REVIEW OF

ALASKAN ROCKFISH

HARVEST STRATEGIES

AND

STOCK ASSESSMENT METHODS

19-22 JUNE, 2006

SEATTLE, WASHINGTON

Prepared by

Patrick Cordue
Fisheries Consultant
New Zealand

for

University of Miami
Independent System for Peer Review

5 July 2006

EXECUTIVE SUMMARY

A CIE Review Panel considered the current harvest strategies and stock assessment methods for Alaskan rockfish stocks from June 19-22, 2006 at Alaska Fisheries Science Center, Seattle, WA. The motivation for the review was the concern of some stakeholders that rockfish harvest strategies are “too aggressive”. The same tier system and general harvest strategy is applied to all groundfish, including rockfish. For this reason many of my conclusions, with regard to harvest strategies, apply to groundfish stocks in general.

The rockfish team did an excellent job of presenting a wide-array of relevant information. I was impressed by many aspects of the current research programmes, stock assessment methods, and harvest strategies. I find the apparent reason for the review understandable but disappointing. The current rockfish harvest strategies are very conservative and proposals to move to more extreme conservatism are most unfortunate.

My main conclusions are:

- There are multiple and cumulative layers of conservatism in the current groundfish harvest strategies which will conserve rockfish stocks at high levels of biomass.
- The multiple layers of conservatism may result in unnecessarily low yields for groundfish stocks in general.
- Current harvest strategies favor conservation over use. If the fishing industry is happy with this circumstance then the strategies do provide an appropriate level of conservatism.
- Stock assessment scientists are required to make value judgments and, in essence, act as managers since their ABC recommendations limit the level at which the TAC can be set.
- Current spatial management of rockfish appears appropriate. Finer scale management is ill-advised until much more is known about stock structure, migration patterns associated with mating and parturition, and the location and stability of any important sources of production
- Stock assessment methods are generally acceptable but could be improved.
- Stock hypotheses are not well founded as little is known about stock structure.
- Current trawl survey biomass indices could mislead to some extent as they do not take account of the proportion of untrawlable ground in each stratum.

My main recommendations are:

- Consider whether so many cumulative layers of conservatism are really needed.
- At the next available opportunity, update the tier structure so that:
    - a trawl survey index need not be considered to provide “a reliable point estimate of B”
    - the number of tiers is reduced

    - the buffer between F_{OFL} and F_{ABC} is based on some prescribed measure of stock assessment uncertainty
    - and hence, F_{ABC} is prescribed (and stock assessment scientists are not required to make management decisions/value judgments).
- In the long term, plan to replace the tier structure with a system tailored to modern stock assessment results where multiple runs are available, with uncertainty estimated for each run.
- ▪ Carefully consider how a much better understanding of stock structure can be achieved (the first step is to obtain data on migration and distribution patterns associated with mating and parturition).
- ▪ Reanalyze the trawl survey indices, in particular for the Gulf of Alaska, with regard to the effect of untrawlable ground on the biomass indices.
- ▪ Review trawl survey design before the next Gulf of Alaska survey.
- ▪ Develop informative priors for the trawl *q*s. Changes in gear setup and operation (e.g., length of trawl, standardization of methods) should be considered for each time series. More than one *q* will probably be needed for each time series.
- ▪ Review natural mortality estimates.
- Allow for parameter uncertainty in the projection modeling.

BACKGROUND

A three person CIE Review Panel meet to review Alaskan rockfish harvest strategies and stock assessment methods from June 19-22, 2006 at Alaska Fisheries Science Center, Seattle, WA. The review was motivated by a concern, expressed by some stakeholders, that the harvest strategies for Alaskan rockfish were "too aggressive" given that they are "long lived" and "late maturing".

This report presents my personal view with regard to current Alaskan rockfish harvest strategies and stock assessment methods. This report should be read in conjunction with those of my fellow reviewers Dr Bob Mohn and Dr Cynthia Jones. Although there was no attempt to reach a consensus on any of the issues it was apparent that the Review Panel shared many common views with regard to the current harvest strategies and stock assessment methods.

REVIEW ACTIVITIES

Meeting Preparation

Prior to the meeting I read the main documents and consulted the background material made available on a website (Appendix 1).

Meeting Attendance

A brief narrative of the meeting is given below. There was no designated chair. This duty was shared by Drs Hollowed, Ianelli, and Rigby (on an ad hoc but effective basis).

19 June

The meeting was convened at 9.00 am and began with a round of introductions. Dr Hollowed discussed the purpose of the review and the "charge for the CIE". The main reason for the review was a concern (by the "public" and some NGOs) that the harvest strategy for rockfish was "too aggressive". This belief could perhaps be traced back to a previous review where the use of $F_{40\%}$ as an F_{MSY} proxy was criticized for rockfish (Goodman et al. 2002).

The powerpoint presentations began with an overview of rockfish management in Alaska (Dr Heifetz) which covered the general biology of rockfish, the fisheries, the Council's tier system and harvest strategies, and the 2002 review of groundfish harvest strategies (Goodman et al. 2002).

Dr Hanselman presented an overview of the available fishery independent data (primarily the RACE groundfish trawl surveys). There was discussion on the potential for vessel effects (given three vessels are used each year, and these vessels change from year to year). It was pointed out that much effort had been put into the standardization of gear setup and operation. Apparent "vessel effects" were actually "skipper and operation effects". However, the standardization was not in effect for the whole duration of each time series.

The observer program was also discussed. I was impressed by the high level of coverage, the real-time supply of data (to managers), the qualifications required of observers, the training program, and the ongoing quality control procedures. Some concern was raised about the potential lack of representativeness of the sampling by *trip* (given that skippers are free to choose, given a minimum level of coverage, which trips observers go on).

Dr Kimura described the ageing procedures and results for rockfish. Dr Kastelle described a validation method (using radiation levels from nuclear bomb tests) which had been used for Pacific ocean perch (POP). The ageing procedures and methods appear to be more than satisfactory. There was discussion on a group of 4-5 outliers in the validation study. The two possible explanations both involved "rogue" fish; they were either badly under-aged or had received very low doses of radiation.

A study of adaptive cluster sampling for POP was briefly presented and discussed (Hanselman et al. 2003). There were problems deciding on appropriate stopping rules. The author suggested using acoustic methods to do this. Given the aggregated nature of the POP schools I suggested that a combined acoustic and trawl survey was the better option.

The Review Panel asked many questions during the presentations. We were aware that slow progress was being made in terms of the original agenda but thought that it was best to fully explore the issues during the presentations. I suggested that we should plan on three days of presentations and a further day for the Review Panel to clarify issues (amongst ourselves) and ask questions of specific presenters if needed.

20 June

The meeting resumed at 9.00 am with presentations on age and growth. Natural mortality estimates were covered. In general they were derived by assuming that the oldest otolith found corresponded to the age attained by 5% of the virgin population. A need for a review of natural mortality estimates was acknowledged. Maturity ogives were briefly discussed as were possible maternal affects on larval viability (older fish having more viable larvae).

Stock structure was discussed after a presentation on genetic investigations. The absence of data on basic migration patterns and mating/parturition distribution was apparent. There appeared to be fine-scale genetic structure, but, as was pointed out by Dr Jones, this was probably due to the "sweep-stakes" effect (different alleles being selected each year purely by chance); no effort had been made, as yet, to compare across areas within cohort (i.e., comparing fish spawned in the same year to rule out the "sweep-stakes" effect).

The recent modeling workshop was briefly discussed before a presentation on the age-structured modeling approach used in tier-3 stock assessments. The methods were described as "quasi Bayesian" as priors were used in the likelihoods and MCMC runs were done. However, it was acknowledged that the priors were formed in an ad hoc manner and were sometimes "tightened" for pragmatic reasons (e.g, to produce sensible estimates of *M*). It was claimed that the mean values of the priors were based on the best *a priori* estimates. The prior mean values for the trawl survey *q*s had been set equal to 1. I pointed out that this was not the best *a priori* estimate as on consideration of the three main factors, areal availability, vertical availability, and vulnerability, one would often arrive at values quite different from 1. We went though the exercise for POP and arrived at a best guess in excess of 1 (which included an additional factor to account for POP's preference for trawlable ground).

The projection model was discussed including the "seven standard scenarios". The last two of these require simulation of fishing at the OFL – it was pointed out that these are needed for determination of stock status according to the current definition of MSST (despite fishing at the OFL being extremely unlikely).

