Workshop on

Status Determination Criteria in Data-Poor Situations

30-31 May 2001
Seattle WA

Introduction

The workshop on Status Determination Criteria in Data-Poor Situations was a follow-on to a previous workshop on National Standard 1 Guidelines held 19-20 July 2000 in Tampa, FL. The agenda is attached as **Appendix 1** and the list of participants as **Appendix 2**. The meeting was chaired by Pamela Mace from the Office of Science and Technology, and Anne Hollowed from the Alaska Fisheries Science Center.

The objectives of the meeting were:

(i) To discuss and evaluate methods currently being used by Fishery Management Councils, or under development by Councils, SSCs, or NMFS scientists to characterize status determination criteria in data-poor situations; i.e., methods for determining thresholds associated with "overfishing" and "overfished" when MSY-based reference points cannot be estimated explicitly or such estimates are deemed unreliable. (Note that the interpretation of "data-poor" should be broad in the sense that, even for species for which considerable data exist, there may be considerable uncertainty in the estimation of MSY-based reference points.)

(ii) To share information on the types of SDC methodologies being employed in different regions and to evaluate their applicability to other species/regions.

(iii) To augment the range of methods currently available for characterizing SDC, while still satisfying the MSFCMA and the National Standard 1 guidelines; i.e., to enhance flexibility while maintaining scientific validity.

Following is a summary of the methods and concepts presented, together with pertinent points raised in workshop discussions.

Regional Presentations

Session 1. Methodologies used in the Alaska (NPFMC) region

NPFMC harvest guidelines - Anne Hollowed (AFSC)

Status determination criteria adopted by the North Pacific Fishery Management in 1998/99 are summarized in **Appendix 3**. The maximum fishing mortality threshold (MFMT) is prescribed on the basis of six tiers corresponding to descending order of information availability.

A minimum stock size threshold (MSST) is also defined for the first three tiers only. The catch corresponding to fishing at a rate equal to the MFMT is referred to as the "overfishing level" (OFL). The acceptable biological catch (ABC) is less than the OFL. Bering Sea pollock is the only stock managed under tier 1. Investigations are underway to evaluate whether selected Bering Sea flatfish stocks could be managed under tier 1. There are also relatively few stocks managed under tier 2, which has similar high data requirements. Most core species are assessed and managed based on tiers 3 and 4. For tier 5, the OFL is defined by $F_{OFL} = M$, and the ABC is defined by $F_{ABC} \leq 0.75 \times M$. For the most data-deficient tier (tier 6), the OFL is based on the average catch from 1978 through 1995 (unless the SSC establishes a different baseline on the basis of best available scientific information), and the ABC is set equal to 75% of the OFL.

In general, for the type of information collected and the length of most time series in the Alaska region, it is much easier to determine whether overfishing is occurring than it is to determine whether a stock is overfished. This is because it is often possible to approximately estimate fishing mortality as the ratio of observed catch to swept area biomass from research surveys and to compare this to an F-based biological reference point, whereas the time series of estimates of biomass itself is usually insufficient to derive biomass-based reference points.

In the Gulf of Alaska, there are 100 management units (stocks, species or groups) included in the annual Report to Congress on the status of fishery resources (the annual Report to Congress). For the Bering Sea & Aleutian Islands, 141 management units are included. In both cases, the status of by far the majority of the management units is unknown in terms of reference points related to either overfishing, or overfished, or both.

"Other" species - Sarah Gaichas (AFSC)

Recently, the NPFMC has become increasingly concerned with determining the status of species such as sharks (e.g., dogfish, sleeper and salmon shark), skates (3 species of *Raja* spp. and 5 or 6 of *Bathyraja* spp.), sculpins (30 or more species), smelts (capelin, eulachon and rainbow smelt), squid (up to 9 species), and octopus (including pelagic octopus and the giant Pacific octopus), which are mainly taken as bycatch. This concern has been fueled by increased emphasis by scientists, managers and the public in general on ecosystem-based management. "Other species" are managed by setting an aggregate annual quota; however, it is also important to prevent overfishing of any single component within the aggregate. In theory, several sources of data can be used to assist in assessing the status of groups within the aggregate. These include catch by species based on observer data with coverage levels of the order of 30%, annual estimates of aggregate total catch, triennial bottom trawl survey biomass estimates, and life history information from similar species. The problem is that data on catches and abundances for these species are extremely "noisy" and result in estimates with high variances. Models accounting for both observation error and process error (which includes all aspects of "natural variability") for multi-species, data-poor situations such as these have been developed by Sarah Gaichas and Jim Ianelli of the Alaska Center (**Appendix 4**) and are currently being investigated further. These models are used to estimate historical exploitation rates and to project future rates. One problem is that impossible exploitation rates (e.g., > 100%) may be estimated for some species that are not sampled well by bottom trawl surveys.

Discussions of this methodology netted diverse opinions about the validity of estimates of absolute abundance based on swept area and catchability. The bias in estimated exploitation rates will be linear with the bias in estimates of absolute abundance. Catchability is extremely difficult to estimate for species that are not well sampled and prior distributions of catchability based on other studies may be of only limited utility. There was, however, general agreement that more and better research surveys should be a data collection priority. Gear mensuration equipment to monitor gear performance is also critical. The area swept can differ with depth and other factors, but with adequate gear mensuration instruments it is possible to measure the actual area swept. Of course, this only solves part of the problem.

Another recent development concerns work by various scientists on the applicability of the data-poor default harvest guidelines for species such as west coast rockfish stocks, many of which have extremely low productivity. Even without invoking the precautionary approach and taking uncertainty in biological estimates into account, optimal harvest rates have been shown to be much more conservative than those invoked in the past (**Appendix 5**). This work is discussed further in the next section.

Session 2. Methodologies used in the Northwest (PFMC) region

Rick Methot (NWFSC)

PFMC harvest guidelines for west coast groundfish are similar in several ways to those used by the NPFMC. Overfishing is defined to occur if $F > F_{MSY}$ and a stock is defined to be overfished if $B < ½ B_{MSY}$. However, even though 17 of the 82 stocks have full assessments, none have sufficient information to estimate MSY-based reference points. For this reason, proxies based on various percentage levels of $F_{\%SPR}$ are used to represent overfishing and $B < 0.25 B_0$ is used to represent the overfished condition. Over time, the default values for the $F_{\%SPR}$ threshold have become increasingly more conservative as experience has demonstrated lower productivity levels than those assumed earlier. Currently, a default of $F_{40\%}$ is used for flatfish, $F_{45\%}$ for roundfish, and $F_{50\%}$ for rockfish. For species with inadequate data to estimate $F_{\%SPR}$ reference points, OY is set even more conservatively.

The evolution towards more conservative default values for $F_{\%SPR}$ thresholds for west coast groundfish is a result of the recognition that some species, particularly rockfish, have low productivity and low resilience as demonstrated by unusually low steepness of the stock-recruitment relationships (**Appendix 5**). A harvest policy workshop convened in March 2000 concluded that the resiliency of Pacific coast groundfish is probably near or below the lower limit for well-studied species throughout the world (**Appendix 6**).

New approaches being investigated for data-poor species include several that “borrow” missing data from related species or fisheries. For example, approximate assessments may be able to be derived using production models that link the catch history for the species of concern with effort data from one or more other fisheries that capture this species using similar gear at a similar time of year. Although this method may not provide good estimates of absolute biomass, it holds promise for deriving time trends in biomass or numbers. This technique has been applied to canary rockfish using the ASPIC non-equilibrium production model.

Session 3. Methodologies used in the Northeast (NEFMC) region

Andy Applegate (NEFMC)

The NEFMC convened an overfishing definition review panel to provide recommendations on status determination criteria in 1998. This panel developed analyses and recommendations for 45 stocks, many of which are “data-poor”. For data-moderate and data-rich cases, the review panel relied heavily on ASPIC to provide estimates of MSY-related reference points. For data-rich cases (i.e., those for which VPA’s are conducted), the panel developed a “biomass-weighted F” in order to facilitate comparability between ASPIC and VPA results.

