PROCEEDINGS OF THE SEVENTH NMFS NATIONAL STOCK ASSESSMENT WORKSHOP

(Re)building Sustainable Fisheries and Marine Ecosystems

hosted by the Southwest Fisheries Science Center
Santa Cruz Laboratory
Santa Cruz, CA
December 11-13, 2001

edited by Pamela M. Mace

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-F/SPO-62
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U.S. Department of Commerce
Donald L. Evans, Secretary

National Oceanic and Atmospheric Administration
Vice Admiral Conrad C. Lautenbacher, Jr., USN (Ret.)
Under Secretary for Oceans and Atmosphere

National Marine Fisheries Service
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INTRODUCTION

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The National Marine Fisheries Service (NMFS) National Stock Assessment Workshops (NSAWs) have two primary general objectives:

(i) to address an important and topical theme of common concern to all NMFS Science Centers, and
(ii) to provide a forum for interaction between the large diversity of NMFS scientists involved in conducting stock assessments, providing management advice, and related activities.

Topics, host Science Centers, and dates for the previous six NSAWs follow:

1ST NSAW: "Determination of Allowable Biological Catches," Southeast Fisheries Science Center, Miami, FL, 19-22 March 1991.

2ND NSAW: "Defining Overfishing -- Defining Stock Rebuilding," Southwest Fisheries Science Center, La Jolla, CA, 31 March - 2 April 1992.

3RD NSAW: "Bycatch and Discard Mortality: Sampling, Estimation and Implications for Scientific Advice," Northeast Fisheries Science Center, Woods Hole, MA, 20-22 July 1993.

4TH NSAW: "Spatial Patterns: Survey Design, Geographic Analysis, and Migration Models," Alaska Fisheries Science Center, Seattle, WA, 10-12 August 1994.

5TH NSAW: "Providing Scientific Advice to Implement the Precautionary Approach Under the Magnuson-Stevens Fishery Conservation and Management Act," Southeast Fisheries Science Center, Key Largo, FL, 24-26 February 1998.

6TH NSAW: "Incorporating Ecosystem Considerations into Stock Assessments and Management Advice," Northwest Fisheries Science Center, Seattle, WA, 28-30 March 2000.

The theme for this, the 7TH NSAW, hosted by the Southwest Fisheries Science Center's Santa Cruz Laboratory on 11-13 December 2001, was "(Re)building Sustainable Fisheries and Ecosystems." This theme was chosen because it is highly topical and has wide appeal. In common with the 6TH NSAW, ecosystem considerations were one of the underlying themes, but for the 7TH NSAW, the focus was on eliminating overfishing, rebuilding overfished stocks, and maintaining healthy assemblages of stocks. The current guidelines written by NMFS in support of National Standard 1 of the Magnuson-Stevens Act specify the need for rebuilding plans when stocks are overfished, but provide relatively little guidance on developing these plans. There are now more than 60 rebuilding plans in place and new questions are arising. For example, how are these plans performing in practice relative to theoretical expectations? What should be done if realized stock sizes are substantially different from predicted stock sizes? Why do some species seem to be more resilient to overfishing than others?

In terms of maintaining healthy assemblages of stocks, the ultimate question is how to define and prevent ecosystem overfishing. Several papers have been written on this topic, but the answer is still far from clear. Similarly, although there has been considerably more progress in incorporating oceanographic factors into stock assessments, this is still not a routine procedure, and oceanographic factors have not been explicitly incorporated into any rebuilding plans.

The workshop consisted of seminars, posters, and discussion groups that addressed basic themes such as these, and formulated conclusions and recommendations. Four theme areas were identified:

1. Defining "ecosystem overfishing"
2. Considerations for stock rebuilding
3. Incorporating oceanographic factors into stock assessments and rebuilding plans
4. Resilience, overfishing, and risk of extinction of marine species

A Steering Committee consisting of one representative from the headquarters Office of Science and Technology and one representative from each of the five Science Centers was formed to further develop the overall theme and organize the workshop. Steering Committee members were Pamela Mace (Office of Science and Technology, Chair), Alec MacCall (Southwest Fisheries Science Center), Rick Methot (Northwest Fisheries Science Center), Grant Thompson (Alaska Fisheries Science Center), Steve Murawski (Northeast Fisheries Science Center), and Doug Vaughan (Southeast Fisheries Science Center).

This Technical Memorandum contains the Proceedings of the 7TH NSAW, including abstracts of seminars and posters presented during the NSAW and discussion group reports. The agenda is reproduced in Appendix I and a list of the 53 participants and their affiliations is contained in Appendix II.

ACKNOWLEDGMENTS

Special thanks to Mark Chandler of the NMFS Office of Science and Technology for handling final edits and seeing this report through to publication.

ABSTRACTS OF PAPERS AND POSTERS

An Overview of Metrics Reflecting Ecosystem Status

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We briefly overview some metrics reflecting the status of the Northeast continental shelf ecosystem for ecosystem-based fishery management (EBFM), a holistic approach to maintaining ecosystem quality and sustaining associated benefits. EBFM requires: (i) **Goals** to set policy; (ii) **Metrics** to translate goals into quantifiable terms; and (iii) **Management** that uses metrics as decision criteria to achieve goals. Data and metrics for this overview were taken from recent Northeast Fisheries Science Center (NEFSC) publications.