The day finished with an interesting presentation on the use of submarine line-transect data to estimate POP trawl survey catchability. It was concluded that the stock assessment estimates of *q* greater than 1 were not only being driven by herding behaviour but also by POP's preference for trawlable (as opposed to untrawlable) ground (as seen in the submarine data).

21 June

The meeting resumed at 9.00 am with a presentation which I made on a problem with the current RACE trawl survey design. The previous evening I had realized that no allowance had been made in the calculation of the trawl survey indices for the fact that POP (and perhaps other species) had different average densities on trawlable and untrawlable ground. I presented equations showing that the trawl survey indices, as calculated, did not result in a biomass index (in that the expected value of each index divided by biomass was not a constant).

Dr Mohn suggested to me that Canadian trawl surveys may suffer from the same problem (having perhaps 10% of untrawlable ground). The problem is that no account is taken of the proportion of untrawlable ground within each stratum – average stratum densities are scaled-up using the full survey area. During subsequent discussions (during and after the meeting) it was generally agreed that this was a problem for any stratified random trawl survey where untrawlable ground had not been entirely blocked off (i.e., excluded from the survey area). At the time we considered that it did not apply to surveys with fixed stations (this is an error – see Appendix 2). There was no general agreement on whether the magnitude of the problem was of any consequence (i.e., perhaps it could be ignored).

The meeting continued with the agenda items. There was a comparison of the differences between stock assessment models used in the GOA and the BSAI assessments. Tier-5 assessments were discussed. The current method of setting maximum ABCs simply uses trawl survey averages assuming $q = 1$. An alternative method using Kalman filters had been explored – it looked useful, but still assumed $q = 1$, thus defeating any utility it may have had (Spencer and Ianelli 2005).

There was a review of papers relating to the use of $F_{40\%}$ as a proxy for F_{MSY}. The most recent research and that directed specifically at Alaskan rockfish species supported its use (papers cited by Goodman et al. 2002 were less recent and/or dealt with west coast rockfish).

Final topics covered were the evidence for localized depletion, the question of whether spatial management was needed on a finer scale than that already used, a simulation study looking at possible retention areas for rockfish larvae (looking for potential MPAs), and the consequences for reference points if older fish produced more viable larvae than younger fish. Dr Thompson gave the meeting a brief update on current research aimed at improving the tier system. He pointed out that the timing of implementing improvements was problematic because of ongoing/imminent changes to legislation and/or guidelines and/or over-arching studies.

22 June

The Review Panel convened at 9.00 am to identify, discuss, and clarify all relevant review issues. We covered the TOR a.-c. in our SOW (Appendix 3). The Panel appeared to be in agreement on most issues.

Dr Hanselman was also in the meeting room and presented some previously requested stock assessment results. In particular, he presented the current estimates of biomass for the six age-structured stock assessments as a proportion of B_{100} (the "virgin" biomass corresponding to mean recruitment under the current regime). These ranged from 0.39 to 0.58. He also presented the BSAI POP and GOA POP biomass trajectories, as a proportion of B_{40}, for the two different stock assessment models (the "GOA" model and the "BSAI" model). For BSAI there was little difference in the trajectories, but for GOA, one model estimated current biomass at approximately B_{40}, while the other model estimated it at 0.6 B_{40}.

We ended our formal discussions at noon (to attend a lunchtime seminar on GOA ecosystem modeling).

Post Meeting Activities

Prior to and during my return journey to New Zealand I considered several review issues. In particular, I further developed the equations relating to the trawl survey indices and considered how the current indices could be corrected and what data would be needed to do this. The Panel had further informal discussions which proved useful in further clarifying some issues.

SUMMARY OF FINDINGS

This section is organized according to the TOR provided in the SOW (Appendix 3). As required, each section is prefaced with an "executive summary" (being the bullet points).

a. A statement of the strengths and weaknesses of the input data and analytical approach used to assess stock condition and stock status and methods used for addressing uncertainty in the assessment.

The stock assessment methods used in the rockfish assessments are generally appropriate given the available data.

Strengths:

- The simple stock hypotheses are appropriate given the lack of detailed information.
- Good ageing data are available for estimating growth parameters.
- There is a wealth of trawl survey data.
- There is a strong observer program.
- Assumed population dynamics are consistent with current knowledge.
- Estimation methods are adequate.
- Modeling of uncertainty is adequate.

Weaknesses:

- Stock hypotheses are not well founded as little is known about stock structure.
- Estimation of M is often done using the oldest otolith ever read – better methods are available.
- The trawl surveys have undergone some changes in standardization of gear setup and operation.
- Trawl survey indices take no account of the proportion of untrawlable ground in each stratum (a particular problem for the GOA survey).
- Little is known about migration and distribution patterns associated with mating and parturition – so assumed population dynamics are necessarily simple.
- More sensitivity tests could be done and estimation methods could be refined.

Stock hypotheses

There appears to have been little research done on the movement and migrations of rockfish in the GOA and BSAI. Apparently, little is know about where mating and parturition occur. Because of this, life cycle information is general rather than stock specific. The stock hypotheses are not well formed – two stocks (GOA and BSAI) are usually assumed. This is a viable default position, but is far from ideal for the stocks which are assessed through age-structured stock assessment models. A basic assumption of these models is that the data relate to a single biological stock. Violation of this assumption can lead to misinterpretation of abundance data and unreliable stock assessments.

Fixed biological parameters

Growth parameters and length-weight relationships are estimated outside the models using standard methods. Natural mortality is usually estimated from maximum age assumptions using the oldest otolith ever aged. It appears that the standard assumption is that 5% of the virgin population attain this age. In general this will be a conservative assumption, but it depends on how many otoliths have been aged and how they were selected. Estimation of M is problematic, whether it is via a maximum age assumption, an early catch-curve, or is estimated within a stock assessment model. How ever it is done, the objective should be to attain a "best" estimate of M – not a conservative estimate of M.

Estimation of the maturity ogive is done outside the model. Histological data are available for some species and this would generally be preferable to macroscopic staging data. However, the key determinant in obtaining reliable estimates of maturity ogives is the representativeness of the fish sampling. Clearly, the sampling needs to be unbiased with regard to maturity (e.g., sampling only from mating fish or predominately mating fish due to a migration to a "mating ground" would introduce bias). However, this is very hard to guarantee, especially if little is known about stock structure and mating/parturition related migrations and distribution.

The distinction between "proportion mature at age" and "proportion *maturing* at age" is not particularly relevant for rockfish (since fishing is not especially targeted at mature fish). However, it should be noted that the proportion mature at age is not constant as it must depend on fishing exploitation rates (which are not constant). If there is a constant with regard to maturity it will be the proportion of immature fish at age which mature.

Recruitment variability can either be estimated in the stock assessment model or fixed. Current attempts to estimate it in the model have been technically incorrect; to do it properly involves hyper-distributions when it is used as the parameter of another prior (recruitment deviations). An alternative to fixing it (and then, if necessary, iterating to make sure that the standard deviation of the estimated recruitment deviations is consistent with the assumed value) is to use an uninformed prior on the recruitment deviations (see Appendix 2).

Fishery independent data

There are three sources of fishery independent data used in the current assessments: trawl surveys; longline surveys; and submarine line transect surveys. I have not reviewed the longline or submarine data in any depth. They were briefly covered in presentations and the methods appear appropriate. The same is true for the methods used to obtain at-age and at-length data from the trawl surveys.

The RACE trawl survey which uses a random stratified design is somewhat unusual in the selection of random grids within a stratum prior to the allocation of a single trawl station in each selected grid. This is not a particular problem, but it introduces an extra level of complexity which interacts with a problem for all trawl surveys where the untrawlable ground is not excluded from the survey area (see Appendix 2). Because of the potential for some species to preferentially inhabit either trawlable or untrawlable ground, and because of the relatively large proportion of untrawlable ground in some strata of the GOA survey, the GOA trawl survey data need to be analyzed further.

The purpose of random station allocation within a stratum is to ensure an unbiased estimate of the average density within the stratum so that scaling-up to the stratum area provides an unbiased estimate of stratum biomass. However, if a stratum has a proportion of untrawlable ground and the average density (for a particular species) differs between the trawlable and untrawlable ground then a stratum biomass estimate will be biased. If such a bias were consistent from year to year it would not be a problem if the data were used to provide *relative* abundance indices (it would be if they were used as *absolute* abundance indices). However, fish distribution is unlikely to stay constant from year to year and a shift in distribution combined with differing biases across strata could well introduce a trend in trawl survey indices which is not related to a change in biomass.

