Review of Assessment Methods

for

Non-Target Species in the North Pacific

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Executive summary

A review of the methods used in the non-target species assessments in the North Pacific was conducted by three independent CIE appointed reviewers. The review consisted of a pre-meeting review of documents, participation in a review meeting at Alaska Fisheries Science Center (AFSC), Seattle, from 28–30 May 2013, and the preparation of an independent report by each reviewer.

The assessments for six species complexes: squid, skates, sharks, sculpins, octopus, and grenadiers, were considered at the review meeting. The complexes were assessed in either tier 5 or tier 6 of the AFSC tier system, either as a complex or by using a dominant species as an "indicator species". The assessments calculate an Overfishing Limit (OFL) and a maximum Allowable Biological Catch (ABC) which is set equal to 75% of the OFL.

I find that the assessments of non-target species in tiers 5 and 6 are not based on the best scientific information available. The main problem is the assumption that trawl survey biomass indices are legitimate estimates of *absolute* biomass. However, there are also some implementation issues that have not been adequately addressed in the current assessments.

Tier 5 is problematic in its definition as it requires "reliable" estimates of natural mortality and *absolute* biomass, uses natural mortality as a proxy for F_{MSY}, and assumes that a 25% buffer between OFL and the maximum ABC is an appropriate allowance for uncertainty. A liberal interpretation of "reliable" is required to fit any stock assessments into tier 5 because reliable estimates of M and absolute biomass are very hard to obtain. The current approach is to accept estimates of natural mortality from "maximum age" and catch curves. This is reasonable if the ageing appears to be fairly sound and the population is very lightly exploited. The use of trawl-survey biomass indices as estimates of absolute biomass, which appears to be current practice, is not defensible.

The use of M as a proxy for F_{MSY} is unnecessary and may be inappropriate for many species (as F_{MSY} depends strongly on the stock-recruitment relationship and the fishery selectivity). It is preferable to construct a simple species/stock-specific simulation model and use it to explore the plausible parameter space to determine an appropriate proxy for F_{MSY}.

Tier 6 assessments require a reliable catch history from 1978-1995 and OFL is calculated as a maximum or average catch over this period. It is inappropriate to predefine a period without reference to a particular stock. An average catch can only be a reasonable proxy for MSY if there has been some stability in catch and effort over the period. Therefore, the period should be chosen on a stock-specific basis. Also, for non-target species the average historical catch could be a gross underestimate of MSY. Therefore, it is preferable to base the OFL estimate on almost anything else, for example, noisy fishery-independent survey biomass indices, or even a food-web or eco-system biomass estimate if such is available.

My main conclusions are:

- Tier 5 is conceptually problematic and current methods of implementing a tier 5 assessment for non-target species are poor.
- The use of historical catch for setting OFL for non-target species should be a method of last resort and the choice of period to use should be stock specific.

- The grenadier biomass estimates are unreliable as they assume that trawl-survey biomass indices are absolute biomass estimates (and the Aleutian Islands estimates are based on an unreliable extrapolation).

My main recommendations are:

- Individual trawl surveys should be analyzed at the station level to determine if reasonable assumptions with regard to fish distribution would lead to better biomass indices than those derived from the area-swept calculations (e.g., post-stratification; use of GLM methods).
- Trawl survey and longline survey biomass indices should be converted to absolute biomass estimates by careful consideration of the factors that determine the survey proportionality constants. This involves the use of "expert knowledge" and some guess work. The results should be presented as a best estimate together with a lower and upper bound.
- Appropriate proxies for F_{MSY} should be determined for each stock using simple simulation models and an exploration of the plausible parameter space.
- When survey data are used, OFL and maximum ABC should be calculated as follows:
    - If $Z < 0.3$ and the size frequency distribution from the survey is similar to the size frequency from the fishery, then OFL = $F_{ref}B$, where F_{ref} is an appropriate proxy for F_{MSY} and B is the best estimate of absolute biomass from the survey (also calculate the range for OFL using the range on absolute biomass).
    - Otherwise, the full Baranov catch equation is used:
        - estimate the fishing selectivity by age (best estimate and range)
        - convert the absolute survey biomass estimates (best estimate and range) into a best estimate and range for full-stock numbers at age
        - apply the Baranov catch equation to get a best estimate and range for OFL = the annual catch at a constant fishing mortality rate of F_{ref}
    - The maximum ABC should be equated to the lower bound on OFL.

Background

The North Pacific Fishery Council (NPFC) is required to set Overfishing Limits (OFLs), Allowable Biological Catches (ABCs), and Annual Catch Limits (ACLs) for several non-target species complexes. A review of the methods used in the non-target species assessments was requested. It is important that the methods be fully defensible because of the potential for ACLs on non-target species to affect important commercial fisheries (e.g., exceeding the ACL on octopus closed down a cod-pot fishery in 2011).

I am one of three CIE reviewers who participated in the review which consisted of a pre-meeting review of documents, participation in a review meeting at Alaska Fisheries Science Center, Seattle, from 28–30 May 2013, and the preparation of an independent report by each reviewer. This report presents my findings and recommendations in accordance with the Terms of Reference (ToRs) for the review (Appendix 2, Annex 2).

Review Activities

Pre-meeting

The main documents provided for the review were made available in a reasonably timely manner. I read the main assessment documents in detail and also looked at the supporting papers. The PowerPoint presentations were made available electronically during and after the meeting which was helpful.

During the meeting

The first three days followed the Agenda (Appendix 2, Annex. 3) closely with very good presentations given by the presenters. The fourth day of the meeting was not used by the reviewers because there was no need for "Panel deliberations" as only independent review reports were being produced. (The Panel did have many joint discussions during the meeting sessions, at lunch, and at dinner – but there was no attempt to reach agreement on issues for a joint report.)

The use of "F = M" as a proxy for F_{MSY} was discussed and I pointed out that there was no need to use a "rule of thumb" to obtain reference points for any of the species. I explained that it is easy to construct a simple model which includes what is known about a stock's population dynamics and parameters. An exploration of the *plausible* parameter space will then yield far better estimates of reference points (such as F_{MSY} or proxies) than any meta-analysis (e.g., Zhou et al. 2012) or generic-model analysis.

The use of trawl-survey biomass indices as absolute abundance (q = 1) is not acceptable without full consideration of each of the factors which determine the proportionality constant (q). My fellow Panel members made it clear that they agreed with this position, but many of the assessment authors seemed not to have considered the issue carefully. Their position seemed to be that if a trawl survey catches a good number of the species of interest and it isn't too noisy, then the resultant wing-tip area-swept biomass estimate is reliable enough to be used in a tier 5 assessment.

A tier 5 assessment requires "reliable" estimates of *M* (natural mortality) and *B* (some type of biomass which is not clearly defined in the documentation). The issue as to what exactly was meant by "reliable" was raised by one of the presenters, but we had little discussion about it. After one of the assessments had been presented I did ask the meeting if anyone was prepared to defend the estimates of *M* and *B* used in the assessment as "reliable", but nobody was willing to do so. The problem is that *M* and *absolute* biomass are very difficult to estimate accurately and hence the requirements of tier 5 are only met if there is a dubious interpretation of "reliable".

I also raised the issue of the comparability of trawl survey indices over the whole period of each time series. As I have noted in previous AFSC reviews, there has been little documentation of the validity of assuming a single *q* for each of the NMFS trawl surveys (Gulf of Alaska, Bering Sea, Aleutian Islands). We discussed changes in area coverage (which is routinely accounted for), and changes in survey vessels, gear, tow duration, and survey timing (which are all generally ignored in AFSC assessments).

The problems with non-trawlable ground were discussed during the meeting on several occasions. My role in alerting people to the issue during the AFSC 2006 rockfish was noted as were some results from recent work by the AFSC (i.e., that for some species much higher densities had been observed on non-trawlable ground than on trawlable ground).

I commented that the use of a *biomass-weighted M* in the sculpin-complex assessment to determine a single fishing mortality rate (following an "F = M" proxy for F_{MSY}) appeared ad hoc. The presenter didn't offer any particular reason for the choice and I noted that I had looked at several alternative criteria on which to obtain a single "M" and none of them had resulted in a simple biomass average. A similar issue arose in the grenadier assessment, where a "calibration constant" between a longline estimate and a trawl survey estimate had been obtained using a ratio of means across years. I asked why that particular estimator had been used but no technical justification was offered – I pointed out that a geometric mean of the individual year ratios was more appropriate (as it was the maximum likelihood estimator under lognormal assumptions).