Metrics to evaluate the goal of sustaining the productivity of the groundfish trawl fishery on Georges Bank included the harvest control rule and survival ratio anomalies of Georges Bank haddock during 1931-1999 as well as primary groundfish yields since 1935. Color-coded summaries of these metrics showed that fishery productivity is currently very low and has not been sustained over the long term. Persistent overfishing was identified as the primary cause of low productivity although effects due to changes in trophic interactions and oceanographic conditions may also have contributed. Similarly, we used metrics on area closures, minimum trawl mesh size, and fishing effort controls to evaluate the competing goal of minimizing the cost of regulation of the Georges Bank fishery system. These metrics showed that regulations to conserve and rebuild depleted groundfish resources increased substantially in the 1990s.

Multiple metrics are needed to account for diverse human goals. Effective management can be challenging when trade-offs between competing goals are necessary. EBFM can improve the transparency of the management process by fostering: (i) **Accountability** - being explicit about decision criteria; (ii) **Legitimacy** - being explicit about policy strategies; and (iii) **Flexibility** - being explicit about uncertainties.

Recently the NEFSC Ecosystem Status Working Group (ESWG) attempted to address "What are the natural and anthropogenic factors underlying changes and variability in the Northeast continental shelf ecosystem?" Oceanographers, economists, and biologists in the ESWG collaborated to synthesize existing knowledge, metrics, and expertise to document ecosystem status. Relative variability in human, biotic, and abiotic metrics over four decades were approximated using principal components analysis (PCA). Results showed that long-term changes in species composition, and in particular groundfish abundance, as well as fishery profitability, average fish size, fishing capacity, biodiversity, and environmental forcing had occurred. A two-dimensional approximation of the system trajectory showed that the system state in the 1960s differed substantially from that in the 1990s, as expected, and this suggested that empirical multivariate approaches could be useful for quantifying ecosystem status.

Report on the ICCAT Workshop on Environment and Tuna Recruitment (Madrid, Spain, May 7-12, 2001)

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The Sub-Committee on Environment, formed by the International Commission for the Conservation of Atlantic Tuna (ICCAT) Standing Committee on Research and Statistics (SCRS), held a special meeting in May of 2003 to discuss the potential relationships between the environment and tuna recruitment as well as the implications of such for fishery assessments. This presentation reports on the documents presented at the meeting, topics discussed, the analyses conducted during the meeting, and the conclusions and recommendations of the group.

The documents presented generally found some (often weak) correlation between long-term trends in environmental indices and tuna recruitment. Other documents, supported by analyses conducted during the meeting, demonstrated that even apparently strong relationships could disappear when the index was de-trended, or that high-frequency ("white noise") variability in recruitment could result in the long-term cycles sometimes observed in spawning biomass or carrying capacity. Therefore, simple correlation studies may be unable to elucidate the influence of an environmental variable on stock dynamics.

Incorporation of environmental considerations within ICCAT stock assessment procedures requires attention to the specific characteristics of large pelagic species, for which general theories developed for small pelagic and demersal species may be of limited value. The group considered that environmental factors could potentially influence recruitment: 1) during the critical period (i.e., a few days after larval yolk has been exhausted) through food limitation, transportation of eggs and larvae by wind and currents, temperature effects, and other relevant factors; 2) before the critical period; for example, by affecting the condition of spawners or spawning behavior; and 3) after the critical period, through food limitation, temperature, predation, cannibalism, competition, and other relevant factors. Furthermore, environmental changes may affect the stock itself, through recruitment, migration, reproductive behavior, and other biological parameters, or environmental factors could affect our *perception* of the status of the stock due to environmental effects on measured variables (e.g., CPUE).

The group concluded that, in order to integrate environmental factors into an assessment, potential factors and the hypothesized relationships with biological characteristics of each species must first be identified (examining conditions prevalent in suitable or preferred habitats could be an initial step in accomplishing this), and the possible biases that might arise if these factors are/are not integrated into an assessment should be noted. To improve the ability to detect trends and shifts, long-term databases should be developed and analyzed.

Rebuilding Atlantic Swordfish: a Ten-Year History

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Swordfish stocks in the Atlantic Ocean are managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT). In 1990 the ICCAT swordfish species working group reported that the current level of fishing effort was not sustainable and that the rate of stock recovery would be greatly improved if fishing effort on juvenile swordfish could be reduced.

Catch and minimum size limits were established in 1991 for both the North and the South Atlantic. Catch quotas have been reduced every year since 1995 in the North Atlantic but South Atlantic catch limits were not further reduced until 1998. One result of quota reduction in the North Atlantic was a shift in effort to the South Atlantic particularly by vessels from the European Community.

Projections indicate that the North Atlantic stock has some chance of increasing to B_{MSY} in 10 years under the current regulations. The South Atlantic stock appears to be closer to B_{MSY}, however, the catch and effort data are not as complete in the South as in the North. The situation is also complicated by considerable fishing effort which occurs just below 5° N Latitude. For purposes of swordfish stock management under ICCAT, fish caught below 5° N Latitude are considered to be South Atlantic swordfish. This is probably not a realistic assumption.

In the U.S. longline fishery the median size of landed fish increased after minimum size limits were imposed, however the numbers of swordfish discarded increased greatly and approximately 70% of the discarded fish were dead. While minimum size limits have reduced the mortality on juvenile swordfish in the western Atlantic, the numbers of dead discards have been discouraging. In 2001 significant U.S. fishing areas were closed to longline fishing. The effect of these closures has not been evaluated.

