Establishing Quantitative Criteria for Assessing Adequacy of Progress Towards Rebuilding Overfished West Coast Groundfish Stocks.

Summary of a meeting held at the SWFSC, Santa Cruz Laboratory, November 16-17, 2004 (participants: Steve Ralston, Alec MacCall, Andre Punt, Xi He, Marc Mangel, Anand Patil, Steve Munch, Rick Methot)

A number of west coast groundfish stocks have been declared overfished and rebuilding plans have been implemented to restore these populations to levels that can support productive, sustainable fisheries. These include: bocaccio (*Sebastes paucispinis*), cowcod (*S. levis*), canary rockfish (*S. pinniger*), darkblotched rockfish (*S. crameri*), Pacific ocean perch (*S. alutus*), widow rockfish (*S. entomelas*), yelloweye rockfish (*S. ruberrimus*) and lingcod (*Ophiodon elongatus*). In 2004 the Pacific Fishery Management Council (PFMC) adopted rebuilding plans for these species in the form of Amendments 16-2 and 16-3 to the groundfish FMP, which were approved by NMFS. All these stocks are currently being managed under very restrictive harvest guidelines that have severely constrained the entire west coast groundfish fishery. Moreover, each of these 8 species will be re-assessed in 2005 and, as a consequence, there will be an opportunity to determine whether or not stocks have responded to recovery efforts.

In developing the rebuilding plans, rebuilding analyses were conducted that were designed to meet the requirements of the NOAA Fisheries National Standard 1 Guidelines for implementing the 1996 Sustainable Fisheries Act. Specifically, these analyses determined the relationship between a rebuilding fishing mortality rate (**F**) and the probability (**P**) that a stock would recover to a population size capable of supporting maximum sustainable yield ($\mathbf{B_{msy}}$) within the maximum time allowable ($\mathbf{T_{max}}$). Under the NS1 Guidelines, $\mathbf{T_{max}}$ has been defined to be equal to $\mathbf{T_{min}}$ plus one mean generation time, where $\mathbf{T_{min}}$ is equal to the minimum amount of time a stock needs to rebuild (i.e., if fishing mortality were reduced to zero)[1]. Moreover, based upon Amendment 11 to the groundfish FMP, the Council adopted a value of $\mathbf{B_{40\%}}$ as a proxy for $\mathbf{B_{msy}}$, which is 40% of the population size that would be expected to occur if there were no fishing.

For ease of comparison among stocks and to standardize the basis of rebuilding calculations, it is useful to express any specific fishing mortality rate in terms of its effect on Spawning Potential Ratio (**SPR** = spawning/recruit relative to the unfished condition). Given fishery selectivity patterns and basic life history parameters, there is a direct inverse relationship between **F** and **SPR** (Figure 1). When there is no fishing, each new female recruit is expected to achieve 100% of its spawning potential. As fishing intensity increases, expected lifetime reproduction declines due to this added source of mortality. Conversion of **F** into the equivalent **SPR** has the benefit of standardizing for differences in growth, maturity, fecundity, natural mortality, and fishery selectivity patterns and, as a consequence, we recommend it be used routinely.

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[1]An exception occurs for stocks that are able to rebuild within 10 years (e.g., lingcod), wherein the Guidelines require rebuilding within that period, although most groundfish stocks are incapable of doing so.

For each of the eight overfished groundfish stocks the Council adopted a **P** value as a policy decision, which established a target harvest rate and implied spawning potential ratio during rebuilding. Note that in all cases the probability of rebuilding within T_{max} exceeded 0.5, ranging between 0.6 and 0.9. As shown in Figure 2, there is a direct tradeoff between the probability of recovery on or before $\mathbf{T_{max}}$ and rebuilding harvests, i.e., given a policy choice on **P**, the harvest rate is determined, which can then be used to calculate the allowable catch each year as the stock rebuilds.[2]