There was some discussion, during the meeting (and outside the meeting between the Panel) on the use of "precautionary science" as a means to precautionary management. The use of "q = 1" is one such tactic (assuming there isn't a lot of herding), but it seemed that AFSC assessment authors were sometimes happy to justify a particular decision or method on the basis that it yielded "conservative" results (by which is meant that it leads to a lower catch limit). I commented on this during the presentation of the octopus "consumption model". The presenter had a list of advantages and disadvantages for the method; given as one of the advantages was that it was "very conservative". I suggested that because it may have had a very large negative bias this should have been given as one of the disadvantages.

Post-meeting

Before leaving Seattle, I spent some time reviewing my notes and beginning my report. I also put together and tested a simple age-structured population model for octopus to illustrate how appropriate reference points could be derived in the absence of good estimates of population parameters. The crucial point for octopus is that they are terminal spawners. Therefore, the use of "F = M" as a proxy for F_{MSY} (where *M* does not include the spawning mortality) is untenable.

Soon after the meeting I reached the conclusion that most of the assessments were not using good methods for calculating OFLs and ABCs (ACLs). On returning to New Zealand, I spent a few days considering how the available data could best be used to provide OFLs and ABCs for the non-target species considered in the review.

Summary of findings

The current approach to tier 5 and 6 assessments for non-target species appears to be far from ideal. Tier 5 is conceptually problematic and there are also implementation problems with the tier 5 assessments which were reviewed. One of the main problems with the assessments is that trawl-survey biomass indices are being used as *absolute* biomass estimates of *exploitable* biomass.

Each ToR is specifically considered below.

1. *Evaluation of data used in the assessments, specifically trawl and longline survey, abundance estimates, survey indices and recommendations for processing data for use in assessments, and whether available age data should be used in the assessments.*

The stock assessments used data from four main trawl surveys and two longline surveys. There are also ADFG surveys available that perhaps should be incorporated into more of the assessments (e.g., even if only to evaluate the spatial extent of a stock).

Both longline and trawl surveys provide *relative* biomass indices at best. To be used in a tier 5 assessment they need to be converted (as well as can be done) to *absolute* biomass estimates (a best estimate and a range). I describe a process by which this can be done under ToR 2 which deals with tier 5 assessments.

Before being converted to absolute biomass estimates, trawl surveys should be analysed at the station level. For any particular species, the swept-area biomass estimates should not be taken at face value. There should be an analysis of the catch rates to see if any plausible assumptions about the distribution of the fish will lead to better biomass estimates. For example, it may be that a simple post-stratification will improve the accuracy of the estimates. Perhaps in one stratum there is sub-area where higher catch rates are typically found. If this is the case then it would be both defensible and sensible to post-stratify the stratum. Another situation where different estimates could be defensibly derived is when the catch rates fall into two *very different* distributions.

For example, if catch rates are typically fairly low and there is the occasional very high catch rate then it could be argued that fish are generally distributed fairly sparsely with the occasional hotspot. If most of the biomass is spread sparsely over a wide area, then an index based on the background catch rates will track biomass better than the area-swept index which includes the occasional very high catch rates – it is defensible to construct and use such an index. If the very high catch rates are more than occasional, they could be put into their own stratum and the "area" of the stratum calculated from the proportion of very high catch rates. (Note, "very high" means at least an order of magnitude different – you certainly cannot just pop all the higher catch rates into their own stratum – but you can consider this approach when it looks like the catch rates are coming from two very different distributions).

In cases where catch rates are often zero it may be worthwhile trying a delta-lognormal GLM approach (i.e., modelling the occurrence of zero catches with a binomial distribution and the positive catches with a lognormal distribution). This approach also allows various nuisance effects to be accounted for (e.g., vessel effects, time of day, season, etc.).

For both trawl surveys and longline surveys there needs to be careful consideration of whether the proportionality constant (q) can be considered constant over the whole period of the time series. Most of the factors that go into this consideration are not species specific and so this analysis should be done in a general way for each time series independent of species. Some factors may be species specific; for example, a change in the survey timing may necessitate a split in the time series for some migratory species but not for others. This is relevant if time series are to be used in a stock assessment model or are to be fitted using a smoother (e.g., Kalman filter).

The use of age data is discussed under ToR 5.

2. *Evaluation of analytical methods presently used in Tier 5 assessments. Evaluation may include: methods for estimating natural mortality (M), alternative biomass estimates (e.g. Kalman filter and survey biomass averaging, and consumption-based models).*

The idea behind the tier 5 approach is derive an OFL estimate by applying "F = M" to an estimate of recent biomass; and then to obtain a maximum ABC by applying 0.75 M to that same biomass estimate. Conceptually, M is being used as a proxy for F_{MSY}. The tier description states that "reliable" estimates of B and M are required.

The description of tier 5 (e.g., see the introduction to a recent SAFE report) does not specify how the OFL and ABC estimates are to be obtained from the estimates of M and B. Nor does it have much to say about what type of biomass B is – it states that "B" refers to "stock biomass (or spawning stock biomass, as appropriate)". Whatever the intent, the (general) approach of assessment authors in this review was to use trawl-survey biomass estimates as "B" and to calculate OFL = MB (and maximum ABC = 0.75 MB).

Conceptual problems with tier 5

Conceptually, there are two serious problems with tier 5.

The use of M as a proxy for F_{MSY} is an often advocated rule of thumb, but it is not appropriate for many species because F_{MSY} (be it deterministic or stochastic) depends strongly on the assumed stock-recruitment relationship and on the fishery selectivity. In these days of readily accessible computers and software, there is no need to rely on a rule of thumb for such reference points. The best estimates of F_{MSY} and proxies come from a species/stock specific model. Such models are easy to construct and an exploration of the *plausible* parameter space can then yield a likely range for any particular reference point. To illustrate how this is done, I formulated a simple octopus model and constructed yield and depletion curves for a range of parameter values (see Appendix 4).

The second conceptual flaw is to think that *reliable* estimates of M and B will be available for stocks that do not have enough information to fit into higher tiers. Accurate estimates of M are very difficult to obtain by any means. The best hope to obtain a good estimate of M is probably within a stock assessment model assuming that there are lots of good quality age data from surveys and fisheries so that recruitment variability and selectivity patterns can be taken account of (which is difficult to do outside of a model). Likewise, accurate estimates of *absolute* biomass are very difficult to obtain except by fitting to data within a stock assessment model. Some survey methods can yield (partially) defensible absolute biomass estimates provided that a whole host of assumptions are met (e.g., well designed tagging survey, acoustic survey, or egg & larval survey). However, trawl surveys do not give defensible absolute biomass estimates – they provide relative biomass indices.

To perform a tier 5 assessment requires a liberal interpretation of "reliable" with regards to the quality of the estimates of M and B. I am comfortable that estimates of M obtained from catch curves (on an almost unexploited population) or from a "maximum age" are good enough to use in this sort of assessment (if M is a reasonable proxy for F_{MSY}). I would reiterate that there is no need to use M as a proxy for F_{MSY} – it is better to use a species-specific model to obtain a more reliable proxy.

With regards to B, it should be clear that *absolute* biomass is needed and that this is unlikely to be provided by an area-swept trawl-survey estimate which is unadjusted for the proportionality constant (q). There is also the question of exactly what type of biomass is needed and this raises an implementation issue.

Implementation issues

The use of the equation OFL = MB to calculate the catch associated with a constant fishing mortality rate of M is incorrect unless $2M$ is "small" and B is *exploitable* biomass. This is a commonly used approximation to the Baranov catch equation, but it seems that the fact that it is an approximation has been overlooked by some of the assessment authors (e.g., sculpin where $M = 0.28$ is used).

The annual catch that will be taken by applying a constant instantaneous fishing mortality rate F_a to a cohort with biomass B_a, according to the Baranov catch equation, is:

$$C_a = \frac{F_a}{F_a + M}\left(1 - \exp\left[-\left(F_a + M\right)\right]\right)B_a$$

When a 1st-order Taylor approximation to the exponential function is applied, we get

$$C_a \approx \frac{F_a}{F_a + M}\left(1 - \left(1 - \left(F_a + M\right)\right)\right)B_a = F_a B_a$$

Letting $F = \max\{ F_a \}$ and $s_a = F_a/F$ and summing across cohorts (be they by length or age), we get

$$C = \sum_a C_a \approx \sum_a F_a B_a = F \sum_a s_a B_a = FB_{expl}$$

where C is total catch and B_{expl} is exploitable biomass.