Ongoing research supported by ICCAT and ICCAT members includes genetic and tagging studies to identify boundary and/or mixing areas particularly between the North and the South Atlantic; biological and modeling efforts to improve growth curve estimates and more fully incorporate biological information in stock assessments; examination of spatial and temporal distributions to identify times and areas where small swordfish are caught; and ecological analyses to include environmental variability in CPUE series.

Overfishing: Single Species and Ecosystems

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Fisheries management is required to generate measures of overfishing and establish harvest rates that are consistent at the various levels of biological organization. Systemic management meets these requirements by providing goals for sustainable harvest rates that are compatible with measures of overfishing from single-species resources to multi-species groups in the marine environment.

Fisheries management must also regulate catch allocation. Catch may be allocated over alternative resource species, across trophic levels, among various groups of resource species, across age groups, over time (e.g., seasonal quotas or catch limits) and over space (e.g., establishing marine reserves or finding advisable locations to harvest). Such allocations can be established through systemic management by using the observed allocations among other predatory species while simultaneously and consistently setting objectives for total harvests from individual species, species groups, and ecosystems. All such objectives must be part of any complete management plan.

Another objective of management is to account for complexity. This would include, but is not limited to, accounting for evolutionary and co-evolutionary dynamics, physiological processes, predator/prey relationships, the varying physical/chemical nature of the environment, competition, behavior, life history strategies, and allometric relationships involving body size - all factors that are under-represented in conventional management practices. Systemic management automatically accounts for complexity by incorporating all possible factors through looking to nature itself as a guide.

The undefinable complexity of nature is accounted for in systemic management by using emergent empirical patterns for guidance. The guidance provided in systemic management precludes (and solves the problems created by) advice based on incomplete consideration of complexity common in conventional management that is based on partially relevant models, meetings, and the judgment of experts. The manipulation, control, or management of any system always has repercussions and consequences beyond our capacity to consider. The dynamic, complex, and interconnected nature of the biosphere is beyond human prediction, and cannot be controlled to avoid the consequences of our actions. Instead, we can achieve sustainability by regulating human influences or impacts so that they fall within the limits of natural variation observed in natural systems. This results in human influence that mimics the successes of other species in the face of, and products of, complexity – using predation rates by other predators, for example, in managing harvests of fish. Systemic management acknowledges that nature cannot be reconstructed from the incomplete set of parts that have been isolated for study by scientists. Nature can be accurately viewed only in its entirety – as a whole with parts and components directly relevant to specific management questions. As such, realistic guidance is best obtained through empirical information, exemplified by looking to other species as role models for the sustainability sought in management.

Comparative Modeling Approaches for Exploited Marine Ecosystems in the North Pacific: What are these Models Good for?

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The Sustainable Fisheries Act amendments of 1996 required the Secretary of Commerce and the National Marine Fisheries Service to establish an Ecosystem Principles Advisory Panel (EPAP). Congress requested that the Panel provide advice on how ecosystem principles should be incorporated into fisheries management, and the Panel subsequently produced a Report to Congress that outlined basic system level principles, goals, and policies, and recommended implementation via Fisheries Ecosystem Plans (FEPs) developed for each region. Among the FEP actions recommended were the development of conceptual models of food webs, and estimating how total removals relate to standing biomass, production, optimum yield, natural mortality, and trophic structure. Models such as Ecopath with Ecosim may be appropriate tools for filling these needs and improving the understanding of ecosystem structure and function for both scientists and managers alike.

Already such models have been developed for many Northeast Pacific ecosystems, and interest in their capabilities and limitations has increased significantly. We have begun to address these questions by comparing the structure and dynamics of two exploited marine ecosystems, the Northern California Current (NCC) and the Gulf of Alaska (GOA) continental shelves. In this presentation we outline the merits of the comparative approach and some of the caveats of the modeling framework. This research is part of an ongoing working group at the National Center for Ecosystem Analysis and Synthesis (NCEAS), which will focus on comparing five large marine ecosystems (the three others being the Eastern Bering Sea (EBS), the Central North Pacific Gyre (CNPG), and the Eastern Tropical Pacific (ETP), and evaluate these models both as a conceptual tool for understanding ecosystem structure and function, as well as their potential utility to managers.

Although the assumptions and premises of these models are not new, and their shortcomings can be substantial, our initial impression is that the simple exercise of gathering all of the information known about a system into a common place and format is extremely useful. Ecopath is designed for this basic accounting procedure, showing where the data are not compatible and perhaps more importantly where data are lacking. Ecopath also forces us to attempt to generate instantaneous snapshots of the whole system which allow us to relate components that we have previously considered only in isolation. This is very useful for comparisons within a single system through time, for example in attempting to show changes in the Northern California Current between the 1960s, thought to be a cool, more productive regime and prior to intensive exploitation of groundfish, and the 1990s following a series of anomalously warm climate events and substantial depletion of many commercially and ecologically important stocks.

Some summary statistics from Ecopath, such as Primary Production Required (PPR) may also be extremely useful in comparing across systems. For example, a comparison of PPR for the NCC in the 1960s vs. the 1990s demonstrates that a much larger proportion of system production was being removed in the 1990s. Further comparisons of this same summary statistic between systems show that the removals in the 1990s NCC accounted for a much higher proportion of system productivity than the much larger catches in the Bering Sea and Gulf of Alaska in similar time periods. An even more straightforward statistic, of catches relative to a unit area, suggests that fisheries in the Northern California Current have been significantly more intensive in this system (Figure 1). The large PPR value in the EBS in the 1950s, which was associated with a relatively small catch per unit area, reflected the intensive harvest of marine mammals in that region during the 1950s and 1960s. While we are not yet convinced that these might be meaningful or appropriate "ecosystem indices," they are certainly illustrative of the *types* of statistics which could play a useful role in assessing ecological health or integrity in an ecosystem context. One key objective of the NCEAS working group is to assess and/or develop various ecosystem metrics or indices that are insightful to all systems by comparing the insights across five very different systems spread throughout the Northeast Pacific.