The relevant equations are developed in Appendix 2. Without a detailed analysis of the GOA trawl survey data it is not possible to determine whether recalculation of the trawl survey indices is necessary. For POP it is known that they have a preference for trawlable ground (from submarine data). I doubt that there are any species where it is *certain* that they do not have a preference for the trawl-ability of the ground. Ideally, data on the proportion of trawlable ground in each stratum should be compiled/collected and the trawl survey indices recalculated. Alternatively, it may be possible to establish that such a recalculation will not result in any substantive changes to the indices and is therefore not necessary. The problem needs to be addressed in the short-term.

Fishery dependent data

The observer sampling program appears well-founded. The sampling methods are appropriate and well documented. Considerable effort goes into training and quality control. Scientists are aware of possible non-representativeness in sampling at the trip level for vessels where skippers can choose which trips observers participate in.

CPUE indices are used in some BSAI assessments (but are down-weighted relative to other indices). With the wealth of available trawl survey data there may appear to be little need to consider abundance indices derived from a fishery. However, for species which have a preference for untrawlable ground, it may be that the trawl survey indices are unreliable. Certainly, trawl survey indices do ***not*** provide reliable estimates of *absolute* biomass, and so it is prudent to consider what other data may aid in the reliable estimation of biomass. CPUE indices should be considered for all of the age-structured stock assessments.

Assessment models

The population dynamics of the models are very simple which is consistent with the absence of detailed information on stock structure and migrations. When more detailed information is collected, it may be necessary to consider spatially explicit models. The use of two-sex models should be considered for any species where there are large growth differences between the sexes and/or there is preferential targeting of males or females, and/or there are sex imbalances in the survey data.

The plus-group at 25 years is at a relatively young age compared to the maximum age of some of the species. Provided that the mean weight in the plus-group is adjusted when calculating virgin/unfished biomass it should not present a problem. However, it would be worthwhile to do some runs with an older plus group to make sure it does not make a difference. When estimating M within the model, the age of the plus group should be increased (as should the plus-group age in the at-age data) – though this may not make a difference either.

Estimation methods

The current estimation methods were described as “quasi-Bayesian”. The estimates are derived by minimizing a negative log-likelihood modified by some prior distributions. The methods are acceptable but should be improved. The full Bayesian tools are available to the stock assessment authors and they should be endeavoring to use them. The likelihood components need to be formed with more care as do the prior distributions.

For example, the likelihood for abundance indices assumed to have lognormal errors should correspond to mean unbiased indices; currently it corresponds to median unbiased indices (see Appendix 2). This is a common assumption which is not generally justifiable (as many surveys are designed to be mean unbiased). The multinomial assumption for at-age and at-length data should be investigated – it is very unlikely to be appropriate for all data sets. The current method of calculating effective sample sizes is ad hoc. Bootstrap estimates of variance should be obtained and used to calculate effective sample sizes (e.g., Bull and Dunn 2002).

The formation of priors should be done with some care. For trawl survey qs, the first step is to derive an equation for q in terms of parameters about which beliefs can be expressed (either using expert opinion or based on data which is not otherwise fitted in the stock assessment model). Bounds and best guesses for each component – together with the equation – can be used to obtain bounds and best guesses for q. These can then be used to determine an informed prior for q, e.g., equate the best guess to the median and the bounds to 99% of a lognormal distribution, (Cordue, in prep. a.).

As already described, the recruitment variance can be dealt with in three ways: fixed (possibly with some iteration); estimated using hyper-distributions and used in the prior on recruitment deviations; or uncoupled from the prior on recruitment deviations and estimated as the standard deviation of the recruitment deviations (Appendix 2).

Estimation of M is difficult. However, if it is to be done in the model then the informed prior should be realistic in terms of what is know about M *a priori*. If the results using this approach provide unrealistic estimates of M, then simply fix M and do sensitivity runs with lower and higher values. The same approach should be adopted with other parameters where the runs with appropriate priors produce unrealistic estimates. One of the benefits of forming priors correctly is that the relationship of the posteriors (or point estimates) to the priors can be used as a diagnostic (if the beliefs about a parameter have not been formalized it is difficult to justify statements like "the estimated q is too low").

The initial conditions of the model can affect the stock assessment results (and so should be explored in sensitivity runs). There are three (main) options: equilibrium age structure at virgin biomass (B_0); equilibrium age structure with the biomass allowed to differ from B_0; and non-equilibrium age structure (i.e., estimate initial numbers at age). In the first option the full catch history would be specified; in the second option the full catch history can be specified (in which case an extra parameter is introduced: $B_{initial}$ = biomass just before fishing), or a constant annual historical catch can be given; the third option should probably only be used if the early catch history is unavailable.

The full biomass trajectory should always be considered in terms of $\%B_0$ or $\%B_{100}$ to check its plausibility. The GOA POP assessment has an initial biomass (before fishing) of only 30% B_{100} – this could well be implausible depending on the estimated recruitment variability.

The calculation of standardized residuals should be routine. As a starting point, the standard deviation of the standardized residuals (SDSR) of each time series should be approximately equal to 1. If they are not, then the statistical assumptions of the model are violated. It is (almost) standard practice in New Zealand to re-weight indices (by adjusting their c.v.s) until the SDSR of all time series are approximately equal to 1. These are the termed the "natural weights" of the indices. Indices may be re-weighted for the final runs (e.g., if a trend in a primary biomass time series is not well fitted) but there must be a compelling reason to depart from the "natural weights".

Modeling of uncertainty

The "art of stock assessment" is in capturing an appropriate level of uncertainty so that assessment results are realistic in terms of the "true" uncertainty but still useful for management purposes. My impression of the rockfish assessments is that an appropriate level of uncertainty is captured at the stock assessment level. However, more sensitivity runs could perhaps be done, certainly with regard to some of the biological parameters (e.g., alternative maturity ogives). Also, more effort should be made to explore alternative formulations and model structures and parameterizations – assessment authors should be looking for plausible and defensible alternative assumptions which may alter the perception of stock status (ideally this is done by using alternative methods, data, or structure, rather than low, medium, and high values of a single parameter). Ideally all runs presented to management should be taken through to the MCMC stage (and have properly formed priors).

b. A statement of the strengths and weaknesses of the simulation models, and the analytical approaches used in estimating future harvest levels.

The simulation or projection model is used to achieve standardized projection results for all stock assessments (seven standard scenarios are done for each assessment run).

Strengths:

- Standard set of scenarios available for each run in each stock assessment.
- Two of the scenarios provide output for determining stock status according to the current definition of MSST (“overfished” and “approaching overfished”).
- Recruitment variability is incorporated into the projections.

Weaknesses:

- Only recruitment variability is incorporated into the projections despite parameter uncertainty also being available for some assessments (i.e., MCMC runs).
- The population dynamics (e.g., annual cycle) of each stock assessment model must be implemented in the projection model to avoid a mis-match of assumptions (this is a future implementation issue – current dynamics are identical).

The current implementation of the projection model does not capture parameter uncertainty even if is available from the stock assessment. In some assessments this could be a major component of uncertainty which is currently ignored. That said, it remains to be seen whether incorporation of such uncertainty would alter the *mean* projection results (nevertheless, this area should be tidied up).

In future stock assessments it is likely that the population dynamics of the models will become more complex (e.g., spatially explicit). The current projection model software would then have to be modified to accommodate the new dynamics (i.e., offer them as an option). This involves the duplication of code since the stock assessment model already has the dynamics coded. An alternative to a separate projection program is to write a C++

projection class. It would incorporate all of the standard scenarios as member functions which would be called within each stock assessment program. The stock assessment program would supply its own dynamics (i.e., the address of the annual cycle function). This is only an efficiency issue. Since C++ is being used, it makes sense to use its full capability.

c. An analysis of current harvest strategies. Specifically do they provide appropriate levels of conservation for Alaskan rockfish fisheries? What harvest control rules might be more appropriate? Are additional spatial management measures required?

The current harvest strategies for Alaskan rockfish are not fully defined since several subjective choices are involved in setting TACs and, for structural reasons, the subsequent catches will often not reach the TAC. Nevertheless, there are identifiable strengths and weaknesses in the current management system:

Strengths:

- There are multiple and cumulative layers of conservatism in the tier system which will conserve rockfish stocks at high levels of biomass.
- The tier system is comprehensive and familiar.
- Tier 1 is supported by sound research.

