GROUNDFISH HARVEST POLICY EVALUATION WORKSHOP REPORT

The Council's Scientific and Statistical Committee (SSC) sponsored a December 18-20, 2006 workshop in La Jolla, California to evaluate current West Coast groundfish harvest policies and the science informing these harvest policies. In previous planning materials this workshop was referred to as the B_0 workshop, reflecting the original emphasis on methods to assess initial, unfished biomass (B_0) as the benchmark from which overfished designations are made. The report of this workshop is provided as Agenda Item E.1.a, Attachment 1.

The workshop agenda included a review of harvest control rules employed by other Councils, an evaluation of the 40-10 harvest policy for stocks with variant life history and recruitment patterns, an evaluation of alternative methods for estimating initial biomass (B_0) and B_{MSY} proxies, and a discussion of the use of priors (i.e., constraints on estimated parameter values in assessment models that use information from other sources) for key parameters in groundfish stock assessments. These discussions may prove quite useful in eventually revising the groundfish harvest policy framework and in providing technical guidance to stock assessment authors. Workshop participants identified several potential problems with current policies, but made no explicit recommendations for immediate changes. Instead, new avenues of further evaluation were outlined and a follow-up workshop on estimating B_{MSY} was recommended to finalize analyses presented in draft form at the workshop.

The Council should consider the results and recommendations from the Groundfish Harvest Policy Evaluation Workshop and the recommendations from the Scientific and Statistical Committee and other advisors before recommending the next steps in exploring changes to current groundfish harvest policies.

Council Action:

1. Discuss the results and recommendations of the Groundfish Harvest Policy Evaluation Workshop.

Reference Materials:

1. Agenda Item E.1.a, Attachment 1: Report of the Groundfish Harvest Policy Evaluation Workshop.

Agenda Order:

a. Agenda Item Overview — John DeVore
b. Reports and Comments of Advisory Bodies
c. Public Comment
d. Council Discussion

PFMC
02/14/07

DRAFT
Report of the Groundfish Harvest Policy Evaluation Workshop

Southwest Fisheries Science Center, La Jolla, California
December 18-20, 2006

A Workshop Sponsored by the Scientific and Statistical Committee of the Pacific Fishery Management Council

The Pacific Fishery Management Council's (Council) Scientific and Statistical Committee hosted a workshop on Dec 18-20, 2006, to evaluate aspects of the Council's groundfish harvest policies. The workshop was held at the Southwest Fisheries Science Center in La Jolla, California.

The goals of the workshop were to address following three issues:

1. Evaluate the performance of the Pacific Council's 40-10 harvest policy for stocks with different life history and stock-recruit patterns.

2. Evaluate alternative methods to estimate B_0 and B_{MSY} proxies and provide recommendations on their use.

3. Provide recommendations on the use of priors for key assessment parameters in stock assessment models. Parameters for which priors could potentially be useful include natural mortality, stock-recruit steepness, survey catchability, and recruitment variability.

This report summarizes the results of the workshop. It is intended to provide recommendations for consideration by the Council and its advisory bodies and also to give guidance to authors preparing stock assessments for the Pacific Council.

Workshop Background

The Pacific Council's current harvest policy for groundfish was established by Amendment 11 of the Groundfish Fisheries Management Plan (FMP) in 1998 in response to new requirements in the 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act. Amendment 11 included proxies for FMSY, a schedule for reducing fishing mortality at low stock size (40-10 policy), and a default minimum stock size threshold (MSST) of 25% of unfished biomass.