Methods employed in data-poor cases include those based on research survey time series with no or little other reliable data to use for calibration, fishing mortality reference points from yield per recruit analysis, and “empirical” estimates of MSY based on catch history data. In some cases, swept area estimates of biomass from research survey data are used; in others, some percentile of the survey time series is selected to represent a threshold.

Some examples of status determination criteria used in data-poor cases

Monkfish: Monkfish in the northern and southern management areas are defined as being overfished when the three year moving average autumn survey weight per tow falls below the 33^{rd} percentile of the time series, 1963-94, or when fishing mortality exceeds $F_{threshold}$, where $F_{threshold}$ is based on conditions of stock stability at high abundance, calculated as the fishing mortality that prevailed during 1970-79.

Offshore hake: Offshore hake is in an overfished condition (overfishing is occurring) when the three-year moving average weight per individual in the autumn survey falls below the 25^{th} percentile of the average weight per individual from the autumn survey time series 1963 - 1997 (0.236) AND when the three-year moving average of the abundance of immature fish less than 30 cm falls below the median value of the 1963-1997 autumn survey abundance of fish less than 30 cm (0.33). The idea behind this definition was to avoid low biomass when recruitment was poor. This definition equates overfishing and overfished.

Southern Red Hake: Southern red hake is in an overfished condition when the three-year moving average weight per individual in the autumn survey falls below the 25^{th} percentile of the average weight per individual from the autumn survey time series 1963 - 1997 (0.12) AND when the three-year moving average of the abundance of immature fish less than 25 cm falls below the median value of the 1963-1997 autumn survey abundance of fish less than 25 cm (4.72). This definition also equates overfishing and overfished.

Winter skates: Winter skate is in an overfished condition when the three year moving average of the autumn survey mean weight per tow is less than one-half of the 75^{th} percentile of the mean weight per tow observed in the autumn trawl survey from 1967-1998 (currently 3.23 kg/tow). Overfishing occurs when fishing mortality, derived from the latest five years of spring survey data, exceeds natural mortality, M (0.1).

Group discussions on these and similar definitions focused on the perceived arbitrariness of the survey estimate percentiles employed, and the fact that these may or may not be related to situations where a stock was overfished or overfishing was occurring. Used of observed percentiles assumes that the stock was overfished during at least some part of the time series. Use of common percentiles in several definitions implies that different stocks and species experienced similar trends in relative stock status over the duration of the survey time series. Several participants commented that the power of arbitrary rules such as these may actually be quite low. It was suggested that these types of rules should be tested by applying them to data-rich stocks and determining how well they work in terms of Type I and Type II errors.

In data-poor situations (and, in fact in many so-called “data-rich” situations), it may often be necessary to choose between two difficult alternatives: (i) restrict analyses to those data contained in a myopic time series, or (ii) try to reconstruct history based on very limited information.

Paul Rago (NEFSC)

Paul Rago presented a summary of graphical and empirical methods for biomass dynamics models, using summer flounder as an illustrative example. One suggestion was to develop “envelope plots” that bracket the likely range for estimates of population size by defining a minimum (e.g., the recorded catch itself; this assumes an infinite F) and a likely maximum (e.g., the recorded catch divided by a small F). These can then be plotted along with swept area biomass estimates based on survey data assuming various efficiency levels. Prior distributions for efficiency (catchability) may be obtainable from VPA analysis tuned using survey data, although it must be kept in mind that catchability can vary substantially between species. Applications of the Cook-Weisberg Confidence Interval method and funnel pots that track how quickly estimates converge as more data are added to a series were also presented. For summer flounder, the funnel plots showed that additional data did not necessarily result in convergence of estimates of F_{MSY}, MSY and catchability. This is at least partly because earlier data were collected during periods of high F and low B, whereas recent rebuilding efforts have led to reduced F and greater B, so that recent data are derived from a totally different part of the biomass spectrum. Similarly, the previous situation was one in which about 90% of the summer flounder population consisted of individuals less than or equal to two years of age. With rebuilding, more age classes have been added. With the increase in contrast of biomass estimates and the expanded age structure, it is not surprising that estimates of MSY-based reference points would change over time.

Session 4. Methodologies used in the Southeast (SAFMC, GMFMC, and CFMC) region

Jerry Scott (SEFSC)

In the southeast region, a system for estimating MSY-based reference points has recently been developed, assuming five tiers of data availability and assessment capability. The first three levels are applicable for data-rich or data-moderate situations. Level IV applies to the case where an estimate of current F relative to an F_{MSY} proxy is available, but biomass cannot be classified even in a qualitative manner. Level V applies to cases where neither estimates of F nor B are available. At both levels, management actions are then based on classifying the catch history into periods when catches are stable and when they are not. For Level IV stocks, it is then assumed that the current catch is equivalent to MSY; $B_{MSY} = (MSY/F_{current})*(F_{current}/F_{MSY})$; and $B_{current} = Catch/F_{current}$. For Level V stocks, it is assumed that $F_{MSY} = M$; $F_{current} = F_{MSY}$; and $B_{current} = B_{MSY}$. Overall, unless there is evidence to show otherwise, it is assumed that a stock is currently at a biomass level of B_{MSY}, with the current catch corresponding to MSY and a fishing mortality rate of F_{MSY}. This general framework has been adopted by the South Atlantic and Caribbean Councils, although at the time of this workshop, it had not yet been adopted by the Gulf Council.

By far the majority of species in the southeast region fall into the Level V category. Two methods for dealing with extremely data-poor (Level V) stocks are:

(i) to link the status of data-poor species to the status of indicator species with better information, and
(ii) to group related stocks and/or species into complexes.

Preliminary estimates of MSY-related reference points and proxies have been made for several FMP stocks using this system.

Discussion of the tiered approach was generally favorable, except that several participants questioned the wisdom of assuming that Level V stocks are being maintained at B_{MSY} and fished at F_{MSY}, unless shown otherwise.

Session 5. Methodologies used in the WPFMC region

Chris Boggs (SWFSC)

Overfishing definitions and control rules have been developed and used to evaluate stock status for Pacific highly migratory species. These studies are summarized in the following reference:

Boggs, C., P. Dalzell, T. Essington, M. Labelle, D. Mason, R. Skillman and J. Wetherall. 2000. Recommended overfishing definitions and control rules for the western Pacific regional fishery management council's pelagic fishery management plan. Southwest Fisheries Science Center Administrative Report H-00-05. National Marine Fisheries Service, NOAA.

Although stock assessments have been conducted for many of the species managed under the WPFMC pelagic fishery management plan, most species are considered to be "data-poor". Analytical methods used include production models and Multifan-CL. For assessed species, most are considered to be underutilized, with current fishing mortalities estimated to be well below F_{MSY} and biomasses well above B_{MSY}. The exceptions are bigeye tuna and eastern Pacific yellowfin tuna where fishing mortalities need to be reduced, although estimated biomasses are well above the level at which the stocks would be defined as overfished.

Paul Dalzell (WPFMC)

Hawaiian Islands reef fish species are exploited by about 5,000 commercial vessels and more than 15,000 recreational vessels. There is a 50+ year time series of catch (since 1948), but no fishery-independent data at all. During the period 1948-70, estimates of catch per fishing day exhibited no discernible trend and, since this period largely precedes the rapid expansion in numbers of fishing vessels, it is assumed to approximately represent the unfished condition. Thus, an index for B_{MSY} is calculated as one half of the average catch per fishing day during 1948-70. However, there is little information on changes in fishing power and other aspects of fishing practices that could influence this index. Knowledge of the basic biology of reef fish species is also generally lacking.

Other Presentations

Marine Mammals - Barbara Taylor (SWFSC)

Fisheries analysts should consider the methodologies used by marine mammal analysts because even though the management objectives may differ, coping with data-poor situations is common to both groups of analysts.

