CENTER FOR INDEPENDENT EXPERTS (CIE) INDEPENDENT PEER REVIEW OF LENGTH-BASED ASSESSMENT METHODS OF CORAL REEF FISH STOCKS IN HAWAII AND OTHER U.S. PACIFIC TERRITORIES

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1 EXECUTIVE SUMMARY

The Center for Independent Experts (CIE) review workshop for the Hawaiian coral reef fish length-based assessments took place in Honolulu, Hawaii, on Sept 8-11 2015. In attendance were review panel members Drs Dichmont, Pilling, and Stokes, stock assessment author Marc Nadon, and other scientists involved in the stock assessment and management of coral reef fish. The review was undertaken in a very co-operative light with requests for additional work met, including providing more diagnostic plots and sensitivity tests. The assessment authors are thanked for a very constructive meeting.

The review investigated the body of work that applies a set of data poor approaches to Hawaii coral reef fish. Much of the work, in various forms, has been applied elsewhere; but this work uniquely combines a series of approaches into an overall package very useful to management.

All Terms of References were met; however, as a package this approach is not robust at all steps in the process in terms of biases and uncertainty (particularly sensitivity to different data and parameter options). Thus, it could not be applied automatically to coral reef fishes and should be used with caution on a case-by-case basis using expert judgment. This judgment needs to be applied at each step of the overall approach. This finding is common for data poor approaches. Despite these words of caution, a very useful package of methods has been developed and could serve as a model for other regions.

A good property of the overall approach is that the propagation of uncertainty works as anticipated in that the more data limited the approach, the greater the variance (but the bias appears inconsistent between species). As a result, the focus on the choice of which method(s) at each step to use should be clearly articulated, and particularly investigated in terms of bias. As a summary and for use with each case, the different steps available should be clearly articulated in a decision chart, and in a single detailed document. More than one scenario should be provided to highlight sensitivity or bias, and combining distributions should be avoided. The reasons for rejecting scenarios should be clearly and transparently explained.

Although there were sources of bias throughout the full approach, the greatest source was often from the different biomass estimates using survey or catch data. In terms of management usefulness to set OFLs, the final application of the approaches reviewed should be taken on a case-by-case basis based on expert judgment with the possibility of the method not applying if bias is too great. SPR, F and related measures were more 'robust' than the OFL calculations.

Several minor adjustments were recommended, including changes to how negative fishing mortality values should be treated. More importantly, the treatment of species that undertake sex change should be treated differently. Suggestions as to how to address these are provided. Presently the SPR calculation could include males and females, which is inappropriate.

This review concentrated on the Hawaii islands, but the method would be applicable to the U.S.A. territories in the Pacific, and may have a much simpler situation since they do not have so many islands in a series and if there are more than one island they tend to be closer together.

2 BACKGROUND

The Center for Independent Experts (CIE) review workshop for the Hawaiian coral reef fish length-based assessments took place in Honolulu, Hawaii, on Sept 8-11 2015. In attendance were review panel members Drs Dichmont, Pilling and Stokes, stock assessment author Marc Nadon, and other scientists involved in the stock assessment and management of coral reef fish. The review was undertaken in a very co-operative light with requests for additional work met, including providing more diagnostic plots and sensitivity tests.

The panel members were presented with material pertaining to the Hawaiian assessments and key relevant documents of past similar work in the USA. Length-frequency plots for the diver survey and fishery dependent data were also provided on request in advance. Further sensitivity runs and more detailed information were undertaken and provided during the review on request.

3 DESCRIPTION OF THE INDIVIDUAL REVIEWER'S ROLE IN THE REVIEW ACTIVITIES

A set of documents was provided to the reviewers prior to the workshop (see section 7 Appendix 1). These included two key chapters from a PhD thesis and a publication as the main documents related to Hawaii, and additional background reading relevant to the methods applied. In addition, size frequency distributions of the fishery dependent and independent data were provided on request. The final agenda and Statement of Works are attached in Section 8. Workshop attendees are listed in Section 9.2.

The review workshop was held from Sept 8 to 11 2015 in Honolulu, Hawaii. In attendance were review panel members Drs Dichmont, Pilling and Stokes, stock assessment authors and other scientists involved in the stock assessment.

The Terms of Reference were discussed, and clarity was sought with respect to ToR 6 and it was explained that this refers to providing an individual CIE report and that a panel report is not required.

A series of presentations, with first authors Drs Brodziak, Nadon, Lowe, Williams, Humphrey, and Makaiau, was provided (see Agenda in section 7).

The panel provided an overview of their findings on the last day of the workshop with some discussion putting these comments in a management context.

The Terms of Reference of the review were:

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

4 SUMMARY OF FINDINGS FOR EACH TOR IN WHICH THE WEAKNESSES AND STRENGTHS ARE DESCRIBED

4.1 BACKGROUND

The review investigated the body of work that applies a set of data poor approaches to Hawaii coral reef fish. Much of the work, in various forms, has been applied elsewhere, but this work uniquely combines a series of approaches into an overall package useful to management. The reasons for using a data poor approach are:

- there are many coral reef fish species in Hawaii to assess,
- these are spatially diffuse,
- good catch and effort data are absent for many reasons but most importantly because there is a large recreational component for which catch and effort data are hard to obtain, and
- there are few known locally estimated life history parameters.

There are three main elements to the overall approach (Figure 1):

1) calculating total mortality (Z) and fishing mortality (F) using mean length from the size composition data and life history parameters;
2) using a population simulation model to calculate Spawning Potential Ratio (SPR) and fishing mortality at Maximum Sustainable Yield (Fmsy), and
3) calculating catch limits such as the Overfishing Limit (OFL) using abundance data and outputs from step 1 and 2.

Within each element, there are several approaches depending on the mix of available data and life history information. For step 1, size composition data can be obtained from either diver survey or commercial logbook data. For step 2, life history parameters can be obtained: a) from a relevant growth study where the data are available (below referred to as a data rich approach), b) from a relevant growth study where only the parameter values are available, but not their associated CV (data moderate), or c) from a step-wise stochastic simulation approach obtained from a meta-analysis of known tropical life history parameters at family level when no growth information is available for the species (data-poor). For step 3, abundance data can be obtained from diver surveys or total catch data (both recreational and commercial catches combined).

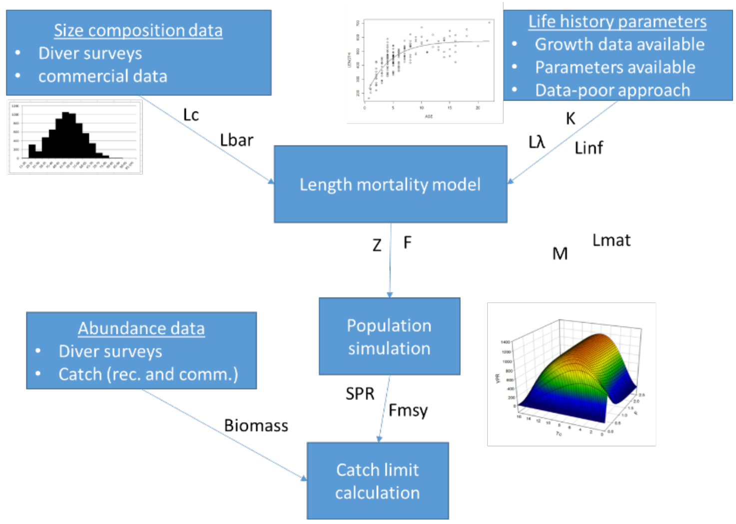

Figure 1: Overview of stepwise approach (modified from Nadon presentation during review)

Overall, the panel were provided with the different approaches in a series of documents, rather than in a single report with all the components provided. Much of this was only described during the review. It would be more appropriate for this work to be described in a single document for use by managers and other scientists. In this document, a decision tree of all the different steps and decisions should also be described. This will provide a more cogent and transparent description of the overall approach.

Recommendation 1. Describe the overall approach in a single document with a decision chart of all the steps and decisions required for transparency and clarity. This decision chart should guide assessors and managers through the overall approach, the decision making process and which component would be most appropriate and under which circumstances.

4.2 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.

This ToR was met.

However, as a package this approach does not appear to be robust in terms of biases and uncertainty. Thus, it could not be applied automatically to coral reef fishes and should be used with caution on a case-by-case basis using expert judgment. This judgment needs to be applied at each step of the overall approach.

This finding of a lack of robustness is not unique to data-poor approaches.

Given this need for expert judgment, the decision making process should be more open and transparent. There are likely to be a number of scenarios available for application, and, consequently, it should be accepted that the results from multiple scenarios should be provided to highlight sensitivity to the different data and assumptions. To facilitate this transparency, a decision chart of the meta-rules for the overall approach should be developed. This will highlight all the major decisions that were made and provide clarity on which of the results are more or equally applicable than others.

Recommendation 2. Develop a decision chart of meta-rules of all the steps taken for the overall approach, so as to allow greater transparency to decision makers and stakeholders. This is especially important given the lack of robustness of the approach and the resultant need for expert judgment at each of the steps.