Given that the initial policy decision made by the PFMC was to select a value of **P**, we suggest that when an updated stock assessments becomes available, the most logical standard to invoke, when evaluating whether a stock is rebuilding at an adequate pace, is to re-calculate **P** as it depends on **SPR** = *f*(**F**), using all the new information available, and to compare the existing and updated probabilities at the prevailing target **SPR**[3]. More explicitly, if a rebuilding analysis exists that has been used to set a rebuilding policy, we denote $\mathbf{P_0}$ to be the nominal probability of stock rebuilding that was adopted by the Council (e.g., 0.60 for widow rockfish) and we denote $\mathbf{SPR_t}$ to be the existing spawning potential ratio being used to rebuild the fishery. Then, if an update occurs at time ***t+1*** we re-estimate the general relationship between **SPR** and probability of rebuilding (i.e., $\mathbf{SPR_{t+1}}$ and $\mathbf{P_{t+1}}$) and determine $\mathbf{P_{t+1}}$ given $\mathbf{SPR_t}$ ($\mathbf{P_{t+1} \mid SPR_t}$). Depending on the relationship between ($\mathbf{P_{t+1} \mid SPR_t}$) and $\mathbf{P_0}$, we envision four possible scenarios. These are:

Case A (see Figure 3): ($\mathbf{P_{t+1} \mid SPR_t}$) > $\mathbf{P_0}$ – the new information indicates that the likelihood of rebuilding the stock by $\mathbf{T_{max}}$ at the current target spawning potential ratio ($\mathbf{SPR_t}$) is greater than the initial policy choice. In this instance, maintain the current target ratio to rebuild the stock as quickly as possible and/or to build a cushion against adverse conditions that may arise in the future.

Case B (see Figure 4): 0.5 < ($\mathbf{P_{t+1} \mid SPR_t}$) ≤ $\mathbf{P_0}$ – the new, updated information indicates that the likelihood of rebuilding at the current spawning potential ratio is less than the initial policy choice but is still more likely than not (i.e., greater than a 50:50 proposition). In this instance,

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[2]Although the relationship between P{rebuilding by T_{max}} and SPR = *f*(F) is represented graphically in a simple deterministic way, in fact there is much uncertainty that is not depicted. That uncertainty is attributable to multiple sources, including: (1) measurement error, (2) process error, and (3) model specification error. The first of these can be overcome by simply increasing the number of simulated trajectories (N) used to calculate the median time to rebuild under any particular fishing rate, given the current state of knowledge. The second, which for example includes uncertainty in stock recruitment variability (σ_r) can be expected to change over time as our knowledge and understanding of stock dynamics improves. The third may also change, but may depend on falsification of assumed population dynamics. In any event, representing the P{recovery by T_{max}} = *f*(SPR) as a simple line on a graph is simplification that overstates our understanding of what we know.

[3]Note that when first applied the conversion SPR =*f*(F) for Bayesian rebuilding analyses should be based on the posterior mode.

because stock rebuilding involves the realization of a sequence of chance events, the current spawning potential ratio could be maintained.

Case C (see Figure 5): $0.0 \leq (\mathbf{P_{t+1}} \mid \mathbf{SPR_t}) \leq 0.5$ – the update suggests that rebuilding is seriously lagging and the biomass target is unlikely to be reached before $\mathbf{T_{max}}$ if the current spawning potential ratio is maintained. When this occurs the spawning potential ratio should be increased (F reduced, $\mathbf{SPR_{t+1}} > \mathbf{SPR_t}$) to insure that $0.5 < \mathbf{P_{t+1}}$.

Case D (see Figure 6): $\mathbf{P_{t+1}} < 0.5$ for all **SPR** – the update indicates that it is unlikely the stock will rebuild to the target stock size by $\mathbf{T_{max}}$, even if fishing is completely eliminated. When this situation arises the entire rebuilding plan may need to be redone and $\mathbf{T_{max}}$ re-estimated.

The group discussed some of the possible reasons why a stock may not rebuild as quickly as initially forecast. Obviously, chance recruitment events during rebuilding may have a very significant influence on the speed of recovery, and that is why rebuilding projections are based on stochastic simulations involving many hundreds or thousands of "realizations." However, another problem that has the potential to retard stock recovery occurs when harvests exceed the calculated allowable catch (i.e., overages). Hence, in order to evaluate how important this issue is, the group suggested that the relationship of $\mathbf{SPR_{t+1}}$ and $\mathbf{P_{t+1}}$ be calculated in two different ways (Figure 7). In the first case, these quantities would be determined using all of the available information, including the actual catches that occurred during the period between **t** and **t+1**. In the second case, the allowable catches that were estimated at time **t** would be substituted for the actual catches that occurred. Thus, any difference in the relationship between $\mathbf{SPR_{t+1}}$ and $\mathbf{P_{t+1}}$ would be attributable to insufficient constraints on fishing, which may then trigger a more aggressive reduction in harvest rate than if there were no appreciable difference in **P** values.