Another key challenge in attempting to share insights as to ecosystem structure and function is the visual representation of ecosystems. In our view, the box-flow model built into Ecopath food web visualizations can be difficult to interpret, especially when targeting audiences of primarily managers and stakeholders. Currently workers at the Alaska Fisheries Science Center are making substantial strides towards improving the means by which this structure can be presented. Figure 2 is an example of progress towards this objective using visualization software designed by Kerim Aydin (AFSC) to improve upon the insights gained by these models through both static and dynamic images. The goals of our work, and that of the participants in the NCEAS working group, are to continue improving upon both the visual representation of complex systems and upon the utility of such representations to managers.

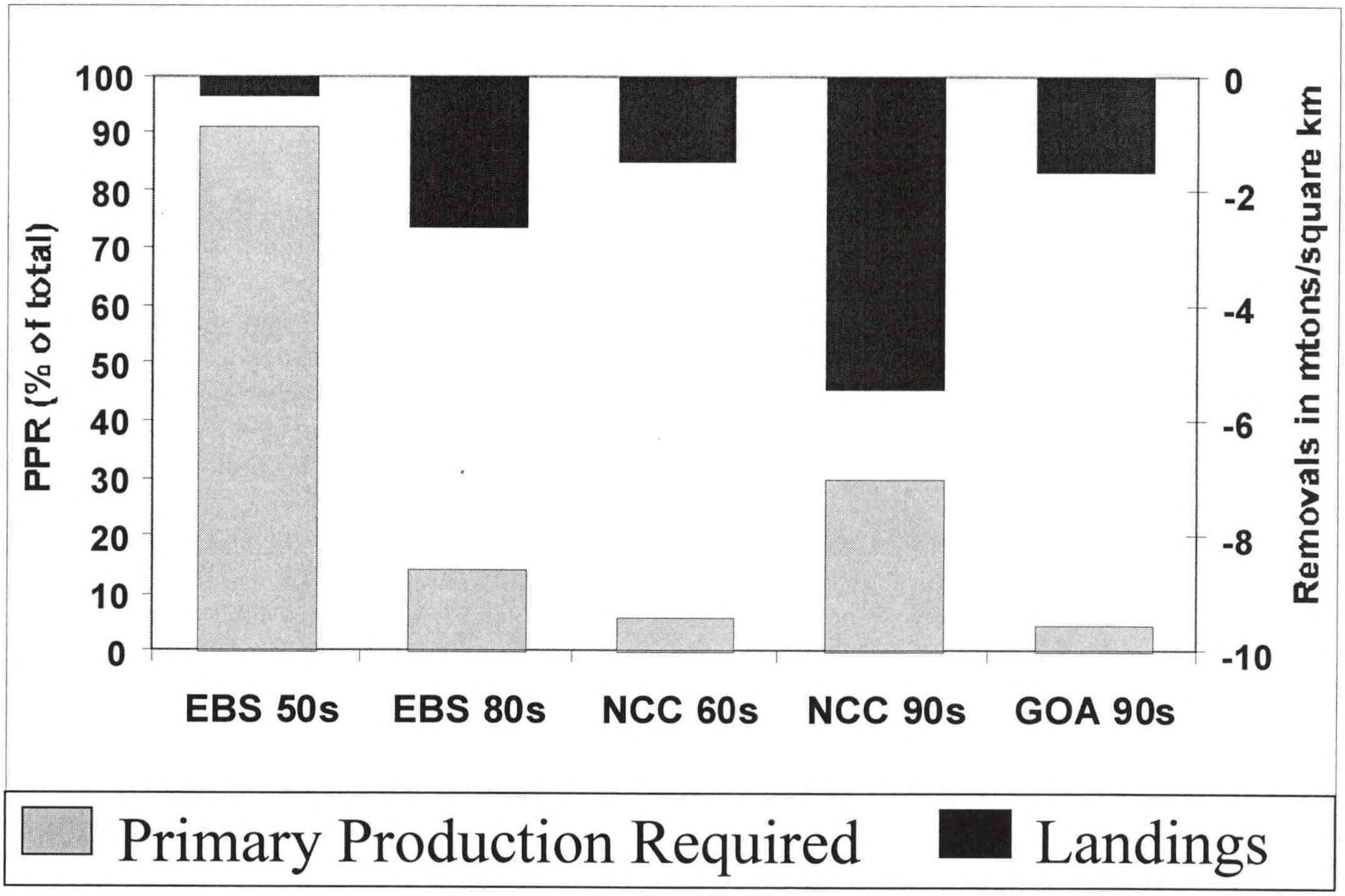

Figure 1. A potential example of ecosystem metrics for three large marine ecosystems in the Northeast Pacific; removals in metric tons per square kilometer and the percentage of new production required to support those landings in the Eastern Bering Sea, Northern California Current, and Gulf of Alaska.