4.2.1 Calculation of SPR and F and related measures

This step is used to calculate SPR, F and Fmsy using mean length from size composition data and life history parameters using a mean length approach, followed by a per recruit population simulation model. This mean length approach is well documented and peer reviewed through independent reviews and in the literature (Ault et al., 2005; Ault et al., 2008; Gedamke and Hoenig 2006). Key sensitivity tests (such as robustness of mean length changes to the equilibrium assumption; comparing the original Beverton and Holt method to the truncated method used here through simulation test (Ehrhardt and Ault 1992)) have been undertaken. For this reason, the approach is supported.

Mean length is obtained from survey data, if available, or converted from catch weight and numbers. The survey mean length is spatially extrapolated across the Main Hawaii Islands (MHI) and the unfished Northwest Hawaii Islands (NWHI). The present extrapolation method is supported, but alternative options are suggested in ToR 2.

Life history parameters are obtained using three approaches. All three approaches are well supported by a growing body of theory (e.g. Beverton and Holt (1959); Prince et al. (2014)) and are therefore supported. However, these three approaches are not equivalent in terms of appropriateness and selection (if needed) of method should be clearly articulated in the decision chart suggested in Recommendation 1 and 2.

Recommendation 3. Clearly articulate the hierarchical nature of the three life history approaches and under which circumstances a method should (or should not) be used for management purposes.

Method 1: The data rich approach uses raw life history data. Generally, one would expect the best approach to be that of using raw data from a local life history study of the species concerned. Parameter variances are determined using a size stratified bootstrapping method. This method is likely to be the most robust, and the evidence provided during the review shows this approach generally also has the lowest variances.

Method 2: The data moderate approach uses life history parameters from a related study (either the same family or same region or both). The missing element would therefore be to add variances, and those from Kritzer et al. (2001) are used. A more detailed discussion on this approach is provided in ToR 2. The usefulness of the method depends on the quality and relevance of the life history parameters used. Although this approach is valid, the value of it is likely to be achieved through case-by-case decisions using expert judgment.

Method 3: The data poor approach obtains life history parameters using Monte Carlo simulation starting with a point estimate of Lmax – the longest length in the growth study or the 99th percentile of length in a population survey – together with relationships obtained from a coral reef fish meta-analysis. Although some simulation testing was undertaken, a much more structured simulation study is required to highlight potential biases and uncertainties, and under which conditions this approach may fail. Simulation work before and during the review showed that this approach is not robust in terms of bias. However, in this simulation study, where the data rich and data poor approaches were compared, it is not always clear which approach is most appropriate.

This set of methods to obtain life history parameters is well implemented and is supported, but would need to be verified on a case-by-case basis using expert judgment. Despite these words of caution, a very useful package of methods to obtain life history parameters has been developed and could serve as a model for other regions.

Recommendation 4. Undertake a simulation study of the different approaches, especially the data poor one, to obtain a better understanding of where these approaches may fail. This work should be structured to address inputs required for the decision chart of recommendation 1.

There are two approaches that were presented for calculating natural mortality (M): 1) using the equation described in Alagaraja (1984); Hewitt and Hoenig (2005); Hoenig (1983) that uses the maximum age (the oldest recorded age, i.e. longevity) and survivorship, and 2) calculating M as part of the data poor approach. The estimation of M is a common issue to both data rich and data limited approaches. The above literature suggests using a survivorship value of 1.5% p.a. or below, but a value of 5% is used in this study. A value of 5% survivorship assumes that 5% of the population still remains at the maximum age of the population. The reason provided for using this 5% value is that the mortality estimates using the unfished population size data from Northwest Hawaii Islands (NWHI) indicate that 5% is more appropriate. This assumption is appropriate and supported in most cases. However, there are cases where this would not be appropriate, e.g. long-lived species, as discussed in ToR 2. There are also issues with the robustness of this measure, as the value of maximum age is sample size dependent. This 5% assumption should therefore be made on a case-by-case basis, rather than made as a default.

An alternative method of calculating M is using the data poor approach based on estimated maximum age from the known relationship of M with some growth parameters. This method is supported; however, results show that it is also not robust, so should be based on a case-by-case judgment by experts.

In most cases, the longevity method is likely to be preferred to the data poor approach.

An important feature of these above different approaches of obtaining life history parameters, including M, is that variance increases as more data limited approaches are used. This is an important and good feature of the approach and is supported. If the estimated output values were unbiased (which they are often not), this increase in variance as a more data poor approach is applied would provide management with the necessary information to potentially impose a larger degree of precaution.

Recommendation 5. Since there are several steps and decisions to be made in the calculation of mortalities, these should be added to the decision chart of Recommendation 1 and 2.

Calculation of SPR is from per recruit simulation analyses using a well-known and commonly applied approach. It uses the output values from all the previous steps, and is correctly implemented.

4.2.2 Calculation of OFLs

The final step is to calculate the OFL, which requires the relative indices produced, such as SPR, to be scaled to absolute values. Two sources of abundance data are used as possible scalars – relative diver survey abundance data scaled to absolute abundance, and total catch from the recreational and commercial fisheries scaled to absolute abundance using the estimated harvest rate[1]. This final step is the greatest source of uncertainty. Results shown during the review highlight that, for the most part, this scaling is the greatest source of potential bias and scenario sensitivity of the whole approach. This is discussed in detail in ToR 4. Great care should therefore be taken with this step. **It is quite possible that not enough rigorous data are available to apply this approach for some species.**

This step is therefore supported, but with the proviso that a case-by-case expert over-ride may be required, including that this approach may not be appropriate. This is most likely when an unbiased scalar to absolute abundance is not available.

Relative to the absolute abundance step, the calculation of SPR and F is more 'robust'.

[1] It should be noted that input data such as catch reporting and the diver survey data collection are not part of this review.

It should be noted that other data limited methods such as catch-based assessments would likely suffer from similar issues.

Since expert judgment is required to define whether dive survey abundance data or catch data are appropriate to use for OFL calculation, this step should also be added to the decision chart of Recommendation 1 and 2.

Recommendation 6. Add the different approaches and decisions of calculating the OFL using catch or survey data to the decision chart in Recommendation 1 and 2.

As a note, if data consistently underestimate the catch, then the OFL is likely to be more precautionary (ignoring all other sources of bias, of course). However, the discussions during the review showed that this under-estimation of total catch may not always be the case given the very high inter-annual variability in the catches shown for several species. As a result, this potential for precautionary model output using catch data should not be relied upon.

4.3 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.

This ToR has been met.

However the results are not robust and should be taken on a case-by-case using expert judgment.

This ToR comments in detail on the use of most of the input data and approaches required to calculate the SPR and OFL.

4.3.1 Calculation of mean length from size composition data, and associated variability

Two sources of data can be used to calculate mean length – size composition data from diver surveys or that derived from commercial catches.

Size composition data are bootstrapped at the site level to get variability of the average length, and then these average lengths are scaled (unweighted) to island group sector where the mean length is again calculated. An overall mean length from the sector mean lengths is weighted by hard bottom habitat area as a proxy for area that would be covered by a healthy population. The overall average length calculation process is repeated in the bootstrap to get CVs. There are two aspects that need to be discussed – whether the weighting is appropriate and whether the CV is appropriately estimated.

The weighting by area is an attempt to scale mean length to the area that an unexploited population would have occupied. This means that a heavily fished population that had shrunk in distribution will not be under-represented in the mean length calculation. In that context, the weighting process is an appropriate attempt at scaling using a data poor approach. Another option would be to scale by fishing mortality at sector level. However, calculating mortality at sector level is only likely to be possible for a few species given the sample sizes. Furthermore, the assumptions of the mean length calculation of fishing mortality should still be true at the sector level.

The pros and cons of the application of the two different sources of data (survey or commercial catch) for the mean length calculation are likely to be very species and case specific. For this reason, discretion is required.

Recommendation 7. Investigate an alternative approach to weighting by hard bottom habitat area by calculating fishing mortality at the sector level, where possible, ensuring that the mean weight method assumptions are still kept. Compare this approach with the habitat area scaling approach.

The uncertainty in mean length is likely to be underestimated as obtaining a (weighted) mean of the mean leads to a CV that is lower. A better option would be to scale up all the distributions and only calculate mean length from the final MHI-wide distribution. This would preserve the full uncertainty. Furthermore, the error in the habitat area weighting is not included, yet it is used as a point prior.

Recommendation 8. Undertake an analysis of the sensitivity to the stage at which the mean length and associated CV is calculated. The suggested alternative is to calculate the mean length from an overall MHI distribution, i.e. combine distributions at the different bootstrap steps, rather than mean lengths.

Mean length from commercial catch data (in weight) is calculated by converting the mean weight per trip (total catch /number caught) using published length-weight relationships. This assumes that the weight and numbers are equally biased or accurately reported and the different gear types within the catch records for the same species have similar selectivity. Data provided before and during the review showed that selectivity of line and spear (the major fishing gear type) are reasonably similar.