When $Z = F + M$ is not "small", use of the approximation leads to increasing over-estimation of the total catch (e.g., for knife-edge recruitment and $Z = 2M$ for $M = 0.2, 0.3, 0.4$, gives over-estimation by 21%, 33%, and 45% respectively). These are not large errors, but they are avoidable. The other issue this raises is that a trawl-survey biomass estimate is not the same as a full-stock biomass estimate or an exploitable biomass estimate. If the approximation to the Baranov catch equation is used (i.e., Z small enough) then exploitable biomass needs to be estimated; and if the full Baranov catch equation is to be used then the fishery selectivity must be estimated together with the stock biomass for all the cohorts that are caught in the fishery (i.e., those: $s_a > 0$).

The main implementation difficulty is getting from a trawl-survey (or longline-survey) biomass index to an *absolute* biomass estimate of the appropriate type (e.g., exploitable). This needs to be done in two steps: converting a trawl-survey index to absolute biomass by estimating q; and converting the trawl-survey absolute vulnerable biomass estimate to the required stock biomass estimate. Whatever information is available for q should be used in its "estimation" – it will not be a strictly quantitative process but will involve the use of "expert" knowledge and some guesswork.

Converting a relative trawl-survey index to absolute biomass

There are four factors that need to be considered when trying to convert a trawl-survey index to an absolute biomass estimate: areal availability (the proportion of the total biomass which is in the survey area); vertical availability (the average proportion of the biomass in the water column, which is in front of the net after vertical herding); vulnerability (the average proportion of the biomass in front of the net, before horizontal herding, which is actually caught); and the relative proportions of biomass on trawlable and non-trawlable ground (see Cordue 2007).

Each survey should be considered at the stratum level to allow for potential differences across strata in vertical availability, vulnerability, and especially the relative proportions of biomass on trawlable and non-trawlable ground. Below is an illustration of the type of method that should be used. A key point is that a range and a "best estimate" should be used for each parameter.

First, deal with the non-trawlable ground. To do this we need to assume values for the relative densities of biomass on trawlable and non-trawlable ground and also the proportion of trawlable ground.

For a given stratum let,

d = average density of biomass on trawlable ground
e = average density of biomass on non-trawlable ground
$\alpha = \frac{e}{d}$
p = proportion of trawlable ground
X = biomass estimate assuming $q = 1$ and using full stratum area
$\bar{c}$ = average catch rate in the stratum
A = stratum area

To obtain an estimate of the "relative biomass in the whole stratum" (Y), accounting for the proportion of non-trawlable ground and the different densities between trawlable and non-trawlable ground we can use the following equation:

$$Y = \bar{c}pA + \alpha\bar{c}(1-p)A = \bar{c}A\left(p + (1-p)\alpha\right) = X\left(p + (1-p)\alpha\right)$$

To convert this to “absolute biomass for the stratum” (b), we divide by vulnerability (v) and vertical availability (u):

$$b = \frac{Y}{uv} = X\left(\frac{p + (1 - p)\alpha}{uv}\right)$$

If we now generalize the notation to the ith stratum, we obtain a “total absolute biomass estimate” (B), by summing across strata and dividing by areal availability (w):

$$B = \frac{1}{w}\sum_i b_i$$

The equations above can be used with a range and best estimate for each parameter to turn a single biomass index into a range and best estimate for absolute biomass. Also, in determining the range and best estimate, it is easier to think about *fully-selected* animals than it is to think about vulnerable biomass. For example, suppose that we have a demersal species which is unlikely to be herded by trawl gear and which we think has a strong preference for rough ground. If a stratum has about 80% trawlable ground, we might choose the following best estimates and ranges on the parameters:

Parameter	**Range**	**Estimate (best estimate)**
p	0.7-0.9	0.8
α	2.0-4.0	3.0
u	0.8-1.0	0.9
v	0.4-1.0	0.8

The above parameters give a range on the multiplier of X from 1.1-5.9 with a best estimate of 1.9 (note, the low value comes from the high values for u, v, p and the *low* value of α). If all of the strata had the same parameter ranges and best estimates then the original index would need to be scaled accordingly (e.g., X = 1000 t, then best estimate = 1,900 t and the range is 1,100–5,900 t). If areal availability was thought to be from 0.8-1.0, with a best estimate of 0.9, then the absolute-biomass best estimate and range would be scaled again to account for that factor.

The best estimate is a natural candidate to be used to determine the OFL and the low point on the range is the obvious one to use for the maximum ABC. However, we still have to get from trawl-survey vulnerable biomass to something appropriate to calculate the catch for a given F_{ref} and the fishery selectivity.

Calculating OFL and ABC

As already noted, some care needs to be taken when calculating OFL and ABC for a given reference fishing mortality F_{ref} (which is perhaps M) and a B. The first step was dealt with above, that of converting a relative index to an absolute estimate – done through a range and a best estimate. However, if the trawl survey catches fish that are very different in size from the fishery then the use of a trawl-survey biomass estimate for calculating OFL is wrong.

If Z is “small” (say, < 0.3) and the size frequency from the trawl survey is similar to that from the fishery then it is defensible to assume that the trawl and fishery selectivities are not too different and the simple formula OFL = $F_{ref}B$ can be used. In other cases, the full Baranov catch equation needs to be used and the trawl-survey biomass estimate needs to be converted to stock numbers to allow the fishery selectivity to be applied. Again, this is "back-of-the-envelope" stuff, but it is more defensible than applying a very inaccurate catch-equation-approximation to an obviously wrong type of biomass.

Assuming cohorts are defined by age (which is probably easiest), we have for an absolute biomass estimate B:

$$B = \sum_{a=0}^{a=n} s_a N_a \bar{w}_a$$

where n is the maximum age, and for age a, N_a is numbers at age, s_a is the survey selectivity, and $\bar{w}_a$ is the mean weight-at-age.

To get stock numbers at age from this we need to use the biomass estimate B, assume values for the selectivities and the mean weights at age, and then finally assume equilibrium age structure for given fishing and natural mortality rates:

$$N_a = N_0 \exp\left[-\sum_{i=0}^{a-1}\left(F_i + M_i\right)\right] = N_0 p_a$$

where the Ms are given by age for generality and p_a is the proportion of fish that survive to age a. We can solve for N_0:

$$B = \sum_{a=0}^{a=n} s_a N_a \bar{w}_a = \sum_{a=0}^{a=n} s_a N_0 p_a \bar{w}_a \quad \rightarrow \quad N_0 = \frac{B}{\sum_{a=0}^{a=n} s_a p_a \bar{w}_a}$$

From N_0 we can calculate each N_a and hence we can calculate OFL using the Baranov catch equation and the fishing selectivity pattern implicit in the F_i assumed above (divide each F_i by the maximum F_i - which is presumably quite low – to get the fishing selectivity at age). This calculation involves assuming a number of parameters which are poorly known (trawl-survey selectivity, fishery selectivity, mean weight at age) and so it is appropriate to use best estimates and a "range". The low, high, and best estimate for absolute biomass should be used in the corresponding calculations here – i.e., best estimate with best estimate, and whatever combinations in the ranges give the lowest and highest values.

Alaskan skate assessment

The Alaskan skate assessment for the Bering Sea was done in tier 3 using SS3 (and then the OFL and ABC estimates were included in the total for a BSAI skate complex). There were three main problems with the assessment.

The trawl-survey time series from the Bering Sea shelf was only included from 1992 and the earlier portion of the series which showed a dramatic increase from 1982 to 1990 was excluded. There were no compelling reasons given for excluding the first portion of the time series. If the trawl survey provides an index for the latter period then it should for the earlier period as well unless there were some fundamental differences in survey design or gear. The time series needs to be carefully examined to see over what period a single constant q can be assumed, or if it needs to be broken into one or more segments (but the first part cannot just be discarded without cause).

The trawl-survey time series was fitted assuming $q = 1$. This is an assumption that cannot reasonably be made without careful consideration of all the factors that affect q (see earlier discussion). In any case, it is not an assumption that should be made for a trawl-survey time series that is fitted in a Bayesian assessment model. Rather, an informed prior should be constructed for the q and the time series fitted as a relative index.