Weaknesses:

- The multiple layers of conservatism may result in unnecessarily low yields for groundfish stocks in general.
- Tiers 2-6 are not supported by substantive research.
- Tiers 4-5 require a reliable point estimate of B – for rockfish, such estimates are only available in tier 3 – the assumption that *q* is known *a priori* for a trawl survey is untenable.
- Scientists are required to act as managers since their ABC recommendations limit the level at which the TAC can be set.

With regard to the specific questions in the TOR:

- Current harvest strategies favor conservation over use. If the fishing industry is happy with this circumstance then the strategies do provide an appropriate level of conservatism.
- At the next opportunity the tier structure should be simplified and based on the availability of reliable abundance indices.
- In the long term the tier structure should be tailored to modern stock assessment results (between run and within run uncertainty for multiple runs).
- Current spatial management appears appropriate. Finer scale management is ill-advised until much more is known about stock structure, migration patterns

associated with mating and parturition, and the location and stability of any important sources of production.

What is a "harvest strategy"?

The current harvest strategies for Alaskan rockfish are perhaps better defined than most harvest strategies used in managed fisheries. Nevertheless they are not fully defined. This is because the method of setting a TAC involves at least four subjective decisions by different groups of individuals (also, for various complex reasons, the subsequent catch is often well below the TAC). First, the assessment author must recommend an ABC (after choosing a run on which to base it). Then the Plan Team must recommend an ABC, which may differ from the assessment author's recommendation. Next, the SSC makes an ABC recommendation (another subjective choice), and finally the Council accepts one of the ABC recommendations and then sets a TAC at a level up to the ABC.

Without knowing how each of these decisions is made it is not possible to fully define the harvest strategy. Without a fully defined harvest strategy and an *explicit* statement of management objectives it is not possible to *accurately* assess whether a harvest strategy is appropriate or not. That said, it is possible to make some general statements about the tier structure and the general management regime and culture.

Multiple levels of conservatism

The "harvest strategies" for Alaskan rockfish provide an ultra-conservative fisheries management regime. There are some components of the tier structure which may not be conservative in their operation – but that is accidental. On the whole, the management regime provides multiple and *cumulative* layers of conservatism.

At the top level, there is an OFL defined by F_{MSY} or an F_{MSY} proxy. It is defensible, in my opinion, to use F_{MSY} based reference points as a target. However, in the U.S. these are used as limit reference points. This is the first level of conservatism. In the National Standard 1 guidelines Restrepo et al. (1998) recommend a default MSY control rule which allows for fluctuations of biomass around (including below) B_{MSY} before there is a reduction in F_{OFL}. However, in the Alaskan tier structure F_{OFL} is reduced at B_{MSY} or its proxy (in tier 3, it is actually reduced above the B_{MSY} proxy). This is the second level of conservatism.

The maximum ABC is always less than the OFL – this is the third level of conservatism. However, the maximum ABC need not be recommended. It appears that if assessment authors, the Plan Team, or the SSC are concerned that the maximum ABC might not be "sustainable" that they will recommend a lower value. Since the ABC limits the TAC, this is the fourth level of conservatism. Next is the TAC setting by the Council. They cannot set the TAC above the ABC, it can only go lower – the fifth level of conservatism. But what is actually caught? The Review Panel were told that (in-season) managers will try to manage the fishery to the TAC and will certainly try to avoid any catch in excess of the ABC. There will be no directed fisheries on a stock after its TAC has been exceeded. Fisheries on one stock can be closed if the bycatch on another stock would cause the TAC of the bycatch stock to be exceeded. This effect is only in one direction – a potential under-catch of a TAC – the sixth level of conservatism.

I will only briefly address the concern of Goodman et al. (2002) that, for rockfish, $F_{40\%}$ is not a good proxy for F_{MSY} and therefore not conservative. I did not find their arguments compelling. On the contrary, I found the arguments of the "response document" (Anon. 2002) more appealing. It does not matter that rockfish are "long lived" and "late maturing"; this is accounted for in the calculation of $F_{40\%}$. There does not appear to be any evidence that Alaskan rockfish stocks lack "resilience" – they appear to have had some of their best recruitment at relatively low stock sizes (see SAFE reports). In any case, whether $F_{40\%}$ is a good proxy for F_{MSY} is somewhat beside the point since the harvest strategy is such that levels as high as $F_{40\%}$ are very unlikely to be achieved.

Separation of science and management

In New Zealand there is a clear separation between the assessment of stock status and the determination of TACs. Scientists perform the stock assessment. Managers set the TAC. A stock assessment is aimed at providing an unbiased assessment of current stock status and the likely (biological) consequences of alternative TACs (obtained through projections at different catch levels). At no stage are scientists required to or allowed to recommend a TAC. Stock assessment choices (e.g., which runs to take forward) are made on "best scientific" judgment. The objective is to provide a realistic and unbiased assessment of the current state of knowledge. In the New Zealand setting, stock assessment choices should never be based on possible consequences for TACs. It is for managers (and politicians), not scientists, to make value judgments about the level of conservatism which should be exercised when managing a stock.

The Alaskan rockfish setting is very different from that in New Zealand. The recommendation of an ABC, be it at the maximum or not, limits the TAC which can be set. Scientists are required to make value judgments. They have the best understanding of the limitations of the assessment and the consequent uncertainties, but they do not perhaps have the best understanding of the political, social, and economic consequences of their choices.

Spatial management

Currently, the GOA and BSAI stocks are managed spatially in relatively large areas. TACs are management-area specific for some stocks. There are suggestions that smaller scale management is needed. In the absence of detailed information on stock structure and migration patterns related to mating and parturition any such attempts are extremely unlikely to have beneficial consequences.

The apparent fine scale genetic structure is not compelling. It could easily be due to the "sweepstakes effect" on individual cohorts. Given that rockfish larvae have a drift phase, followed by a “swimming” pelagic phase, it is hard to conceive of a mechanism for fine scale stock structure. Even if there were a large number of “distinct stocks” how important can any particular stock be? Yes, do protect important habitat using closed areas. Yes, do protect important and stable sources of productivity – but find them first.

Simplify and modernize

The current tier structure has six levels based on different levels of available information. However, apart from tier 1 (Thompson 1999), there is no substantive research supporting the use of the tiers or the definitions of F_{OFL} or F_{ABC} within each tier. I think that the system has been successful in conserving fish stocks. I am not convinced that it needs to be so conservative or so detailed. Certainly, there is a problem with some of the wording: “reliable point estimates of B”.

In tier 3 these “reliable estimates” come from an age-structured stock assessment. That is defensible. Tier 4 is problematic. There is a reliable estimate of B, but not of B_{40} – apparently because mean recruitment cannot be reliably estimated. In that case, I assume that the “reliable” estimate of B is coming from a trawl survey. The same must be true in tier 5. The problem is that a trawl survey does not provide reliable estimates of biomass, according to any defensible definition of “reliable”.

I understand that there is a long history, in the U.S. and in Alaska, of using trawl survey estimates to provide absolute biomass estimates. That does not make it defensible. It will require a difficult cultural change, but, with strong leadership, I am sure that such a change can be made.

At the next opportunity to update the tier system it should be simplified. Tier 1 is fine, but other tiers (perhaps just two more) should be based on whether there are reliable abundance indices available or not. Also, the buffer between OFL and ABC should to be based on the uncertainty in the assessment – the recent work of Dr Thompson should be useful here. The ABC should be prescriptive and not left to a value judgment on the behalf of scientists (at least not on a case by case basis – the initial formulation may require a value judgment). In the long term, the tier system should be replaced by a system which is tailored to modern stock assessments: between-run and within-run uncertainty (i.e., multiple MCMC runs) with a suite of performance indicators calculated for each run.

