SCIENTIFIC AND STATISTICAL COMMITTEE STATEMENT ON DEFAULT MAXIMUM SUSTAINABLE YIELD FISHING RATE WITHIN THE HARVEST RATE POLICY

Due to concern over declines in West Coast groundfish populations, and the inability of those stocks to sustain historical harvest rates, the Scientific and Statistical Committee (SSC) sponsored a workshop to evaluate the issue and to make recommendations to the Pacific Fishery Management Council (PFMC) concerning the suitability of the Council's default harvest rates. The West Coast Groundfish Harvest Rate Policy Workshop was held from March 20-23, 2000 at the Alaska Fishery Science Center in Seattle, Washington (Terms of Reference are presented in Appendix A). The format of the meeting consisted of a series of 12 presentations by interested scientists, which were made to a panel of three SSC and three outside reviewers. The panel evaluated and considered all of the oral and written material presented at the workshop, as well as other information available in the published scientific literature, and issued a Panel Report (Appendix B). The Panel Report was available at the PFMC meeting in April, 2000 and the whole SSC provided preliminary comment on the findings of the workshop at that time. In particular, the SSC's initial review supported the panel's consensus findings that groundfish harvest rates should be reduced.

Having had the opportunity to examine the Panel Report in detail, the SSC agrees with the panel's recommended "risk-neutral" proxies for F_{msy}. Namely,

Sebastes and *Sebastolobus*	$F_{50\%}$
Pacific whiting	$F_{40\%}$
Flatfishes	$F_{40\%}$
Other groundfish	$F_{45\%}$
"Remaining Rockfish"	0.75 M

Due to the apparent low productivity of west coast groundfish stocks, the SSC recommends that harvest rates be reduced to these levels to support risk-neutral management, and to even lower harvest rates to support risk-averse or precautionary management. According to the best available scientific information at this time, these fishing mortality rates should be viewed as harvest rates that will produce the maximum sustainable yields (MSY) for the stock complexes in question. They represent proxies for F_{msy} because they are based on information summarized from a wide variety of stock-specific analyses and they are applied generically within each group. One problem with this approach is that, within each complex, one would expect some stocks to be overfished and some stocks to be underutilized. As more information becomes available, and credible analysis supports it, the SSC recommends that species-specific analyses of productivity be conducted whenever possible.

Because these values are properly considered risk-neutral (i.e., they are just as likely to overestimate as underestimate the actual F_{msy} rate), the issue of precautionary adjustments has been raised. Precautionary adjustments to harvest control rules are appropriate when the repercussions of over-harvesting a resource are less acceptable than under-harvesting it. Within the context of setting west coast groundfish catch levels, it is important to identify where and when precautionary adjustments are incorporated, to insure a proper understanding of the process by all concerned.
Under current Council procedures, catch levels are set based on guidelines provided in Amendment 11 to the groundfish Fishery Management Plan (FMP). Specifically, language in that amendment states:

> "In general, ABC will be calculated by applying $F_{35\%}$ (or $F_{40\%}$ or other established MSY proxy) to the best estimate of current biomass."

Note that the effect of the recommended revisions to the default harvest rate proxies (see above) will be realized here and here only, i.e., in the calculation of the Allowable Biological Catch (ABC). However, the FMP also states:

> "Reduction in catches or fishing rates for either precautionary or rebuilding purposes is an important component of converting values of ABC to values of OY."

> "For category 1 species, in addition to the overfished/rebuilding threshold, a precautionary threshold is established. The default value will be 40% of mean $B_{unfished}$. This level of biomass is expected to be near B_{msy}, and if abundance is between the overfished/rebuilding threshold and the precautionary threshold, a precautionary reduction in harvest will implemented [*sic*] to avoid further declines in abundance."

The harvest control rule used to specify the amount of precautionary reduction is the "40-10" policy, which states that OY declines linearly from OY=ABC at $B_{40\%}$ to OY=0 at $B_{10\%}$ (see glossary in Appendix C for definitions). For stock sizes that are greater than $B_{40\%}$, no precautionary adjustment is required (i.e., OY=ABC). In addition, Amendment 11 stipulates:

> "Uncertainty adjustments: In cases where there is a high degree of uncertainty about the biomass estimate and other parameters, OY may be further reduced accordingly."

From these citations it is clear that, at this time, the primary form of precautionary adjustment to be made in the setting of OYs for west coast groundfish is through use of the "40-10" harvest control rule. No further precautionary reduction in harvest rate *per se* is required, beyond the reduction required to meet the harvest policy itself. However, the FMP allows for additional reductions in OY in situations where there is a high degree of uncertainty, particularly about stock size. Improvements in the analytical software available to stock assessment scientists now permit a much better characterization of the statistical uncertainty in the estimated size of exploited stocks and it is increasingly possible to generate more realistic confidence intervals (i.e., biomass ± ***xx***% with 95% certainty). In situations where "***xx***" is large, uncertainty is high and the likelihood of severely overestimating stock size is not inconsequential. Therefore, it may often be prudent to further reduce OY when stock size has been estimated imprecisely, although this apparently is not required by Amendment 11.