Previously, the MSY level (MSYL) was defined under the Marine Mammal Protection Act (MMPA) to be equal to the ratio, N_{MSY}/N_0. If a stock was above this level, management was deemed unnecessary; below this level, actions were required to rebuild the stock. The method was considered unworkable due to the difficulty of estimating N_0. A new method was therefore developed that eliminated the requirement to estimate historical unexploited stock sizes. Data needs for the new method include:

A. Basic life history knowledge (defaults for population growth rates)
B. Abundance estimates with estimates of precision
C. Take estimates

The management goals were defined as follows:

(i) For populations recovering from depletion, there should be at least a 95% probability that the population will be above the Maximum Net Productivity Level (MNPL) within 100 years.

(ii) For healthy populations, there should be at least a 95% probability that the population will remain above MNPL in 20 years
(iii) For populations at high risk of extinction, there should be at least a 95% probability of not delaying the time to MNPL by more than 10% compared to a zero human-induced mortality scenario.

The potential biological removals are then defined as:

$$PBR = N_{min} * \frac{1}{2} R_{max} * F_r$$

where PBR = Potential Biological Removals,

N_{min} = the lower 20th percentile of the probability distribution of absolute abundance (to take account of the degree of precision in estimates),

R_{max} = the intrinsic rate of natural increase. Where data are lacking, defaults based on life history characteristics are used; e.g., for whales and dolphins, the default is 4% per annum, while for seals, it is 12% per annum, and

F_r = an ignorance penalty or safety factor. The default is 0.5 for a species with completely unknown status.

Thus, the less that is known (i.e., the greater the uncertainty), the more conservative the management strategy. The combination of using a lower percentile of the abundance distribution and an ignorance factor is obviously far more precautionary than most fisheries management procedures. However, the management goals for targeted species and protected species are obviously also very different.

Evaluating Alternative Empirical Classification Methods - Andre Punt (University of Washington)

Rather than deriving arbitrary cutoff points, management rules need to be tested in an ideal world represented on a computer. If a management rule doesn't work in this situation, there is little basis for assuming it will work in the real world. Simulation models tailored to specific situations can be used to simulate the process of applying a management rule and estimating the probability of getting it right. If an empirical rule is applied to data-rich species, it should generate results similar to those from current assessments. Where possible, information derived from data-rich species should be applied to data-poor species (e.g., in the form of priors on parameters of interest). These ideas are elaborated further in **Appendix 7**.

General Discussion

1. Of the 905 stocks included in the 2000 annual Report to Congress on the Status of Fisheries, 623 had "unknown" status with respect to SDC defining overfishing and overfished. Can / should we ever expect to be able to provide separate assessments for all 905 stocks? Can / should we attempt to group these stocks into categories of (i) stocks for which "direct" management approaches (e.g., individual species TACs or days at sea) are the most relevant , appropriate and realistic; and (ii) stocks for which "indirect" management approaches (e.g., closed areas and seasons, and gear restrictions) are the most relevant, appropriate and realistic (i.e., cost-effective)? Which is the greater priority: converting stocks of unknown status to known, or improving assessments for "core" species? Discussion leader: Anne Hollowed (AFSC)

Species that would fall into category (i) would include a) those that are subjected to directed fishing, b) bycatch species for which the catch represents a substantial fraction of the spawning stock or where catch has an appreciable impact on reproductive potential, and c) "keystone" species (e.g., key forage species or species that are highly sensitive to environmental change). The minimum information required to assess type a or b stocks includes: a reliable index of catch by size or age and possibly sex; a reliable index of stock abundance by size or age and possibly sex; information on selectivity, catchability and availability (i.e., factors that affect partial recruitment); basic biological information such as growth rates, natural mortality and maturity schedules; and information that will allow assessments of environmental effects. When reliable information on catch and stock biomass are available, single species reference points can be estimated. If the species is managed in a complex, then catch can be monitored to ensure that directed catches for a single member of the complex do not exceed the single species biological reference points. Alternative management measures are possible for non-target species that are primarily taken as bycatch. For these species, fishing could be restricted in regions where bycatch rates are high.

The minimum information requirements for assessing type c stocks (keystone species) include a reliable index of stock production by size or age; basic biological information such as growth rates, natural mortality and maturity schedules, food habits of predators and prey, bioenergetics, and prey switching.

The best case is one for which there is reliable information on catch and biomass. In this case, the appropriate approach is to estimate single species reference points but to manage in terms of species complexes to ensure that catches of incidental species do not exceed appropriate reference points. In order to manage bycatch species with small TACs, the probability of exceeding the TAC should be evaluated with respect to the expected distribution of the target species. Time-area allocations can be modified to minimize overlap with bycatch species. A likely outcome of such management tactics will be to increase fishing on stocks during the spawning period. Indirect measures for managing bycatch species include marine protected areas and/or other restrictions on fishing in areas with high incidental catch.

Keystone species have high monitoring needs. Ideally, monitoring and research studies should include juvenile surveys, early life history studies, predator-prey data collection and analyses, and information on weight at age, maturity schedules and spatial distributions. Management intervention is required when there is localized depletion of key prey or a perceived change in community structure based on such indicators as the size spectrum of the population, diversity indices, or shifts in species assemblages.

Despite the above lists of data needs, lack of availability of data should not be an excuse for lack of management action. However, it must also be recognized that optimal targets cannot be achieved for all species simultaneously. It was suggested that, in each FMP, fishery management councils should split species into “core” species with direct management, and “minor” species with indirect management (although the word, “minor” may not be the best term to use). Regardless of the categorization, there is still a need to monitor all species impacted by fisheries (or other activities affecting marine ecosystems).

Regarding the question, “Which is the greater priority: converting stocks of unknown status to known, or improving assessments for “core” species?”, the answer is essentially that it is case-specific.

2. Does the SFA and the NS1 guidelines constrain (creative) assessment and management options unduly? If so how? Or, do we actually have sufficient flexibility within these laws and guidelines, if interpreted appropriately? Discussion leader: Pamela Mace (Office of Science and Technology)

The SFA and NS1 guidelines are constraining in many ways, some good and some bad. They constrain managers to take action to rebuild depleted stocks. In cases where long-overfished stocks have exhibited some amount of rebuilding, the amount of contrast in observed biomass levels has increased, thus providing new knowledge about biomass potential and stock dynamics at high biomass. However, the requirements also impede endeavors such as some adaptive management experiments; for example, experiments to increase fishing intensity on stocks believed to be under-exploited. It may also make it difficult to implement some novel management strategies such as pulse fishing or rotational fisheries.

One particularly constraining and illogical aspect of the NS1 guidelines is the discontinuity in rebuilding time horizons: depleted stocks must be rebuilt in 10 years if it is possible to do so even with F=0; else in the time to rebuild at F=0 plus one mean generation. This means that a fishery that can be rebuilt in 10 years with F=0 must be shut down for 10 years, whereas a fishery that would take 11 years to rebuild at F=0 can actually be managed so that it rebuilds in 11 years plus one mean generation.

The task of attempting to estimate biological reference points with limited data has created “busy work”. On the other hand, it has also stimulated some creative approaches to this problem, and has encouraged mining of existing databases and data rescue operations.

3. Have the SFA and revised NS1 guidelines been overall positive or overall negative, with respect to stock assessments and to management procedures used for FMP stocks? Discussion leader: Alec MacCall (SWFSC)

On the positive side:

With respect to science, the new requirements have helped to establish a clear focus, and have helped to leverage funds for new and expanded programs to improve data collection and analysis (although this has not kept pace with the increased expectations of the data and analyses).

With respect to management, some fishery management councils have been forced to take much needed management actions. The new requirements have required a refocusing of goals and efforts. Under the previous rules, the appearance of one or two good year classes could be used as an excuse for abandoning management actions.

On the negative side:

With respect to science, the new requirements have generated a huge workload for stock assessment scientists, and have necessitated a large degree of "ad hocery", especially for data-poor situations. Also, scientific advice is now more tenuous – "prevent recruitment overfishing" was an easier concept to sell than "fish below MSY". The new requirements may also impede adaptive management experiments designed to increase the knowledge base for fish stocks (by, for example, increasing the contrast in the range of observed biomass levels).