RECOMMENDATIONS

My recommendations are organized according to the three TOR (with abbreviated headings):

a. Input data and stock assessment methods

- Carefully consider how a much better understanding of stock structure can be achieved (the first step is to obtain data on migration and distribution patterns associated with mating and parturition).
- The trawl survey indices, in particular for the GOA, should be analyzed with regard to the effect of untrawlable ground on the biomass indices (at the same time, any potential effects from different vertical availability or vulnerability by stratum could also be considered – see Appendix 2).
- Trawl survey design should be reviewed before the next GOA survey.
- Informative priors should be developed for trawl *q*s. Changes in gear setup and operation (e.g., length of trawl, standardization of methods) should be considered for each time series. More than one *q* will probably be needed for each time series. Common factors between the *q*s within a time series can be accounted for by putting a prior on the ratio of pairs of *q*s (see Cordue in prep.).
- The use of catch and effort data to develop abundance indices should be considered for more species (descriptive analyses of catch and effort data should be done routinely; on an annual basis for major stocks).
- Natural mortality estimates should be reviewed. Informative priors could be developed at the same time.
- Likelihood equations should be briefly reviewed. In particular, use one of the three suggested options for recruitment variability, and use a likelihood corresponding to mean unbiased abundance indices (see Appendix 2).
- Implement alternative initial conditions for model biomass and age structure.
- Routinely calculate standardized residuals and “natural weights” for time series.
- Always examine biomass trajectories as $\%B_0$ or $\%B_{100}$, checking for plausibility.
- Do more sensitivity runs, looking for the assumptions which really do make a difference (e.g., structural, statistical, assumed fixed parameters, priors used).

b. Projection model

- Include parameter uncertainty in the projections.
- Plan for the future by implementing a C++ projection class (the separate projection software will still be needed for multi-species projections, but that is a separate application from production-line stock assessment).

c. Harvest strategies

- Consider whether so many cumulative layers of conservatism are really needed. Are *all* stakeholders happy with this?

- At the next available opportunity, update the tier structure so that:
    - o a trawl survey index need not be considered to provide "a reliable point estimate of B"
    - o the number of tiers is reduced
    - o the buffer between F_{OFL} and F_{ABC} is based on some a prescribed measure of stock assessment uncertainty
    - o and hence, F_{ABC} is prescribed (and stock assessment scientists are not required to make management decisions/value judgments).
- In the long term, plan to replace the tier structure with a system tailored to modern stock assessment results where multiple runs are available, with uncertainty presented for each run.

REFERENCES

(see Appendix 1 for further references)

Bull, B. and Dunn, A. 2002. Catch-at-age user manual. NIWA Internal Report 114. 23 p.

Cordue, P.L. (in prep.) a. Prior distributions for trawl and acoustic survey proportionality constants used in the 2006 orange roughy stock assessments. Draft *New Zealand Fisheries Assessment Report*. 22 p.

Cordue, P.L. (in prep.) b. A note on potential errors in the calculation of trawl survey indices. Short communication to be submitted to *ICES Journal of Marine Science*.

APPENDIX 1: MATERIAL PROVIDED

Safe Reports

A'mar, T. et al. The Plan Team for the Pacific Groundfish Fisheries of the Gulf of Alaska. 2005. Appendix B. Stock Assessment and Fisheries Evaluation Report for the Groundfish Resources for the Gulf of Alaska. NPFMC. GOA Introduction 40 p.

Aydin, K. et al. The Plan Team for the Pacific Groundfish Fisheries of the Bering Sea and Aleutian Islands. 2005. Appendix A. Stock Assessment and Fisheries Evaluation Report for the Groundfish Resources for the Bering Sea/ Aleutian Islands Region. NPFMC. BSAI Introduction 30 p.

Clausen, D.M. 2005. Chapter 11 Shortraker and Other Slope Rockfish. NPFMC 42 p.

Gaichais. S. and J. Ianelli. 2005. Chapter 14. Gulf of Alaska Thornyheads. NPFMC 36 p.

Hanselman, D., Heifetz, J., Fujioka, J.T., Ianelli, J.N. 2005. Chapter 8. Gulf of Alaska Pacific ocean perch. 54 p.

Kalei Shotwell, S., Hanselman, D.H., and Clausen, D.M. 2005. Chapter 10. Rougheye Rockfish. GOA Rougheye Rockfish. 44 p.

Lunsford, C.R. Kalei Shotwell, S., Hanselman, D.H., Clausen, D.M., and Courtney, D.L. 2005. Chapter 12. Pelagic Shelf Rockfish. GOA Pelagic Shelf Rockfish. 54 p.

North Pacific Fishery Management Council (The Plan Team). 2005. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources for the Bering Sea Region / Aleutian Islands. 30 p.

O'Connell, V., Brynlinsky, C., and Carlile, D. 2005. Chapter 13. Assessment of the Demersal Shelf Rockfish Stock for 2006 in the Southeast Outside District for the Gulf of Alaska. ADFG Executive Summary. 44 p.

Reuter, R.F. and P.D. Spencer. 2005. Chapter 14. 2005 BSAI Other Rockfish (Executive Summary). 4 p.

Spencer, P.D. Ianelli, J.N. and Lee, Y-W. 2005.Chapter 12. Northern Rockfish. NPFMC Bering Sea and Aleutian Islands SAFE. 42p.

Spencer, P.D. Ianelli, J.N. and Zenger, H. 2004. Chapter 11 Pacific ocean perch. NPFMC Bering Sea and Aleutian Islands SAFE. 72p.

Spencer, P.D. and R.F. Reuter. 2004. Chapter 13. Shortraker and Rougheye Rockfish. NPFMC Bering Sea and Aleutian Island SAFE. 30 p.

Workshop Reports

Rockfish Modeling Workshop: May 23rd – May 25th 2006. 7 p.
Rockfish Modeling Workshop Agenda May 23rd – May 25th. 2 p.
.

General Supplemental Material

<u>NMFS AFSC and NPFMC Reports and other Documents</u>

Anon. 2003. Discussion paper of 2003 management of BSAI rockfish species. AFSC. 10 p.

Anon. 2005. Developments on the population projection model used for Alaskan groundfish. Alaska Fisheries Science Center. 34 p.

Courtney, D.L., Inaelli, J.N., Hanselman, D., and Heifetz. No Date. Selected Results from Stock Assessments of Rockfish (*Sebastes* ssp) Populations in the North Pacific with AD Modelbuilder Software. AFSC report (no number), 33p.

DiCosimo, J., Spencer, P., Hanselman, D., Reuter, R., Stockhausen, B., and others. 2005. Bering Sea/Aleutian Islands and Gulf of Alaska Rockfishes, their fisheries and management: Focus on Pacific ocean perch, rougheye and dusky rockfishes. AFSC document, 72 p

Dorn, M.W. 2002.Advice on West Coast Rockfish Harvest Rates from Bayesian Meta-analysis of Stock Recruit Relationships. *N. Amer. J. Fish Manag. 22*: 280-300.

Funk.F, Gunderson, D., Mayo, R.,Richards, L.,and Roger. J. 1997. Rockfish Stock Assessment Review. AFSC Report .9p.

Gharrett, A., Matala, A.P., Peterson, E.L., Gray, A.K., Li, Z., and Heifetz, J. No date. Chapter III. Distribution and population structure of sibling species of rougheye rockfish based on microsatellite and mitochondrial variation. No publication source listed. 33 p..

Goodman, D., Mangel, M., Parkes, G., Quinn, T., Restrepo, V., Smith, T., Stokes, K. (with help from G. Thompson). 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fisheries Management Plans. Draft Report Prepared for the NPFMC. 138 p.

Hanselman, D. Spencer, P., Shotwell, K., and Reuter, R. In. Press. Localized depletion of three rockfish species. No journal indicated. 24 p.

Hanselman, D.H., and Quinn II, T.J. Performance of modern age-structured stock assessments with large survey measurement errors. AFSC draft document.

Ianelli, J., and Spencer, P. 2006. An evaluation of using commercial fisheries data to estimate northern rockfish biomass in the Eastern Bering Sea. AFSC Draft document 6/7/06. 11 p.

NPFMC (Oliver, C). 2006 North Pacific Fishery Management Council Research Priorities. 7 p plus letter.

Restrepo, V. R., Thompson, G.G., Mace, P.M., Gabriel, W,L., Low, L.L., MacCall, A.D., Methot, R.D., Powers, J.E., Taylor, B.L., Wade, P.R., and Witzig, J.F. 1998. Technical Guidance on the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-##.

Spencer, P. and Dorn. M. No Date. Evaluation of Bering Sea/Aleutian Islands Pacific ocean perch management parameters using Bayesian stock-recruit analysis. Draft Document. AFSC.

Spencer, P., Hanselman, D., and Dorn, M. In Press. The effect of maternal age of spawning on estimation of F_{msy} for Pacific ocean perch. No journal listed. 30 p.

Smoker, A. and Furuness, M. 2005. Alaska region groundfish harvest specification and inseason management overview. 4 p.