A comparison of mean length from commercial catch and diver survey data for a few specific cases shows a small amount of bias, but very good correlation.

The pros and cons of the application of the two different sources of data are likely to be very species and case specific. For this reason, discretion is required.

4.3.2 Calculation of life history parameters

4.3.2.1 Growth and natural mortality

Calculation of growth and associated uncertainty is obtained using three approaches: 1) bootstrap of the raw data from a life history study, 2) parameter values and CVs from the literature where these are provided, but without the raw data, and 3) the data poor approach (see ToR 1). For the first two approaches, M is calculated using longevity and maximum observed age based on Hewitt and Hoenig (2005); Hoenig (1983) and Alagaraja (1984), whereas the data poor approach includes the estimation of M.

In the case where the raw data are available, uncertainty is estimated by bootstrapping from these data to create different data sets and estimate a new von Bertalanffy growth function (VBGF). Bootstrap sampling of the data is stratified by large, medium and small lengths, which is appropriate. From these data, the maximum observed age is obtained and used to calculate the natural mortality and associated uncertainty. This maximum age is discussed further below, but the bias in this value would be dependent on the raw data sample size and design.

Where the life history parameters are available, but the raw data are not, CVs are added based on Kritzer et al. (2001). This study investigated the effect of sample size on life history parameters. This study was based on four Great Barrier Reef species, which do not overlap with Hawaiian species. However, it should be noted that the bootstrap method with known data can produce higher CVs than the Kritzer et al. (2001) values, which is not ideal as greater variances are expected as more data poor approaches are used. This study was mostly on larger animals which may have underestimated variances compared to Hawaii.

Recommendation 9. Since the bootstrap method using raw data from Hawaii is showing larger CVs than that from Kritzer et al. (2001), undertake a similar study with the few species that have more than 100 age data points to see how well the published CVs compare.

The data poor approach is based on several studies that have shown that there are key relationships between life history parameters (e.g. Beverton and Holt (1959)), although these need to be considered at the family level (Prince et al., 2014). Nadon and Ault (unpublished) used meta-analyses of published life history parameters at the family level to create statistical relationships between life history parameter pairs for six families of coral reef fishes. The method starts with maximum length (Lmax) as a point prior (see below) and a Monte Carlo simulation steps through the relationships to obtain SPR and its associated distribution. Although some of the variance in Lmax is included in the Linf-Lmax relationship, these are actually computed as pairs from the study, whereas its use is from an unrelated single Lmax draw. Thus, the error in the Lmax should also be considered, and therefore Lmax should be drawn from a distribution rather than a point prior.

Recommendation 10. Draw maximum length for the data poor life history simulation approach from a distribution rather than using a single point prior.

4.3.2.2 Maximum age and maximum length

Lmax is an important parameter, especially in the data poor simulation method, for estimating life history parameters. Lmax is the maximum length obtained in a study or the 99th percentile from the size data. The Lmax obtained is dependent on sample size and how well large animals were selected for the study. Despite the bootstrap or Monte Carlo approaches used, one is obviously unable to get animals larger or older than that in the study. This will result in the M value being bounded by the oldest animal in the data set.

The Lmax is also affected by the amount of fishing. If the sampled population is heavily fished, then Lmax would be smaller and result in estimating a faster growing and more productive animal. In Hawaii, this may have been the case for the Lutjanids and Carangidae, but Lmax from the other groups was based on a greater attempt to obtain samples of larger animals. In the cases where this error is possible, it would be worthwhile obtaining maximum sizes from the unfished NWHI.

Recommendation 11. Explore the impact of heavily truncated size data in which the sampled Lmax is not representative of the biological Lmax, what is a safe error in Lmax (from the point of management measures) in terms of biases, false positives and negatives; and relate this to the decision tree.

There were cases (e.g. goatfish) in which the Lmax value used was larger than the meta-analysis sample of the Linf - Lmax relationship for that family. This may be reasonable for a tight distribution, but could nevertheless be a symptom of other issues and it should at least be noted when this occurs.

Recommendation 12. Highlight when a case is extending beyond the relationship data in the data poor approach.

During the review, a plot of Lmax from a growth study in Hawaii was plotted against the Lmax of a population from size data using the 99th percentile (Figure 2). This showed a good relationship, and that generally the 99th percentile is an appropriate default value. However, a few cases were biased (e.g. *Naso unicornis*, *Scarus rubroviolaceus*, *Caranx ignoblis*, *Caranx melampygus*) and should be considered on a case-by-case basis.

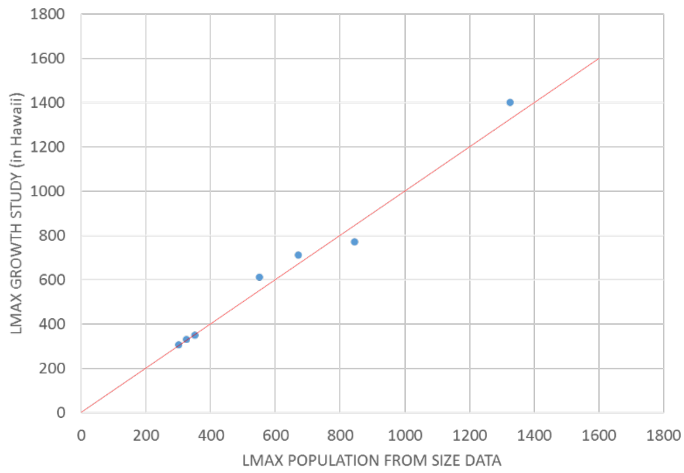

Figure 2: Lmax from a Hawaiian growth study compared to the Lmax calculated as the 99th percentile from size data – provided during the review and is therefore preliminary.

4.3.2.3 Maturity

In the case where the raw data are available, the raw maturity data are bootstrapped to obtain uncertainty in the maturity. This is used to obtain the length at female maturity and is likely to be the best approach.

4.3.3 Comparison of the data poor with the data rich approach

Extensive testing of the data poor approach relative to the data rich approach (where the raw data are available) has been undertaken. This is particularly evident in the documents provided and further tests undertaken during the review (Figure 3). This shows that there are clear differences in the biases between the different species. These also highlight that biases flow through the stepwise approach. Although the M value biases and variance appear small in some of the species, this is deceptive and should be highlighted when the longevity is included. It should be noted that the surgeon fish draw from a flat distribution of Linf to K relationship (see Figure 2 in Nadon and Ault (unpublished)).

These results demonstrate that the key management values of F and SPR are highly variable using the data poor approach. However, there is a feature of the data poor approach that is valuable and supported. It appears to amplify variance from each of the streams of calculations to the resultant Fopt and SPR. [Note: Given the treatment of negative F, the SPR and OFL distribution is not a reasonable reflection of the actual distribution].

Discussions during the review highlighted that it is unclear whether the data rich or data poor approach is more accurate. **Neither of these methods is robust to bias and results are very case specific for both methods**. Although these types of analyses highlight the issues, it does not provide a definitive guide under which conditions the different approaches are best applied. In that regard, the only approach to further this investigation of bias (especially) is to undertake a simulation study, where bias and variance are known and test these in a rigorous sampling approach to quantify the effect of the different sources of error and bias. This study should calculate the management measures, including the OFL.

Recommendation 13. Undertake a simulation study where bias and variance are known to test a sampling approach to quantify the effect on management measures of the different sources of error and bias. This study should proceed to calculate all the way through to the management measures including the OFL.

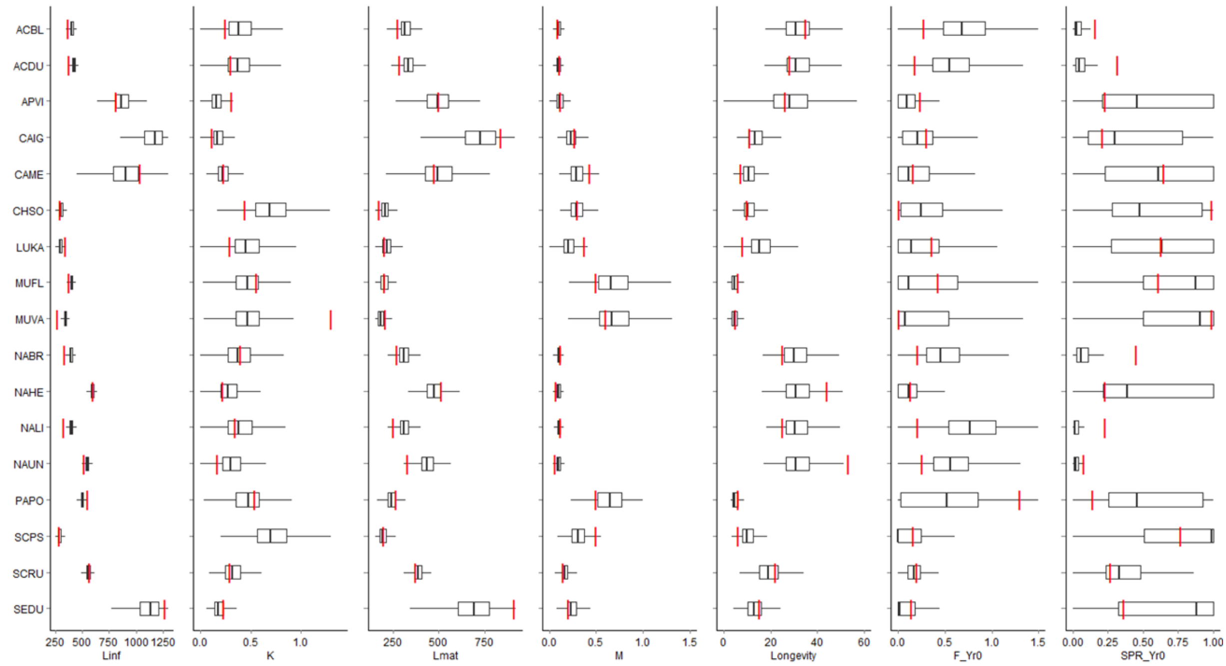

Figure 3: Box plot of the data poor approach life history parameters. Red line from the data rich approach of using the raw data. Provided during review and may be preliminary.