Another factor that should be considered, and may provide some flexibility to the Council, is the effect of a change in the estimate of exploitable biomass from assessments conducted at times **t** and **t+1**. Even if the target **SPR** rate has been achieved and actual catches have been equal to projected catches, the total allowable catch (TAC) may change markedly if there is a change in the estimate of exploitable biomass.

Recommendation:

- We recommend that a series of simulations be conducted to evaluate the stability and performance of the management system relative to the choice of $\mathbf{P_0}$, i.e., the initial rebuilding policy established by the Council. Obviously, conservative management (selection of a high $\mathbf{P_0}$) will require less adjustment to the target **SPR** rate (Cases C and D) and would be expected to rebuild stocks more quickly, but will require a greater reduction in catch in the short-term. The simulations should: (1) explore the relationship between $\mathbf{P_0}$ and the frequency of occurrence of the 4 cases described above and (2) estimate the optimal increase in SPR (i.e., reduction in fishing) when appropriate (i.e., optional in Case B, required in Cases C and D).

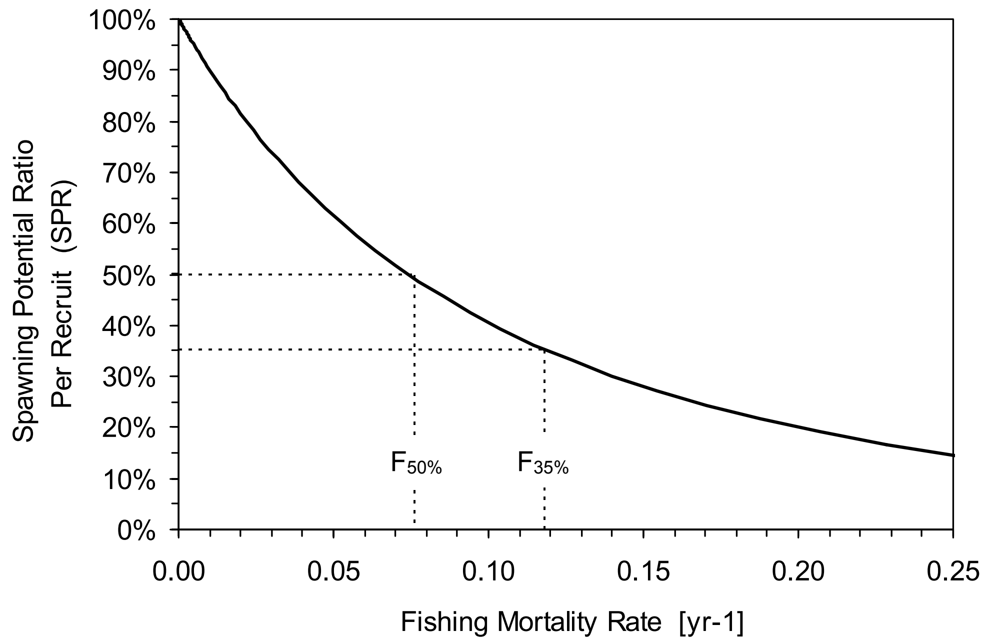

Figure 1. Relationship between spawning potential ratio (SPR) and instantaneous fishing mortality for a hypothetical rockfish.

