. Ault, I. D. Williams, S. G. Smith, and G. T. DiNardo. 2015. Length-based assessment of coral reef fish populations in the Main and Northwestern Hawaiian Islands. Unpublished: 1–28.

Powerpoint presentations and further references provided during the meeting:

- CIE Introduction
- Fishery description
- Deterministic stock assessment
- Incorporating uncertainty in stock assessment
- Estimating data-poor life history
- Generating ACLs (updated version supplied later in the week)
- CIE Reef Fish Life History Information_Humphreys_FINAL_08Sept2015
- Dunlap_CIE reef fish lengths management overview
- Hawaii Commercial Data_MKLowe_2015_0908_NadonCIE
- Williams CRED Reef Fish Visual Survey Program Overview

Kritzer, J.P., Davies, C.R. and Mapstone, B.D. (2001). Characterising fish populations: effects of sample size and population structure on the precision of demographic parameter estimates. Canadian Journal of Fisheries and Aquatic Sciences 58: 1557-1568.

Information on species length frequency distributions:

- Size frequency in MHI from diver surveys.pdf

- Commercial size structure.xlsx

Additional references used in this report:

- Beverton, R.J.H and Holt, S.J. (1957). On the dynamics of exploited fish populations. Chapman-Hall, London.
- Froese, R. and Binohlan, C. (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology 56, 758-773.
- Hoenig, J.M. (1983). Empirical use of longevity data to estimate mortality rates. Fisheries Bulletin 82, 898-903.
- Kenchington, T.J. (2013). Natural mortality estimators for information-limited fisheries. Fish and Fisheries 15, 533-562.
- Restrepo, V. R., Thompson, G. G., Mace, P.M., Gabriel, W. L., Low, L. L., MacCall, A. D., Methot, R. D., Powers, J. E., Taylor, B. L., Wade, P. R., and Witzig, J. F. (1998). Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. National Oceanic and Atmospheric Administration (U.S.) Technical Memorandum NMFS-F/SPO-31. 54 pp.

8. Appendix 2. CIE Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories

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

Project Description: The Pacific Islands Fisheries Science Center (PIFSC) is conducting stock assessments on exploited coral reef fish species in Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands which are listed in the Western Pacific Regional Fishery Management Council's Fishery Ecosystem Plans. These stocks are generally classified as data-poor due to a lack of reliable, long-term, catch and fishing effort data. However, some parsimonious assessment models rely on more easily obtainable length composition data and certain key population demographic parameters related to growth, maturity, and longevity. PIFSC scientists have been implementing an approach that uses the average length in the exploited phase of the population (L_{bar}) to obtain an estimate of total and fishing mortality rates for coral reef fish stocks (Beverton & Holt 1956; Ehrhardt & Ault 1992). These rates, combined with population demographic parameters, are used in numerical population models to obtain stock sustainability metrics (e.g., spawning potential ratio, F/F_{msy}, B/B_{msy}; see Ault et al. 1998, 2008). Acceptable Biological Catches (ABCs) can be generated by obtaining recent total catch estimates and specifying new ABCs based on the results of the population sustainability analyses. Furthermore, a novel meta-analytical approach using stochastic simulations was developed at PIFSC to obtain demographic parameter estimates for species with even less data than data-poor species ("data-less" species). These scientific analyses have not previously been applied for management purposes in the Pacific Islands Region, so there is a need to conduct an independent peer review of the analyses to improve the scientific basis for management.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.
Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall

have working knowledge and recent experience in the application of: general fisheries stock assessment, familiarity with length and age-based fishery models, and data-poor approaches to conducting stock assessments.

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

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in Honolulu, HI during September 8th-11th, 2015.

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

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

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

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

Material to be provided: Published scientific papers describing the approach and how it was applied in Florida (Ault et al. 1998) and Puerto Rico (Ault et al. 2008). Submitted paper applying this method to Hawaii (Nadon et al. 2015). Two un-published papers explaining and testing a new approach to obtain missing life history parameters (Nadon & Ault 2015a, 2015b). Other articles describing length-based methods or examining certain aspects of this approach (Ehrhardt & Ault 1992; Ault et al. 2005; Gedamke & Hoenig 2006).

Ault, J. S., J. A. Bohnsack, and G. A. Meester. 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fishery Bulletin 96:395–414.

Ault, J. S., S. G. Smith, and J. A. Bohnsack. 2005. Evaluation of average length as an estimator of exploitation status for the Florida coral-reef fish community. ICES Journal of Marine Science 62:417–423.

Ault, J. S., S. G. Smith, J. Luo, M. E. Monaco, and R. S. Appeldoorn. 2008. Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico. Environmental Conservation 35:221–231.

Beverton, R. J. H., and S. J. Holt. 1956. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapports et proces-verbaux des reunions du Conseil International pour l'Exploration de la Mer 140:67–83.

Ehrhardt, N. M., and J. S. Ault. 1992. Analysis of two length-based mortality models applied to bounded catch length frequencies. Transactions of the American Fisheries Society 121:115–122.