It would be possible to modify the Council's current harvest control rule, i.e. the "40-10" rule, so as to automatically undertake "uncertainty adjustments" that would be based on the statistical imprecision in the estimation of stock size, i.e., the greater the level uncertainty (***xx*** above), the greater the reduction in OY. Undoubtedly the development of such a rule to more fully embrace the precautionary principle would require significant analytical work. But fundamentally, a decision to lower risk when uncertainty is great reduces to a policy decision, akin to the choices made by a portfolio manager investing in the stock market. Namely, how does one value the risks of stock collapse against the rewards of higher yields. On this spectrum of risk and return, the Council properly exercises its judgement and authority. We note that this type of adjustment for "uncertainty" is not presently codified into a control rule, like the "40-10" policy, although that is something the Council may wish implement at some point in the future, with assistance from the SSC and/or GMT. If the Council wishes to pursue the issue of further precautionary adjustments to the "40-10" harvest control rule (to incorporate uncertainty in stock size estimates), the SSC recommends a two-step procedure:

(1) The North Pacific Fishery Management Council (NPFMC) has been incorporating a precautionary adjustment to their harvest control rule that incorporates uncertainty in stock size estimates. In the near future, invite the NPFMC SSC Chair to discuss this policy with the PFMC SSC and full Council.

(2) Convene a scientific workshop (similar in scope to the recent SSC-convened Harvest Rate Policy Workshop) to address the analytic procedures and methods, and to prepare a report to the SSC addressing the full range of scientific and implementation issues involved.

Although the "40-10" harvest control rule automatically results in some precautionary (or risk-averse) adjustment for Category 1 species (i.e., those stocks that have been fully assessed and have time series of biomass and recruitment), there are other stocks with less information available for management purposes. For example, how does one implement precautionary adjustments for the "remaining rockfish" category? If the new F_{MSY} proxies (see above) are approved by the Council, the ABCs for those stocks will now be calculated using a risk-neutral harvest rate equal to 0.75 M.

We draw the Council's attention to text within the current 1999 SAFE document, which states:

> "For 1999 the Council endorsed the GMT's proposal to reduce the remaining rockfish component by 25% (i.e., to 75% of the current level) and the other rockfish component by 50%. These reductions of 25% and 50% were based on suggested target catch levels for data-poor situations from Restrepo *et al.* (1998. Technical Guidance on the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. Draft NOAA Tech. Memo.). This technical guidance suggests a 25% reduction for stocks above the B_{msy} level and a 50% reduction for stocks between the minimum stock size threshold (i.e., the overfished/rebuilding threshold) and the B_{msy} level. The GMT recommends continuation of this reduction."

The Council may, therefore, wish to consider maintaining a *status quo* percentage reduction in setting the OYs of the "remaining" and "other" rockfish. The old, risk-neutral, harvest rate for the remaining rockfish was 1.00 M, which was reduced to 0.75 M as a precautionary measure, amounting to a 25% reduction off of the ABC. An equivalent 25% precautionary reduction from ABC to OY under the new proposed rate would be ABC = 0.75 M·B and OY = 0.56 M·B.

As one of two alternatives to this *status quo* percentage reduction option, Walters and Parma[1] have stated:

> "Patterson's (1992) finding that pelagic stocks have generally been able to sustain exploitation rates of approximately only 0.5 to 1 times the natural mortality rate, as predicted from some modeling studies (reviewed in Patterson 1992), appears to work for demersal species as well. A worrisome point about the Patterson (1992) finding is that the popular $F_{0.1}$ harvest rate, which usually implies F ≈ M and is generally considered to be quite conservative (Deriso 1987), may in fact be too high for the majority of natural populations. Because underestimation of the optimal exploitation rate for long-lived species is not particularly costly ... , we consider the prudent approach to assume $\mu_e \leq 0.5$ M [μ_e is the optimal harvest rate] and to place the burden of proof on whoever advocates a higher rate to demonstrate that it is sustainable (by substantial direct analysis of historical stock-recruit data)."

Based on the arguments of these leading authorities, the Council may want to consider a more conservative precautionary adjustment of the risk-neutral ABC = 0.75 M·B policy for the remaining rockfish to a policy of OY = 0.5 M·B.

A third approach to implementing precautionary management for the remaining rockfish might be to utilize the "risk-averse" results presented in Dorn's harvest policy workshop paper (see Workshop Agenda, pg. 13 of Panel Report [Appendix B]): Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit dynamics). He showed that for west coast *Sebastes* stocks, exclusive of Pacific ocean perch, optimal risk-neutral SPR harvest rates were in the range of $F_{45\%}$-$F_{54\%} \approx F_{50\%}$ (see above). In contrast, the equivalent risk-averse SPR harvest rates[2] were in the range $F_{47\%}$-$F_{57\%} \approx F_{52\%}$, which amounts to a 7% reduction in harvest rate. This option would embrace a relatively small amount of precaution in the setting of the optimum yields of the remaining rockfish at OY = 0.70 M·B.