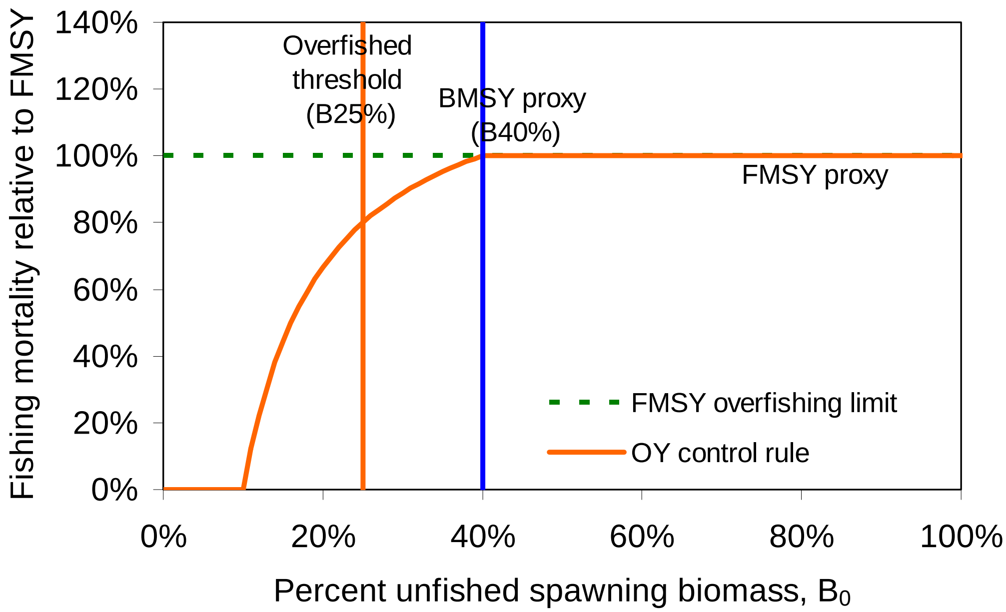

Figure 1. Pacific Council's harvest policy for groundfish.

Proxies for FMSY were revised in 2000 to reflect new estimates of groundfish productivity. A series of workshops in 1999 and 2000 led to a scientific recommendation that different FMSY proxies be adopted for rockfish ($F_{50\%}$), flatfish and Pacific whiting ($F_{40\%}$), and for other species ($F_{45\%}$). Harvest policies should be expected to evolve over time as experience is gained in their application and as new scientific findings are taken into account. A single workshop will not be able to address definitively all issues, and evaluation and refinement of harvest policies should be regarded as an ongoing process. The modeling and analyses needed to support a change in harvest policy is complex and time-consuming, and aligning the necessary resources (i.e., skilled modelers) to address these issues can be difficult given competing demands.

The first objective of the workshop was to evaluate the overall performance of the Pacific Council's OY control rule for groundfish. In an ideal situation, the OY control rule should maintain stock size close to BMSY and produce mean annual catches close to MSY. A stock exploited according to the OY control rule should not decline below the overfished limit except on rare occasions. Species managed under the groundfish FMP have diverse biology and stock dynamics. The performance of the Pacific Council's harvest policy across this biological diversity has not been evaluated.

A second objective of the workshop was to evaluate whether improvements are possible in the methods used to obtain the biomass reference points used in the harvest policy. The Pacific Council's Groundfish FMP establishes default proxies for FMSY, BMSY and the overfished threshold, but allows alternatives to be used if there is scientific justification: "The Council will consider any new scientific information relating to calculation of MSY or MSY proxies and may adopt new values based on improved understanding of the population dynamics and harvest of any species or group of species." Under the existing Groundfish FMP, the scope for changes in biomass reference point includes the following:

1. Using alternative methods of estimating B_0 and derived quantities such as $B_{40\%}$ and $B_{25\%}$.

2. Replacing current B_{MSY} proxies with more suitable proxies or stock-specific estimates of BMSY.

3. Using alternative minimum stock size thresholds (MSST) based on stock-specific characteristics rather than the $B_{25\%}$ default. The FMP stipulates that the default MSST when B_{MSY} is known is 50% of BMSY, although other alternatives could be used if justified by scientific analysis.

The method currently recommended in the FMP for estimating B_0 is to multiply unfished spawning biomass per recruit by average recruitment during a period when the stock was at high biomass. An alternative method is to use the estimate of B_0 derived from a stock-recruit relationship, either fit within assessment model or externally. Estimating B_0 within the assessment model became the standard approach in 2005 stock assessments, partially due to the ease with which it could be applied in the new modeling software. A third method is a dynamic estimate of B_0 obtained by replaying stock dynamics in the absence of fishing. At present it is unclear which of these methods performs best for the data available for West Coast groundfish, and under decadal-scale environmental variability characteristic of the California Current ecosystem.

A final objective for the workshop was to develop recommendations on the use of priors in groundfish stock assessments. At the Groundfish Stock Assessment Process Review Workshop following the 2005 stock assessments, it was noted that a variety of approaches had taken by STAR panels and STAT teams for parameters that are difficult to estimate freely in stock assessment models. Explicit guidelines might ensure consistency of approach while acknowledging scientific uncertainty. The workshop developed recommendations for estimating natural mortality (*M*). A more quantitative approach, using priors generated from Bayesian meta-analysis, was evaluated for stock-recruit steepness (*h*).

Context in which the Council's groundfish harvest policy was developed

The Pacific Council's harvest policy was developed to satisfy requirements of fisheries legislation and regulations promulgated by the National Marine Fisheries Service, specifically the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and a guidance document by NMFS instructing Councils about how to comply with the Act. The Act contains a set of ten national standards for fishery conservation and management. National Standard 1 states "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry." The Act clarifies that “the term “optimum”, with respect to the yield from a fishery, means the amount of fish which--(A) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems; (B) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and (C) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.”