Available age data were only used in the model to provide mean length-at-age and yet recruitment deviations were estimated. Clearly to make the most of the ageing data it should be worked up (as best as possible) to provide age frequencies and/or conditional length-at-age data.

Octopus consumption model

The estimates of "*MB*" for BSAI and GOA from an octopus consumption-model based on Pacific cod were presented to the meeting as the best options from a number of very bad options. It was noted that it was a "minimum" estimate in that cod was only one predator of octopus.

Other problems with the consumption-model estimates were noted by myself and others at the meeting. The estimate of "*MB*" is for young octopus, whereas the fishery (mainly cod pots) catches much older octopus. The difference in mean weight between octopus caught in the fishery and those consumed by cod is very large (for pots the mode is at 16 kg and the distribution goes up to 28 kg, but cod eat octopus of about 1-2 kg in weight). Also, the trawl-survey numbers of cod were used in the consumption model but the cod stock assessment estimates a highly domed trawl-survey selectivity and a $q \sim 0.5$. This means that the cod consumption of (young) octopus was hugely under-estimated compared to what would have resulted had the stock-assessment model numbers of cod been used. However, there is no point refining the consumption model. Including more predators of young octopus and using better estimates of the absolute numbers of predators will not help because the wrong quantity is being estimated – F_{MSY} and suitable proxies do not depend on the natural mortality rate of juvenile octopus; instead, they are driven by the stock-recruitment relationship and the proportions spawning at age (see Appendix 4).

I cannot recommend the consumption model for use in estimating OFL. Certainly, it provides better/larger estimates than using average or maximum historical catch – but that is just comparing very bad OFL estimates with extremely bad estimates.

To get a defensible estimate of OFL for octopus (with suitably wide bounds) two steps are required. First, a realistic proxy for F_{MSY} needs to be chosen/determined. "F = M" (whatever this means for terminal spawners) is unlikely to be a good choice. Second, to estimate the stock numbers needed in OFL/ABC calculations, I suggest using the trawl-survey estimates with appropriate adjustments for q and the size difference between the trawl-survey caught animals and those in the fishery (see the method described above). The best estimate could be used as the OFL and perhaps the lower bound on the range as the maximum ABC.

Why not use a "minimum" biomass?

The plan teams appear to be treating the tier 5 requirement for a "reliable" biomass estimate as a "reliable minimum" biomass estimate. I can sympathise with the idea that what is needed for a bycatch species is simply an ABC that allows the target fisheries (on other species) to carry on without impediment and also poses no threat to the sustainability of the bycatch species. If a minimum biomass estimate, B, a reasonable estimate of M, and the simple equation ABC = $0.75MB$ gives what looks like a suitable number then perhaps there is no need for anything more complicated?

The problem comes down to whether the number coming out of such an approach really is "suitable". The first issue of checking that it is big enough to allow the target fisheries to carry on unimpeded is fairly straightforward – if it is at least a couple of times the maximum catch in the last 10 years or so, then it should be fine. However, it is difficult to know if the number is too big. The test here is much more complicated because we need to know whether M is a suitable proxy for F_{MSY} and also how much of a "minimum" the biomass estimate is in relationship to the *exploitable* biomass. Testing whether M is a suitable F_{ref} is not difficult – simply construct a simple species/stock-specific simulation model and explore the plausible parameter space (e.g., see Appendix 4).

To determine the nature of the "minimum" biomass estimate, we really need to attempt to estimate the full-stock or exploitable biomass using the type of procedure that I have described. And, given that the procedure has to be done to confirm that we have a "safe" minimum, then the procedure and the results also have to be documented. Therefore, why not simply use the best estimate to calculate the OFL? That would be using the best available science. The "minimum" biomass estimate, once it has been established that it is safe, could be used in calculations of the ABC, or the lower bound on the best estimate could be used.

Other tier 5 issues

When a number of trawl surveys are being combined to get a total estimate for a single area (e.g., Bering Sea shelf + Bering Sea slope + Aleutian Islands) then each individual survey needs to be converted to absolute biomass before the survey estimates are added together. The four trawl surveys in the Gulf of Alaska, Bering Sea, and Aleutian Islands use different gear and have different proportions of trawlable ground and so are not additive until these differences are accounted for.

Averaging the "last three surveys" to obtain a current biomass estimate from a trawl time series is not a good approach if the life span of the fish is short relative to the period covered by the last three surveys (e.g., sculpin used surveys from 2004, 2010, and 2012). There needs to be some expectation that the biomass was relatively stable over the period used for averaging. Use of a smoother seems a better idea (e.g., Kalman filter or random-walk model). The smoother needs to be applied after each survey in the time series has been analysed for "variance reduction" (see ToR 1) and converted to absolute biomass (see above).

For the sculpin complex a single M was chosen for use as a proxy for F_{MSY}. It was calculated as a *biomass-weighted* average of the estimated Ms for the main sculpin species. The biomass estimates were taken from the trawl surveys. The choice of biomass weighting is ad hoc. Given a single M is needed the method of calculating it should be derived based on some criteria. For example, to minimize the difference, in terms of total species-complex biomass, between applying a single $F = M$ and applying the individual Ms to each species, the following objective function would be minimized for F:

$$H(F) = \left[\sum_i B_i \exp\left(-\left(M_i + M_i\right)\right) - \sum_i B_i \exp\left(-\left(F + M_i\right)\right) \right]^2$$

The equation is the squared difference between the total species-complex biomass if the individual M_i are applied for a year as opposed to a single F (i is indexing species, B_i is the biomass of the ith species at the start of year). If the equation is minimized with regard to F, the solution is:

$$F = \ln\left(\frac{\sum_i B_i \exp(-M_i)}{\sum_i B_i \exp(-2M_i)}\right)$$

Other criteria could be used and different formulae would result for F. However, the approach should be to decide on appropriate criteria and to derive the solution (rather than just choose an averaging method that somebody thinks is a good idea). Of course, the trawl-survey biomass estimates cannot be used directly in the weighting as they need to be adjusted for potentially different qs (which would change their relative values). Also, long-term, rather than single year criteria, could be examined using a simple multi-species simulation model.

3. *Evaluation, findings and recommendations on the analytic approach used for "data-poor" stocks that have no reliable estimate of biomass, specifically, Tier 6 species/stock complexes.*

For a target fishery where the catch and effort have been fairly stable over a large number of years it makes some sense to use average catch as a proxy for MSY. For a non-target fishery it makes much less sense. If the fish are not targeted, the bycatch level is likely to be less than MSY and, potentially, hugely less than MSY.

Certainly it is not appropriate to determine average catch over a pre-defined range of years, for a number of bycatch species, and take the averages as proxies for MSY. The pre-defined year range of 1978-1995 was used for BSAI squid which is inappropriate as it was a target fishery in the first part of that period and then changed to a bycatch fishery – there was no stability in catch or effort. A period when there is some stability in catch and effort should be used – so for squid, this would be a later period when it was a non-target species.

If fishery-independent survey indices are available, they should be used in preference to historical catch even if they are quite noisy. Also, I suggest that if food-web or eco-system based estimates are available, they would also be preferable to historical-catch based estimates for non-target species. If historical catch has to be used then the *average* over a period is not appropriate – it is just asking for trouble in that more than half of the time (because of the 25% buffer between OFL and ABC and assuming the distribution of catches is symmetric) the ABC will be exceeded. Use of the maximum provides more of a buffer for variation in catches, but it would be better to use the upper bound of a one-sided 95% or 99% confidence interval as this directly incorporates information on catch variability. Either a lognormal or normal distribution could be assumed for the annual catches (depending on what the distribution of annual catches looks like over the period chosen). Obviously, catches would have to be monitored to make sure that they were varying within the provided buffer rather than increasing from the previous average level (which might mean that the species was being targeted).

4. Review of the grenadier assessment and the reliability of the estimation of biomass.

The method used to estimate grenadier biomass assumes that the trawl survey in each area is providing absolute biomass estimates – which is not true. Also, the extrapolations used to obtain a "trawl-survey" biomass estimate for the Aleutian Islands are difficult to defend.