4.3.4 Mean length method to obtain total mortality (Z) and F

The mean length method used in this review and described in Ault et al. (2015) is used to calculate total mortality and, combined with an estimate of M from the previous steps, fishing mortality. The method applied uses the length truncated version of the original (Beverton and Holt 1957) as described in Ehrhardt and Ault (1992). This method adds a new term; mean length at maximum age (Lmax), rather than relying on the length at infinite age (Linf). For some species, the two length values would be the same or close together, but species such as the *Caranx ignoblis* do not have a strongly asymptotic growth function and therefore the Lmax (and world record size) is much smaller than the Linf. For this reason, the use of the truncated version is supported.

Both the truncated and original versions have several key assumptions (modified from Gedamke and Hoenig (2006)):

1. Constant K and Linf over time – this is a common assumption with both data poor and rich approaches.
2. No individual variability in growth (if deterministic) – the stochastic approach applies variable growth parameters.
3. Constant M for ages greater than those that are fully selected – a common assumption for data rich approaches as well.
4. Constant M over time – also commonly assumed in data rich approaches.
5. Constant and continuous recruitment over time – this is a strong assumption and not assumed by data rich approaches. This would have to be tested on a case-by-case basis, but is in general supported based on the mean length data presented NWHI and MHI coral fish species.
6. Population is in equilibrium – similar to assumption 5, this is the strongest assumption and not assumed by data rich approaches. Unless this assumption is tested (as was the case

here), this method would not be appropriate. For equilibrium to be possible, recruitment is constant, there were no large changes in selectivity and fishing mortality during time series. Nadon et al. (2015) tested for this (Fig. 3) for nine of the Hawaiian reef fish species and showed that, in general, there were no major trends in mean length which was taken as evidence of population equilibrium. Again, this would need to be tested on a case-by-case basis and periodically, especially if strong management action has occurred. This assumption is supported.

7. No change in size regulations or selectivity – see no. 6.
8. Knife edged selectivity – this assumption is based on the mathematical equations used, and is only assumed in a few data rich approaches, but usually not. To conform to this assumption (at least in part), a length at first capture (Lc) is chosen that describes a fully selected size and excludes any fishing mortality of animals below that size. This is a commonly used approach for the mean length method and other length-based data poor approaches. However, the choice of Lc is quite difficult if selectivity is not known and has to be inferred from the size frequency distributions on a case-by-case basis. In this study, the observed frequencies were compared with simulated frequencies to note where they converge. No standard approach was taken. In this regard, the more common approach is to use a cumulative frequency plot rather than the length-frequency plot used or to use the difference between the observed and simulated plots.

Recommendation 14. Undertake a more standardised and rigorous approach to obtaining length at first capture (Lc) that can be repeated by other assessors.

9. Size distribution data are representative of the true population – this is a key assumption to many size based approaches, and is likely to be appropriate to varying degrees depending on the species and data source (survey or catch). Diver surveys were restricted to <30m depth and are therefore reflective of nearshore populations, but were able to sample more remote and exposed areas. Commercial data were more reflective of near and deeper communities, but not to the inaccessible parts of the coastline. However, in tests provided, there was good agreement between the two data sets in terms of mean length.
10. Population life history parameters were representative of local populations in Hawaii – these are discussed extensively above in section 4.3.2.
11. No sex change – commonly many coral fish do undertake sex change (see comments in sections ToR 3 and 4). An adaptation of the mean length approach to accommodate for sex change is undertaken in Ault et al. (2008). This approach should be adapted for those species that change sex.

Recommendation 15. Apply the sex change adaptation of Ault et al. (2008) for species that chance sex. Also note other recommendations in this regard.

4.3.5 Population simulation to calculate SPR and MSY-related reference points

A standard per recruit simulation model is used to calculate spawning biomass per recruit at current fishing, and for an unfished population using the life history, natural mortality, and fishing mortality values from the previous steps. The ratio of the SSB exploited and SSB unfished is the spawning potential ratio (SPR). This allows calculations of appropriate Federal reference points as discussed below. Beneficially, this step also allows the calculation of several minimum sizes such as the minimum size expected at the SPR of 30% and at maximum yield. These are useful management measures. In many cases, these results are also cross-checked with the unfished NWHI size data which is extremely informative, and again highlights the case-by-case nature of the results. In the stochastic approach, error is appropriately propagated to the SPR and OFL calculation.

Recommendation 16. Output relevant minimum size values during the analyses for management purposes.

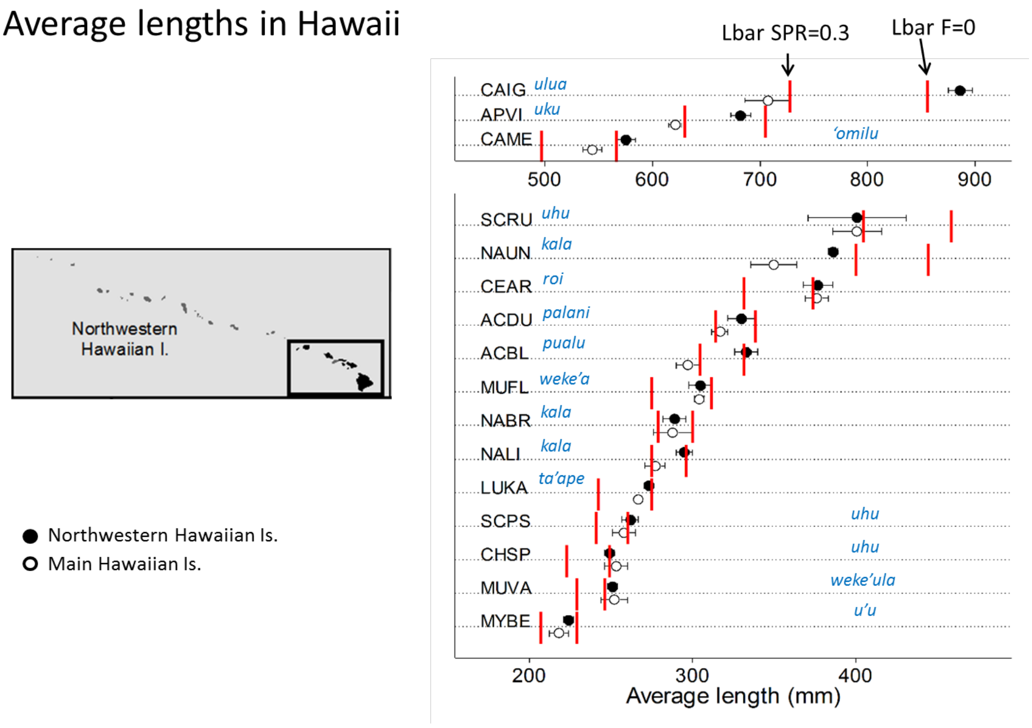

Figure 4: Output from deterministic stock assessment by species comparing simulated and observed mean length for MHI and NWHI. Left hand red bar is the mean length at SPR 30% and the right hand is the mean length expected for an unfished population. Taken from presentation during review and based on Nadon et al. (2015).

4.3.6 Estimation of biomass and its associated variance

In order to calculate the OFL, an estimate of absolute biomass is required. This is calculated from two sources – diver surveys and catch data.

Site specific survey data are scaled up to the MHI region using a series of steps. It should be noted that these are not well explained in the documents provided, and the description was provided as part of the review presentations. Using survey data, each island is divided into strata based on human population size (a surrogate for fishing intensity), accessibility and habitat types. In Figure 5, the areas labelled “simple” are dominated by low reefs (lower density), “complex” (more boulder areas), and “coral” (largely coral reef). These area classifications were not developed using a quantitative approach, but rather expert opinion of the stock assessors. This means that there is little repeatability of this approach. The density is then calculated by region.