The MSFCMA also requires the Secretary of Commerce to “establish advisory guidelines (which shall not have the force and effect of law), based on the national standards, to assist in the development of fishery management plans.” The National Standard Guidelines define maximum sustainable yield (MSY): “MSY is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY stock size means the long-term average size of the stock or stock complex, measured in terms of spawning biomass or other appropriate units, that would be achieved under an MSY control rule in which the fishing mortality rate is constant.” “MSY control rule” means a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY.

The National Standard Guidelines also establish status determination criteria as follows: “Each FMP must specify, to the extent possible, objective and measurable status determination criteria for each stock or stock complex covered by that FMP. In all cases, status determination criteria must specify both of the following: a maximum fishing mortality threshold or reasonable proxy thereof, and a minimum stock size threshold or reasonable proxy thereof. The stock size threshold should equal whichever of the following is greater: One-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock were exploited at FMSY.”

Performance of the Pacific Council’s 40-10 harvest policy

Andre Punt, Martin Dorn and Melissa Haltuch: “Simulation Evaluation of Threshold Management Strategies for Groundfish off the U.S. West Coast.” A Monte Carlo simulation approach was used to explore the implications of applying the Pacific Council’s 40-10 harvest policy and two alternative harvest policies (60-20 and constant fishing mortality). The 40-10 and 60-20 harvest policies are simply a schedule for reducing target mortality at low stock sizes, so this evaluation should be understood to include both the schedule for reducing fishing mortality and the F_{MSY} proxies currently being used. The analysis was not a comprehensive evaluation of the Council’s management strategy because no attempt was made to model the development and implementation of rebuilding plans for stocks assessed to have dropped below the overfished threshold. Simulations of stock dynamics were performed for several representative species with contrasting life history characteristics, including a representative rockfish, a representative flatfish, and Pacific whiting. The simulations explored the medium- to long-term implications of uncertainty in steepness, recruitment variation and its possible temporal auto-correlation, the state of the resource when the management strategy is first applied, as well as implementation and estimation uncertainty.

Performance statistics were chosen to capture the intent of the harvest control rules selected for west coast groundfish resources, i.e. high stable catches and a low probability of dropping the resource below the overfished threshold. The results identified uncertainty regarding steepness as the major source of variation in the final size of the resource and whether it is below the overfished threshold, although extent of recruitment variation was also found to impact these quantities. The extent of inter-annual variation in catches was determined primarily by the extent of implementation and estimation error. The analyses also highlighted the implications of a single fixed choice for the overfished threshold given among-species variation in biological characteristics such as the rate of natural mortality and the extent of variation in recruitment.

In general, the performance of the 40-10 harvest control rule with the current F_{MSY} proxies appeared to be adequate for most species. However, the results of the simulations highlighted a potential problem for short-lived species with high recruitment variability, such as Pacific whiting. Application of the Council's harvest control rule was predicted to lead to frequent cases in which the stock drops below the overfished threshold of $B_{25\%}$ even if $F_{40\%}$ is the appropriate harvest rate on average (i.e., $F_{40\%}$ equals the true F_{MSY}). The workshop was not able to determine how best the current harvest policy could be revised to address this problem. One approach would be case-specific, such as developing a unique harvest policy for species with high recruitment variability; another would be to develop a generic approach that would deal comprehensively with the problem by, for example, making the MSST a function of the estimated extent of recruitment variability (analogously to how productivity is currently treated).

A second concern is the apparent low productivity of some rockfish species. If current estimates of productivity are correct, applying the 40-10 harvest policy with the current F_{MSY} proxy will not maintain stock size close to the B_{MSY} proxy for some species. However, all of the West Coast rockfish species for which productivity is estimated to be low are currently under rebuilding plans. Since the 40-10 harvest policy will not be applied to these stocks until after they are rebuilt, there will be an opportunity to monitor stock response while rebuilding and perhaps adjust proxies for F_{MSY}. Recent sablefish assessments have also resulted in estimates of very low productivity, raising similar concerns for rockfish. It is also important to note that the Monte Carlo simulations considered only a relatively simple pattern of environmental forcing, i.e. correlated recruitment. More complex patterns of forcing, such as climatic regime shifts or directional climate change were not evaluated, and would likely significantly impact harvest control rule performance. The Workshop recommended that the impact of estimation error on the performance of the 40-10 and alternative harvest rules be explored further as the current simulations only examine one way in which estimation error might impact the implementation of possible harvest control rules.