With respect to management, it is possible that some actions mandated by the SFA and NS1 guidelines may prove to have been unnecessary for responsible management. The new requirements may also impede development of new fisheries.

With respect to legal implications, it is possible that the SFA and NS1 guidelines have resulted in an increase in counter-productive lawsuits.

Overall:

Overall, if this approach had been implemented in 1976 or 1980, it is highly likely that fish stocks and the fisheries that depend on them would be better off today.

4. What data needs are most crucial for curing data-poor evaluations? Discussion leader: Rick Methot (NWFSC)

One important question is, "Is there a difference between the data needs necessary for conducting a stock assessment and the data needs necessary for status determination?" In some cases, the answer is probably no. The Stock Assessment Improvement Plan defines a stock assessment as something that allows one to define stock status. However, at some level, it should be easier to estimate or infer stock status than to conduct a full-fledged assessment. The data needed to assess stock status should be a sub-set of the information needed to conduct full stock assessments. On the other hand, the investment required to conduct an assessment is typically beneficial to maximizing long-term yield. Detailed data are needed to conduct stock forecasting.

A related question to that above is, “Are the data needs for a data-poor species different from the data needs for a data-rich species?”. One challenge that we face is that the public may not accept ad-hoc methods for assessing stock status when there are marked economic or ecosystem implications. It is difficult enough to convince the public of the need for restrictive management in data-rich situations, let alone data-poor. One partial solution is to involve the industry more in data collection programs. However, NMFS will need to develop protocols for accepting information from outside sources. How to deal with industry-sponsored assessments is an issue that has not yet been fully-addressed, but a two-way exchange of information is almost certain to be beneficial both to the actual quality of stock assessments and to their credibility with stakeholders.

Is there a suite of key indices that could be used to indicate stock status that are easy to understand? It is likely that participation of fishers in the assessment process may create a system that is more complex, rather than more simple.

Is there a difference between the data needs necessary for conducting a stock assessment and the data needs necessary for rebuilding? The answer to this question depends on the extent to which timeframes and milestones are defined. It is necessary to define a recovery standard in order to define data needs.

5. Can / should we have a “red-face” standard, recognizing what may happen if scientists say “we don't know?” Discussion leader: Terry Quinn (NPFMC SSC)

The short answer is yes. If scientists are to maintain their objectivity and credibility, they must base their advice on adequate data and rigorous analyses. On the other hand, a refusal to provide “best possible advice” on the basis of a red-face test may be interpreted as an abdication of responsibility.

Although managers prefer definitive advice, assessment scientists should take more account of the phrase in the NS1 guidelines, “to the extent possible.” It is also important to take account of the potential for both Type I and Type II errors. In addition, the methodology should be kept as simple and easy to explain to the public as possible.

There was a strong consensus that the greatest need is for more and better data, rather than better models. Ideally, there should be some minimum standards to define “reliable” data; e.g., in order to fit stock-recruitment relationships, there should be some minimum number of data points and some minimum amount of contrast in the biomass data. Robust models and management procedures should also be explored further.

It was generally agreed that the term “overfished” should be replaced with “depleted”.

Depleted stocks need to be rebuilt regardless of the cause, but use of the term overfished puts an additional burden on assessment scientists to distinguish between fishing effects and environmental effects. This can be difficult in data-rich situations, let alone data-poor.

Possible Future Workshop Topics

Participants felt that the presentations and discussions in the workshop were helpful and stimulating, and that they provided useful ideas that could be further developed. It was also illuminating to find out how fisheries scientists and managers in other parts of the country have been attempting to deal with the pervasive problem of data-poor situations. There was agreement that this type of format should be followed to address related topics in the future. However, given busy schedules with stock assessments and Council-related activities, a frequency greater than once annually is probably not realistic. It was also suggested that the workshops could alternate between the east coast and west coast, rather than being oriented at the national level. On the other hand, there are many issues that are common to all regions, and that would benefit from input from everyone involved.

Suggested possible future workshop topics include:

- An evaluation of control rules and overfishing definitions from all regions
- How to account for environmental influences, particularly regime shifts
- How to derive overfishing definitions and management measures for multispecies assemblages
- Recommendations for revision of National Standard 1 guidelines (possibly not until the next revision of the Magnuson Act, because this itself may necessitate changes to the guidelines).

Appendix 1: Workshop Agenda

Workshop on

Status Determination Criteria in Data-Poor Situations

30-31 May 2001
Building 9 Conference Room
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle WA

Objectives:

1. To discuss and evaluate methods currently being used by Fishery Management Councils, or under development by Councils, SSCs, or NMFS scientists, to characterize status determination criteria in data-poor situations; i.e., methods for determining thresholds associated with "overfishing" and "overfished" when MSY-based reference points cannot be estimated explicitly or such estimates are deemed unreliable.
(Note that the interpretation of "data-poor" should be broad in the sense that, even for species for which considerable data exist, there may be considerable uncertainty in the estimation of MSY-based reference points.)

2. To share information on the types of SDC methodologies being employed in different regions and to evaluate their applicability to other species/regions.

3. To augment the range of methods currently available for characterizing SDC, while still satisfying the MSFCMA and the National Standard 1 guidelines; i.e., to enhance flexibility while maintaining scientific validity.

Workshop format:

Prior to the workshop, representatives from each Council or region should compile a brief description of methodology(ies) currently being used or developed for species under that region's jurisdiction. This could be "cut and pasted" from existing materials or summarized anew. In either case, the documentation should be brief. Complete papers are not required, although they could be provided as additional background, if desired. It would be more efficient if there were just one document per region, but any individual participant in the workshop is also welcome to submit a new idea for consideration by the workshop. Regional summary documents and other submissions will be circulated to participants about 10 days prior to the workshop.

Agenda

Wednesday **30 May**

8:30 am Opening of Meeting & Introductions

8:50 am Review of Objectives; Compilation of Background Materials; Revision of Agenda

9:15 am Brief presentation & discussion on requirements for characterizing status determination criteria under the MSFCMA and the National Standard 1 guidelines. Pamela Mace & Grant Thompson

10:00 am **30 May** to 3:30 pm **31 May**: Brief presentations by regions, followed by in-depth discussions. Different people may be volunteered to moderate different sessions.

Morning coffee breaks: 10:00 - 10:30 am
Lunch: 12:00 - 1:30 pm
Afternoon coffee breaks: 3:00 - 3:30 pm

Session 1. Methodologies used in the Alaska (NPFMC) region: brief presentation(s), moderated discussion

Session 2. Methodologies used in the Northwest (PFMC) region: brief presentation(s), moderated discussion

Session 3. Methodologies used in the Northeast (NEFMC and MAFMC) region: brief presentation(s), moderated discussion

Session 4. Methodologies used in the Southeast (SAFMC, GMFMC, and CFMC) region: brief presentation(s), moderated discussion

Session 5. Methodologies used in the Southwest (PFMC & WPFMC) region: brief presentation(s), moderated discussion

3:30 pm 31 May: ***General discussion***
(a) summary of methodologies discussed
(b) examination of the flexibility within the law and guidelines for accommodating the various methodologies
(c) overall evaluation of the utility of the workshop and suggestions for topics for future workshops of this nature

5:30 pm Adjourn

Products:

NMFS assessment scientists (Pamela Mace and Anne Hollowed and possibly others) will prepare a summary of the workshop, including a list of methods discussed and evaluated, together with the pros and cons of each, and workshop recommendations for further research.