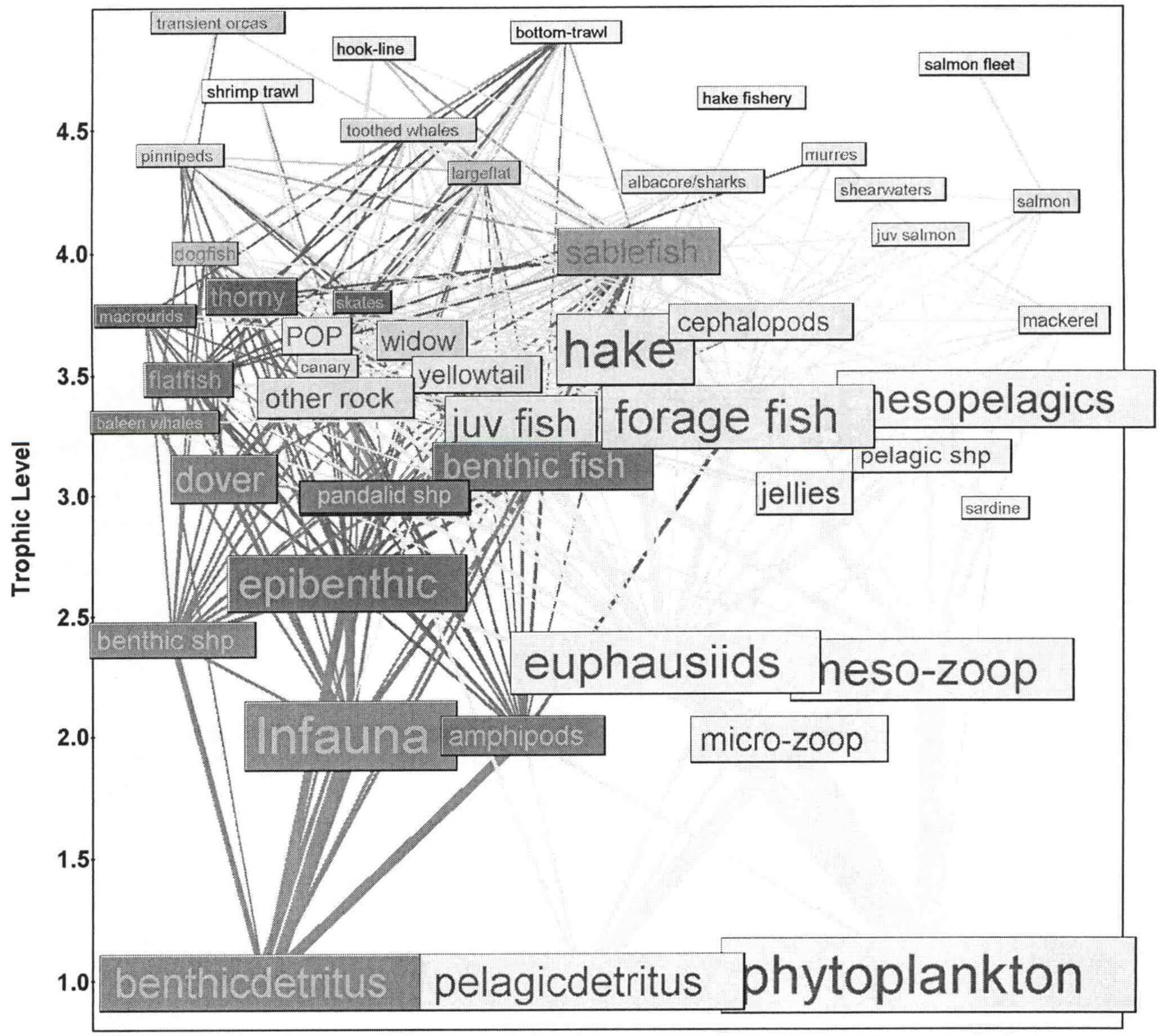

Figure 2. An example of energy flow through a simple food web for the Northern California Current, using visualization software developed by Kerim Ayden (AFSC/NMFS). Dark boxes and flows represent benthic energy paths and light boxes represent pelagic (new production) pathways; the size of the boxes is relative to the square root of the mean standing biomass (with both a maximum and a minimum font size range).

Rebuilding and Management of Sedentary Stocks Using Area Closures and Rotational Fishing: the Atlantic Sea Scallop Example

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Prior to 1995, the U.S. sea scallop fishery displayed typical symptoms of overfishing, with long-term declines in biomass and commercial catch rates. In 1994, a number of new management measures were introduced, including gradual effort reduction, gear restrictions, and limitations on crew size. Additionally, in December 1994, three large areas of Georges Bank and Nantucket Shoals were closed to groundfish and scallop fishing. Two areas in the Mid-Atlantic were also closed to scallop fishing for three years in April 1998 in order to protect concentrations of small scallops there. Sea scallop biomass in the Georges Bank closed areas increased by more than a factor of twenty since 1994, while biomass in the Mid-Atlantic closed areas increased by about a factor of four during the three years those areas were closed. Portions of the Georges Bank closed areas were briefly reopened in 1999-2001, resulting in the landings of about 5000 MT of scallop meats (adductor muscle only), even as biomass in these areas continued to rise. Responses in the open areas were delayed and more gradual, but still clearly evident. Open area biomass, landings-per-day, and landings have each more than tripled since 1998.