For the Aleutian Islands, the eastern area is surveyed by longline down to 1000m and the western area is not surveyed. The eastern longline estimate is scaled up to account for fish in the western area using early longline surveys which covered both areas. Then the total longline estimate is converted into "trawl-survey biomass" by multiplying by a conversion factor derived from the *minor* overlap between the trawl survey, which surveys down to 500 m, and the longline survey. The overlap is minor because most of the grenadier biomass is shown by the longline survey to be below 500 m. Furthermore, the conversion factor shows a trend, being equal to about 0.3 for 2000, 2002, 2004, and 2006, and then dropping to 0.06 in 2010 and increasing to 0.10 in 2012 (Rodgveller et al. 2012b). Intuitively, the whole procedure looks extremely shaky, and a five-fold difference in the "calibration constant" between years confirms this. In any case, the procedure is aimed at converting the longline index to the units of a trawl-survey estimate on the basis that the trawl-survey estimate is *absolute* biomass – which it is not.

I see two ways that more defensible estimates could be derived.

The first approach is to develop a stock assessment model. This would be difficult but not impossible. Catches would not be input into the model except in recent years where they are relatively accurate. The grenadier catches in the model would have to be driven by an index of effort derived from standardised CPUE analysis in the fisheries that catch (giant) grenadier. There is no shortage of biomass indices from the trawl and longline surveys. These would be fitted in the model only for the years and areas where there were actually surveys – there would be *no extrapolation*. Informed priors would be developed for the survey *q*s and for ratios of *q*s between areas.

An alternative approach – which is quicker and easier than a stock assessment model – is to develop best estimatees and ranges on the trawl survey *q*s in the areas where they go relatively deep (not the Aleutian Islands) and to do the same for the longline surveys. I have covered the factors for a trawl-survey *q* already. For a longline survey the factors are not that different. Areal and vertical availability are still relevant, and the interpretation of vulnerability just changes a bit; the proportion of trawlable ground is not relevant. An extra factor is the size of the area from which fish are attracted to the baited hooks and other factors are potential hook competition with sablefish and predation of hooked fish by whales and orca. The factors are different, but the approach is the same as I described for a trawl survey – "expert knowledge" and any relevant data/information that are available is used to form best estimates and a lower and upper bound on each factor. The factors are then combined to get a best estimate and range on absolute biomass for each survey.

5. *Review age information that is available for a number of the Alaska "non-target" species, including spiny dogfish, giant grenadier, yellow Irish lord, great sculpin, and plain sculpin. Age of maturity information is also available for giant grenadier. Although the ages have not been validated, use of these age data in the assessment process could result in moving these species to a higher assessment tier. Provide recommendations on how to proceed with the age data.*

We were not given much information on the available age data for the non-target species. We were directed to a website that could provide data on the number of otoliths that were available from fishery-independent surveys and catch sampling for each species. We were also given an extract from a cruise program which gave some detail on the sampling scheme for species on that particular cruise. However, sampling schemes can vary from cruise to cruise depending on the requests from staff responsible for each species.

A presentation was made on the ageing methods used for the species and also on some results for between-reader variability. The consistency of the readers looked quite good and could perhaps be improved upon by tightening protocols on a given species. For some species there are laboratories which have much more experience at reading similar otoliths and it would be worthwhile consulting with such labs (e.g., NIWA for grenadier).

Even though the ageing is not validated, I think it is worthwhile using the age readings for estimation of M on the basis of "maximum age". The construction of age frequencies for use in catch curve estimation of Z and/or use in stock assessment models could also be worthwhile, but should only be done after a careful review of exactly how the otoliths were collected. The main point is how many otoliths were collected at each station and, in particular, if a number were required for each length bin, how the otoliths for each length bin were filled (it is better to have a few otoliths at lots of stations rather than lots of otoliths at a few stations).

For a given species, the ideal method is to collect a set number of otoliths, at random, from the animals caught on each trawl/set. This will give a large number of otoliths for a given cruise or fishery each year which can be sub-sampled for the otoliths which are prepared and read. The method of sub-sampling depends on whether age-length keys are required or whether the otoliths are to be directly sampled for age (the latter would be used for a fishery where the animals grow substantially during the period of the fishery each year).

In terms of future otolith collection from fishery-independent surveys and catch sampling, a rotation schedule should be set up for the minor species where 1-2 minor species are well-sampled in a particular year. The point being that a small number of otoliths collected from lots of species each year is of little use.

6. Recommendations for further improvements

The review process used by the NPFC of having strategic reviews of assessments, methods, and control rules periodically is a good approach. In terms of stock assessment review, I think it is more effective, in improving stock assessments, than having reject-or-accept reviews of assessments (e.g., SARC) or very intense but somewhat brief "workshops" which review (but often modify) an assessment (e.g., STAR Panels). However, to get the most out of stock assessment and methods reviews, there are some improvements that could be made.

For each time series of data that are produced as an input to a stock assessment there should be documentation which reviews the data as a potential stock assessment *time series*. The potential limitations of the time series need to be transparent for assessment authors and for reviewers. This can only be the case if someone has taken the time to set out all of the strengths and weaknesses of the time series in a widely available document.

Also, after a review, a formal document responding to the recommendations of the reviewers should be produced. This would be very helpful for future reviewers who could then see which recommendations were followed and which were not and, most importantly, the reasons why. It is also important that a formal written response is produced so that reasons for following or not following recommendations are fully thought through and recorded.

Conclusions and Recommendations

The existing methods used for non-target species in tier 5 and 6 assessments are less than ideal.

Tier 5 is problematic in its definition as it requires "reliable" estimates of natural mortality (*M*) and *absolute* biomass, uses *M* as a proxy for F_{MSY}, and assumes that a 25% buffer between OFL and the maximum ABC is an appropriate allowance for uncertainty. A liberal interpretation of "reliable" is required to fit any stock assessments into tier 5 because reliable estimates of *M* and absolute biomass are very hard to obtain. The current approach is to accept estimates of natural mortality from "maximum age" and catch curves. This is reasonable if the ageing appears to be fairly sound and the population is very lightly exploited. The use of trawl-survey biomass indices as estimates of absolute biomass, which appears to be current practice, is not defensible.

The use of *M* as a proxy for F_{MSY} is unnecessary and may be inappropriate for many species (as F_{MSY} depends strongly on the stock-recruitment relationship and the fishery selectivity). It is preferable to construct a simple species/stock-specific simulation model and use it to explore the plausible parameter space to determine an appropriate proxy for F_{MSY}.

Tier 6 assessments requires a reliable catch history from 1978-1995 and OFL is calculated as a maximum or average catch over this period. It is inappropriate to predefine a period without reference to a particular stock. An average catch can only be a reasonable proxy for MSY if there has been some stability in catch and effort over the period. Therefore, the period should be chosen on a stock-specific basis. Also, for non-target species the average historical catch could be a gross underestimate of MSY. Therefore, it is preferable to base the OFL estimate on almost anything else, for example, noisy fishery-independent survey biomass indices, or even a food-web or eco-system biomass estimate if such is available.

My main conclusions are:

- Tier 5 is conceptually problematic and current methods of implementing a tier 5 assessment for non-target species are poor.
- The use of historical catch for setting OFL for non-target species should be a method of last resort and the choice of period to use should be stock specific.
- The grenadier biomass estimates are unreliable as they assume that trawl-survey biomass indices are absolute biomass estimates (and the Aleutian Islands estimates are based on an unreliable extrapolation).

My main recommendations are:

- Individual trawl surveys should be analyzed at the station level to determine if reasonable assumptions with regard to fish distribution would lead to better biomass indices than those derived from the area-swept calculations (e.g., post-stratification; use of GLM methods).
- Trawl survey and longline survey biomass indices should be converted to absolute biomass estimates by careful consideration of the factors that determine the survey proportionality constants. This involves the use of "expert knowledge" and some guesswork. The results should be presented as a best estimate together with a lower and upper bound.

- Appropriate proxies for F_{MSY} should be determined for each stock using simple simulation models and an exploration of the plausible parameter space.
- When survey data are used, OFL and maximum ABC should be calculated as follows:
    - If $Z < 0.3$ and the size frequency distribution from the survey is similar to the size frequency from the fishery, then OFL = $F_{ref}B$ where F_{ref} is an appropriate proxy for F_{MSY} and B is the best estimate of absolute biomass from the survey (also calculate the range for OFL using the range on absolute biomass).
    - Otherwise, the full Baranov catch equation is used:
        - estimate the fishing selectivity by age (best estimate and range)
        - convert the absolute survey biomass estimates (best estimate and range) into a best estimate and range for full-stock numbers at age
        - apply the Baranov catch equation to get a best estimate and range for OFL = the annual catch at a constant fishing mortality rate of F_{ref}
    - The maximum ABC should be equated to the lower bound on OFL.