Gedamke, T., and J. M. Hoenig. 2006. Estimating mortality from mean length data in nonequilibrium situations, with application to the assessment of goosefish. Transactions of the American Fisheries Society 135:476–487.

Nadon, M. O., and J. S. Ault. 2015a. A stepwise stochastic simulation approach to obtain missing life history parameters for data-poor fisheries. Unpublished:1–34.

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Nadon, M. O., J. S. Ault, I. D. Williams, S. G. Smith, and G. T. DiNardo. 2015. Length-based assessment of coral reef fish populations in the Main and Northwestern Hawaiian Islands. Unpublished:1–28.

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

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

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

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting in Honolulu, HI, from September 8th-September 11th, 2015, and conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than September 25, 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlanim@ntvifederal.com, and Dr. David, Die, CIE Regional Coordinator, via email to ddie@rsmas.miami. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

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

August 4, 2015	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
August 25,2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
September 8 – September 11, 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
September 25, 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
October 9, 2015	CIE submits CIE independent peer review reports to the COTR
October 16, 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

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

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

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

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

Support Personnel:
Allen Shimada, COR
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

Manoj Shivlani, CIE Lead Coordinator
Northern Taiga Ventures, Inc. Communications
10600 SW 131st Court, Miami, FL 33186
mshivlani@ntvifederal.com Phone: 305-968-7136

Key Personnel:

NMFS Project Contact:
Marc Nadon
Stock Assessment Scientist
Fisheries Research and Monitoring Division
National Marine Fisheries Service
Pacific Islands Fisheries Science Center
1845 Wasp Boulevard, Bldg. #176
Honolulu, Hawaii 96818
marc.nadon@noaa.gov
808-725-5317

Annie Yau
Annie.yau@noaa.gov
808-725-5350

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

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

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

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

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

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

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

3. The reviewer report shall include the following appendices:

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

Annex 2: Terms of Reference for the Peer Review

Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories

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

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

3. Comment on the scientific soundness of the estimated population benchmarks and management parameters (e.g., spawning potential ratio, F/F_{msy}, B/B_{msy}, stock status) and their potential efficacy in addressing the management goals stated in the relevant FEP or other documents provided to the review panel.

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

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

6. Draft a report of the WPSAR Panel conclusions and findings, addressing each Term of Reference.

Annex 3: Agenda

Review of length-based stock assessment methods for coral reef fish stocks in Hawaii and other U.S. Pacific territories

University of Hawaii at Manoa, Hemenway Hall, Room 208

8-11 September 2015

Tuesday September 8 (9:00 am – 4:00 pm)

1. Introduction (Brodziak)
2. Objectives and Terms of Reference (Brodziak)
3. Fishery (Nadon)
4. Data
    - Commercial data (Lowe)
    - Diver survey data (Williams)
    - Age & Growth (Humphrey)
5. Management process (Makaiau)
6. Review of Stock Assessment (Nadon)

Wednesday September 9 (9:00 am – 4:00 pm)

6. Review of Stock Assessment - continued (Nadon)

Thursday September 10 (9:00 am – 4:00 pm)

7. Continue Assessment Review (1/2 day)
8. Panel discussions (Closed)

Friday September 11 (9:00 am – 4:00 pm)

9. Panel Discussions (1/2 day)
10. Present Results (afternoon)
11. Adjourn

9. Appendix 3. Attendance list for the length-based assessment CIE review

Tuesday, September 8th 2015

- Marc Nadon, NOAA Pacific Islands Fisheries Science Center (PIFSC)
- Cathy Dichmont, CIE reviewer
- Kevin Stokes, CIE reviewer
- Graham Pilling, CIE reviewer
- Ivor Williams, PIFSC
- Beth Lumsden, PIFSC
- Jon Brodziak, PIFSC
- Robert Humphreys, PIFSC
- Kimberley Lowe, PIFSC
- Adel Heenan, PIFSC
- Matt Dunlap, NOAA Pacific Islands Regional Office (PIRO)
- Adel Heenan, PIFSC

Wednesday, September 9th 2015

- Marc Nadon, PIFSC
- Cathy Dichmont, CIE reviewer
- Kevin Stokes, CIE reviewer
- Graham Pilling, CIE reviewer
- Ivor Williams, PIFSC
- Annie Yau, PIFSC
- Christopher Boggs, PIFSC
- Matt Dunlap, PIRO
- Marlowe Sabater, Western Pacific Fishery Council

Thursday, September 10th 2015

- Marc Nadon, PIFSC
- Cathy Dichmont, CIE reviewer
- Kevin Stokes, CIE reviewer
- Graham Pilling, CIE reviewer
- Christopher Boggs, PIFSC
- Annie Yau, PIFSC

Friday, September 11th 2015

- Marc Nadon, PIFSC
- Cathy Dichmont, CIE reviewer
- Kevin Stokes, CIE reviewer
- Graham Pilling, CIE reviewer
- Annie Yau, PIFSC
- Christopher Boggs, PIFSC