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Appendix 2: List of Participants

AFSC – Sarah Gaichas, Anne Hollowed, Rebecca Reuter, Paul Spencer, Tom Wilderbeur, Chang-Ik Zhang
GMFMC & Assessment Panels – Steven Atran, Doug Gregory, Peter Hood, Mike Murphy
NWFSC – Rick Methot, Beth Horness
MAFMC – Tom Hoff, Lee Anderson
SAFMC & SSC – John Carmichael
NPFMC & SSC – Terry Quinn
SEFSC – Mike Prager, Jerry Scott
SERO – Phil Steele
SWRO – Jim Morgan
PFMC – Dan Waldeck, Andre Punt
SWFSC – Alec MacCall, Gerard DiNardo, Chris Boggs, Barbara Taylor
NEFSC – Paul Rago
NEFMC – Andy Applegate
CFMC – Graciela Garcia-Moliner, Miguel Rolon
WPFMC – Paul Dalzell
NMFS HQ – Pamela Mace
Washington Department of Fish and Wildlife – Brian Culver, Michele Robinson
Natural Resources Defense Council – Kate Wing
Ocean People Resources – Kristan Stahl-Johnson

Total = 36

Appendix 3: Summary of Status Determination Criteria Used in Fishery Management Plans Maintained by the North Pacific Fishery Management Council

Groundfish

The current status determination criteria were approved by the Council in June of 1998 and by NMFS in January of 1999. "Overfishing" is defined as any rate of fishing in excess of the maximum fishing mortality threshold (MFMT). The catch corresponding to fishing at a rate equal to the MFMT is referred to as the "overfishing level" (OFL). The MFMT is prescribed through a set of six tiers which are listed in Table 1 in descending order of preference, corresponding to descending order of information availability. The SSC will have final authority for determining whether a given item of information is "reliable" for the purpose of this definition, and may use either objective or subjective criteria in making such determinations. For Tier 1, a "pdf" refers to a probability density function. For Tiers 1-2, if a reliable pdf of B_{MSY} is available, the preferred point estimate of B_{MSY} is the geometric mean of its pdf. For Tiers 1-5, if a reliable pdf of B is available, the preferred point estimate is the geometric mean of its pdf. For Tiers 1-3, the coefficient α is set at a default value of 0.05, with the understanding that the SSC may establish a different value for a specific stock or stock complex as merited by the best available scientific information. For Tiers 2-4, a designation of the form "$F_{X\%}$" refers to the F associated with an equilibrium level of spawning per recruit (SPR) equal to $X\%$ of the equilibrium level of spawning per recruit in the absence of any fishing. If reliable information sufficient to characterize the entire maturity schedule of a species is not available, the SSC may choose to view SPR calculations based on a knife-edge maturity assumption as reliable. For Tier 3, the term $B_{40\%}$ refers to the long-term average biomass that would be expected under average recruitment and $F=F_{40\%}$. A stock is determined to be "overfished" whenever it has fallen below its minimum stock size threshold (MSST), defined as 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 the MFMT. The MSY level is interpreted as B_{MSY} in Tiers 1-2 and $B_{35\%}$ in Tier 3. No MSY level, and therefore no MSST, can be specified for Tiers 4-6.

Crabs

Annually Surveyed Crab Stocks: The following specifications apply to crab stocks surveyed annually by NMFS:

- MSY is estimated as the average catch from 1983-1997.

- The MSY control rule is of the constant-F variety, where F_{MSY} is approximated by the natural mortality rate M, currently estimated at a value of 0.2 for king crabs and 0.3 for Tanner and snow crabs.

Table 1. Six tiers comprising the overfishing definition for North Pacific groundfish.

1) Information available: Reliable point estimates of B and B_{MSY} and reliable pdf of F_{MSY} .

1a) Stock status: $B/B_{MSY} > 1$

$F_{OFL} = \mu_A$, the arithmetic mean of the pdf

$F_{ABC} \leq \mu_H$, the harmonic mean of the pdf

1b) Stock status: $\alpha < B/B_{MSY} \leq 1$

$F_{OFL} = \mu_A \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

$F_{ABC} \leq \mu_H \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

1c) Stock status: $B/B_{MSY} \leq \alpha$

$F_{OFL} = 0$

$F_{ABC} = 0$

2) Information available: Reliable point estimates of B, B_{MSY} , F_{MSY} , $F_{35\%}$, and $F_{40\%}$.

2a) Stock status: $B/B_{MSY} > 1$

$F_{OFL} = F_{MSY}$

$F_{ABC} \leq F_{MSY} \times (F_{40\%}/F_{35\%})$

2b) Stock status: $\alpha < B/B_{MSY} \leq 1$

$F_{OFL} = F_{MSY} \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

$F_{ABC} \leq F_{MSY} \times (F_{40\%}/F_{35\%}) \times (B/B_{MSY} - \alpha)/(1 - \alpha)$

2c) Stock status: $B/B_{MSY} \leq \alpha$

$F_{OFL} = 0$

$F_{ABC} = 0$

3) Information available: Reliable point estimates of B, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$.

3a) Stock status: $B/B_{40\%} > 1$

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

3b) Stock status: $\alpha < B/B_{40\%} \leq 1$

$F_{OFL} = F_{35\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha)$

$F_{ABC} \leq F_{40\%} \times (B/B_{40\%} - \alpha)/(1 - \alpha)$

3c) Stock status: $B/B_{40\%} \leq \alpha$

$F_{OFL} = 0$

$F_{ABC} = 0$

4) Information available: Reliable point estimates of B, $F_{35\%}$, and $F_{40\%}$.

$F_{OFL} = F_{35\%}$

$F_{ABC} \leq F_{40\%}$

5) Information available: Reliable point estimates of B and natural mortality rate M.

$F_{OFL} = M$

$F_{ABC} \leq 0.75 \times M$

6) Information available: Reliable catch history from 1978 through 1995.

OFL = the average catch from 1978 through 1995, unless an alternative value is established by the SSC on the basis of the best available scientific information

ABC ≤ 0.75 × OFL

- B_{MSY} is estimated as the average total spawning biomass (mature males and females) from the period 1983-1997.

- The maximum fishing mortality threshold is set equal to the MSY control rule.

- The minimum stock size threshold is set equal to ½ B_{MSY}.

In addition to the MFMT and MSST, other thresholds for use in crab management are established in State of Alaska harvest strategies and regulations. Survey results are compared to these thresholds to determine if a fishery should be opened and to calculate the guideline harvest level.

Crab Stocks With No Annual Survey: Stock status is unknown in many cases due to lack of survey biomass estimates. Directed fisheries for these stocks are conducted by ADF&G commissioner's permit only, though most of these stocks are also taken as bycatch in other crab fisheries. Estimation of MSST for these stocks is not possible at this time because of insufficient data on the basic stock abundance.

Salmon

The FMP, which has not been amended since passage of the Sustainable Fisheries Act, defines overfishing as a failure to comply with the salmon management policies of the State of Alaska and the Pacific Salmon Commission. In implementing the State's policy, the Alaska Department of Fish and Game has the long-term goal of achieving maximum sustainable yield for Alaska's salmon fisheries. To this end, the Department has strived, within fiscal resources, to establish stock-specific escapement goal ranges with the midpoint being the optimal escapement level. Commensurate with this objective, ADF&G has endeavored to implement data collection programs and management systems necessary to achieve these escapement goals. With these escapement goals, fishing opportunities are limited during years of weak runs and expanded during years of strong runs. Currently, escapement goal ranges together with real-time escapement enumeration (i.e., visual counts from towers, weir counts, aerial survey counts, sonar counts) and intensive fishery monitoring programs have been established for most of Alaska's major salmon stocks.

In certain fisheries where it is not cost effective to manage for escapement goal ranges, either because the magnitude of the resource is low or it is difficult or impossible to enumerate escapement, fishing is limited to conservative weekly fishing periods. These fishing periods are set to provide liberal windows of time for salmon to move through the fishery, and reflect the level of fishing that has provided a sustainable level of catch based on the historical performance of the fishery. For these fisheries, fishing periods may be shortened or lengthened depending on qualitative indicators of run strength such as catch-per-unit-of-effort in directed or test fisheries. The fishing-period strategy is reviewed annually on the basis of post-season evaluations of escapement levels and fishery performance.