References

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Appendix 1: Bibliography of supplied material

The following documents were supplied before the meeting. Also, during the meeting, some additional papers and several PowerPoint presentations were supplied.

AFSC, 2013. 2013 Annual Deployment Plan for Observers in the Groundfish and Halibut Fisheries off Alaska. Fisheries Monitoring and Analysis Division, Alaska Fisheries Science Center. 83 p.

Brewer, R.S., Norcross, B.L. 2012. Long-term retention of internal elastomer tags in a wild population of North Pacific giant octopus (*Enteroctopus dofleini*). *Fisheries Research 134–136*: 17– 20.

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Cahalan, J., Mondragon, J., Gasper, J. 2010. Catch sampling and estimation in the Federal groundfish fisheries off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-205, 42 p.

Clausen, D.M., Rodgveller, C.J. DRAFT April 2013. Deep-water longline experimental survey for giant grenadier, Pacific grenadier, and sablefish in the Western Gulf of Alaska. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-AFSC-247, 30 p.

Conners, M.E., Aydin, K., Conrath, C.L. 2012. Assessment of the Octopus Stock Complex in the Gulf of Alaska. NPFMC Gulf of Alaska SAFE: 647–688.

Conners, M.E., Conrath, C.L., Aydin, K. 2012. Assessment of the Octopus Stock Complex in the Bering Sea and Aleutian Islands. NPFMC Bering Sea and Aleutian Islands SAFE: 1887–1938.

Conners, M.E., Conrath, C.L., Brewer, R. 2012. Field studies in support of stock assessment for the giant Pacific octopus *Enteroctopus dofleini.* NPRB Project 906 Final Report. 49 p.

DiCosimo, J., Methot, R. D., Ormseth, O. A. 2010. Use of annual catch limits to avoid stock depletion in the Bering Sea and Aleutian Islands management area (Northeast Pacific). *ICES Journal of Marine Science 67*: 1861–1865.

NMFS. 2001. Marine Fisheries Stock Assessment Improvement Plan. Report of the National Marine Fisheries Service National Task Force for Improving Fish Stock Assessments. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-56, 69 p., 25 appendices.

Ormseth, O.A. 2012. Assessment of the skate stock complex in the Bering Sea and Aleutian Islands. NPFMC Bering Sea and Aleutian Islands SAFE: 1647–1734.

Ormseth, O.A. 2012. Assessment of the squid stock complex in the Bering Sea and Aleutian Islands. NPFMC Bering Sea and Aleutian Islands SAFE: 1849–1886.

Ormseth, O.A. 2012. Assessment of the skate stock complex in the Gulf of Alaska. NPFMC Gulf of Alaska SAFE: 629–636.

Ormseth, O.A. 2012. Assessment of the squid stock complex in the Gulf of Alaska. NPFMC Gulf of Alaska SAFE: 643–646.

Rodgveller, C., Clausen, D., Hulson, P. 2012a. Proposed Aleutian Islands biomass and variance estimates for giant grenadier. Grenadier Plan Team document. 11 p.

Rodgveller, C., Clausen, D., Hulson, P. 2012b. Assessment of the Grenadier Stock Complex in the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. Appendix 1 – Gulf of Alaska and Bering Sea/Aleutian Islands SAFE Reports: 689–758.

Rodgveller, C. J., Clausen, D. M., Nagler, J.J., Hutchinson, C. 2010. Reproductive Characteristics and Mortality of Female Giant Grenadiers in the Northern Pacific Ocean. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2*:73–82.

Spies, I., Nichol, D., TenBrink, T.T. 2012. Assessment of the sculpin complex in the Gulf of Alaska. NPFMC Gulf of Alaska SAFE: 637–638.

Spies, I., Ormseth, O.A., TenBrink, T.T. 2012. Bering Sea and Aleutian Islands sculpins. NPFMC Bering Sea and Aleutian Islands SAFE: 1735–1770.

Taylor, I.G., Gertseva, V., Matson, S.E. DRAFT 2013. Spine-based ageing methods in the spiny dogfish shark, *Squalus suckleyi*: how they measure up. Draft manuscript. 34 p.

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Tribuzio, C.A., Echave, K., Rodgveller, C., Hulson, P.J. 2012. Assessment of the shark stock complex in the Bering Sea and Aleutian Islands. NPFMC Bering Sea and Aleutian Islands SAFE: 1771–1848.

Tribuzio, C.A., Echave, K., Rodgveller, C., Hulson, P.J. 2012. Assessment of the Shark stock complex in the Gulf of Alaska (Executive Summary). NPFMC Gulf of Alaska SAFE: 639–642.

Zhou, S., Yin, S., Thorson, J.T., Smith, A.D.M., Fuller, M. 2012. Linking fishing mortality reference points to life history traits: an empirical study. *Can. J. Fish. Aquat. Sci. 69*: 1292–1301.

Appendix 2: Statement of Work for Patrick Cordue

External Independent Peer Review by the Center for Independent Experts

Review of Assessment Methods for Non-Target Species in the North Pacific

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 Representative (COR), 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. The CIE reviewer is selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance with the predetermined Terms of Reference (ToRs) of the peer review. The 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 Alaska Fisheries Science Center (AFSC) is responsible for stock assessment for 10 stocks/complexes in the Gulf of Alaska (GOA) and Bering Sea/Aleutian Islands (BSAI) which are considered "non-target", as well as two species complexes which are currently not included in the fishery management plan (FMP). The requirement in the re-authorized Magnuson-Stevens Act (2007) to set annual catch limits (ACLs) based on science recommendations implies some kind of basic assessment is required for all species in the FMPs. In response to these new requirements, the North Pacific Fishery Management Council divided the non-target species formerly managed as "other species" complex into five species complexes: squid, skates, sharks, sculpins and octopus. Assessments were developed for each species group. Grenadiers were not in the other species complex and are not currently in either of the FMPs; however, an unofficial stock assessment has been done since 2006 and grenadiers are under consideration for inclusion in the FMPs. The amount and quality of fishery dependent and fishery independent data available to conduct the assessment varies by complex. Some species such as skates, sculpins, and giant grenadier are adequately assessed by existing fishery independent surveys; the key challenge for skates and sculpins has been to improve species identification of the catch. Other species such as squid, sharks and octopus lack reliable fishery independent data and have imprecise fishery dependent data. Further, bycatch in unobserved fisheries may be significant, such as in Alaska state-managed salmon fisheries. Scientists at the AFSC have developed techniques to assign annual catch limits and overfishing levels to these non-target species groups. In some cases (e.g. sharks) these annual catch limits could limit commercial harvest of target species. Because of this potential interaction with commercially targeted species and the key role of these non-target species within the Bering Sea/Aleutian Islands and Gulf of Alaska ecosystems, the methodology used to derive biological reference points for non-target species has been the focus of considerable attention by the public and scientific community. A variety of assessment techniques are used, from simple historical catch to estimation of natural mortality based on predation.

While these species/complexes are considered as non-targets, there are commercial concerns to be considered. Some species/complexes have either been targeted or have some market value (e.g. skates, grenadier), promoting retention of the catch. In the case of grenadier, because they are not included in the FMP, there are no catch limits in place. Further, some of these non-target species are highly migratory (e.g. sharks and skates) and move between Alaska state, federal and international waters. Catch of these species outside of the FMPs may be relevant to the assessments.

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 Reviewer: Two CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. The CIE reviewers shall have working knowledge and recent experience in the application of fishery stock assessment methods, especially for data-limited stocks. One reviewer should have expertise in length or –age based stock assessment modeling. Two reviewers should have expertise in population dynamics, survey design and abundance estimation. 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 Seattle, Washington during 28-31 May 2013.

Statement of Tasks: The 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, and contact details) to the COR, who forwards this information to the NMFS Project Contact no later than 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 reviewer with the background documents, report, foreign national security clearance, and 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 COR prior to the commencement of the peer review.

Foreign National Security Clearance: When the 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 each CIE reviewer if a non-US citizens. For this reason, each CIE reviewer 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/sponsor.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 each CIE reviewer the necessary background information and report 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. Each CIE reviewer is responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. Each CIE reviewer shall read all documents in preparation for the peer review.

AFSC will provide copies of the statement of work, stock assessment documents, prior CIE review documents, and other background materials to include both primary and grey literature.