In the following summary table, the SSC-recommended risk-neutral proxies for F_{MSY} and precautionary adjustments to the harvest rates are provided, and compared to the status quo. Note, however, that these precautionary adjustments (both "SSC-Recommended" and "Status Quo") do not fully incorporate the uncertainty in stock size estimation, as described above.

Risk-Neutral Proxies for F_{MSY} and Precautionary Harvest Rates

	----SSC Recommended----		--------Status Quo--------	
	Risk-Neutral	Precautionary F based on:	Risk-Neutral	Precautionary F based on:
Sebastes and *Sebastolobus*	$F_{50\%}$	40-10	$F_{40\%}$?	40-10
Pacific whiting	$F_{40\%}$	40-10	$F_{40\%HYBRID}$	40-10
Flatfishes	$F_{40\%}$	40-10	$F_{35\%}$	40-10
Other groundfish	$F_{45\%}$	40-10	$F_{35\%}$	40-10
"Remaining Rockfish"	0.75 M	0.5-0.7M	M	0.75M

[1] Walters, C., and A. M Parma. 1996. Fixed exploitation rate strategies for coping with effects of climate change. Can. J. Fish. Aquat. Sci. 53:148-158.

[2] Wherein λ=0.5 in the fishery loss function of Thompson, G. G. 1992. A Bayesian approach to management advice when stock-recruitment parameters are uncertain. Fish. Bull., U. S. 90:561-573.

APPENDIX A

The terms of reference of the workshop, as specified in the minutes of the November 1999 SSC meeting, were as follows:

> Recent scientific studies have suggested that the proxies currently used for West Coast groundfish may overestimate the true F_{msy} for these species. The SSC will convene a Harvest Rate Policy Review Workshop to address this issue. The review will be chaired by Dr. Steve Ralston of the SSC. It will be held at the National Marine Fisheries Service (NMFS) Alaska Fisheries Science Center (Seattle, Washington) during March 20-24, 2000.
>
> The formal review panel will consist of five scientists (in addition to the Chairman): (1) two additional SSC members; (2) two external experts; and (3) one expert from within the west coast groundfish scientific community. In addition, the Groundfish Management Team (GMT) and Groundfish Advisory Subpanel (GAP) will each designate one representative to contribute to the review, but the GMT and GAP representatives will not serve as formal panel members. The principal investigators involved in recent scientific studies on this issue will be invited to present their work to the review panel. The process will also be open for other scientists to present relevant work to the review panel (at the discretion of the Chairman).
>
> The terms of reference for the review panel are:
>
> - Review the current body of existing scientific work and any additional (relevant) work presented during the review panel meeting. All scientific contributions must be well documented with draft papers provided to the review panel in advance of the meeting.
> - Evaluate the appropriateness of the current Council F_{msy} proxies (i.e., $F_{40\%}$) for *Sebastes* species and $F_{35\%}$ for other groundfish.
> - Suggest procedures for incorporating uncertainty, risk, and the precautionary approach in establishing harvest rate policies.
> - Provide a comprehensive report to the SSC and the Council that clearly documents the findings and recommendations of the review panel.

APPENDIX B

Panel Report

West Coast Groundfish Harvest Rate Policy Workshop
AFSC, Seattle, Washington: March 20-23, 2000
Sponsored by the Scientific & Statistical Committee of the Pacific Fishery Management Council

Panel Report

Stephen Ralston (chairman), James R. Bence, William G. Clark,
Ramon J. Conser, Thomas Jagielo, and Terrance J. Quinn II.

Scientific and Management Background

Through 1998 the policy of the Pacific Fishery Management Council (PFMC) was to set the Allowable Biological Catch (ABC) of a stock by applying the fishing mortality rate that produces Maximum Sustainable Yield (F_{MSY}) to an estimate of exploitable stock biomass. Policies of this kind are termed constant rate policies because, once the estimate of F_{MSY} is determined, the annual ABC is strictly proportional to estimates of exploitable biomass. However, owing to short data series and other technical issues, it generally has not been possible to directly estimate F_{MSY} reliably for any stock. Consequently, during the 1980s and into the early 1990s, one of several common surrogate or proxy estimates of F_{MSY} was used (e.g., $F_{0.1}$ or F=M).