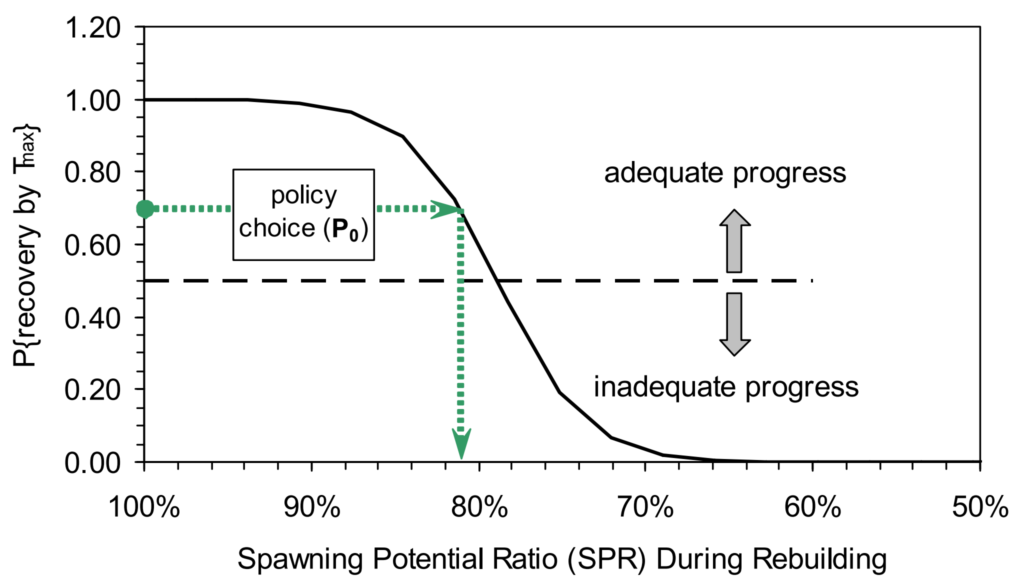

Figure 2. How management policy defines harvest rate during the rebuilding period. The more certain rebuilding, the lower the harvest rate. Minimally, there must be at least a 50% probability of rebuilding within T_{max}.

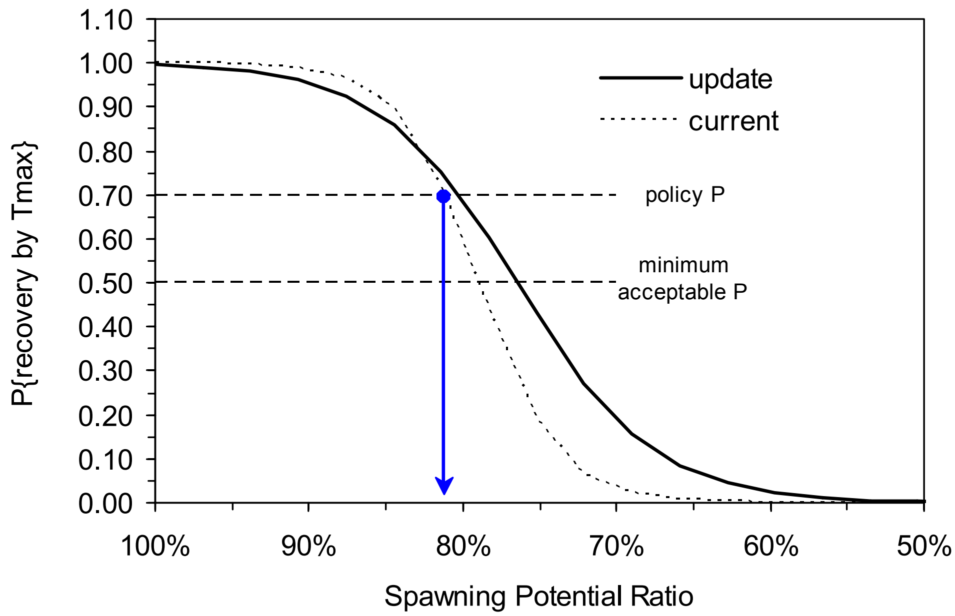

Figure 3. Case A: $(\mathbf{P_{t+1}} \mid \mathbf{SPR_t}) > \mathbf{P_0}$ – Status improves and rebuilding is more certain if catches are based on the current harvest rate.