Alternative methods to estimate B_0 and B_{MSY} proxies

Comparisons with other fishery management councils. Each of the eight Fishery Management Councils has implemented the requirements of the Magnuson-Stevens Act and the National Standard Guidelines somewhat differently. This review focuses primarily on the Pacific

Council, the North Pacific Council and the New England Council. Each Council is dealing with a set of stocks with unique biology and exploitation history and, potentially, a distinctive pattern of environmental forcing. In many cases, differences between management systems reflect these unique characteristics.

North Pacific Council harvest policies are specified by a tier system, which defines how ABC (acceptable biological catch) and OFL (overfishing level) are calculated based on the information available from stock assessments. At the lowest tier, only a time-series of catches is available, while at the highest tier a quantitative stock assessment allows estimation of both point estimates of F_{MSY} and B_{MSY} and the uncertainty associated with them. Tier 3 is most analogous to the Pacific Council's groundfish harvest policy, and is the tier in which most North Pacific stocks with assessment models are placed. Tier 3 uses a target fishing mortality rate of $F_{40\%}$ for all stocks, and provides for reductions in the fishing rate at low stock size. Rather than reducing catches linearly, as in the Pacific Council harvest policy, the North Pacific Council harvest policy reduces fishing mortality linearly once the stock size drops below $B_{40\%}$. Reducing fishing mortality rather than catch is a more aggressive response to declining stock size when the stock is between the target biomass and the overfished threshold, but becomes less aggressive at lower stock sizes.

$B_{40\%}$ is the biomass at which fishing mortality begins to ramp down for both the North Pacific and the Pacific Council harvest policies. However, $B_{40\%}$ is defined and calculated differently by the two Councils. The Pacific Council's groundfish FMP defines $B_{40\%}$ as 40% of unfished stock size whereas the North Pacific Council defines $B_{40\%}$ as the mean spawning biomass when fishing at $F_{40\%}$. In the North Pacific, an estimate of $B_{40\%}$ is obtained using mean post-1977 recruitment. Use of post-1977 recruitment recognizes the climatic regime shift that occurred in 1977 in the North Pacific. Many stocks in Alaska experienced higher recruitment after the 1977 regime shift, so the use of recent recruitment when estimating $B_{40\%}$ leads to higher estimates than would have been the case had the entire time-series of recruitment been used.

The North Pacific management system emphasizes control of fishing mortality rather than using biomass thresholds to identify overfished status. The North Pacific Council has declined to establish an overfished threshold for groundfish, arguing that their harvest policy provides for automatic rebuilding. A projection model is used to show that stocks can rebuild from current status to a B_{MSY} proxy of $B_{35\%}$ within 10 years. NMFS scientists perform the required status determination using one-half of $B_{35\%}$ as the default threshold. What would happen if a stock dropped below this level has not been resolved?

In New England, where fishing mortality has been significant for over the last 100 yrs, estimation of the properties of an unexploited ecosystem is a dubious undertaking. Since nearly all New England groundfish stocks have been declared overfished, analyses have focused on estimating B_{MSY} to establish a rebuilding target for these stocks, rather than harvest control rules for stocks that are not overfished.

A major re-evaluation of biological reference points was completed in 2002 (Anon 2002). The objective of this re-evaluation was to revise estimates of F_{MSY} and B_{MSY} for the New England Multispecies FMP (19 groundfish stocks). A suite of estimation methods was applied to estimate spawning stock biomass and recruitment from assessment models and hence fishing mortality and biomass reference points. Methods included a non-parametric approach of estimating B_{MSY} by multiplying average recruitment by the spawning biomass per at $F_{40\%}$. This is analogous to the Pacific Council's to the approach to estimate $B_{40\%}$, but differs in the range of years to calculate average recruitment. The range was generally intended to represent an earlier period when the stock was at higher abundance and stable (i.e., potentially close to B_{MSY} rather than B_0). Parametric approaches using Beverton-Holt and Ricker SR relationships were also used, with and without Bayesian priors. Explicit model selection criteria were use to select the best model, with the philosophy being that parametric approaches would be used when they were "reasonable" and did not differ greatly from the non-parametric approach.

Only the Pacific Council uses B_0 in its harvest policy to calculate proxies for B_{MSY} and the overfished threshold. Other Councils use proxies for B_{MSY} that are estimated directly, but there may be legitimate reasons for these differences. In New England, the long history of exploitation precludes the use of B_0 as a useful concept. In the North Pacific, dramatic increases in recruitment following the 1977 regime shift made it necessary to develop biomass reference levels using recruitment during a more recent time period. Neither of these approaches would be applicable to West Coast groundfish. An issue that remains problematic for the Pacific Council's use of B_0 is whether biomass estimated at the start of the assessment period is representative of the long-term average unfished biomass.