Clark (1991) proposed the $F_{35\%}$ harvest rate as a more general and rational surrogate rate. $F_{35\%}$ is the fishing mortality rate that reduces the spawning potential *per recruit* to 35% of the unfished level. By reasonably assuming that fecundity is proportional to average weight, it is the rate of fishing that reduces the spawning biomass *per recruit* to 35% of what would exist if there were no fishing. Clark showed that this rate would produce a yield close to MSY for a range of life history parameters and productivity relationships that were intended to cover the great majority of well-studied groundfish stocks with long histories of exploitation (most of which were Atlantic stocks). He also showed that $F_{35\%}$ was very close to both $F_{0.1}$ and F=M when the schedules of recruitment and maturity coincided, and were sensibly higher or lower when they differed. However, a later paper extended the original analysis to cases with random and serially correlated recruitment variation (Clark 1993), and concluded that $F_{40\%}$ would be a better choice overall than $F_{35\%}$. Mace (1994) also recommended $F_{40\%}$ on the basis of deterministic calculations. The current scientific consensus now indicates that $F_{40\%}$ is an appropriate default harvest rate for stocks with unknown productivity parameters.

The PFMC adopted $F_{35\%}$ as its standard surrogate in 1992, and switched to $F_{40\%}$ for *Sebastes* only in 1997, based principally on the conclusions of Clark (1993) and Mace (1994). In 1998 it then adopted the so-called "40-10" rule under Amendment 11 to the groundfish FMP. The 40-10 rule represented a departure from prior constant rate harvest policies, wherein the target fishing mortality rate is reduced for stocks whose biomass is below 40% of the estimated unfished biomass (B_0).

Common Confusion Over Relative Biomass and Relative Biomass per Recruit

In addition to recommending the $F_{35\%}$ strategy, Clark (1991) suggested a more robust biomass-based strategy that consists of simply maintaining spawning biomass at around 40% of the estimated unfished level. Perhaps partly because of the shared "40%" level, it is often supposed that the $F_{40\%}$ harvest rate will reduce spawning biomass to 40% of unfished biomass, but that is only true for stocks with highly resilient spawner-recruit relationships. For less resilient stocks, $F_{40\%}$ will reduce biomass to a lower level, possibly much lower, while still providing a yield near MSY. That is possible because yield is not very sensitive to equilibrium biomass over a wide range of biomass levels, so a yield near MSY can be obtained even when biomass is well below B_{MSY}. It is this feature of yield curves that makes it possible for a rate like $F_{40\%}$ to perform well in terms of yield over a wide range of spawner-recruit productivity curves. For some curves $F_{40\%}$ is well above F_{MSY} and for some of the curves it is well below, but in none of the cases considered is it so far above or below F_{MSY} that yield is much lower than MSY.

For the most likely sort of groundfish spawner-recruit relationships (i.e., asymptotic curves such as the Beverton-Holt model), and if other forms of stock compensation are negligible, B_{MSY} is likely to lie in the range of 25-40% of unfished biomass. Therefore, even if F_{MSY} was known and was implemented for a stock, the resulting biomass level would generally be less than 40% of B_0 on average. For some stocks, recruitment variations alone might then result in biomass levels falling below 25% of the unfished level, which is the overfished threshold as implemented in Amendment 11 to the groundfish FMP. Thus, fishing at $F_{40\%}$, which can be well above (or below) F_{MSY}, can be expected to result in biomass levels that are occasionally or on average very low for some stocks. Thus, given the new requirement of biomass-based overfished thresholds (Department of Commerce 1998), the relationship between harvest rates and biomass levels becomes more critical.

Declines of Pacific Coast Stocks Fished at $F_{35\text{-}40\%}$

Ralston (1998) showed that a number of Pacific coast rockfish stocks declined to low levels during the last two decades, contributing to concerns about the wisdom of the $F_{35\%}$ policy. His findings, as well as analyses conducted by the GMT during the preparation of Amendment 11, led to a series of workshops, including this latest review. This panel received a number of papers dealing with the productivity of the stocks in question and considered arguments for and against retaining the $F_{35\%}/F_{40\%}$ rate (in conjunction with the 40-10 rule) for all stocks.

We believe there are at least three possible factors that are responsible for the observed declines in groundfish stocks:

1. Normal operation of the $F_{35\%}/F_{40\%}$ strategy.

As explained above, either an $F_{35\%}$ or $F_{40\%}$ harvest rate will often lead to biomass levels that are well below what many people commonly expect, even when the rate is no larger than F_{MSY}. When it is larger, as will happen for some stocks, resulting biomasses can be very low. The important point is that both F_{MSY} and the proxy rate are calculated to achieve a certain level of yield, not biomass. In addition, harvesting at $F_{35\%}/F_{40\%}$ should be viewed as a risk-neutral policy in that, being a compromise intermediate rate, some stocks will be over-exploited and some stocks will be under-exploited, with no penalty imposed for over-exploitation.

2. Higher than intended harvest rates.

Recent assessments show that in many cases, actual fishing mortality rates were well above $F_{35\%}$. This can happen in any fishery when quotas are set on the basis of current biomass estimates, which are subsequently revised downward in a later assessment.

3. Apparently low productivity of Pacific coast stocks.

The spawner-recruit estimates that have accumulated over the last twenty years on Pacific coast groundfish stocks indicate very low resiliency in the spawner-recruit relationships — at or below the lowest values estimated for well-studied stocks elsewhere in the world (Myers *et al.* 1999). It is not surprising then, that the estimated productivity of these stocks is in many instances lower than the range of values considered plausible by Clark (1991) in his derivation of the $F_{35\%}$ strategy.