The above results suggest that sea scallops could be managed by rotating open and closed areas. Rotational yield-per-recruit analysis indicates that rotation improves both yield and biomass slightly at F_{MAX}. Rotation gives a greater advantage at higher fishing mortalities because it allows at least a portion of the scallops to grow to a large size regardless of the level of fishing mortality. Further improvements in yield can be obtained by adaptive rotation, where areas with high densities of small, rapidly growing scallops are temporarily closed. Both theory and practice indicate that rotational closures and re-openings can increase sea scallop biomass and yields.

Multispecies Catch at Age Model (MSCAGEAN): Incorporating Predation Interactions and Statistical Assumptions for a Predator-Prey System in the Eastern Bering Sea

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Several methods currently used in fisheries stock assessment rely on catch at age data. These models permit the reconstruction of the population dynamics of exploited fish stocks and provide estimates of population parameters that serve as a basis for advice in fisheries management. One of most common types of models used in fisheries is "statistical catch-at-age models", which relies on assumptions about observation/process error structure. In contrast, virtual population analysis is based on recursive algorithms that calculate stock size, based on catches with no underlying statistical assumptions. These two types of single species models have been used extensively in the management of fisheries resources. However, due to the significant management problems caused by possible multispecies interactions, there is an increasing tendency to recognize that fish populations are not isolated. Therefore, several attempts have been made to include biological interactions in models. Among them, the multispecies virtual population analysis (MSVPA) incorporates predator stomach data into the virtual population. One of the main weaknesses of the MSVPA is its lack of statistical assumptions that impede the inclusion of uncertainty into the decision-making process in a multispecies context. The inclusion of statistical assumptions on process and observation errors in a multispecies context will allow testing hypotheses on parameters and states of nature. This task requires a change in the approach used to assess the dynamics of populations in a multispecies framework. Currently, the MSVPA is based in the Gulland backward nonlinear sequential method. A new approach requires the inclusion of the separable fishing mortality assumption. This way, the maximum likelihood procedures can be used in a multispecies context, allowing the estimation of the likelihood profile or the posterior distribution of parameters and indicators of performance.

This approach also allows the assessment of uncertainty of parameters and indicators in a multispecies context, a task that is not possible with the current MSVPA model. This approach will significantly improve the multispecies approach for fisheries management. In the present work, we introduce the predation equations from the MSVPA model into the single species CAGEAN model creating a multispecies version of this last model. Both models MSVPA-MSFOR and multispecies CAGEAN (MSCAGEAN) were applied to a system of two species (Walleye pollock and Pacific cod) from the eastern Bering Sea. Results from the two methods were comparable. However MSCAGEAN was able to provide posterior distributions of some parameters for which there were only point estimates from the MSVPA. Preliminary results suggest it is possible to incorporate the predation equations used in MSVPA into a multispecies statistical catch at age model. The next steps are to further validate the results from this simple MSCAGEAN model and then apply the technique to link the statistical age structured model of the Alaska Fisheries Science Center, which rely on the AD model builder framework.

Variations in the Growth of Bigeye Tuna (*Thunnus obesus*) in the Equatorial Western Pacific Ocean

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Since 1986, the island of Guam has become a significant port for the Japanese coastal and Taiwanese offshore longliners fishing in the equatorial western Pacific (2-5°N latitude and 140-160°E longitude) and transshipping fresh fish to the markets in Japan. In 1990, 7,006 and 5,016 t of fresh bigeye (*Thunnus obesus*) and yellowfin (*T. albacares*) tunas, respectively, were transshipped, of which the Japanese longliners accounted for 74% of the landings. Annually, bigeye landings peaked in 1990 at 5,760 t but fell to a low of 1,214 t in 1996 (slope = -458.6, $p = 0.002$) (Kikkawa *et al.* in prep). As part of the transshipment monitoring program we investigated the possibility of determining individual year class growth rates of bigeye tuna *(Thunnus obesus*) through mode progression analysis on monthly size frequency distributions of Japanese landed bigeye tuna from 1989 to 1998.

Recruitment was highly seasonal and occurred around the first quarter of each year. There were five or six highly identifiable modes or year classes within each size frequency distribution, and from time of recruitment the modes could be tracked for about four or five years before they overlapped near the asymptotic size. Because growth was based on relative age, the Von Bertalanffy growth model was modified to include a conversion parameter for converting relative to real age.

Of the seven identified year classes, the 1989 age-group recorded the highest growth rate (K) at 0.465 per year and correspondingly the lowest asymptotic size (L_∞) of 157.9 cm FL. The lowest growth rates of 0.224 and 0.201 were from the 1991 and 1992 year classes, respectively; asymptotic sizes were very similar at 204.9 and 204.1 cm FL. Age at length zero or t_0 ranged from a low of -0.0061 to a high of -0.0034 for the seven year classes. At the recruitment size of 80 cm fl, age extended from a low of 1.52 yr to a high of 2.47 yr and averaged 1.83 yr.

Time of hatching for each of the year classes was correlated to one of four oceanic conditions: El Niño, La Niña, or the transitional phases. For the highest growth rate age group, the 1989 year class, hatching occurred during a prominent El Niño event extending from 1986 to 1988 with a peak in 1987. By contrast, during the low growth rate year classes of 1991 and 1992, hatching occurred during a three-year La Niña event that started in 1988. In the moderate growth rate age groups of 1990 and 1993, hatching occurred during the transitional phases of ENSO.