Historical non-terminal mixed-stock fisheries (e.g., South Peninsula June fishery, Lower Yukon River fisheries) are managed for preseason guideline harvest levels. These guideline harvest levels are set to ensure that exploitation rates in these non-terminal mixed-stock fisheries are low compared to the exploitation rates experienced by the stocks intercepted in their respective terminal harvest areas. This procedure insures that sufficient surplus fish are available in the terminal harvest area to meet escapement goals and provide for some level of harvest. The guideline harvest levels are reviewed every 2 years by the Alaska Board of Fisheries and are subject to reduction in situations of forecasted weak runs or declining runs. The Board has consistently acted to reduce historical non-terminal mixed-stock fisheries during periods of weak or declining runs and to eliminate or severely restrict new non-terminal mixed-stock fisheries whenever they developed.

No MSST is specified.

Scallops

The following specifications apply to weathervane scallops:

- MSY is estimated as the average catch from 1990-1997, excluding 1995, giving a value of 1.24 million pounds of meats.
- The MSY control rule is of the constant-F variety, where F_{MSY} is approximated by the natural mortality rate M, currently estimated at a value of 0.13.
- B_{MSY} is estimated by the relationship MSY/F_{MSY} = 9.54 million pounds of meats.
- The maximum fishing mortality threshold is set equal to the MSY control rule.
- The minimum stock size threshold is set equal to ½ B_{MSY} = 4.77 million pounds of meats.
- Optimum yield is specified as a range extending from zero to MSY.

OY, MSY, and status determination criteria are not specified for pink, spiny, or rock scallops as these are undeveloped fisheries that are managed through ADF&G via special permit.

Appendix 4: An Approach to Analyzing Multi-species Complexes in Data-limiting Situations

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Abstract

The Gulf of Alaska "other species" management category comprises multiple non-target species groups: sharks, skates, smelts, squids, octopus, and sculpins. "Other species" are considered ecologically important and may have future economic potential; therefore an aggregate annual quota limits their catch. One management goal is to prevent overfishing of any single component of the category within the allowable aggregate catch. However, data on catch and abundance for these species are extremely "noisy" and result in estimates with high variance. The problem facing analysts is thus to find appropriate methods to deal with this "signal to noise" problem. Such methods should provide conservation recommendations that are robust to problems with the data while giving stability that managers desire. For example, in the Gulf of Alaska, managers may want to avoid linking conservation regulations directly to survey data recognizing that survey biomass estimates for certain species have high variability due to measurement error. We attempt to account for both observation error and process error in estimating biomass and exploitation rates for each species group using a simple state-space model. Here, process error was assumed to be different for species groups reflecting the diversity expected between short-lived smelts and long-lived sharks. We illustrate the potential problem of incorrectly specifying the ratio of process to observation error. In practice, specifying the variance ratio may be less problematic since a species life history traits are generally known, as are the problems associated with survey abundance estimates.

The complete paper can be found on the web at

http://www.refm.noaa.gov/docs/othspp99.pdf

by scrolling down to Appendix E beginning on page 43 of that document.

Appendix 5: Harvest Rates for Information-Poor West Coast Rockfish Stocks: a Comparative Approach

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For many West Coast rockfish, information on stock status is extremely limited. A common situation is to have a time-series of abundance estimates from the NMFS shelf trawl survey, and limited age composition data that allows the natural mortality rate to be approximated. The most recent assessment of the *Sebastes* complex (Rogers et al. 1996) identified 13 rockfish stocks in this category. The problem considered here is how to obtain an ABC for these stocks that approximates a target spawning biomass per recruit (SPR) harvest rate, i.e., $F_{50\%}$. I use a comparative approach that relies on information from related stocks. Since a SPR harvest rate is strongly dependent on longevity, the relationship between natural mortality and the SPR harvest rate for well-studied stocks is used to provide advice for other rockfish. This approach is similar to the most recent *Sebastes* complex assessment (Rogers et al. 1996), except that here the relationship between natural mortality and SPR harvest rate is evaluated, rather than taking an F = M policy as given.

Methods

Consider a harvest rule of the form

$$ABC = (a\ M)\ \frac{\hat{B}}{q}$$

where M is the natural mortality rate, and $\hat{B}$ is a biomass estimate derived from the NMFS shelf survey. There are two constants in this equation: a is a multiplier that converts natural mortality to a harvest rate, and q is a catchability coefficient that converts population biomass to survey biomass for fully-selected fish. Both the a and q terms are amenable to comparative approaches.

For an SPR harvest rate of $F_{50\%}$ (for example), a is a linear term in the equilibrium relationship

$$\frac{YPR_{50\%}}{BPR_{50\%}} = a\ M\ ,$$

where $YPR_{50\%}$ is yield per recruit at $F_{50\%}$, and $BPR_{50\%}$ is the survey biomass per recruit at $F_{50\%}$.

For rockfish stocks that are assessed with a full age or length-structured assessment models, the information required to calculate the Y/B ratio is available as model output or from ancillary analyses, and does not depend on the shape of the stock-recruit curve. This information includes fishery and survey selectivity curves, weight at age, natural mortality, and maturity vectors. It should be noted that this relationship is constant only for an equilibrium age composition, however amount of error due to the equilibrium assumption should be small relative to other potential sources of error.

$YPR_{50\%}$ is given by

$$YPR_{50\%} = \sum_i \sum_j w_{ij} \, N_{ij} \, \frac{s_{ij}^F F_{50\%}}{s_{ij}^F F_{50\%} + M} \, [1 - \exp(M_{ij} + s_{ij}^F F_{50\%})]$$

where s_{ij}^F is fishery selectivity of fish of age i and sex j, and N_{ij} is the proportion surviving to age i by sex under an exponential mortality model with equal numbers of males and female at recruitment.

$BPR_{50\%}$ is the biomass per recruit at $F_{50\%}$ that is *selected* by survey gear:

$$BPR_{50\%} = \sum_i \sum_j s_{ij} \, w_{ij} \, N_{ij} \, \exp[-\varphi \, (M_{ij} + s_{ij}^F F_{50\%})]$$

where φ is the time of year when the NMFS shelf survey is conducted (= 0.6), and s_{ij} is a survey selectivity coefficient where $\max(s_{ij}) = 1$.

Equilibrium Y/B ratios were calculated for all West Coast rockfish with full age-structured assessments (chilipepper, bocaccio, widow, canary, and yellowtail rockfish, and Pacific Ocean perch) based on the most recent assessment information (Table 1). Although the widow rockfish assessment does not use the triennial survey to tune the assessment model, a selectivity curve was estimated in model explorations and provided by the assessment author (Erik Williams, pers. commun. May 12, 2000). The survey selectivity curve for bocaccio shows a peak at very young age. This may be artifact of infrequent large catches of juvenile bocaccio during the shelf survey (Alec MacCall, pers. commun. April 6, 2000). Based on advice from the assessment author, I used a flat selectivity curve ($s_{ij} = 1$) to calculate the Y/B ratio for bocaccio. The mean age at 50% selection to survey gear is approximately two years earlier than the mean age at 50% selectivity to the fishery (Fig. 1), although there are departures from this general pattern for individual stocks. The mean age at 50% maturity occurs approximately one year later than the age at 50% selectivity. This suggests that simple "rules of thumb," such as an F = M policy where fishery and survey selectivity are assumed equal, could result in harvest rates that are different than intended.

Zero-intercept regression was used to estimate the relationship between the Y/B and natural mortality at SPR harvest rates of $F_{40\%}$, $F_{50\%}$, and $F_{60\%}$. A ratio estimator was also evaluated. Several rockfish assessments use age-and sex-specific natural mortality schedules (chilipepper, canary, and yellowtail rockfish). In these cases, the mean female natural mortality for ages greater than the age at 50% maturity was used in the regression.

Results and Discussion

Zero-intercept regression and the ratio estimator gave nearly identical estimates of the relationship between Y/B and natural mortality (Table 2). Results are consistent with Clark (1991) who found that an F = M strategy was comparable to a $F_{42\%}$ harvest rate when maturity, survey and selectivity curves coincided. An F = 0.5M strategy recommended by Walters and Parma (1996) as a default precautionary harvest rate for information-poor stocks corresponds approximately to $F_{60\%}$. With the exception of canary rockfish, the relationship between natural mortality and Y/B is surprisingly precise (Fig. 2). Canary rockfish are unusual because they mature several years before they recruit to the fishery, and because female natural mortality increases with age.