Because these low productivity estimates are so common among Pacific coast groundfish stocks, and so uncommon elsewhere, there is some suspicion that they result from some unrecognized flaw common to all of the Pacific coast groundfish assessments. However, with the exception of discards (see below), the panel has no reason to doubt the accuracy of west coast groundfish stock assessments. The same methods and models have produced estimates of higher productivity elsewhere (e.g., in Alaska). For the time being, therefore, we believe that all of the assessment results should be taken at face value, and that the Council's harvest strategy should be reconsidered in light of the apparently low productivity of many of the stocks.

The reason for anomalously low productivity in this region is not certain, but it may well be linked to the climatic regime shift that occurred in the eastern Pacific ocean around 1977-78. Since then, ocean conditions have been generally more favorable for many Alaskan stocks and have been less favorable for many Pacific coast stocks. Sometime in the future conditions on the west coast are likely to change again. Still, there is no assurance that this will occur in the near future and so, in the interim, the PFMC should manage groundfish stocks according to their current productive capacity.

The panel reviewed results presented by Williams (see Appendix A), which suggest that discards of small fish could contribute to the perception of low groundfish productivity. To the extent that this occurs, its effect is to reduce apparent recruitments and therefore to make groundfish stocks appear to be less resilient. This scenario depends on: (1) an increasing exploitation rate over time and (2) substantial unaccounted for discarding of the smallest fish captured. While groundfish exploitation rates have certainly risen, and substantial unaccounted for discards of small fish is likely in some fisheries, discards are generally not documented for these stock and cannot be quantified at present. Clearly more research on this issue is desirable and, in general, the panel stresses that a full accounting of total catch is necessary for the PFMC to adequately manage any of the resources under its authority.

Panel Recommendations for Default Groundfish Harvest Rates

The panel reviewed the information presented by each presenter (see Appendix A), as well as other recently published material (e.g., Myers *et al.* 1999). Of particular importance were the works of Brodziak, Dorn, MacCall, and Parrish because each of these studies broadly re-analyzed the information presented in historical PFMC stock assessments in an attempt to estimate F_{MSY} for each stock and their F_{spr} equivalents (i.e., the spawning potential per recuit fishing mortality rate). Significantly, each of these studies indicated that in many instances groundfish productivity, as estimated from the results of stock assessments, is insufficient to support harvests at the $F_{35\%}$ or even $F_{40\%}$ rates.

With respect to the rockfishes (*Sebastes* spp.) the panel found the work of Dorn to be very compelling. His results showed that, when the genus is examined as a whole through the use of meta-analysis, west coast rockfish stocks (exclusive of Pacific ocean perch) have F_{MSY} rates that range between $F_{45\%}$ – $F_{67\%}$ for risk-neutral models, assuming either the Beverton-Holt or Ricker models with lognormal or gamma errors (four cases). However, gamma error models fit the data more poorly than models with a lognormal error structure and, as a consequence, the panel supported the use of Dorn's lognormal analysis only. For that subset of cases, the estimated F_{MSY} rates ranged $F_{45\%}$ – $F_{54\%}$ over the two recruitment models. The panel then adopted $F_{50\%}$ as a midpoint, risk-neutral, proxy for rockfish F_{MSY}. In addition, the panel recommends including the thorneyheads (genus *Sebastolobus*) with the rockfish in the setting of default harvest rate proxies.

The panel discussed results for Pacific whiting and concluded that the information base for that species was the best available for any west coast groundfish. Harvests are currently determined using the 40-10 policy in association with a fishing mortality rate equal to $F_{40\%}$. This rate is based on a separate and distinct meta-analysis of worldwide *Merluccius* productivity that was conducted as part of the last stock assessment (Dorn *et al.* 1999) and seems appropriate as a risk-neutral harvest policy. Consequently, the panel does not recommend any changes in harvest rate for Pacific whiting.

For flatfishes (including Dover sole), the panel concluded that resiliency is typically higher than in other taxa (e.g., Brodziak *et al.* 1997, Mace and Sissenwine 1993, Myers *et al.* 1999). As a consequence, the panel recommends using a default rate of $F_{40\%}$ for all flatfish species in the groundfish FMP. This rate is consistent with the general findings of Clark (1993) and Mace (1994).

For all other species in the groundfish FMP (including sablefish and lingcod) the panel recommends an intermediate harvest rate of $F_{45\%}$. This intermediate rate was selected as a sensible risk-neutral alternative that would afford increased protection to all the remaining groundfish stocks. However, the level of certainty in setting this default rate is very low. Consequently, the panel makes two recommendations with respect to the estimation of groundfish productivity, i.e.,

(1) Assessment authors are encouraged to evaluate the resiliency of the specific stocks they model. When such analysis produces scientifically credible estimates of productivity, the analyst is encouraged to present those findings as part of their stock assessment.