Recruitment strength was also highly correlated to growth rates such that stronger recruitment year classes have higher growth rates, and the weaker year classes have lower growth. Much of the variability in recruitment strength and growth rates was related to prevailing oceanic conditions during the early life stages. During El Niño, higher primary and secondary production conditions prevailed in the western Pacific, which were conducive for increased larvae growth. Faster growing larvae would experience a lower mortality during the critical period and in turn resulted in larger recruitment classes.

Overfishing Review of Queets River Coho Salmon

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In 1997, 1998, and 1999, the Queets River coho salmon stock failed to meet the lower bound of its MSY escapement goal range, but did meet its escapement goal in 2000. In September of 2000, new overfishing criteria became effective with the adoption of Amendment 14 to the Salmon Framework Management Plan (FMP). Under the new criteria an overfishing review was required. Subsequently, the Council instructed its Salmon Technical Team (STT) to complete a stock assessment of Queets coho in response to this overfishing concern.

The STT evaluated the degree to which various factors (freshwater production, marine survival, and harvest) may have contributed to the low spawning escapements in 1997 through 1999. All three of these factors were implicated in the failure of the stock to meet its escapement goal. Floods and mass wasting events within the Queets River drainage had resulted in poor production of smolts from the 1996 brood year. Marine survival of all coastal coho populations declined in the late 1970s, and declined even further in the 1990s. For Queets River coho salmon, outmigrant monitoring has allowed estimation of marine survival rates for the last 20 years. Marine survival rates of the broods returning in 1997 through 1999 were among the five lowest survival rates estimated in the 20 years of monitoring. These problems with production and survival were anticipated, and fishing mortality rates in 1997 through 1999 were lower than in any previous year.

The relative roles of freshwater production, marine survival, and fishing mortality were examined through simulations incorporating observed values for two of the factors while holding the third factor constant. This hindcasting exercise revealed that eliminating variability in freshwater production would have met the escapement goal in only one of the three years. Eliminating all fishing mortality would also have resulted in the stock meeting its escapement goal in only one of the three years. However, stabilization of marine survival, even at the low average levels experienced through the 1990s, would have resulted in the stock meeting its escapement goal in all three years.

The STT concluded that harvest was not the primary cause of the Queets River coho stock failing to meet its escapement goal, and thus it was not overfished. Consequently, development of a rebuilding plan and criteria for determining an end of overfishing are not warranted at this time.

A Feasible Framework for Ecosystem Based Fisheries Management

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There are several reasons why the topic of ecosystem based fisheries management (EBFM) is currently very germane, including multiple and potentially conflicting legislation that can influence living marine resources. Recent progress in the scientific community demonstrates a movement of the debate from issues of when should we do EBFM, why would we want to do EBFM, or what exactly is EBFM, to addressing how we might actually do EBFM. To further the eventual implementation of EBFM, I propose a strawman framework consisting of three pillars.

The first pillar of EBFM is establishing ecosystem goals. These goals should be clear, quantifiable, and not simple altruisms (e.g., "health"); should explicitly allocate biomass tradeoffs within an ecosystem; should be holistic (i.e., consider both top-down and bottom-up processes); should evaluate the sustainability or obtainability of a desired ecosystem state; and should include as many possible stakeholders as is feasible. The goal setting process should occur in public policy arenas and our role as scientists should be primarily to lay out the viable options (of biomass allocation) from which policy makers can make informed decisions.

The second pillar of EBFM is assessing the status of an ecosystem. I present multiple examples of abiotic, biotic, and human metrics from the northwest Atlantic ecosystem. Collectively these metrics provide an assessment of the status of the ecosystem relative to past ecosystem states. There are several multivariate methods that can help assess the status of an ecosystem and can also serve as useful ecosystem reference points.

The third pillar of EBFM is achieving ecosystem goals. It is currently feasible to map ecosystem goals to multivariate points of reference. By determining where the current status of an ecosystem is relative to the ecosystem goals, a multivariate direction of desired change can then be established. However we need to remember that some elements of ecosystem change are beyond human control (e.g., climate and weather). In reality, there are only about a half dozen management tools available for fisheries managers and in order to achieve ecosystem goals, novel and clever ways of using (and combining) these tools will be required.

The major challenge remaining is to develop mechanistic, process model-based control rules, limits, thresholds, and other reference points for EBFM decision criteria that recommend not only the direction of needed change (which we have) but also the magnitude of a required change. This proposed three pillar framework is a quite standard decision theoretic approach, is parallel to the one currently used for single species fisheries management, and has simply been adapted for the particulars of EBFM. I conclude by noting that in many respects, EBFM is feasible now.

A Comparison Between the Requirements of ESA and MSFCMA for Overfished Stocks

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During the last 25 years, the Endangered Species Act (ESA) has been a tool for increasing the abundance of depleted fish stocks. During that period, very few marine fish were petitioned for listing as "threatened" or "endangered" under the ESA. The Sustainable Fisheries Act (SFA), which is the part of the most recent reauthorization of the Magnuson-Stevens Fishery Management and Conservation Act (MSFCMA), introduced a somewhat parallel requirement to rebuild overfished stocks. The following comparison of the requirements and implementation of these two acts provides some insight into their utility and potential effectiveness under various circumstances.