It should be kept in mind that these multipliers are only applicable to a biomass estimate from the West Coast triennial shelf survey. For other trawl surveys, or other surveying methods (ROV or submersible transects), differences in selectivity could change the natural morality multipliers.

Survey catchability (*q*) can also be addressed using a comparative approach. Rogers et al. (1996) found that the average full-selection *q* for assessed rockfish stocks was 0.5 and reported a range of 0.2 to 0.9. Rogers et al. (1996) also examined habitat preferences and the spatial overlap between different rockfish species to determine whether evidence supported departing from that average value.

Evaluation of risk-averse harvest strategies for rockfish needs to consider the following major sources of assessment uncertainty:
1. Is the assumed survey catchability (q) correct?
2. Is the survey estimate of current biomass precise?
3. Is $F_{50\%}$ an appropriate proxy for F_{MSY} for other rockfish, which are less common and may grow and mature differently than stocks with age-structured assessments?

These sources of uncertainty are not present to the same degree for rockfish stocks with full assessments. Where greater uncertainty exists, greater precaution should be exercised. Since F = 0.71 M gives a harvest rate comparable to the recommended F50% default proxy for rockfish (Dorn 2002), a reasonable approach may be a harvest strategy in the range of F = 0.5 M to F = 0.6 M, but this a topic for deliberation by the Pacific Fisheries Management Council and its advisory bodies. It is important to be explicit about where the precaution is applied. An alternative to applying a conservative harvest rate would be to use a conservative procedure to estimate biomass, such as using a lower quantile rather than the mean. One could also be “doubly” conservative by applying a conservative harvest rate to a conservative biomass estimate, just as long as it is made clear that this is the strategy intended, and the benefits and costs of such an approach are clearly identified.

References

Clark, W. G. 1991. Groundfish exploitation rates based on life history parameters. Canadian Journal of Fisheries and Aquatic Sciences 48:734-750.

Dorn, M. W. 2002. Advice on West Coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. North American Journal of Fisheries Management 21:000-000.

Rogers, J.B., M. Wilkins, D. Kamikawa, F. Wallace, T. Builder, M. Zimmerman, M. Kander, and B. Culver. 1996. Status of the remaining rockfish in the *Sebastes* complex in 1996 and recommendations for management in 1997. In: Status of the Pacific coast groundfish fishery through 1996 and recommended acceptable biological catches for 1997. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland, OR 97201.

Walters, C. and A.M. Parma. 1996. Fixed exploitation rate strategies for coping with effects of climate change. Canadian Journal of Fisheries and Aquatic Sciences 53:148-158.

Table 1. Natural mortality rates and equilibrium yield/survey biomass ratios for six West Coast rockfish stocks with age-structured assessments.

		Y/B		
Stock	Average M	F40%	F50%	F60%
Chilipepper	0.22	0.22	0.15	0.10
Bocaccio	0.20	0.19	0.14	0.10
Widow rockfish	0.15	0.15	0.10	0.07
Canary rockfish	0.12	0.17	0.11	0.08
Yellowtail rockfish	0.19	0.19	0.14	0.10
Pacific Ocean Perch (West Coast)	0.06	0.05	0.04	0.03
Zero-intercept regression slope		1.01	0.71	0.49
Ratio estimate		1.03	0.72	0.49

Table 2. Natural mortality multipliers that produce SPR harvest rates of $F_{40\%}$, $F_{50\%}$, and $F_{60\%}$ based on zero-intercept regression of Y/B on natural mortality for six West Coast rockfish stocks with full age-structured assessments.

SPR rate	F = a M
$F_{40\%}$	F = 1.01 M
$F_{50\%}$	F = 0.71 M
$F_{60\%}$	F = 0.49 M

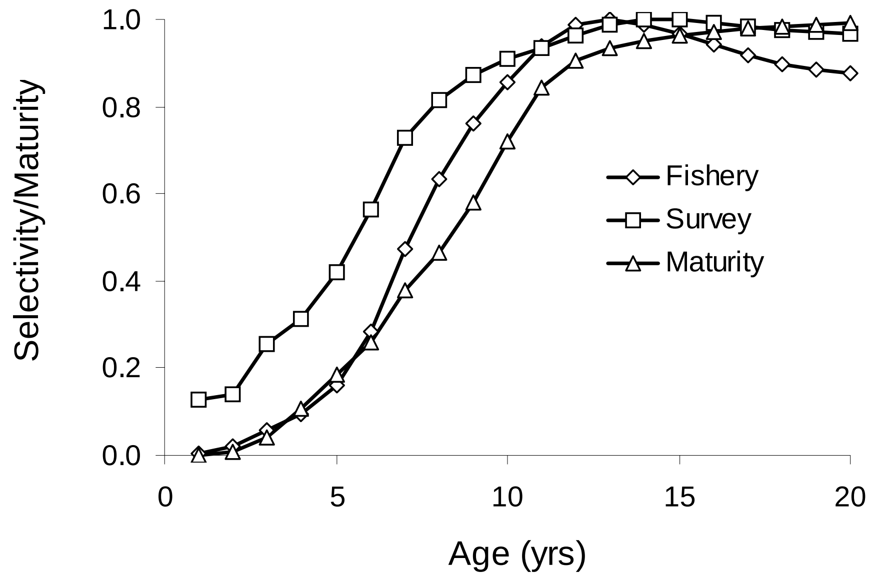

Figure 1. Mean rockfish fishery selectivity, selectivity to the NMFS shelf survey, and proportion mature based on chilipepper, bocaccio, widow, canary, and yellowtail rockfish and Pacific ocean perch assessments.

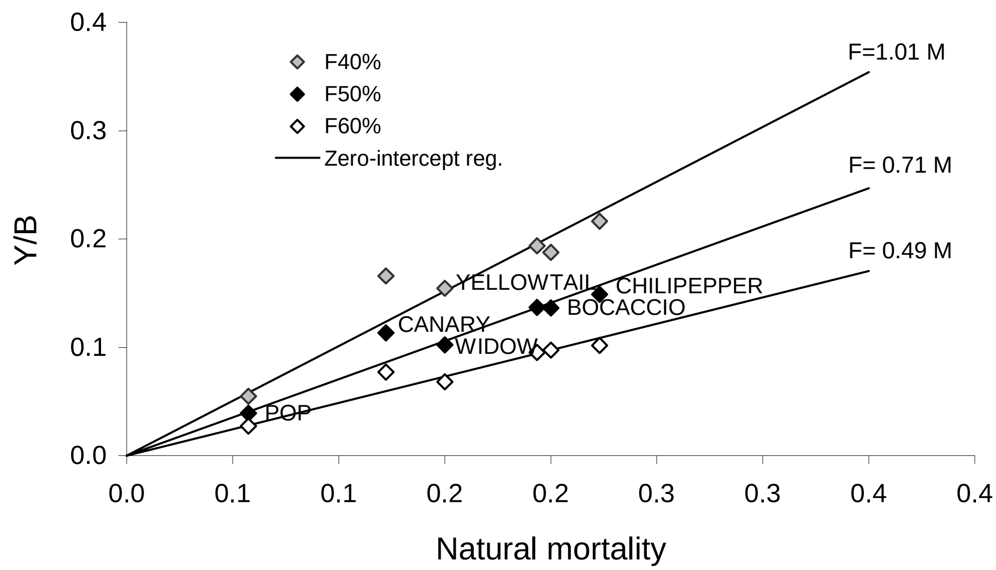

Figure 2. Relationship between natural mortality and yield/biomass ratios for six West Coast rockfish stocks at $F_{40\%}$, $F_{50\%}$, and $F_{60\%}$.