However, any productivity analysis should always include a measure of the uncertainty in the point estimates of management reference points (e.g., F_{MSY}, B_{MSY}, and B_0).

(2) A proper consideration of risk is essential in the setting of optimum yields for west coast groundfish stocks. Utilization of a risk-neutral harvest rate proxy (e.g., $F_{50\%}$ for *Sebastes* and *Sebastolobus*) implies that some stocks within the group are quite likely to be over-exploited. Similarly, calculation of an ABC using an unbiased stock-specific point estimate of F_{MSY} will result in overfishing if the estimate is, by chance, too high. It is the PFMC's responsibility to account for these risks of overfishing through the use of a precautionary approach in the establishment of optimum yields. In addition, the NMFS Guidelines specify that status determination criteria must specify a maximum fishing mortality rate threshold that is less than or equal to F_{MSY} (Department of Commerce 1998). While this issue is not specifically addressed in this report, the choice of the threshold should depend on the level of uncertainty associated with the estimate of F_{MSY} or its proxy.

In summary, panel recommendations with respect to risk-neutral default harvest rate F_{MSY} proxies for west coast groundfish are:

Pacific whiting	$F_{40\%}$
Sebastes & Sebastolobus	$F_{50\%}$
Flatfish	$F_{40\%}$
Other groundfish	$F_{45\%}$

Due to a lack of detailed life history and stock status information, it will not be possible to implement these recommendations for many stocks. In particular, the "remaining rockfish" management unit (PFMC 1999) includes a number of species for which the ABC has been set using the F=M harvest rate proxy (Rogers *et al.* 1996). Currently, the optimum yield (OY) of those species is reduced by 25% as a "precautionary adjustment" (PFMC 1999), amounting to an F=0.75M policy. The panel discussed the remaining rockfish category in light of results presented in MacCall's production model analysis (Appendix A), which indicated that 0.40M may be a better proxy for an optimal exploitation rate. However, due to the review panel's unwillingness to fully endorse production modeling as a viable means of estimating groundfish productivity (see below), the panel recommended that the PFMC establish F=0.75M as the default, risk-neutral policy for the remaining rockfish management category. This determination was consistent with results presented for Pacific ocean perch, for which $F_{MSY} \approx 0.80M$. Even so, concern was expressed within the panel that a more conservative harvest rate might be warranted, such as that used by the North Pacific Fishery Management Council, which in similar swept-area applications assumes that q=1.0. In either case, given the high degree of uncertainty underlying the technical basis of this recommendation, and the real possibility that MacCall's findings are accurate, precautionary adjustments in setting the OY of the remaining rockfish are recommended.

The panel discussed the hardship to the fishing industry that the immediate application of these new, more restrictive, rates will cause. The National Standard Guidelines for implementation of the Magnuson-Stevens Act specify (Department of Commerce 1998): "Overfishing occurs whenever a stock of stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis." The PFMC may, therefore, wish to consider the propriety and legality of a short-term phase-in of these new rates to ameliorate the immediate impact to the groundfish industry.

Surplus Production Models

During the workshop, methods considering an examination of the relationship between surplus production and stock biomass were discussed as potential alternatives to methods based on stock-recruit models for determining appropriate exploitation rates. The panel generally agreed that an examination of estimates of surplus production and their relationship with estimates of biomass or other variables is useful. However, the panel does not endorse the general replacement of a stock-recruitment based approach at this time, nor the requirement of using a biomass-based surplus production model as one approach for estimating MSY, F_{MSY} and B_{MSY} for all assessed stocks. The panel concluded that this is an area that could benefit from additional research.

There were three presentations dealing with biomass-based production model approaches on the agenda (Jacobson *et al*, MacCall, and Parrish; see Appendix A). The fundamental premise of these approaches was to use the output from a detailed age-structured model as an accurate representation of exploitable stock biomass (i.e., assume $q = 1.0$) and to estimate the relationship between catches and changes in biomass to determine production. Most of the panel concluded that this kind of approach has potential application when applied to estimates generated from age-structured or delay-difference assessments. This is possible because absolute stock biomass estimates are generally available from the assessment models and, by definition, estimated surplus production can be calculated from the time series of catch and estimated biomass. The disadvantage of this approach, however, is that the various biological processes underlying stock compensation are not directly addressed, whereas in age-structured approaches these processes can be treated explicitly. Whether surplus production is estimated internally within the model (e.g., Jacobson *et al.*) or externally after the fact (MacCall, Parrish), is an issue deserving of more study (see also results from Ianelli).

Although the full panel saw benefits to explicit consideration of biomass production implied by assessments, some panelists expressed significant reservations regarding the use of production models to determine F_{MSY} and related quantities. These reservations were largely based on the view that this approach discards important information contained in the original age-structured model results. For example, age-structure can influence production because young fish generally have higher weight-specific growth rates than older fish. As a result, the same biomass can lead to different levels of production, depending upon the age composition of the population. Likewise, changes in selectivity over time will change the amount of surplus production at a given biomass. Although such variation in surplus production could be dealt with as correlated process error (Jacobson *et al.*) this converts variation explained by the age-structured model into additional error. In any event, age-structured analyses can provide specific information on the nature of compensation (e.g., in individual growth, maturation, or recruitment), which is not possible from an examination of the aggregate surplus production-biomass relationship alone.