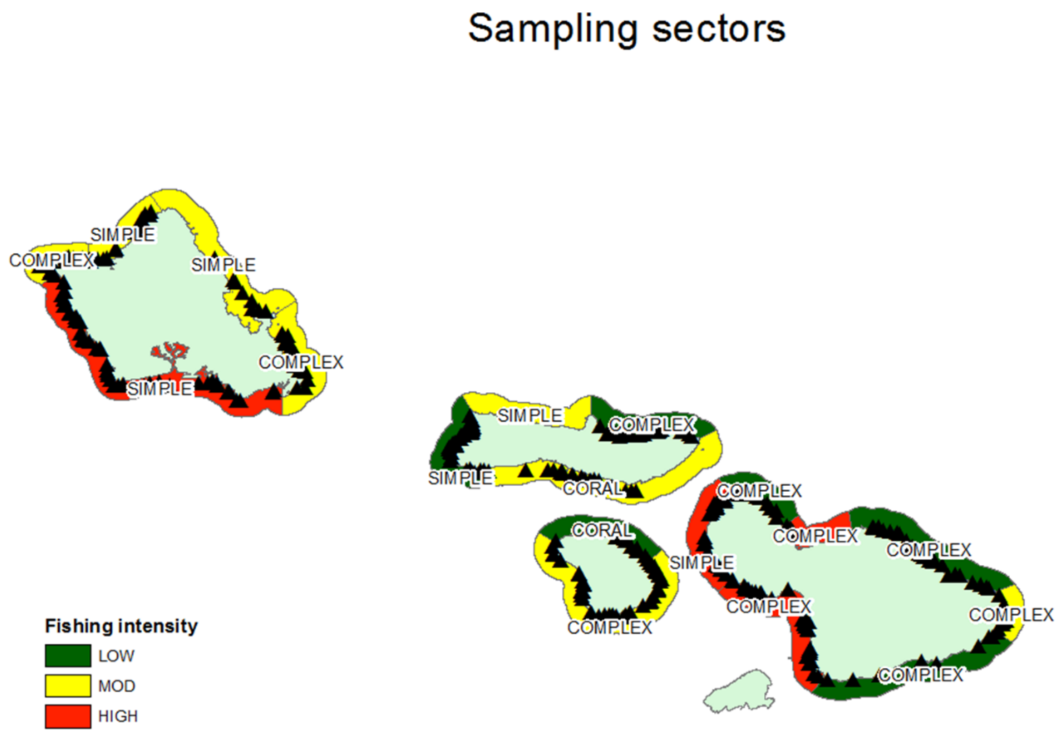

Figure 5: Example of strata within a sampling sector for the survey density to absolute abundance calculation (from Nadon presentation during review).

The total catch approach calculates absolute abundance from the total catch over the past decade or so, and fishing mortality (or exploitation rate) from the mean length approach. The annual catch series is bootstrapped to obtain a catch and biomass distribution. This approach underestimates the actual variance as the within year catch variance is not included, which is generally unknown. However, the inter-annual variance in total catch for many of the species presented are large, highlighting the issues with these data such as:

1. For many species, the recreational catch is far greater than commercial, yet is less known of it. Hawaii only has recreational catch values from phone and other surveys for the past 10 years, and they are assumed to be biased because the fishery is diffuse and compliance levels are lower.
2. Collection of commercial catch data relies on self-reporting, with reports often not checked through a paper trail, such as catch disposal records from distributors or processors.

This scalar from the catch data is likely to be the least accurate compared to the survey data. For this reason the output should be investigated on a case-by-case basis.

4.3.7 Alternative approaches

Although not part of this review, catch only methods are also being tested for these species. This would be a useful check, although is likely to suffer from some of the similar issues discussed herein, most notably the accuracy of the catch data and the population scalar used. Alternately, the catch only methods usually do not assume equilibrium.

A further approach would be to compare these approaches with catch rate data from commercial logbooks (or a sub-set) and the diver survey relative indices. Although the logbook data would be unstandardized, the catch data used in this study assume a constant fishing mortality in that series (the equilibrium assumption) which implies no changes to catchability. As a result, the diver survey data are more likely to be more appropriate as a relative index of abundance. These would be an appropriate check of the catch only and mean length approaches.

Recommendation 17. Investigate the use of catch rate data from commercial logbook and diver relative indices as a verification of the mean length approach.

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

This ToR is met.

However, the results should be reviewed on a case-by-case basis as the approach is not robust.

The biases and sensitivities of the reference points and management measures are discussed in detail in ToR 4. In overview the approach to estimating SPR, F and Fmsy is more robust than that of calculating the OFL, although both can be used for management to meet its objectives only on a case-by-case basis. This is because, all the steps used in the study are not robust in terms of bias, and sensitivity to different options; and these biases and sensitivities differ by species. The largest source of bias and sensitivity is the absolute biomass estimate used to calculate the OFL. From information provided prior to and during the review, the scenario uncertainty with regard to the different methods of calculating SPR, F and Fmsy (e.g. the different approaches of calculating life history parameters) is usually lower than the two approaches of scaling up these values (catch or survey data) to the OFL. If there is a good estimate of the scalar (catch and/or abundance), then this approach is likely to be supported. Where there is potentially an unknown bias in the scalar, then the approach is highly uncertain and not likely to be robust for use by management.

As a general rule, the survey data are likely to a better estimate of abundance and should be used in preference to the catch data. This is, of course, not true for all species, most notably migratory or mobile species.

From information provided during the review, there may be better information from the diver surveys undertaken in the territories (due to higher sampling intensities and 'simpler' systems (e.g. single isolated islands, less complex habitats) than MHI. This sampling intensity for the purposes of an absolute abundance index is low within a sector in MHI. The survey data are being used to create an absolute index of abundance which is beyond the intention of its original design.

As a result, the final application of the approaches reviewed should be taken on a case-by-case basis based on expert judgment with the possibility of the method not applying if bias is too great.

A good property of the overall approach is that the propagation of uncertainty works as anticipated in that the more data limited the approach, the greater the variance (but the bias appears inconsistent between species). As a result, the focus on the choice of which method(s) at each step to use should be clearly articulated and particularly investigated in terms of bias, and well described in a methods paper. As a summary and for use with each case, the different steps available should be clearly articulated in a decision chart. More than one scenario should be provided if sensitivity or bias increases. The reasons for rejecting scenarios should be clearly and transparently explained.

Recommendation 18. The decision tree from Recommendation 1 should include the OFL step and clearly articulate why a scenario was rejected or accepted. As a default, all options should be reflected rather than use methods that combine distributions, as were shown during the review.

The choice of the reference point of 30% SPR as a proxy for Bmsy is well supported in the literature (Restrepo et al., 1998) and is recommended for data limited situations. Although this is ultimately a policy and science decision, other percentage values can easily be calculated from this approach.

The documents provided, calculated Hawaii SPR values using a risk of 30% (as opposed to the 30% SPR reference point), i.e. 70% of the runs must be above the 30% SPR limit reference points. Although this is a policy decision, this 30% risk was not the agreed value and does not fit that implied by the Magnuson-Steven Fishery Management and Conservation Act and its associated National Standards document. The use of the risk feature in the analyses should therefore be updated to the appropriate value as discussed during the review.

Recommendation 19. Update the risk value with respect to the reference points to that set by policy. The presented risk of 30% has not been agreed. This 30% risk value should not be confused with the reference point value of 30% SPR, which is appropriate.

During the calculation of SPR in the Monte Carlo simulation where F is required, however, there were occasions where the chosen life history parameters for a particular run produced a negative F (F is bounded to a positive number). The present approach was to count this occasion and then to not calculate the SPR and catch-derived OFL (F is only used in the catch-derived OFL calculations) values. This is not appropriate. An alternative approach is to set this value to zero and continue with the calculation of SPR and the catch-derived OFL. The occasions where a negative F occurred should be identified. The present approach would correctly calculate risk of overfishing, but any distribution-based calculations (means, medians, etc.) and the actual presented distribution of these values (and hence OFL distribution) would be affected.

Recommendation 20. Treat negative F values by setting these to zero and flagging that this has occurred. This would mean distribution of SPR and OFL would be correctly shown. The number of runs that fell below zero should be displayed.

It is well known that some species of coral fishes change sex (male to female or vice versa), yet all the calculations apply to females. SPR is a measure of spawning biomass, which traditionally is assumed to be female spawning biomass. This would not be true for a sex change species. Although on the face of it, this discrepancy may not seem important, it is important to note that all the simulation studies of appropriate reference points (e.g. 30% SPR from Restrepo et al. (1998)) assume that this applies to the female spawning biomass of the population. What an appropriate reference value for an SPR that has a varied degree of male and females greater than the age/length at female maturity in the population is, can be questioned. This is considered by Ault et al. (2008) in Puerto Rico where only the female part of the population is considered, and an additional term is added in the mean length mortality estimation method. However, the reference point and consequence on management is perhaps still not clearly articulated in cases where sex change occur and requires further study.

Recommendation 21. The effect of sex change should be considered. At the least, the integrity of the SPR and associated reference points should be kept at its traditional definition of being relevant to the female spawning biomass. This would require modification to the mean length method when a species undergoes sex change in its life cycle. An additional measure

of precaution or an added reference point could be added, but this should be tested through simulation.