There are differences in how the Councils have defined and applied the overfished threshold (or minimum stock size threshold). Some Councils, such as the New England Council, use the default of one-half of B_{MSY} as the overfished threshold. The North Pacific has declined to establish an overfished threshold, but NMFS makes its own status determinations of North Pacific stocks using a threshold of one-half of B_{MSY}. The Pacific Council's overfished threshold is $B_{25\%}$, which is higher than the default in the National Standard Guidelines (since the B_{MSY} proxy is $B_{40\%}$), but lower than the $(1\text{-}M)*B_{MSY}$ used by the South Atlantic Council. The overfished threshold acts as safety net if the primary harvest policy fails. An advantage of using a relatively high overfished threshold is that it is quicker to protect stocks that are in decline for any reason, including a harvest policy that is potentially too aggressive. The disadvantages are, of course, is that rebuilding plans tend be disruptive of the management system and cause adverse economic impacts on the fishery. There are benefits to adopting a standard approach across Councils for national status reviews. The use of different overfished thresholds could result in stocks with similar status being categorized differently depending on the Council that is managing them.

Melissa Haltuch, Andre Punt and Martin Dorn: "Evaluating Alternative Estimators for Fisheries Biomass Reference Points." The control rules used to determine fishery harvest levels depend on estimates of 'biological reference points'. Commonly-used biological reference points include the level of unfished spawning biomass (B_0), the spawning biomass corresponding to maximum sustainable yield (B_{MSY}), and the current size of the stock in relation to B_0 and B_{MSY}. Although several methods exist for estimating these quantities, it is unclear which methods perform best. Simulation was therefore used to evaluate alternative estimators for B_0, B_{MSY}, current biomass relative to B_{MSY}, and current biomass relative to B_0. These estimators differed in terms of whether a stock-recruitment relationship was used when estimating $B_{0,}$ and whether a prior was placed on the steepness of the stock-recruitment model. The simulations involved first simulating the dynamics of a population for several decades, then simulating sampling from that population to generate assessment data, and finally fitting a simplified stock assessment model to those data. This simulation-estimation scheme was repeated multiple times to determinate the statistical properties of the various estimators, for example, how precise they are, and whether or not they are biased.

The simulations considered three life histories (a long-lived unproductive rockfish, a moderately long-lived and productive flatfish, and a moderately long-lived and highly variable but productive hake) since life history characteristics may impact estimator performance. Initial results suggested that estimator performance varies among both reference points and species. The performance of the estimators was better for the rockfish and flatfish life histories than for the hake life history. A draft version of this analysis was presented at the workshop, and a number of recommendations were made for improvement. It was not possible to identify the best estimators of B_0 and B_{MSY} at the workshop due to the preliminary nature of the simulations, but a revised paper should provide some basis for developing recommendations.

Michael Schirripa: "The potential effects of including/excluding environmental factors into stock assessments" A simulation-estimation framework was developed specifically for sablefish using FSIM, a population and fishery simulator (Goodyear 2004). The estimation model used is the SS2 model used in the sablefish assessment. Environmental forcing on recruitment was modelled using an actual time series of sea surface height data to drive recruitment variability around the mean stock- recruitment relationship. A random component was also included to model residual variability not associated with sea surface height. A number of scenarios were considered, including those with and without environmental forcing on recruitment, and assessment models that attempted to estimate the environmental forcing and those that did not. All results are for scenarios in which the data using in the assessment is nearly perfect, i.e., there is minimal sampling error. To develop recommendations based on this work, the analyses need to be repeated for more realistic data-moderate and/or data-poor situation.

The workshop identified several issues related to how the bias-correction factor associated with the stock-recruitment should be calculated when modelling environmental forcing on recruitment deviations. These issues need to be resolved before this approach can be recommended. In addition, misleading results for sablefish could be occurring due to the timing of the environmental signal (sea surface height) and the draw-down from the fishery. Workshop participants concluded that a high standard was needed when deciding whether to include environmental forcing on recruitment. This is because process error is being modelled by the environmental data, rather than sampling error as for all other data inputs. A further concern is that modelling environmental forcing on recruitment has direct implications on stock productivity, which in turn effects how stocks are expected to respond to fishing.

An alternative approach of using environmental data as a survey-like data input was discussed briefly at the workshop. While this approach appears promising, there was no opportunity to compare approaches or review results at the workshop. Further evaluation of this and other methods of incorporating environmental data in assessment models is encouraged. The workshop considered it important to conduct simulation testing of estimators before including environmental data in assessment models used for management advice.