This list of pre-review documents may be updated up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables.

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 cannot be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COR 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 reviewer 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 Report: 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 Reviewer: The following chronological list of tasks shall be completed by the CIE reviewers 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 report provided by the NMFS Project Contact in advance of the peer review.
2) Participate during the panel review meeting at the AFSC in Seattle, WA during 28-31 May 2013 as called for in the SoW.
3) During the review meeting in Seattle, WA during 28-31 May 2013 as specified herein, each CIE reviewer shall conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 14 June 2013, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Mr. Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas.miami.edu. 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.

3 May 2013	CIE sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
14 May 2013	NMFS Project Contact sends the CIE Reviewer the pre-review documents
28-31 May 2013	The reviewer participates and conducts an independent peer review during the panel review meeting
14 June 2013	The CIE reviewer submits draft CIE independent peer review report to the CIE Lead Coordinator and CIE Regional Coordinator
28 June 2013	The CIE submits CIE independent peer review report to the COR
5 July 2013	The COR distributes the final CIE report to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COR within 10 working days after receipt of all required information of the decision on substitutions. The COR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the 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 report by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, this report shall be sent to the COR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review report) to the COR (William Michaels, via William.Michaels@noaa.gov).

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

Distribution of Approved Deliverables: Upon acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The COR 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, and specify whether the science reviewed is the best scientific information available.

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. The reviewer 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. The reviewer 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. The reviewer should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. The reviewer shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

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

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the 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 of Assessment Methods for Data-Moderate Stocks

The reviewers will participate in the Panel review meeting to conduct independent peer reviews of the non-target species assessment methods to apply to groundfish stocks managed by the North Pacific Fishery Management Council. The review solely concerns technical aspects of the methods, and addresses the following ToR:

1. Evaluation of data used in the assessments, specifically trawl and longline survey, abundance estimates, survey indices and recommendations for processing data for use in assessments, and whether available age data should be used in the assessments.
2. Evaluation of analytical methods presently used in Tier 5 assessments. Evaluation may include: methods for estimating natural mortality (M), alternative biomass estimates (e.g. Kalman filter and survey biomass averaging, and consumption-based models.
3. Evaluation, findings and recommendations on the analytic approach used for "data-poor" stocks that have no reliable estimate of biomass, specifically, Tier 6 species/stock complexes.
4. Review of the grenadier assessment and the reliability of the estimation of biomass.
5. Review age information that is available for a number of the Alaska "non-target" species, including spiny dogfish, giant grenadier, yellow Irish lord, great sculpin, and plain sculpin. Age of maturity information is also available for giant grenadier. Although the ages have not been validated, use of these age data in the assessment process could result in moving these species to a higher assessment tier. Provide recommendations on how to proceed with the age data.
6. Recommendations for further improvements

Annex 3: Tentative Agenda

2013 CIE Review of Non-target Species Groups in Alaska

Alaska Fisheries Science Center, Building 4 room 2143
7600 Sand Point Way NE, Seattle, WA 98115
Phone: (206) 526-4000

Contact for security and check-in: Julie Pearce
Contacts for additional documents: Elizabeth Conners

Tuesday, May 28

9:00 Introductions, agenda, and meeting format. *Sandra Lowe, AFSC, meeting chair*

9:15 Structure of NPFMC and regulatory history of non-target species in Alaska. *Jane DiCosimo, North Pacific Fishery Management Council*

9:40 Overview of models for setting catch limits with limited data. *Olav Ormseth, AFSC*

10:00 Discussion

10:30 Break

10:45 Fishery-dependent data collection for non-target species and observer program restructuring. *Martin Loefflad, AFSC, FMA Division*

11:15 Catch accounting and catch estimation for non-target species. TBD*, NMFS AK Regional Office*

11:30 Discussion

12:00 LUNCH

1:00 AFSC bottom trawl surveys and biomass estimates, Bering Sea, Gulf of Alaska, and Aleutian islands. *Wayne Palsson and Robert Lauth, AFSC RACE Division*

1:45 Discussion

2:15 Overview of AFSC longline survey. *Cara Rodgveller, AFSC*

2:30 Discussion

2:45 Break

3:00 Averaging and smoothing methods for trawl biomass time series. *Paul Spencer, AFSC*

3:20 Discussion

3:40 Aging methods for selected non-target species in Alaska. *Tom Helser, AFSC*

4:10 Discussion

5:00 Conclude

CIE Review of Non-target Species Groups in Alaska

Wednesday, May 29

9:00 Stock assessment of sculpins in the BSAI and GOA. *Ingrid Spies, AFSC*
9:30 Mortality rate estimation for sculpins in the BSAI and GOA – *Todd TenBrink, AFSC*
10:00 Discussion
10:30 Break
10:45 Stock assessment of skates in the BSAI and GOA. *Olav Ormseth, AFSC*
11:30 Discussion
12:00 LUNCH
1:00 Stock assessment model for Alaskan skate. *Olav Ormseth, AFSC*
1:30 Discussion
2:00 Stock assessment of sharks in the BSAI and GOA. *Cindy Tribuzio, AFSC*
3:00 Discussion
4:00 Analysis requests from panel, panel deliberations
5:00 Conclude

Thursday, May 30
9:00 Stock assessment of grenadiers in the BSAI and GOA. *Cara Rodgveller, AFSC*
9:45 Discussion
10:30 Break
10:45 Stock assessment of squids in the BSAI and GOA. *Olav Ormseth, AFSC*
11:15 Discussion
12:00 LUNCH
1:00 Stock assessment of octopus in the BSAI and GOA. *Elizabeth Conners, AFSC*
1:45 Discussion
2:30 Estimating octopus mortality from predator consumption models. *Kerim Aydin, AFSC*
3:00 Break
3:15 Discussion
4:00 Analysis requests from panel, panel deliberations
5:00 Conclude

Friday, May 31
9:00 Panel deliberations, panel and reviewer reports.
12:00 LUNCH
1:00 Panel deliberations, panel and reviewer reports
4:00 Conclude

Appendix 3: Panel membership

The review panel consisted of three CIE appointed reviewers:

Mr. Patrick Cordue, Fisheries Consultant, New Zealand
Dr. Matthew Cieri, Department of Marine Resources, Maine, USA.
Dr. Jon Helge Vølstad, Institute of Marine Research, Bergen, Norway

Appendix 4: Octopus model

I constructed an age-structured model with terminal spawning to illustrate how easy it is to obtain suitable reference points from simulation modelling, even with limited knowledge of population parameters. The point of the exercise is to see how reference points change in response to different assumed parameters. By fully exploring the *plausible* parameter space for a particular stock, sensible and defensible choices can be made with regard to reference points.

The key features of the model (see Annex 1 for all R functions used in the model):

- age-structured
- annual cycle: full-year fishery, end-of-year spawning, then ageing and recruitment
- terminal spawning
- deterministic recruitment
- Beverton-Holt stock-recruitment relationship
- equilibrium biomass and age-structure in the virgin population
- Baranov catch equation
- constant F

The parameters I used in the model (see Annex 1) are based on my scant knowledge of octopus gleaned from the presentations during the meeting. The results are just for illustrative purposes.

The parameters in the model (excluding steepness) were all specified at ages from 0-5 years:

Age (y)	0	1	2	3	4	5
Fishing selectivity	0	0.0	0.5	1.0	1.0	1.0
M	0	0.7	0.5	0.2	0.1	0.1
Mean weight (kg)	0	2	8	16	22	24
Proportion spawning	0	0	0.1	0.5	0.7	1.0

I have not fully explored the plausible parameter space, but I have derived $F_{40\%B0}$ (the F which causes the SSB to reach equilibrium at 40% B_0) and F_{MSY} for a range of steepness values from 0.6 to 0.9:

Steepness (h)	$F_{40\%B0}$	F_{MSY}
0.60	0.34	0.44
0.65	0.36	0.51
0.70	0.38	0.57
0.75	0.40	0.63
0.80	0.41	0.71
0.85	0.42	0.81
0.90	0.44	0.95

The results were derived from yield and equilibrium stock depletion (ESD) curves created by running the model over a range of *F*s from 0-2 (e.g., Figure A4.1).

The above table illustrates a number of points. Using any measure of M is going to give a poor proxy for (deterministic) F_{MSY} as it depends strongly on the assumed steepness value (this is typical of most species/stocks). Also, $F_{40\%B0}$ is lower than F_{MSY} (which is to be expected) and it is much less dependent on the assumed value of steepness. It would be my preferred choice as a proxy for the "real" F_{MSY}.