Thompson, G.G. 1998. Environmental assessment and regulatory impact review for Amendment 56 to the FMP for the groundfish fishery of the Bering Sea and

Aleutian Islands area and Amendment 56 to the FMP for the groundfish fishery of the GOA. Public review draft. 27 p.

Thompson, G.G. 1999. Optimizing harvest control rules in the presence of natural variability and parameter uncertainty. *In*: *NOAA Tech. Memo. NMFS-F/SPO-40*:124-145.

Thompson, G.G. 2004. Report on the first Management Strategy Evaluation Working Group meeting. 4 p.

Recent relevant publications

Berkely, S. A., Chapman, C. and Sogard, S.M. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. *Ecology 85*: 1258-1264.

Bobko, S.J. and Berkely, S.A. 2004. Maturity, ovarian cycle, fecundity, and age-specific partuition of black rockfish (Sebastes melanops). *Fish. Bull. 102*: 418-429.

Clausen, D.M. and Heifetz, J. Date? The Northern rockfish, Sebastes polyspinis, in Alaska: commercial fishery, distribution, and biology. *Mar. Fish. Rev. 64*: 1-28.

Gharrett, A.J. et al. 2006. Do genetically distinct rougheye rockfish sibling species differ phenotypically? *Transactions of the American Fisheries Society 135*: 792-800.

Hanselman, D. H., Quinn II, T.J., Lunsford, C, Heifetz, J. and Clausen, D. 2003. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. 2003. *Fish. Bull. 101*: 501-513.

Hanselman, D.H., and Quinn II, T.J. 2004. Chapter 14: Sampling rockfish populations:Adaptive sampling and hydroacoustics. Pp 271-296. Rest of citation missing.

Hawkins, S.L., Heifetz, J., Kondzela, C.M., Pohl, J.E., Wilmot, R.L., Katugin, O.N, and Tuponogov, V.N. 2005. Genetic variation of rougheye rockfish (*Sebastes aleutianus*) and shortraker rockfish (*S. borealis*) inferred from allozymes. *Fish. Bull. 103*: 524-535.

Ianelli, J.N. 2002. Simulation analysis testing the robustness of productivity determinations from West Coast Pacific ocean perch stock assessment data. *N. Amer. J. Fish. Manag. 22*: 301- 310.

Kendall, Jr., A.W. 2000. An Historical Review of *Sebastes* Taxonomy and Systematics. *Marine Fish. Rev. 62*:1-23.

Kimura, D.K., Ander, D.M. 2005. Quality control of age data at the Alska Fisheries Science Center. *Australian Journal of Marine and Freshwater Research 56*: 783-789.

Krieger, K., Heifetz, J., and Ito, D. 2001. Rockfish assessed acoustically and compared to bottom-trawl catch rates. *Alaska Fishery Research Bulletin 8*: 71-77.

Matata, A.P., Gray, A.K., Heifetz, J., and Gharrett, A. J. 2004. Population structure of Alaskan shortraker rockfish, *Sebastes borealis*, inferred from microsatellite variation. *Environ. Bio. Fishes 69*: 201-210.

Miller, J.A., and Shanks, A.L. 2004. Evidence for limited larval dispersal in black rockfish (*Sebastes melanops*): implications for population structure and marine-reserved design. *Can. J. Fish. Aquat. Sci. 61*: 1723-1735.

Orr, J.W. and Blackburn, J.E. 2004. The dusty rockfishes (Teleostei: Scorpaeniformes) of the North Pacific Ocean: resurrection of Sebastes variabilis (Pallas, 1814) and a redescription of Sebastes ciliatus (Tilesius, 1813). *Fish. Bull. 102*: 328-348.

Spencer, P.D., and Ianelli, J.N. 2005. Application of a Kalman filter method to a multi-species complex. Pp 613-634. In Fisheries Assessment and Management in Data-limited Situations. Alaska Sea Grant Program. AK-SG-05-02.

Other regions' rockfish assessments

Hamel, O.S. 2005. Status and future prospects for the Pacific ocean perch resource in waters off Washington and Oregon as assessed in 2005. NWFSC. 76 p.

Schnute, J.T., Haigh, R., Krishka, B.A., and Starr, P. 2001. Pacific ocean perch assessment for the west coast of Canada in 2001. Canadian Science Advisory Secretariat. Research Doc. 2001/138.96 p.

Björnsson, H. and Sigurdsson, T. 2003. Assessment of Golden Redfish (*Sebastes mentella, L*) in Icelantic waters. Scient. Mar. 67 (suppl 1): 301-314.

Extracts (date and source generally unknown)

Development of Alaska's fisheries management programme. 2 p.
Precautionary approach. 1 p.
Conservative catch limits. 1 p.
Bycatch and discards. 4 p.
Effective monitoring and enforcement. 1 p.
Alternatives 1-5 for setting TACs. 1 p.
GOA trawl survey results, east, west and central, 1984-2005. 1 p.
Proposed rule to Amendment 68. Federal Register 71: 33040-33043.
An NGO's recommendations for the EIS. 2 p.
GOA dark rockfish. NPFMC, April 2006. 1 p.
Bearing Sea habitat conservation, NPFMC, June 2006. 1 p.
Estimation procedures for bycatch and discards in the Alaska region. 4p.
A decision theoretic approach to ecosystem-based fishery management. Abstract.1 p.

Presentations made during the review

The authors (if identified) and title are from the first slide. The name of the PowerPoint file follows in brackets. Sometimes the file name at the FTP site will not agree with the PowerPoint name, but these have not been included to reduce confusion.

Anon. Age and growth information for Alaska rockfish. (age and growth.ppt)
Anon. Conservation of harvest policy. (conservation of harvest policy.ppt}
Anon. General age-structured modeling methodology. (Tier 3 methods.ppt)
Anon. Genetics and stock delineations. (Genetics and stock structure.ppt)
Anon. How our models differ (Tier 3 age-structured models). (ModelContrasts.ppt)
Anon. Rockfish modeling workshop. (Natural mortality-maturity.ppt)

Anon. Spatial management. (Spatial-management.ppt)
Anon. Survey overview. (Survey overview2.ppt)
Anon. Tier 5. (Tier 5.ppt)
Anon. Why isn't the buffer between F_{OFL} and $maxF_{ABC}$ explicitly tied to uncertainty. (Uncertainty.ppt)
Hanselman,D. Stock assessment workshop review. (WORKSHOP_REVIEW.ppt)
Hanselman, D., K. Shotwell, P. Spencer & R. Reuter Short-term localized depletion and longer-term localized population changes for Alaskan rockfish. (Depletion.ppt)
Heifetz, J. Overview of rockfish biology and management in Alaska. (HISTORY_CIE_.ppt)
Kastelle, C., D. Kimura. B. Goetz. Age validation of Pacific ocean perch (*Sebasetes alutus)* using bomb produced radiocarbon. (POP C!$ CIE.ppt)
Kimura, D. Rockfish age data at the Alaska Fisheries Science Center. (Age_Determination.ppt)
Spencer, P., D. Hanselman and M. Dorn. The effect of maternal age of spawning on estimation of Fmsy for Alaskan Pacific ocean perch. (maternal effect.ppt)
Spencer,P. & J. Ianelli. Application of the Kalman filter to Bering Sea-Aleutian Island rockfish. (Kalman filter.ppt)

APPENDIX 2: TECHNICAL DETAILS

This appendix contains three sections. The first section deals with potential problems for stratified random trawl surveys. The issue of untrawlable ground is particularly relevant to the GOA survey. More details, on the general problems, will appear in Cordue (in prep. b.). The remaining two sections are very similar to appendices in some of my other CIE reports. They contain technical details on lognormal likelihood components and the treatment of recruitment variability.

A. RANDOM STRATIFIED TRAWL SURVEY INDICES

The ideal random stratified trawl survey design has all untrawlable ground blocked-off from the survey strata. In practice, this is not usually possible (as not all untrawlable ground is identified *a priori*) and a survey design will include contingencies if a random station is in an untrawlable location. If most strata have little untrawlable ground this should not present a problem. However, when there are some strata with a large proportion of untrawlable ground and/or many strata with some untrawlable ground there is a potential problem: the trawl survey proportionality constant, q, may not be constant.

We shall first look at the equations for the ideal random stratified trawl survey and then we will consider the equations for the RACE trawl surveys which sample random grids within strata.