Alec MacCall and John Field: "Comparison of dynamic and static estimates of B0 and stock depletion." Current practice is to compare current spawning biomass to a reference point that represents the average abundance of an unfished resource (treated as a constant). It is unlikely that an unfished resource would be of constant abundance, as ecosystem processes are dynamic across both space and time. An alternative is to use the information generated by stock assessments to consider how an unfished resource would change over time, based on recruitment deviations and the shape of the spawner-recruit relationship. This provides an opportunity to consider alternative reference points that explicitly recognize that stocks would have varied across time in the absence of fishing.

Two approaches were evaluated: DSPR (Dynamic Spawner per Recruit) is the time series of ratios of the estimated spawning biomass to the spawning biomass that would have resulted had the same sequence of recruitments not been fished. DB0 (Dynamic B0) is the time series of spawning potentials that would have resulted if the estimated recruitment deviations in the assessment model were fixed, but the absolute recruitment values themselves are modified by the stock-recruitment relationship. Based on this, DRS (Dynamic Reference Spawning Status) is the time series of ratios of estimated spawning potential to corresponding estimates of dynamic B_0. DSPR and DRS, as defined here, are fully analogous to the current practice of defining spawning biomass potential to static B_0.

Estimates of DSPR, DBO and DRS were calculated for most of the existing West Coast groundfish stocks and compared to the current approach of using a static definition of B_0 and stock depletion. In many cases estimates of stock status were similar. A common difference was that DRS tended to show less extreme behavior than stock depletion estimates based on a static B_0. Pacific whiting, currently approaching an overfished condition, would be close to target biomass levels with this approach. However, the stock status of sablefish would be more pessimistic, as "all else equal" the spawning biomass would have been higher in recent years.

There were several proposals for incorporating these dynamic estimators into the current groundfish harvest policy. One proposal was to use a DRS of 25% as an overfished threshold to screen out stocks that have declined due to environmental changes from those that have declined due to overfishing. A second proposal was to use the existing static B_0 and the dynamic DRS and DSPR to determine whether a stock will be declared rebuilt. Again the purpose of using the dynamic estimates is to recognize that stocks may fail to rebuild due to ecological change even after fishing mortality has been restricted.

This Workshop welcomed these proposals, but the ideas are not sufficiently well-tested and developed yet so as to form the basis for recommendations for changes to how harvest control rules for West Coast Groundfish are applied. This is because, for example, the dynamic approach implicitly assumes that the same recruitment deviation would have occurred had there been no fishing, an untested and potentially untestable assumption. Furthermore, the imprecision and statistical properties of recruitment deviations also need to be explored. The approach may be conditioned on the deviations being calculated relative to a well-estimated spawner-recruitment relationship that captures the central tendency of recruitment. Simulation testing of dynamic B_0 estimators is currently underway, and the results of this work need to be reviewed. The Workshop also recommended that stock assessments report dynamic biomass time-series such as DSPR, DB0 and DRS so that more can be learned about how these status indicators perform in practice.

<u>Advice to assessment authors</u>

Natural mortality. This section provides recommendations for selecting an appropriate value for natural mortality, *M*. It is intended to guide the development of new assessments or assessments where a change in *M* is contemplated. At this point it is not possible to be prescriptive about how to choose a value of *M* for stock assessment, and these guidelines are intended to describe a default approach, with the understanding that other methods and approaches can be considered if accompanied by a reasoned argument. Analysts are expected to consider the value of *M* used in previous assessments, and values of *M* used for similar stocks. Continuity in advice is an important consideration in stock assessment and proposed changes in M should represent a genuine scientific advance and not the preference of the assessment author.

A number of papers have dealt with obtaining suitable values of *M* for stock assessment modeling. These methods depend on deriving a relationship between *M* and a more easily measured life history characteristic. Many (if not all) of these methods have significant limitations that restrict their applicability. Experience has shown that empirical methods of Hoenig (1983), Gunderson (1992), and Beverton (1992) tend to be the most reliable. However, it is still necessary to be judicious in even using these methods, as each is capable of producing nonsensical results. Other empirical methods for estimating *M* are not recommended.

In addition to evaluating these empirical methods, a likelihood profile on M should be produced. Analysts should consider generating the full likelihood surface of M versus steepness, although it is recognized that this represents a significant computational undertaking. Analysts should also be aware of the potential for unrealistic selectivity patterns to be generated when doing such a likelihood profile due to the interaction between M and selectivity. These potential pathologies should be investigated to the extent possible, for example both tracking the values of other key parameters while stepping through the likelihood profile.

One potential advance in stock assessment practice is to use a Bayesian prior for M that reflects both the estimate and the uncertainty from the empirical relationship (such as the relationship between GSI and M). Prediction intervals around such relationships are much wider than confidence intervals (which are already quite large). At present it is unclear which expression of uncertainty is more appropriate to use in a Bayesian prior, but these two alternatives may be suitable endpoints for sensitivity analysis. Confidence intervals are appropriate only if the scatter around the mean relationship between the other life history parameter and M is due purely to observation error. In contrast, prediction intervals should be used if the scatter is due purely to true variation about the mean relationship. The truth is undoubtedly somewhere in the middle, and is complicated by probable bias introduced by the methods for estimating M values used in the meta-analyses.