The key parameters to explore further are the proportions spawning and perhaps the maximum age. Also, the timing of spawning could be looked at (i.e., moving it from end-of-year to mid-year). The values assumed for M are probably unimportant (e.g., halving and doubling them make almost no difference to $F_{40\%B0}$ at h= 0.75: 0.39 and 0.41 respectively).

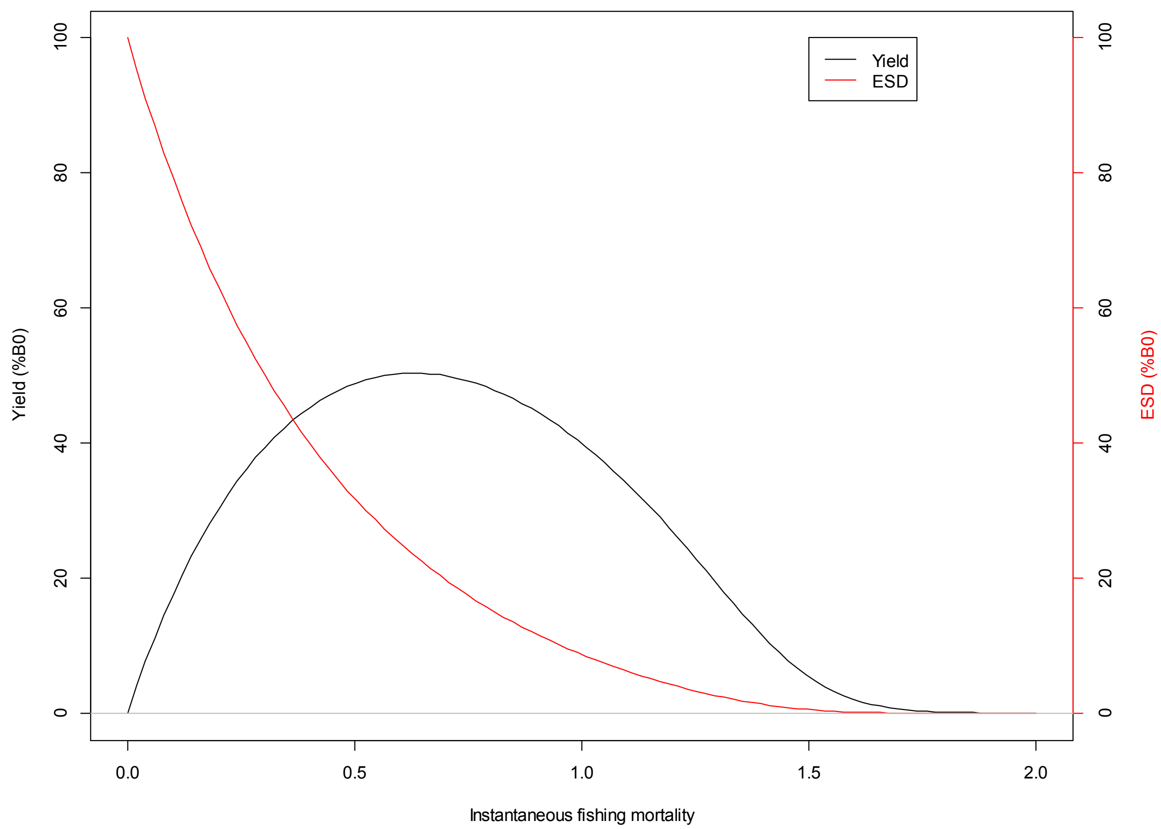

Figure A4.1: Yield and equilibrium stock depletion (ESD) curves (as a function of maximum *F* in the fishery) for the octopus model with steepness = 0.75. Yield and ESD are both in terms of %B_0 (and are therefore independent of stock size).

Annex 1: R functions for the octopus model

h = steepness in the Beverton-Holt stock recruitment relationship
Fvec = vector of instantaneous fishing mortalities (for constructing the yield and ESD curves)
nyr = number of years to run the model (to get to equilibrium)
sel = fishing selectivity (from age 0 to maximum age = 5 in the examples)
M = natural mortality at age (from age 0 to maximum age = 5 in the examples)
w = mean weight at age
msel = proportion spawning at age

In the examples given above, profile.pl() was run for values of steepness from 0.6 to 0.9 in steps of 0.05. The default values, given in the function header for profile.pl(), were used for the other parameters.

Note, the symbol "<-" is said "gets" – it is how assignment is generally done in R.

profile.pl:

```
function(h,
Fvec=seq(0,2,length=100),nyr=50,
sel=c(0,0,.5,1,1,1),
M=c(0,.7,.5,.2,.1,.1),
w=c(0,2,8,16,22,24),
msel=c(0,0,.1,.5,.7,1))
{
par(mar=c(4,4,1,4)+.1)
tem <- get.profile(h,Fvec,nyr,sel,M,w,msel)
plot(tem$F,100*tem$Y,type="l",ylim=c(0,100),xlab="Instantaneous fishing mortality",
        ylab="Yield (%B0)")
points(tem$F,100*tem$ESD,type="l",col=2)
axis(4,col=2)
mtext("ESD (%B0)",4,line=3,col=2)
abline(h=0,col="grey")
legend(1.5,100,c("Yield","ESD"),col=1:2,lty=1)

res <- cbind(tem$F,tem$ESD,tem$Y)
colnames(res) <- c("F","ESD","Y")
return(res)
}
```

get.profile:

```
function(h,
Fvec=seq(0,2,length=100),nyr=50,
sel=c(0,0,.1,.2,1,1),
M=c(0,.7,.5,.2,.1,.1),
w=c(0,1,2,4,10,15),
msel=c(0,0,0,.1,.7,1))
{
# For given h, get the yield curve and ESD curve
```

```
yield <- esd <- NULL
for (i in 1:length(Fvec)){
        tem <- My.octopus(Fvec[i],sel,M,w,msel,h,nyr)
        yield <- c(yield,tem$pC[nyr])
        esd <- c(esd,tem$pB[nyr])
}

return(list(F=Fvec,Y=yield,ESD=esd))
}
```

My.octopus:

```
function (Ff = 0, sel = c(0, 0, 0.1, 0.2, 1, 1), M = c(0, 0.7,
    0.5, 0.2, 0.1, 0.1), w = c(0, 1, 2, 4, 10, 15), msel = c(0,
    0, 0, 0.1, 0.7, 1), h = 0.75, nyr = 50, R0 = 100)
{
    n <- length(msel)
    N <- rep(0, n)
    for (i in 1:(n + 2)) {
        tem <- oct.virgcyc(N, M, msel, w, R0)
        N <- tem$N
    }
    B0 <- tem$B0
    spB <- NULL
    catch <- NULL
    for (i in 1:nyr) {
        tem <- oct.cyc(N, M, Ff, sel, w, h, msel, R0, B0)
        spB <- c(spB, tem$B)
        catch <- c(catch, tem$C)
        N <- tem$N
    }
    return(list(B0 = B0, spB = spB, C = catch, pB = spB/B0, pC = catch/B0,
        N = N, vulB = sum(N * sel * w)))
}
```

oct.virgcyc:

```
function (N, M, msel, w, R0)
{
    Nend <- N * exp(-M)
    B0 <- sum(Nend * msel * w)
    Nend <- Nend * (1 - msel)
    n <- length(N)
    Nend <- c(R0, Nend[1:(n - 1)])
    return(list(N = Nend, B0 = B0))
}
```

oct.cyc:

```
function (N, M, Ff, sel, w, h, msel, R0, B0)
{
   Z <- M + Ff * sel
   Nend <- N * exp(-Z)
   id <- Z != 0
   catch <- sum((Ff * sel[id]/Z[id]) * (1 - exp(-Z[id])) * N[id] *
      w[id])
   B <- sum(Nend * msel * w)
   Nend <- Nend * (1 - msel)
   R <- R0 * BHsr(B, B0, h)
   n <- length(N)
   Nend <- c(R, Nend[1:(n - 1)])
   return(list(B = B, C = catch, N = Nend))
}
```

BHsr:

```
function (B, B0, h)
{
   sr <- (B/B0)/(1 - ((5 * h - 1)/(4 * h)) * (1 - B/B0))
   return(sr)
}
```