Other panelists argued that estimates of F_{MSY} from surplus production models might be more robust than those that depend upon solely on stock-recruitment relationships. The idea here is that (1) error in assessment model estimates of biomass may cancel-out because production estimates involve differencing model biomass estimates, and (2) potentially biased estimates of recruitment (e.g., discards of small fish) play a less critical role in the analysis. Simulations presented by MacCall at the second Groundfish Productivity Workshop in Monterey, CA suggested this was the case. However, given the few number of replicate simulations and the limited suite of scenarios in that paper, the panel did not view this work as definitive.

Estimation of B_0, B_{40} and Related Problems

Although variable rate biomass-based harvest policies were not the primary focus of the workshop, the newly implemented 40-10 harvest policy was, nonetheless, the subject of much discussion. While in practice it is possible to consider F_{MSY} proxies in isolation from biomass targets and thresholds, in principle these two subjects are inextricably linked.

The main concern about the 40-10 harvest policy is that it involves the calculation of two biomass reference points, i.e., the virgin biomass that would exist in the absence of fishing (B_0) and the exploited biomass that is 40% of that pristine level ($B_{40\%}$). Within the PFMC, it appears that parameter B_0 is usually obtained from a stock assessment model and estimates of what biomass may have been in the far past.

A number of problems are likely to occur in the estimation of this parameter. First, its estimated value may be far larger than any historical observed biomass due to vagaries of parameter estimation and the age composition of the population at the start of the data series (e.g., Pacific ocean perch; see Ianelli in Appendix A). In some cases, it may be justifiable to constrain the value of B_0 to be near the historical maximum or some other value, as long as a clear rationale is provided and the sensitivity of the constraint is examined.

A second problem is that models are frequently configured to assume that the age composition is at equilibrium at the start of the modeled period. If this assumption fails, then the estimate of parameter B_0 may be biased. Third, there is no guarantee that under any fishing mortality regime, including zero fishing, that the population will rebuild to this level. The reason for this is that the amount of recruitment needed to produce historical levels of spawning biomass may not occur in the future. Given that many West Coast stocks have been on a "one-way trip" downward, a sensible harvest policy would first reverse the decline, and then rebuild to a level that could be expected based on current and expected future conditions. Once that level of rebuilding is accomplished, it may then be possible to rebuild toward a level consistent with historical patterns.

Therefore, some alternatives for calculating B_0 that look toward the future instead of the past should probably be considered. Two clear alternatives involve determining: (1) whether a spawner-recruit model is used to project the population forward and (2) if not, what exact values of the recruitment time series are to be used in forecasting future biomass. If a spawner-recruit model is used, then it should be possible to determine pristine biomass and B_{MSY} as reference points automatically. These points can then be implemented in the harvest policy, as is done by the North Pacific Fishery Management Council. However, it is often quite difficult to assert that a reliable spawner-recruit relationship is known, so typically such a relationship would not be invoked. Nevertheless, it is often wise to provide for reduced recruitment at low spawning biomass levels, particularly if the stock has been fished down to a point where recruitment is believed to have been impacted. Some recent modeling efforts with ADMB and Bayesian considerations (e.g., Pacific hake) lend hope to better determining MSY parameters.

If a spawner-recruit relationship is not used, then a projection of future unfished equilibrium biomass can be made by multiplying contemporary recruitment values by the corresponding spawner biomass per recruit (SPR) function. For example, the average recruitment over the time series might be used with an SPR function at a fishing mortality of 0 to arrive at the expected equilibrium unfished biomass in the future, to be used as B_0. From this information $B_{40\%}$ could be obtained. This type of approach is especially appropriate if it is known there has been a change in stock productivity. A caveat to doing this, however, is that it can be very difficult to detect a change in productivity, so the rationale for restricting the time period must be carefully considered.

Whichever approach is used, it should be documented carefully and properly justified. The same methodology should be used for all biomass reference points and it should be clearly stated whether a reference point is based on SPR calculations that are fully independent of spawning biomass, or whether recruitments have been adjusted downward by a spawner-recruit relationship. We think justification for the calculation of biomass reference points should address consistency between the assumptions used in their derivation and those underlying F_{MSY} estimates or proxies.

We note that another type of calculation is required by the NMFS overfishing guidelines, which could lead to further confusion. Namely, a threshold level that provides for a 10-year rebuilding to a target level such as B_{MSY} must be found (Department of Commerce 1998). This level is also a function of the recruitment series used and depends on whether a spawner-recruit relation exists. Consequently, for consistency the same process that is used for determining other reference points should be used here. The PFMC has apparently been allowed to use $B_{25\%}$ for this threshold, but it is unclear how rebuilding plans, which are triggered when biomass drops below this value, will interface with the 40-10 rule, which in itself, is an automatic rebuilding plan. Other Councils are currently experiencing this confusion as well, so hopefully there will be more flexibility and clarity in the NMFS overfishing guidelines in the future.