Consider a stratified random trawl survey with all untrawlable ground blocked-off from the survey strata.

Let,

C_{ij} = catch rate of the jth tow in the ith stratum
a_i = area of ith stratum
n_i = number of random trawls in ith stratum
b_i = biomass in ith stratum
d_i = average density in ith stratum

The biomass index is:

$$X = \sum_i a_i \overline{C}_i$$

where

$$\overline{C}_i = \frac{1}{n_i} \sum_j C_{ij}$$

Let,

u_a = areal availability (the proportion of the total biomass which is in the survey area)
u_v = vertical availability (the average proportion of the biomass in the water column, which is in front of the net after vertical herding)
v = vulnerability (the average proportion of the biomass in front of the net, before horizontal herding, which is actually caught)

Assume, for the moment, that u_v and v are the same for all strata. Then, within strata, the C_{ij} are independent and identically distributed:

$$\mathrm{E}(\bar{C}_i) = \mathrm{E}(C_{ij}) = u_v v d_i$$

and

$$\mathrm{E}(X) = \sum_i a_i u_v v \frac{b_i}{a_i} = u_v v \sum_i b_i$$

Let,

B = total biomass
q = trawl survey proportionality constant

Then,

$$q = \frac{\mathrm{E}(X)}{B} = u_v v \frac{\sum_i b_i}{B} = u_v u_a v$$

which is the usual expression assumed for q.

Now consider the RACE trawl survey design and initially just consider a single stratum. It is divided up into equal sized grids. Some grids have no trawlable ground, and if they are initially selected a replacement grid will be chosen. For selected grids a single trawl station is allocated within the grid. Label the grids:

trawlable: $1, \ldots, g$
untrawlable: $g+1, \ldots, m$.

Let,

a = area of each grid
b_j = biomass in grid j
t_j = proportion of trawlable ground in grid j
d_j = average density on trawlable ground in grid j
e_j = average density on untrawlable ground in grid j

then

$$b_j = a\left[t_j d_j + (1-t_j)e_j\right]$$

Assume that n trawlable grids are chosen at random with replacement (a convenient and reasonable approximation – assuming there is a large number of grids in the stratum).

Let,

C_{j_k} = catch rate in grid j_k $\quad k = 1, \ldots, n$

Then the biomass estimate for the stratum is

$$Y = ma\overline{C}$$

To obtain the expected value of each C_{j_k} we use conditional expectation on the random grid selection:

$$\mathrm{E}(C_{j_k}) = \mathrm{E}[E(C_{j_k} \mid j_k)] = \mathrm{E}\left[u_v v d_{j_k}\right]$$

Since there is an equal probability of selecting any of the trawlable grids, it follows that

$$\mathrm{E}(C_{j_k}) = \frac{1}{g}\sum_{j=1}^{g} u_v v d_j = u_v v\overline{d}$$

and hence,

$$\mathrm{E}(Y) = m a u_v v\overline{d}$$

Now, the biomass in the stratum is:

$$B = \sum_{j=1}^{m} b_j = \sum_{j=1}^{g} a\left[t_j d_j + (1-t_j)e_j\right] + \sum_{j=g+1}^{m} b_j$$

If we add and subtract d_j inside the square brackets, we get:

$$B = \sum_{j=1}^{m} b_j = ag\overline{d} + a\sum_{j=1}^{g}(1-t_j)(e_j - d_j) + \sum_{j=g+1}^{m} b_j$$

Let

$$f_j = (1-t_j)(d_j - e_j)$$

and define p as the proportion of stratum biomass on trawlable ground, so that,

$$\sum_{j=g+1}^{m} b_j = (1-p)B$$

Then we have,

$$\bar{d} = \bar{f} + \frac{pB}{ag}$$

and hence,

$$\mathrm{E}(Y) = \frac{m}{g} u_v vpB + mau_v v\bar{f}$$

If the average densities on trawlable and untrawlable ground are equal then the second term in the above equation is zero. However, if they are not, then the biomass estimate is not proportional to the stratum biomass.

Let us extend the above equation to the full survey area. Assume now that there are *n* strata (with n_i trawls in each stratum) and let Y_i be the biomass estimate for the *i*th stratum. Let the index for a given year be *X*:

$$X = \sum_{i=1}^{n} Y_i$$

Then,

$$\mathrm{E}(X) = \sum_i \mathrm{E}(Y_i) = \sum_i \left(\frac{m_i}{g_i} u_i v_i p_i B_i + m_i u_i v_i a \bar{f}_i \right)$$

where the previous notation has been generalized for the *i*th stratum (and the subscript *v* has been dropped from u_v). For generality we are no longer assuming that vertical availability and vulnerability are constant across strata. We are working towards a general expression for the annual trawl survey proportionality “constant”.

Let,

$$r_i = \frac{p_i}{\left(\frac{g_i}{m_i} \right)}$$

and

$$s_i = r_i u_i v_i = \frac{m_i}{g_i} p_i u_i v_i$$

The reason for distinguishing r_i is because it is the proportional of biomass on the trawlable grids divided by the proportion of trawlable grids. We then have,

$$\mathrm{E}(X) = \bar{s}\sum_i B_i + \sum_i \left(s_i - \bar{s}\right)B_i + \sum_i a_i u_i v_i \bar{f}_i$$

where $a_i = am_i$ is the area of the ith stratum.

Let B denote the total stock biomass and let,

$$B_i = h_i B$$
$$\sum_i B_i = wB$$

then

$$\mathrm{E}(X) = \left[\bar{s}w + \sum_i \left(s_i - \bar{s}\right)h_i\right]B + \sum_i a_i u_i v_i \bar{f}_i$$

and

$$q = \frac{\mathrm{E}(X)}{B} = \bar{s}w + \sum_i \left(s_i - \bar{s}\right)h_i + \frac{\sum_i a_i u_i v_i \bar{f}_i}{B}$$

As a quick check on the equation, notice that if vertical availability and vulnerability are constant across strata and the fish have the same average density on trawlable and untrawlable ground, then the last two terms are zero, and we have the usual expression for q (as the product of areal availability (w), vertical availability, and vulnerability.

Finally, let us generalize the above equation to a multi-year time series indexed by y:

$$q_y = \frac{\mathrm{E}(X_y)}{B_y} = \bar{s}_y w_y + \sum_i \left(s_{yi} - \bar{s}_y\right)h_{yi} + \frac{\sum_i a_i u_{yi} v_{yi} \bar{f}_{yi}}{B_y}$$

The only parameters in the above equation which cannot vary annually are the stratum areas (assuming the same survey area and stratification).

The last term in the equation is present because of the grid design and will be non-zero for any species which has a preference for trawlable or untrawlable ground. Unless there is a major distributional change in biomass which interacts with the strata which contain grids with a high proportion of untrawlable ground, there is unlikely to be much annual variation in the term. Nevertheless, its variability and magnitude needs to be considered on a case-by-case basis for each survey (and each species). In particular, is its magnitude significant compared to the other terms and could there be a trend in this term, as opposed to just some extra noise.

The second term is non-zero when there is stratum variation in the vertical availability or vulnerability, or the ratio of the proportion of biomass on trawlable grids to the proportion of trawlable grids. This term will be present whether a grid design is used or not (if not, the ratio will be the proportion of biomass on trawlable ground to the proportion of trawlable ground). The potential magnitude and variability of this term also needs to be investigated on a case-by-case basis.

To recalculate existing biomass indices so that they exclude non-random error structure requires that average stratum catch rates are calculated from weighted averages of individual station catch rates. The weights are intuitively obvious and can easily be derived (simply hypothesis them and check that they give unbiased biomass estimates – see Cordue in prep. b.) It should be feasible to collect information on the proportion of untrawlable ground in each stratum and this will probably be adequate to correct the trawl survey indices (to allow for any preferences that species may have for trawlable or untrawlable ground).

B. LIKELIHOOD AND LOGNORMAL ERRORS

For biomass indices it is usually appropriate to assume in a stock assessment that the indices are "mean unbiased" rather than "median unbiased". When a lognormal error structure is assumed the likelihood should be derived with some care.