4.5 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.

This ToR has been met.

However the results are not robust and should be taken on a case-by-case with expert judgment.

The full stochastic approach using Monte Carlo is run to provide SPR, OFLs and associated distributions. These provide a series of OFL scenarios based on which life history approach, biomass scalar, and F estimate is used. Several examples were provided and discussed during the review, most notably *Naso unicornus* (NAUN in some figures), which tended to be the least robust at most of the steps (of the species reviewed). To concentrate on good and bad cases, several species were investigated in depth during the review to demonstrate the biases and sensitivities of the full approach. The first species was *Aprion virescens* (APVI), which generally performs *reasonably* well in terms of the first step of calculating life history parameters and SPR. For this species, the average length is determined from catch data given the survey data are fewer. This species also does not have a local growth curve, so the growth rate of Loubens (1980) from New Caledonia is used with the standard deviations from Kritzer et al. (2001) i.e. the data moderate approach. The absolute abundance value is obtained from: a) diver survey data, b) from the catch and the data moderate growth approach, and c) catch and the data poor life history approach (Figure 6).

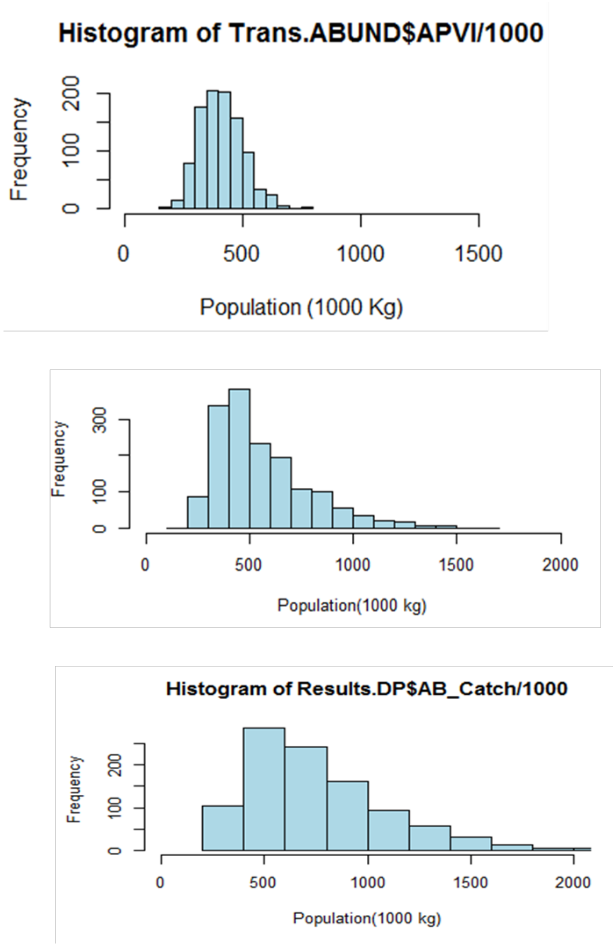

Figure 6: Histogram of abundance from the survey data (top), data moderate growth and catch (middle) and data poor life history and catch approach for Aprion virescens as provided during the review*. Note: axes differ.*

From these above results, the appropriate property of greater variance from data rich to data moderate can be observed (Figure 6). However, the median values are reasonably different.

The source of bias is mainly from the different biomass estimates using survey or catch data. These differences in median values are carried through to the OFL calculations (Figure 7).

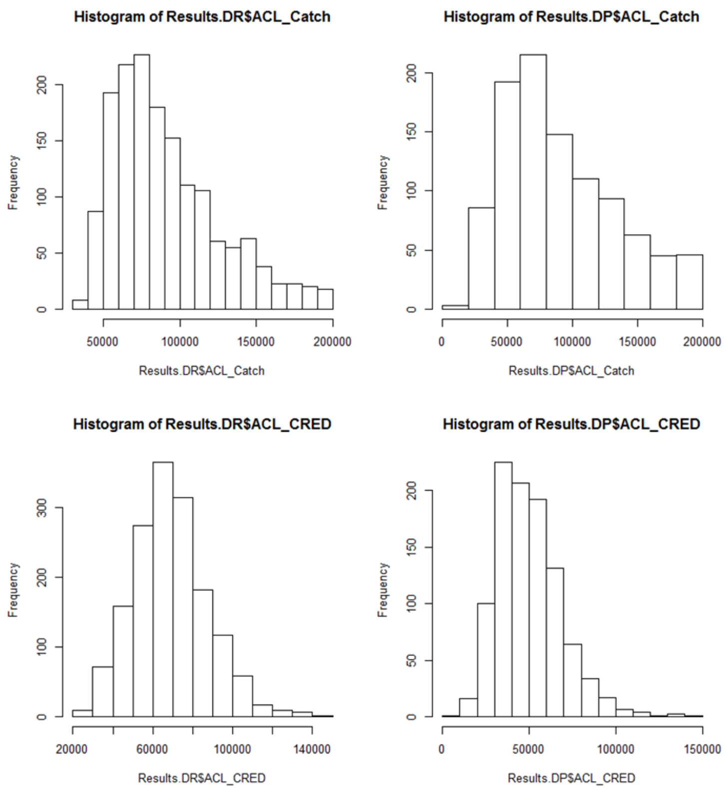

Figure 7: Distribution of OFLs for Aprion virescens *using the data moderate growth (left column) and the data poor life history approach (right column) with abundance from catch data (top row) and diver survey data (bottom row). Presented during review and may be preliminary. Note also that runs with negative F values, if any, were excluded from these plots. Note: axes differ.*

Figure 7 shows substantially different final OFL results – based on the preliminary results the 50% probability OFL was 105,000 kg from catch data as opposed to 57,000 kg from the diver survey data due to the differences in (mainly) the biomass scalar, as can be seen when the different growth scenario distributions are combined using Hamel (2015), assuming equal weighting (Figure 8). Although the combining of distributions is well published, this is usually not an approach supported for management. The equal weighting in itself would be not seen as appropriate in some cases given that data rich approaches are usually favoured over data poor approaches, yet then it would be unclear what weighting should be used. For transparency, it is therefore usual practice to provide all the different scenarios, and to either choose a base case or a reference set.

Recommendation 22. It is recommended that distributions are not combined, given equal or other appropriate weighting is not obvious. The norm is to provide the various options for transparency.

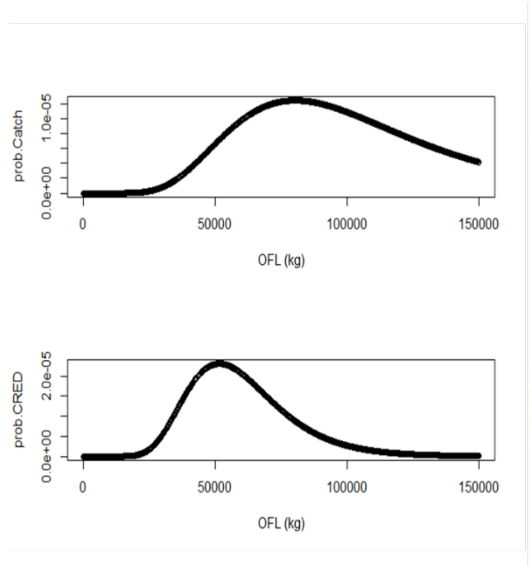

Figure 8: OFL for Aprion virescens *from catch data (top row) and diver survey (bottom row) as a frequency (left hand column) or cumulative frequency (right hand column) plot. Presented during review and may be preliminary. Note also that runs with negative F values, if any, were excluded from these plots.*

Several other cases were investigated during the review, based on whether: a) the growth parameters were reasonably similar between the data poor and moderate/rich approach, b) overall reasonable performance between data moderate and poor approaches due to similar biomass estimates, and c) lack of agreement between parameters across approaches. For ease of comparison here, the final combined OFL values are shown from best match to worst of those tested (Figure 9 to Figure 11).

Parupeneus porphyreus is endemic to Hawaii, and Hawaii specific growth rates are available. The best species for overall comparison between the two scalar methods is *Scarus rubroviolaceus* (chosen during the review for this potential property). For this species there is no differentiation in the catch and they are recorded as parrotfish, but the catch is dominated by this species. The growth data are from Hawaii and raw data are available, therefore the data rich approach is used. There was a resultant good match between the Hawaii growth estimate and the length data, which was carried through to similar F and Fmsy values. For this species the diver abundance is a more reliable abundance value, but it is similar to the catch abundance value, with the overall result that the OFLs are similar. *Parupeneus porphyreus*, an endemic goatfish, have growth curves from Hawaii, but the raw data are not available. These fish would be seen by experienced divers (they are non-mobile) and are also caught (they are easily recognised and reasonably abundant in the catch). This species is highly prized. The data poor approach used about 12-15 species to create the life history relationships, yet there are some important differences between the data moderate and poor approaches. Finally, there is some difference to the final OFL from the different abundance sources although they are still reasonably similar.