The use of an arbitrary prior to constrain the estimate of M to a previously-used value is not recommended, particularly if the prior variance was chosen by iterating until "satisfactory" results are obtained. Instead, a likelihood profile should be provided, and (if uncertainty in M is considered a major component of assessment uncertainty) alternative model runs should be produced using alternative values of M. Estimation of M within a model (with or without an informative prior) is complicated by the reality of dome-shaped selectivity, since the value of M and the rate of decrease in selection with age (or size) are correlated. Only if at least one selectivity curve can reasonably be assumed to be asymptotic should an attempt be made to estimate M within the model.

Application of these methods collectively should allow the analyst to focus in on a value of M or a range of values to use in the stock assessment. Of course, the true natural mortality is likely to vary between ages and from one year to the next, but estimating this variation is not possible using data currently available for stock assessment, and may not be all that important. Stock assessments do not require a highly precise estimate of natural mortality to serve their purpose in managing fish stocks.

Stock recruit steepness. The latest version of the assessment model used for most West Coast groundfish species, SS2, includes a stock-recruit relationship as an intrinsic part of the population dynamics. Stock-recruit parameters, such as steepness, must therefore be either assumed or estimated in the model. Other assessment models, such as VPA and its more advanced variants, do not include a stock recruit relationship. Including a stock recruit relationship adds additional structure to model, which can help the estimation in data-poor situations. However, it is not a necessary feature of assessment models, and most assessment models used in North Pacific do not include a stock-recruit relationship. In the previous assessment cycle, about 40% of the assessments estimated stock-recruit steepness, while the remainder assumed a fixed value for steepness. Fixed values of steepness were obtained using a variety of rationales, including the results of meta-analysis, expert judgement, or on the basis of preliminary runs which indicated a need to constrain steepness to avoid hitting a bound (i.e., a steepness of 0..2 or 1.0).

One possibility for more rigorous and consistent treatment of this important assessment parameter is to incorporate a Bayesian prior for steepness in the assessment model. Workshop participants reviewed results presented by Dorn of a meta-analysis of steepness for Pacific Coast rockfish and flatfish. This analysis was an update of earlier work (Dorn 2002) that jointly estimated steepness for a group of stocks with age structured assessments. Results indicated a mean steepness for rockfish of 0.55 (range 0.41-0.85). The mean is lower than the mean of 0.65 from the previous meta-analysis. For flatfish, the mean steepness was 0.89 (range 0.74-0.92).

For rockfish and flatfish assessed during the next assessment cycle, analysts are requested to consider the appropriate prior for steepness derived from the Dorn meta-analysis. A comparison of the final model with and without this prior is requested (if the final model doesn't include the prior). Rockfish stocks being assessed in 2007 that were included in the meta-analysis are black rockfish, bocaccio, chillipepper rockfish, darkblotched rockfish, and canary rockfish. For these species, the prior should be based on a meta-analysis with the stock in question omitted to avoid double use of data (Minte-Vera et al 2006). Blue rockfish, which has not been assessed previously, would use a prior derived from data for all stocks. Stock assessment updates would not be able to use meta-analysis results and still be considered updates. Dorn will complete the paper on the undated meta-analysis and provide the appropriate priors for consideration by assessment authors. Assessment authors are also requested to do a likelihood profile on steepness (with the prior removed) to enable routine updates of the meta-analysis to be done.

The next steps

There is an on-going need to hold methods workshops that focus directly on the Council's harvest policies and stock assessment methods. This need is not limited to groundfish, but extends to CPS species for which management policies and assessment methods are comparable. There is also broad interest in management strategy evaluations in the North Pacific Council, and collaborations should be pursued on topics of mutual interest. The SSC would like to be involved in an active and on-going research program related to the practical matters associated with implementation of Council policies to improve its advisory role to the Council. However, it is recognized that methods are complex and require a significant time commitment that may prevent SSC from doing more than guiding and reviewing the research. How to align resources is an unanswered question and was a challenge for the present workshop. Future methods workshops might deal with:

- A follow-up workshop is needed to develop recommendations on estimating B_0 and B_{MSY} if the suggestions made due the workshop to the analysts working on comparing alternative estimators are implemented.

- A harvest policy evaluation should be undertaken for Pacific whiting due to the apparent poor performance of the current policy for this species as a result of high recruitment variability.