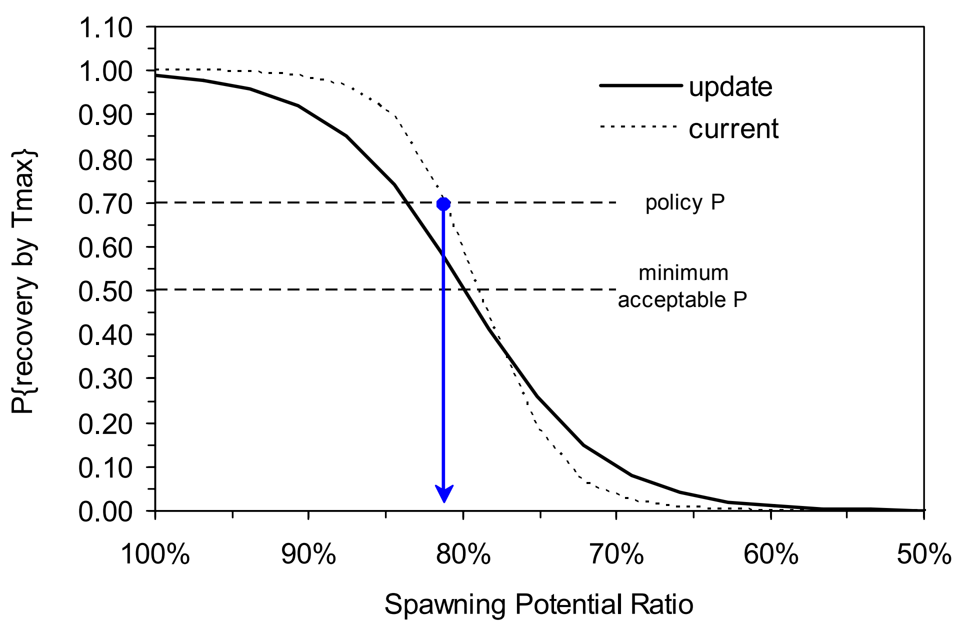

Figure 4. Case B: $0.5 < (\mathbf{P_{t+1}} \mid \mathbf{SPR_t}) \leq \mathbf{P_0}$ – Status deteriorates but rebuilding is still likely to occur if catches are based on the current harvest rate.

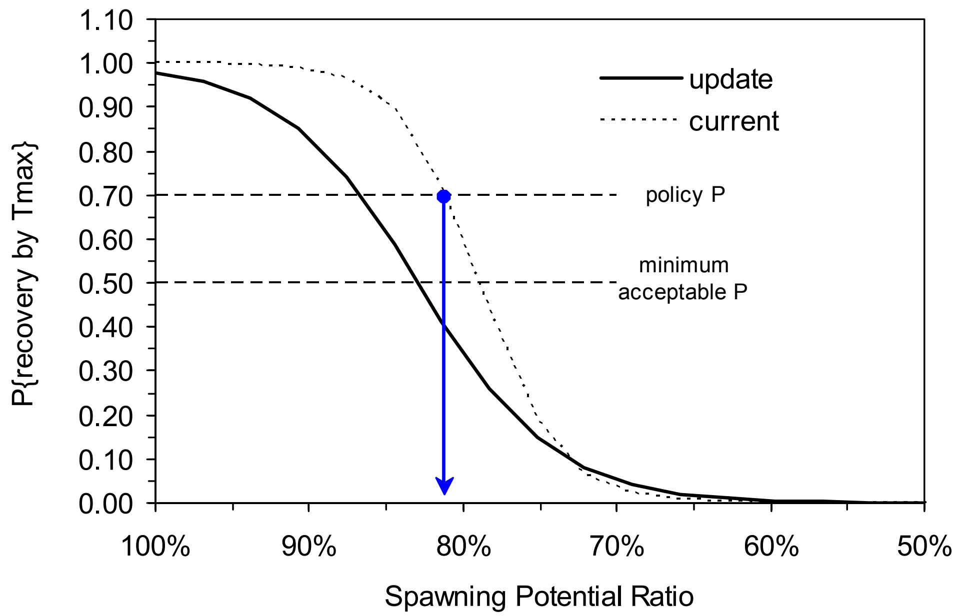

Figure 5. Case C: $0.0 \leq (\mathbf{P_{t+1}} \mid \mathbf{SPR_t}) \leq 0.5$ – Status deteriorates and stock rebuilding is deemed to be inadequate – harvest rate must be lowered.