The worst performance is from *Naso unicornis* (chosen for this feature) in that there are large differences between the data poor and moderate approaches, longevity and the scalar. This overall set of biases results in an order of magnitude difference in the 50% risk OFLs using catch or diver survey data. However, the variances in these figures (especially those from the diver survey data) are large. This latter case shows that the 5% survivorship assumption may not be appropriate, but if a smaller value is chosen such as the literature suggested 1.5%, this order of magnitude difference in OFLs is not removed (a very large change in M would be required). This case does highlight that life history parameter issues also influence the final OFL result.

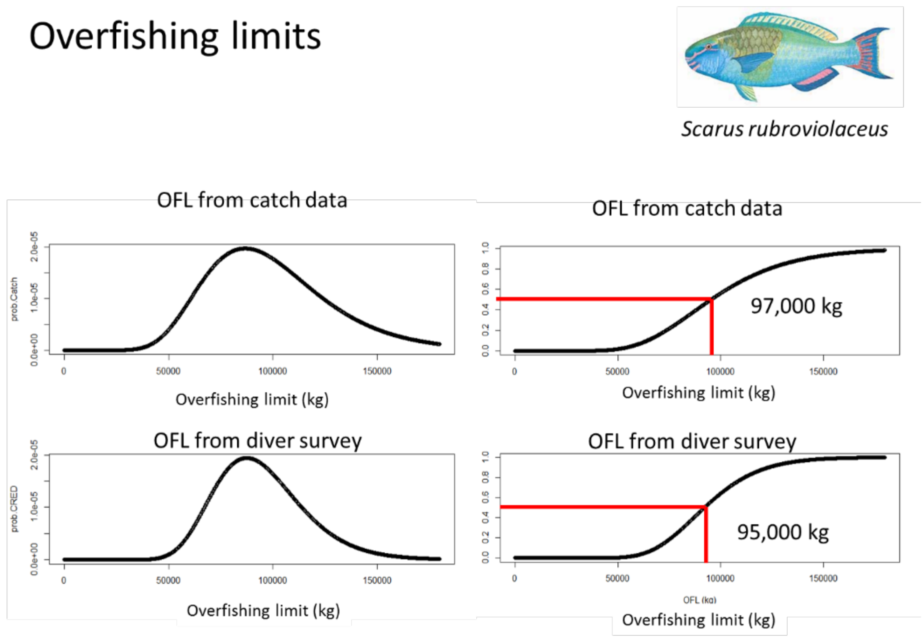

Figure 9: OFLs for Scarus rubroviolaceus *as a frequency (left hand column) and cumulative frequency (right hand column) plot for the combined life history approaches scaled to the biomass estimate from the catch (top row) or diver survey (bottom row) data. Presented during the review and should be treated as preliminary.*

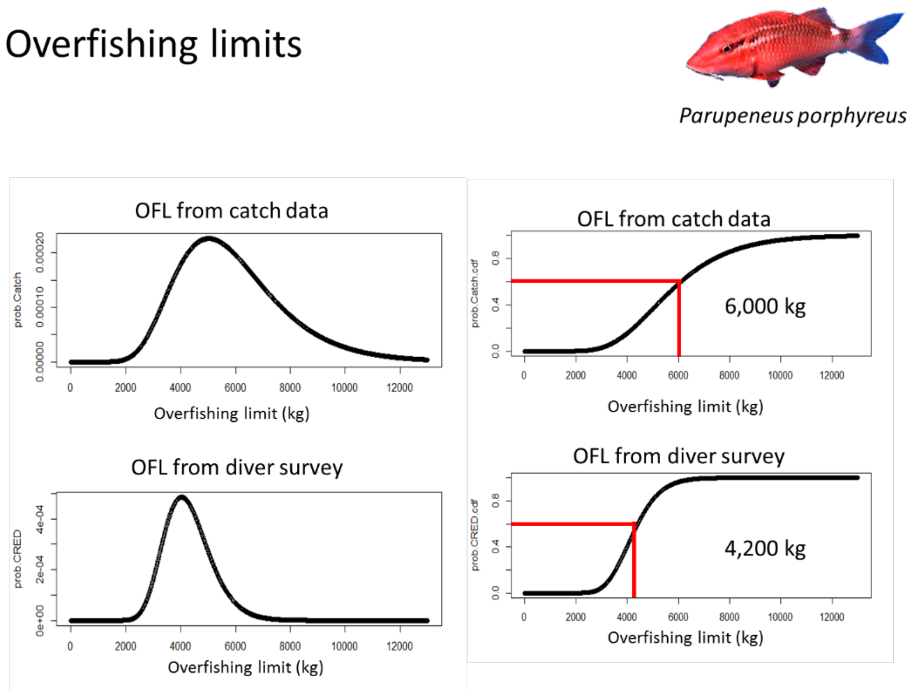

Figure 10: OFLs for Parupeneus porphyreus *as a frequency (left hand column) and cumulative frequency (right hand column) plot for the combined life history approaches scaled to the biomass estimate from the catch (top row) or diver survey (bottom row) data. Presented during the review and should be treated as preliminary.*

Overfishing limits

Naso unicornis

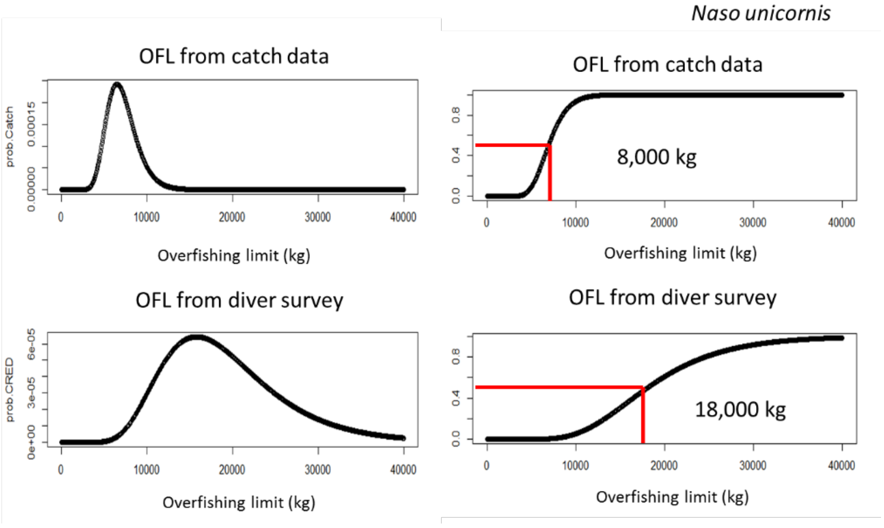

Figure 11: OFLs for Naso unicornis *as a frequency (left hand column) and cumulative frequency (right hand column) plot for the combined life history approaches scaled to the biomass estimate from the catch (top row) or diver survey (bottom row) data. Presented during the review and should be treated as preliminary.*

The overall conclusions from these individual results are that:

1. a very useful series of approaches are available to calculate management measures and these are well implemented,
2. but the approach is not robust and the results should be taken on a case-by-case basis, both between species and using the different approaches within a species.
3. The tests undertaken before and during the review demonstrate that the biggest sensitivity within the overall approach is the biomass scalar, and to a lesser extent the longevity and the growth values.
4. At all times, unless there is obvious error in the data source, decisions and reasons relating to all options should be provided so that all the sources of biases and variances can be openly displayed.
5. A decision tree will help this transparency by highlighting which steps are available and which were not applied (and why).

It should be noted that the full process of undertaking the OFL calculation annually need only be taken if there is a major change to the mean length or scalar. This change should also be seen in the context of keeping to the mean length assumptions such as equilibrium. If large changes have occurred, then the equilibrium assumption may be invalid.

4.6 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. (prioritised in terms of management utility)

4.6.1 High priority research

1. Describe the overall approach in a single document of all the steps and decisions required for transparency and clarity. Develop a decision chart of meta-rules of all the steps taken for the overall approach so as to allow greater transparency to decision makers and stakeholders. This decision chart should guide assessors and managers through the whole approach, the decision making process, and which approach would be most appropriate and under which circumstances. This is especially important given the lack of robustness of some of the approaches and the resultant need for expert judgment at each of the steps. In this decisions chart, clearly articulate the hierarchical nature of the different options at each step in the overall approach.
2. Undertake a structured simulation study with known properties of bias and variance of the different steps in the overall approach to obtain a better understanding of where these approaches may fail and their impact on management measures. For example, explore the impact of heavily truncated size data in which the sampled Lmax is not representative of the biological Lmax so as to test what is a safe error in Lmax (from the viewpoint of management measures) in terms of biases, false positives and negatives. Relate these to the decision tree.
3. Modify the approach for species that change sex by: a) applying the sex change adaptation of Ault et al. (2008), and b) potentially developing another performance measure for the male component of the population (especially in the case of any protogynous species).
4. Treat negative F values by setting these to zero and flagging that this has occurred. This would mean distribution of SPR and OFL would be correctly shown. The number of runs that fell below zero should be displayed.
5. Investigate the value of increasing sample sizes or obtaining specific data at the different steps of the overall approach, i.e. which data are more valuable to collect for management purposes. This could be undertaken in the simulation study or in a Management Strategy Evaluation (Sainsbury et al., 2000) model, such as that model developed in the GBR called ELFSIM (Little et al., 2009; Little et al., 2007). The MSE approach is better designed for this research, but is more complex and time consuming to develop.