Appendix 6: Optimal Fishing Rates for West Coast Groundfish

Alec MacCall
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Monitoring of the west coast groundfish fisheries began in the early 1980's, during a period of rapidly expanding fishing capacity. It wasn't until the 1990's that stock assessments were able to produce abundance estimates for major species, and the relatively small number of estimated data points still did not allow reliable estimation of optimal fishing rates and stock sizes. Both worldwide experience and local research was accumulating that $F_{35\%}$ would be a safe and reasonable proxy for F_{MSY}, and the Pacific Fishery Management Council (PFMC) adopted an OY policy based on $F_{35\%}$ for general management of west coast groundfish. It was expected that abundances would tend to level off somewhere near B_{MSY} (without that quantity having been explicitly estimated) as fish production came into equilibrium with $F_{35\%}$.

By the mid-1990's it was becoming apparent that the declines in groundfish abundances were continuing with little, if any, tendency toward equilibrium. In 1997, an ad-hoc workshop formally recognized that $F_{35\%}$ did not appear to be sustainable, and recommended that the F_{MSY} proxy be changed to $F_{40\%}$. This decision was based on simulation modeling, including effects of recruitment variability, and a generally qualitative consideration of abundance trajectories. Because relatively little quantitative analysis of fishery-specific data was attempted, this management decision was still in what could be called a “data-poor” mode.

Transition to a more “data-rich” approach began with the recent Sustainable Fisheries Act requirement for harvest policies based on more explicit management reference points, combined with a precautionary approach. Given the current proxy-based management policy, quantitative analyses of various groundfish data sets showed that “precautionary adjustments” to an $F_{40\%}$ harvest rate would have to be severe to prevent further declines in abundance. The reason clearly was that $F_{40\%}$ was still too high a harvesting rate.

A more formal process of quantitative investigation was initiated, with several stock assessment scientists independently looking at the problem. The resulting research papers (NAJFM, in press) were presented to an outside scientific review panel at a workshop in March, 2000. In some cases, the variety of inferences that can be drawn from the same stock-recruitment data set was striking. For example, choice of a Beverton-Holt or a Ricker SRR could result in extreme differences in estimated management reference points, and yet be indistinguishable on the basis of goodness of fit, or any other selection criterion. A meta-analysis by Martin Dorn (AFSC) was especially influential because of its internal consistency and ease of interpretation. Dorn found that the SRRs of west coast stocks of rockfish exhibited much lower steepnesses than their counterparts in Canada and Alaska. However, evidence of decadal-scale climate shifts confounds inferences regarding stock resilience. Either west coast stock truly have lower resilience, or we have had the historical accident of fishing these stocks down to low abundance levels during the low productivity regime that began around 1977. In either case, current recruitment is low and rebuilding is slow, typically requiring 30 to 40 years.

The Review Panel commented that the SRRs for Pacific coast groundfish exhibit very low resiliency, “at or below the lowest values estimated for well-studied stocks elsewhere in the world.” Dorn’s multispecies analysis showed the maximum likelihood SPR at MSY to range from 45% (Beverton-Holt SRR) to 54% (Ricker SRR). The Review Panel proposed $F_{50\%}$ as a proxy for F_{MSY}, recognizing that this value contains no element of precaution, and is likely to be too high for some of the stocks. The Panel also proposed that the rule-of-thumb of $F_{MSY} = M$ for data-poor stocks be revised to $F_{MSY} = 0.75M$, and the PFMC further reduced this value to $F_{MSY} = 0.5M$ on the basis of precaution.

Appendix 7: Evaluating Alternative Empirical Classification Methods

Andre Punt
University of Washington
Seattle, WA

An empirical method for determining whether a population is above or below some target or limit level involves comparing the value of some quantity that can be measured based on data collected from the fishery or during surveys with a threshold level. Intuitively, use of such methods is appealing, particularly for "data-poor" situations, as they are simple to understand and are not tightly linked to any particular model of the resource. However, it is not straightforward to determine the most appropriate threshold level nor the likelihood that any particular empirical method will be 'triggered' when the event it was designed to trigger actually occurs. Errors can occur if the method is not triggered when it should be ("under-protection") and if it is triggered when it should not be ("over-protection"). These errors will, of course, occur for any classification scheme no matter how complicated – the key issue is to assess the magnitude of these errors for different potential quantities and thresholds.

In principle, Monte Carlo simulation can be used to determine expected error rates for candidate empirical methods (e.g., Punt *et al*. 2001). The basic approach involves:

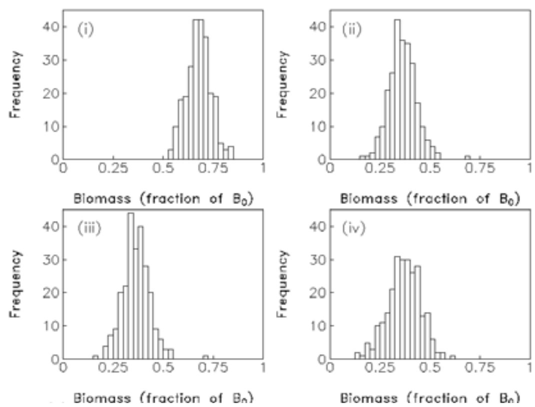
- Select the event of interest (e.g., being below x% of B_0) and the probability of not correctly detecting this when it is true (the analogy of type I error).
- Develop a model (or more likely models) of the system, parameterized, to the extent possible, for the situation in question.
- Specify the data to be collected and the candidate empirical methods.
- Simulate the process of applying the various candidate methods for cases in which the event of interest is true and in which it is false and determine the success rate.

Table 1 shows results comparing two candidate empirical methods for several scenarios in terms of the degree of over-protection (column "Triggered but should not have been") and under-protection (column "Not triggered but should have been"). The column "loss" in Table 1 is an attempt to combine the probability of making errors and the magnitude of those errors when they occur into a single measure. The figure shows histograms of the biomass (relative to B_0) at which four empirical methods (i – iv) designed to be triggered at 0.4 B_0 are actually triggered.

The work conducted by Punt *et al*. (2001) was for a specific case (the fishery for broadbill swordfish, *Xiphias gladius*, off the east coast of Australia) so the candidate empirical methods and the types and levels of uncertainty considered were relatively constrained. If empirical methods are to be used generally to classify species, there would seem to be value in conducting generic studies into their performance (similar to the types of studies conducted by Clark (1991, 1993) on "robust" levels of fishing mortality).

Table 1. Comparison of two candidate empirical methods (from Punt *et al*. 2001; Table 6).

Scenario	Method 1			Method 2		
	Probability		Loss	Probability		Loss
	Triggered but should not have been	Not triggered but should have been		Triggered but should not have been	Not triggered but should have been	
Base-case	0.30	0.16	9.49	0.27	0.09	9.41
ρ=0.7	0.29	0.07	16.03	0.26	0.06	18.35
$\sigma_s = 0.4$	0.25	0.18	10.11	0.28	0.16	11.17
Sample size=100	0.35	0.06	9.44	0.38	0.04	15.68
Sample size=100	0.35	0.06	9.44	0.38	0.04	15.68



A potential general modeling framework

It is potentially possible to combine the features of the methods outlined by Ianelli and Gaichas (see Appendix 4) and those outlined by MacCall (see Appendix 6) into a single analytical framework that includes all species in a single analysis. Such a analytical framework would be based on two key principles: (i) the results for stocks that are "data-rich" should be virtually identically those that would have been obtained had the data for such stocks been analyzed using conventional single stock approaches, and (ii) the results for stocks that are "data-poor" should be enhanced through inferences from "data-rich" species.

The basic approach involves conducting an analysis in which the data for several species are analyzed simultaneously using an appropriate form of population dynamics model (e.g., ASPIC, Stock Synthesis, etc.). The likelihood function would be the identical to that which would apply if each species was analyzed separately, except that some account could be taken of among-species correlations in survey errors. The prior distributions (for a Bayesian assessment – constraints /

penalties for a Maximum Likelihood assessment) could include hyper-priors on catchability, selectivity, steepness, and annual fishing mortality relative to its temporal mean. Account could be taken of the relative reliability of the different sources of information through the priors for the parameters of the hyper-priors.

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