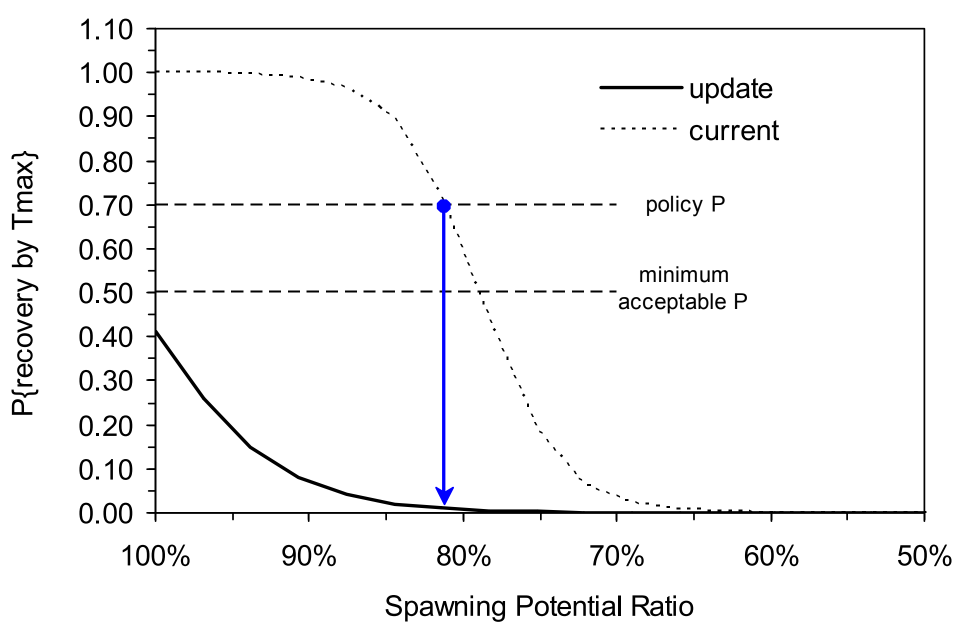

Figure 6. Case D: $\mathbf{P_{t+1}} < 0.5$ for all **SPR** – Rebuilding is unlikely to occur even if harvest rate is reduced to zero.

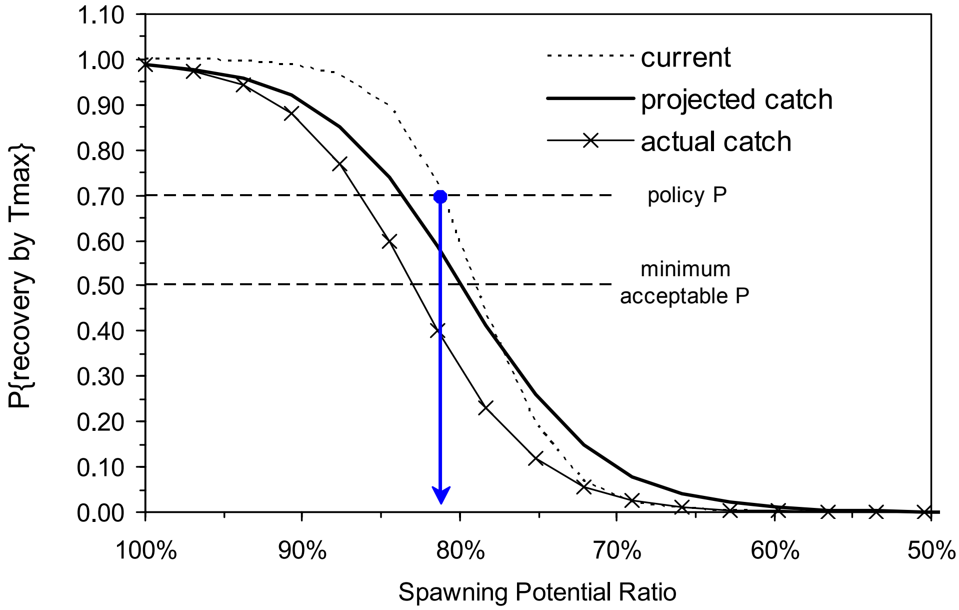

Figure 7. Evaluating the effect of actual catches versus projected catches on rebuilding success. In this example, if projected catches had actually occurred the stock would be recovering at an acceptable pace. However, because actual catches exceeded the allowable catch, recovery has been retarded to the extent that a change in SPR is warranted.