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WEST COAST GROUNDFISH PRODUCTIVITY WORKSHOP
Scientific & Statistical Committee, Pacific Fisheries Management Council
Room 2079, Building 4, Alaska Fisheries Science Center
7600 Sand Point Way NE, Seattle, Washington

AGENDA

Monday, March 20

1:00 pm Workshop Introduction

James Hastie: *An historical overview of Pacific Fishery Management Council groundfish harvest policy.*

William Clark: $F_{35\%}$ *revisited after ten years.*

Alec MacCall: *Designing fishery management and stock rebuilding policies for conditions of low frequency climate variability.* (preview of a paper to be presented at the PICES meeting in San Diego later this week)

Tuesday, March 21

8:00 am R. A. Myers: *The meta-analysis of the maximum reproductive rate for fish populations to estimate harvest policy; a review.*

Martin Dorn: *Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit dynamics.*

Ray Hilborn: *Exploitation rate reference points for west coast rockfish: are they robust and are there better alternatives?*

12:30 pm Lunch

1:30 pm Larry Jacobson: *Try and estimate* F_{msy} *in every stock assessment model!*

David Sampson: *FINDFMSY: a fishery simulator for exploring constant harvest rate policies.*

Wednesday, March 22

8:00 am Richard Parrish: *A synthesis of the surplus production and exploitation rates of 10 west coast groundfish species.*

Alec MacCall: *Summary of known-biomass production model fits to west coast groundfish stocks.*

Jon Brodziak: *In search of optimal harvest policies for west coast groundfish.*

12:30 pm Lunch

1:30 pm James N. Ianelli: *Simulation analyses testing the robustness of harvest rate determinations from typical west-coast rockfish stock assessment data.*

Erik Williams: *The effects of unaccounted discards and mis-specified natural mortality on estimates of spawner-per-recruit based harvest policies.*

Thursday, March 23

8:00 am Discussion / Public comment

12:00 Lunch

1:00 pm Panel deliberation

Friday, March 24

8:00 am Panel deliberation (if required)

APPENDIX C

Glossary of Terms

ABC	allowable biological catch; the product of the fishing mortality rate that produces MSY (or its proxy) and the current exploitable biomass of a stock.
B	The current exploitable biomass of a stock.
$B_{unfished}$	the size of a stock (in biomass) if there were no fishing.
B_{msy}	the size of a stock (in biomass) if it is fished indefinitely at a constant rate equal to F_{msy}.
$B_{40\%}$	the size of a stock when it is 40% of $B_{unfished}$; this is currently the precautionary threshold if B_{msy} has not been explicitly estimated.
$B_{25\%}$	the size of a stock when it is 25% of $B_{unfished}$; this is currently the overfished threshold if B_{msy} has not been explicitly estimated.
$B_{10\%}$	the size of a stock when it is 10% of $B_{unfished}$.
F_{msy}	the fishing mortality rate that produces MSY.
$F_{40\%}$	the fishing mortality rate that reduces the reproductive output of a female to 40% of what it would be in the absence of fishing.
$F_{45\%}$	the fishing mortality rate that reduces the reproductive output of a female to 45% of what it would be in the absence of fishing.
$F_{50\%}$	the fishing mortality rate that reduces the reproductive output of a female to 50% of what it would be in the absence of fishing.
GMT	Groundfish Management Team; a task-oriented advisory committee to the Council that deals principally with management issues.
M	the natural mortality rate of a stock, i.e., the expectation of death due to all other sources of mortality other than fishing (e.g., predators, parasites, starvation, etc.).
MSY	maximum sustainable yield; in theory, the largest amount of catch that can be obtained on a continuing basis by applying a constant harvest rate.
OY	optimum yield; the amount of fish that is prescribed on the basis of MSY from the fishery as reduced by any relevant economic, social, or ecological factors.
risk-averse	(e.g. as in a risk-averse estimate of F_{msy}) more likely to be an underestimate than an overestimate of the actual F_{msy} (precautionary)

risk-neutral	(e.g. as in a risk-neutral estimate of F_{msy}) equally likely to be an overestimate or an underestimate of the actual F_{msy}
risk-prone	(e.g. as in a risk-prone estimate of F_{msy}) more likely to be an overestimate than an underestimate of the actual F_{msy}
SAFE	Stock Assessment and Fishery Evaluation; the Council's annual report on the status of groundfish resources.
SPR	spawning potential per recruit; a way of rescaling fishing mortality rate to standardize its effect on the reproductive potential of a individual fish entering the exploitable phase of the population.
SSC	Scientific and Statistical Committee; an advisory body to the Council that deals primarily with scientific and technical issues.