4.6.2 Medium priority

6. Investigate an alternative approach to weighting by habitat area by calculating fishing mortality at the sector level, where possible, ensuring that the mean weight method assumptions are still kept. Compare this approach with the habitat area scaling approach.
7. Since the bootstrap method using raw data from Hawaii is at times showing larger CVs than that from Kritzer et al. (2001), undertake a similar study with the few species that have more than 100 age data points to see how well the published CVs compare.
8. Investigate the use of catch rate data from commercial logbook and diver relative indices as a check to the mean length approach.

4.6.3 Lower priority

9. Undertake an analysis of the sensitivity of the mean length and associated CV calculation to the stage at which the mean length summary statistic is calculated. The suggested alternative is to

calculate the mean length from an overall MHI distribution, i.e. combine distributions at the different bootstrap steps, rather than mean lengths.

10. Source maximum length figures for the data poor life history simulation approach from a distribution rather than using a single point prior.
11. Undertake a study that develops a spatial model of the habitat use and movement of species between habitats and islands. This work should be linked to testing the management strategies being used or that could be used. An example would the Management Strategy Evaluation (Sainsbury et al., 2000) model developed in the GBR called ELFSIM (Little et al., 2009; Little et al., 2007).

4.7 TOR 6. DRAFT A REPORT OF THE WPSAR PANEL CONCLUSIONS AND FINDINGS, ADDRESSING EACH TERM OF REFERENCE.

Provided by this report.

5 CONCLUSIONS AND RECOMMENDATIONS IN ACCORDANCE WITH THE TORS.

5.1 CONCLUSIONS

The overall approach to managing the species within these fisheries is correctly implemented and all the terms of references are met. The approach uses a series of steps that are well referenced in the literature, have themselves been benchmarked or based on a specific implementation of approaches well used elsewhere. However, the overall approach is not robust, and the results should be taken on a case-by-case basis, both between species and using the different approaches within a species. The tests undertaken before and during the review demonstrate that the biggest sensitivity within the overall approach is the biomass scalar, and to a lesser extent the longevity and the growth values. At all times, unless there is obvious error in the data source, all options should be provided so that all the sources of biases and variances can be openly displayed.

The overall approach is not well documented as, at present, it must be sourced from several documents and information provided in the review. This is a key priority from the review. As part of the recommended description, a decision chart of meta-rules of all the steps taken for the overall approach, so as to allow greater transparency to decision makers and stakeholders, should be produced. This is especially important given the lack of robustness of the approach and the resultant need for expert judgment at each of the steps. To better support this decision chart and overall description, it would be much more appropriate to undertake a well-designed simulation study of all the different steps (rather than the present approach of comparing data rich and data poor, and different sources of abundance when it is unclear which is more accurate) to obtain a better understanding of where this approach may fail.

It should be noted that the overall process of undertaking the OFL calculation annually need only be taken if there is a major change to the mean length or scalar. This change should also be seen in the context of keeping to the mean length assumptions such as equilibrium. If large changes have occurred, then the equilibrium assumption may be invalid.

5.2 RECOMMENDATIONS

6 REVIEW PROCESS

The review was undertaken in a very constructive light with all requests met in a timely manner. The assessors should be complimented on their open and positive approach to any comments.

The documentation provided prior to the review did not cover the full extent of the work especially the full stochastic approach to calculating the OFL, and much of the detail was only provided during the review. It is especially important that this aspect is addressed.

Furthermore, no documentation on management system, objectives and management plan as implied to be required for ToR 2 was provided during the review. A summary of major management changes was provided during the review (

Appendix 4: Management measures document supplied during the review (section 0).

The differences between ToR 1 and 2 and ToR 3 and 4 were unclear to the reviewers and it was agreed that 1 and 3 would be an overview of the approach and 2 and 4 would be about the details of the approach. Furthermore, after a request for clarification, it was agreed by NOAA staff that ToR 6 should be interpreted as only providing individual reports and a panel report is not required – this interpretation was their original intent.

7 APPENDIX 1: BIBLIOGRAPHY OF MATERIALS PROVIDED FOR REVIEW

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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.

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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.

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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.

Size frequency in MHI from diver surveys

Commercial size structure (466643)

Final Agenda

Statement of Work

8 APPENDIX 2: CIE STATEMENT OF WORK

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.

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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.

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.

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

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations following Annex 2 Terms of Reference 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: PANEL MEMBERSHIP OR OTHER PERTINENT INFORMATION FROM THE PANEL REVIEW MEETING

9.1 PANEL MEMBERSHIP

Drs Cathy Dichmont, Graham Pilling and Kevin Stokes

9.2 ATTENDANCE LIST FOR THE LENGTH-BASED ASSESSMENT CIE REVIEW

9.2.1 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

9.2.2 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

9.2.3 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

9.2.4 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

10 APPENDIX 4: MANAGEMENT MEASURES DOCUMENT SUPPLIED DURING

10.1 A SHORT HISTORY OF STATE REEF FISH FISHING REGULATIONS IN HAWAII

In December 1998, bill HAR 13-95 was introduced which sets size limits for about 17 species of reef fishes, valid statewide. In November 2014, a new version of this bill (HAR 13-95.1) was introduced for the island of Maui which increased the minimum size for certain species and introduced bag limits for parrotfishes and some of the goatfishes. These regulations are enforced with limited resources and it is not entirely clear how effective they are.

10.2 MARINE PROTECTED AREAS IN HAWAII

Some of the marine protected areas (MPA) in Hawaii are fairly old and well-protected (Hanauma Bay, established in 1967). However, most of these areas are small and managed with limited resources. Overall, no-take MPAs cover only 0.4% of the coastline in the main Hawaiian Islands.

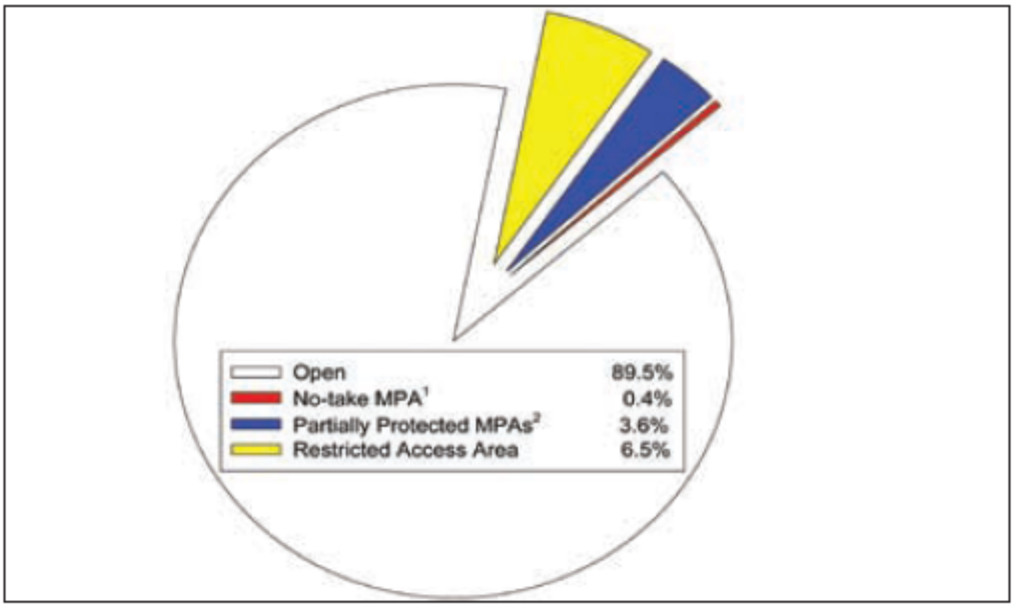

Figure 8.45. MMAs and restricted-access areas by management category (<60 ft deep nearshore marine areas) in the MHI. ***Notes: (1)*** *no-take portions of MLCDs, plus Ahihi-Kinau NAR and Coconut Island HMLR;* ***(2)*** *mostly FMAs and portions of MLCDs where some fishing is allowed, plus various harbors, wharfs and piers;* ***(3)*** *Military and security zones with no access to the public (total of 2.7%), with access by permits which require background security checks (total of 1.6%), Kahoolawe Island Reserve (1.7%) which limits access to the public and allows subsistence fishing by permit only, and Hawaii Volcanoes National Park (0.5%), in which shore-line fishing is restricted to native Hawaiians and their guests. Source: DLNR/DAR, unpub. data.*

11 APPENDIX 5: REFERENCES

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Sainsbury, K.J.; Punt, A.E.; Smith, A.D.M. Design of operational management strategies for achieving fishery ecosystem objectives. ICES Journal of Marine Science. 57:731–741; 2000