- Management policies for data-limited stocks should be developed and evaluated. This is because Council harvest policies for species without full age-structured assessments are not fully developed.

- The harvest policies for the CPS species should be reviewed and perhaps modified given the results of research since the current harvest policies were selected.

- Harvest policies that perform robustly in the face of climatic regime shifts should be developed and evaluated.

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Appendix A: Workshop agenda

Groundfish Harvest Policy Evaluation Workshop

Pacific Fishery Management Council

Scientific and Statistical Committee

Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037

December 18-20, 2006

Monday, December 18, 2006

9:00 a.m.	Welcome (Bill Fox, SWFSC Center Director) and Introductions
9:15 a.m.	Review Goals and Objectives of the Workshop

Session 1. Workshop Background

9:30 a.m.	Martin Dorn: "Review of methods of estimating biomass reference points used in harvest control rules employed by US Fisheries Management Councils."
10:30 a.m.	Break
10:45 a.m.	Neil Klaer: "Recent experience with implementation of a 40-20 harvest rule in a SE Australian multispecies demersal fishery."
11:45 a.m.	Discussion
12:00 p.m.	Lunch

Session 2: Evaluate the performance of the 40-10 harvest policy for stocks with different life history and stock-recruit patterns

1:00 p.m.	Andre Punt, Martin Dorn and Melissa Haltuch: "Simulation evaluation of the 40-10 and 60-20 control rules under semi-ideal conditions."
2:00 p.m.	Discussion and requests to analysts.
3:00 p.m.	Break

Session 3: Evaluate alternative methods to estimate B0 and BMSY proxies and provide recommendations on their use

3:30 p.m.	Melissa Haltuch, Andre Punt, Martin Dorn: "Simulation testing alternative estimators of unfished stock size."
4:30 p.m.	Discussion and requests to analysts

Tuesday, December 19, 2006

9:00 a.m. Michael Schirripa: "Simulation testing estimators of sablefish biomass reference levels under decadal environmental variability."

10:00 a.m. Alec Maccall and John Field: "Comparison of dynamic and static estimates of B0 and stock depletion."

11:00 a.m. Break

11:15 a.m. Discussion and requests to analysts

12:00 p.m. Lunch

Session 4: Provide recommendations on the use of priors for key assessment parameters in stock assessment models

1:00 p.m. Martin Dorn: "Advice on priors for stock-recruit steepness for use in West Coast stock assessments."

2:00 p.m. Owen Hamel: "Advice on priors for natural mortality."

3:00 p.m. Break

3:30 p.m. Discussion and analysts report on progress.

Wednesday, December 20, 2006

Session 5. Workshop Discussion

9:00 a.m. Analysts report on progress.

10:00 a.m. Begin drafting workshop report

11:30 a.m. Wrap-Up—workshop recommendations

12:00 p.m. Workshop Adjourns

Appendix B: Workshop participants

Martin Dorn, National Marine Fisheries Service Alaska Fisheries Science Center, SSC Groundfish Subcommittee and workshop chair
Jim Ianelli, National Marine Fisheries Service Alaska Fisheries Science Center
Andre Punt, University of Washington
Dan Waldeck, Pacific Whiting Conservation Cooperative
Michael Schirripa, National Marine Fisheries Service Northwest Fisheries Science Center
Owen Hamel, National Marine Fisheries Service Northwest Fisheries Science Center
Tom Jagielo, Washington Department of Fish and Wildlife
Melissa Haltuch, University of Washington
Ray Conser, National Marine Fisheries Service Southwest Fisheries Science Center
Rick Methot, National Marine Fisheries Service Northwest Fisheries Science Center
David Sampson, Oregon State University
Theresa Tsou, Washington Department of Fish and Wildlife
Steve Ralston, National Marine Fisheries Service Southwest Fisheries Science Center
John Field, National Marine Fisheries Service Southwest Fisheries Science Center
Meisha Key, California Department of Fish and Game
Debbie Aseltine-Neilson, California Department of Fish and Game
Pete Leipzig, Fishermen's Marketing Association
Mark Maunder, IATTC
Roger Hewitt, National Marine Fisheries Service Northwest Fisheries Science Center
Neil Klaer, CSIRO Australia
Gway Kirchner, Oregon Department of Fish and Wildlife
Bill Herberer, Oregon Department of Fish and Wildlife
Brad Pettinger, Oregon Trawl Commission
Emmanis Dorval, National Marine Fisheries Service Southwest Fisheries Science Center
William Fox, National Marine Fisheries Service Southwest Fisheries Science Center
Paul Krone, National Marine Fisheries Service Southwest Fisheries Science Center
Don McIsaac, Pacific Fishery Management Council
John DeVore, Pacific Fishery Management Council