Consider a biomass index X_i:

$$X_i = qB_i\varepsilon_i$$

where B_i is the biomass (in year i), q is the proportionality constant, and ε_i is the error (in year i). Suppose that the errors are lognormal: $\log(\varepsilon_i) \sim \mathrm{N}(\mu_i\ ,\ \sigma_i^2)$. It then follows that,

$$\log(X_i) \sim N(\log(qB_i) + \mu_i, \sigma_i^2)$$

and the negative log-likelihood (ignoring constants) is

$$\frac{1}{2}\sum_i \left[\log(\sigma_i^2) + \frac{(\log(X_i) - \log(qB_i) - \mu_i)^2}{\sigma_i^2} \right]$$

If the variances are assumed known, then the first term in the square brackets in the above equation can be ignored. It is not uncommon to assume, in every year, that $\mu_i = 0$. However, under this assumption it follows that:

$$\mathrm{E}(X_i) = qB_i\mathrm{E}(\varepsilon_i) = qB_i e^{\frac{\sigma_i^2}{2}} = qB_i\sqrt{cv_i^2 + 1}$$

where cv_i is the specified c.v. in year i.

When the c.v.s are relatively small (< 0.35), there is a very small bias in the indices. However, by definition, they are no longer indices in the usual sense. The assumption is consistent with "median" unbiased indices, in that there is a 50% probability that an index will be above or below the true value (qB_i). This would be acceptable if the random variables in question could be expected to have this property. However, this would not generally be true and it would be preferable to use "mean" unbiased indices:

$$\mathrm{E}(X_i) = qB_i\mathrm{E}(\varepsilon_i) = qB_i$$

This requires $\log(\varepsilon_i) \sim N(-0.5\sigma_i^2, \sigma_i^2)$ and for known variance the negative log-likelihood (ignoring constants) is:

$$\frac{1}{2}\sum_i \left[\frac{(\log(X_i) - \log(qB_i) + \frac{\sigma_i^2}{2})^2}{\sigma_i^2} \right]$$

When the likelihood is expressed as a function of q and differentiated one can derive a formula for the q which minimizes the negative log-likelihood for given biomass:

$$\frac{dL(q)}{dq} = \frac{-1}{q}\sum_i \left[\frac{\log(X_i) - \log(qB_i) + \frac{\sigma_i^2}{2}}{\sigma_i^2} \right] = 0$$

Which implies:

$$\log(q) = \frac{\frac{n}{2} + \sum_i \frac{\log\left(\frac{X_i}{B_i}\right)}{\sigma_i^2}}{\sum_i \frac{1}{\sigma_i^2}}$$

This formula can be used to speed up the minimization if an uninformed prior is specified for q (of course, when an informed prior is used, q must remain as one of the estimated parameters).

C. ALTERNATIVE PRIOR FOR YEAR CLASS STRENGTH

It is common in stock assessment models for the recruitment variability σ_R (the s.d. of the log-deviations) to be used as the s.d. of a lognormal prior on the recruitment deviations (or year class strengths (YCS) if recruitments are parameterized as multipliers of expected recruitment – or average recruitment in the absence of a stock-recruit relationship).

Such a formulation requires that σ_R is specified despite there generally being information in the data with regard to recruitment variation. It could be useful to allow alternative priors to be specified for the recruitment deviations, or the YCS, and to estimate σ_R as a derived parameter (i.e., being the s.d. of the estimated YCS).

Since each YCS is a multiplier, the natural uninformed prior for a YCS is a uniform on log(YCS) with E(YCS) = 1. A method for specifying this type of prior is given below.

Let $Y = \log(X) \sim \mathrm{U}(a, b) : \mathrm{E}(X) = 1$. The specified expectation requires:

$$\mathrm{E}(X) = \frac{e^b - e^a}{b - a} = 1$$

The problem is to find bounds on YCS, e^a, e^b which are sensible and also satisfy the above equation. The bounds should be wide because we are looking for an uninformed prior. There is no analytical solution to the above equation for a given upper (or lower) bound. However, for given b, e^b the following equation quickly converges to a solution (with starting value $a_0 = 0$):

$$a_{n+1} = e^{a_n} - e^b + b$$

A sample table of solutions is given below:

a	b	e^a	e^b
-7.70	2.30	4.54×10^{-4}	10
-4.19	1.79	1.51×10^{-2}	6
-3.36	1.61	3.49×10^{-2}	5

The pdf for X is:

$$f_X(x) = \frac{1}{(b-a)x} \quad \text{for} \quad e^a \le x \le e^b$$

If $X_1, \ldots, X_n$ (being n YCS) are given identical independent priors as above, then the negative log likelihood (ignoring constants) is:

$$\sum_i \log(X_i)$$

Because of this, MPD (mode of posterior distribution) estimates will tend to e^a if there is little or no information for an estimated YCS in the data. However, for such cases in MCMC runs the posterior will tend to the prior which sensibly has a mean of 1. If these priors were to be used for MPD estimates then it might be sensible to impose a penalty encouraging the estimated YCS to average to 1.

APPENDIX 3: STATEMENT OF WORK

Consulting Agreement between the University of Miami and Patrick Cordue

General

The Alaska Fisheries Science Center (AFSC) requests review of rockfish (*Sebastes* and *Sebastolobus*) stock assessments and the current harvest strategy used to set Acceptable Biological Catch (ABC) and the Overfishing Level (OFL). The North Pacific Fishery Management Council (NPFMC) has received numerous requests for review and comment on the harvest strategy currently used for management of Alaskan rockfish. In response to these inquiries, NOAA Fisheries solicits a thorough review of Alaskan rockfish assessments and their associated harvest strategies.

There are currently 12 rockfish species managed under the Bering Sea and Aleutian Islands Fisheries Management Plan and 32 rockfish species managed under the Gulf of Alaska Fisheries Management Plan. Of these, three species are targeted by commercial fisheries: Pacific ocean perch, northern rockfish, and dusky rockfish. Although some other species are commercially important, the remaining rockfish species groups are captured incidentally during target fisheries for other groundfish and they are managed as bycatch only. Single-species assessments of rockfish indicate that stock status is "not overfished" and "not overfishing." While these stocks appear to be above threshold biological reference points, some stakeholders contend that the harvest policy is too aggressive and that further conservation is warranted.

CIE Panel

A panel of three experts shall be provided for this review. Each reviewer shall spend a maximum of 16 days working on their review, so that the maximum number of reviewer days for the project shall not exceed 48. The panel shall include representatives with broad range of expertise. Important areas of expertise should include: analytical stock assessment, including population dynamics, age/length based stock assessment models, Bayesian analysis/uncertainty, rebuilding analyses, estimation of biological reference points, harvest strategy modeling, and fisheries biology.

Specific Activities and Products

1. Prior to the review, AFSC will provide copies to reviewers of the stock assessment documents, groundfish overfishing definitions, a description of the simulation model used to project future stock levels, and the AD Model Builder code used to estimate stock status.

2. The reviewers will convene in a panel with scientists from the Alaska Fisheries Science Center and the Alaska Department of Fish and Game from June 19 to June 23, 2006, in Seattle, Washington.

3. Each reviewer is to generate a written, non-consensus report that should include:

   a. A statement of the strengths and weaknesses of the input data and analytical approach used to assess stock condition and stock status and methods used for addressing uncertainty in the assessment.
   b. A statement of the strengths and weaknesses of the simulation models, and the analytical approaches used in estimating future harvest levels.
   c. An analysis of current harvest strategies. Specifically do they provide appropriate levels of conservation for Alaskan rockfish fisheries? What harvest control rules might be more appropriate? Are additional spatial management measures required?

   Within the main body, the report is to contain an executive summary paragraph of the reviewer's findings and conclusions for each of the terms of reference (a-c) listed above, followed by the detailed comments for each term.

4. No later than July 7, 2006, all three reviewers are to submit their reports[1] consisting of the findings, analysis, and conclusions to Dr. David Die, via email to ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via email to mshivlani@rsmas.miami.edu. See Annex 1 for additional details on the report contents and organization.

5. The CIE shall provide a summary report documenting the areas of agreement and disagreement among the three reviewers. This report shall contain the information provided by each reviewer in the "executive summary paragraph" for each term of reference, as detailed under item 3 above.

[1] Every report will undergo an internal CIE review before it is considered final. After completion, the CIE will create a PDF version of each report that will be submitted to NMFS and the reviewer.

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report should be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report should consist of a background, description of review activities, summary of findings, and conclusions/recommendations.

3. The report should also include as separate appendices the bibliography of materials provided by the Center for Independent Experts and the Alaska Fisheries Science Center and a copy of the statement of work.

Please refer to the following website for additional information on report generation: http://www.rsmas.miami.edu/groups/cimas/Report_Standard_Format.html