The SFA requires a more quantitative and explicit treatment of what constitutes an overfished stock (e.g., when abundance falls below one-half the abundance providing maximum sustainable yield, B_{MSY}), whereas ESA listings are based on probabilities of extinction at some future time (neither the length of time, critical probability level, or abundance corresponding to extinction are explicitly defined by the ESA, and in recent salmon listing determinations, these factors were addressed by preponderance of expert opinion; a.k.a. a vote). Both Acts are similar in that a formal process for increasing stock abundance ("Rebuilding Plans" under the SFA, and "Recovery Plans" under the ESA) is required for subject stocks. Again, the SFA is more quantitative and explicit, requiring that stocks be rebuilt to a specific level (B_{MSY}) within ten years (if that is not possible, the NMFS National Standard Guidelines specify a time not to exceed the minimum time under no fishing plus one generation time). The ESA does not explicitly specify time limits or conditions for recovery, and time to recovery is rarely treated explicitly in ESA Recovery Plans. Rebuilding Plans and associated fishery management under the SFA are subject to a variety of regulatory reviews including the National Environmental Policy Act and the Regulatory Flexibility Act, whereas the regulatory review of ESA Recovery Plans appears to be minimal. On the other hand, the ESA mandates coordination with other governmental actions and policies, but the SFA provides relatively little ability to influence governmental policy other than through fishery management. The ESA also provides a means for regulation of international trade (through CITES), whereas the SFA provides little or no control either over U.S. fleets operating in foreign waters or transboundary shipments of subject species.

If stock depletion and remedial actions are primarily associated with fishing activity in U.S. waters, the SFA provides the stronger basis for rebuilding stock abundance. If remediation requires actions other than domestic fishery management (e.g., habitat conservation), the ESA provides the stronger authority.

A Critique of the Scientific Basis for Listing Species on the IUCN Red List, CITES Appendices, and the AFS List of Species at Risk: Can We Do Better?

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A NMFS / Interagency Working Group was formed in September 2000 to evaluate the utility of the current criteria and guidelines used by the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) to list species on its Appendices. Although the focus of the Working Group was on marine taxa, other taxa were also considered. In addition to reviewing CITES' own criteria, the group also considered the criteria adopted for similar purposes by the World Conservation Union (IUCN), the American Fisheries Society (AFS), and others.

The current criteria used by the IUCN for placing species in their "Red List" categories contain numerous rigidly-defined cut-off points that may work for selected taxonomic groups, but cannot possibly apply across all taxa. In contrast, the criteria used by CITES contain relatively few numeric cut-offs, but still retain the concept of single absolute numbers (e.g., by defining a "small" population as one of less than 5,000 individuals) that should presumably apply across all taxa. Criteria recommended for use by AFS also use thresholds, but differ from IUCN and CITES in two fundamental ways: (i) by focusing on percent decline rather than absolute population size or area of distribution, and (ii) by introducing the concept of the level of population productivity and linking this to decline thresholds.

The main questions addressed by the Working Group related to the utility of considering the historical extent of decline versus the recent rate of decline, time frames over which to consider declines, the utility of absolute numbers for defining species at risk, the need for different numbers or criteria for different life histories or taxonomic groupings, and the overall utility of developing generic numeric guidelines to trigger consideration for listing species on the CITES Appendices. The Working Group concluded that the primary trigger for consideration for listing should be the historical extent of decline with the time horizon stretching as far back into history as possible and the percent decline threshold being inversely related to population productivity. The suggested range of percent decline was a decline down to 5-30% of an appropriate historical baseline, with 5% being used for high productivity species and 30% for species with very low productivity. It was concluded that a somewhat narrower range of 5-20% might be more appropriate for commercially exploited marine taxa. The working group also concluded that generation times (used by IUCN, CITES, and AFS) are not particularly useful for defining time horizons over which to evaluate declines. Regardless of the generation time, the evaluation should extend as far back in time as data allow. Overall, it was agreed that (i) there is utility in developing generic numeric guidelines, (ii) these numbers need to be customized for different life history groups, particularly in terms of population productivity, (iii) there are a number of specific life history characteristics that may modify the level of concern for particular species, and (iv) there is no escaping the need to consider candidates on a case-by-case basis, and the ultimate need for "reasoned scientific judgment".

Salmon Recovery Planning: Conservation and Fisheries

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One of the first steps in recovery planning is establishing recovery goals. Technical Recovery Teams for Pacific salmonids are using the "Viable Salmonid Population" (VSP) concept to establish these goals. The first step in a VSP analysis is to identify boundaries of demographically independent populations. While data on straying rates would be ideal for this effort, this information is not commonly available. Thus, genetic, geographic, life history, morphological, and habitat data play a role in population identification efforts.

Once populations are identified, four parameters influencing extinction risk form the key to evaluating population viability status: abundance, productivity, spatial structure, and diversity. Abundance is an important predictor of extinction risk, since populations at low abundance are at higher risk of extinction due to genetic processes, demographic stochasticity, deterministic density effects, environmental variation, and other processes. Thus, populations should be large enough to minimize these risks. Productivity across the life cycle provides information about how well the population is "performing" in the habitats it occupies, and is a primary driver of extinction risk. Population spatial structure contributes to the risk of extinction in that fragmented populations and subpopulations with low connectivity (low rates of migration between adjacent groups) are more subject to extinction due to catastrophic events. Finally, diversity (genetic and phenotypic) is an important protection against short-term spatial and temporal changes in the environment and allows a greater array of environments to be utilized.

A final step in recovery planning, after recovery goals have been established, is to evaluate the potential impact of a variety of conservation actions. Modeling work in the Snake River spring/summer chinook evolutionarily significant unit (ESU) suggests that a high proportion of mortality occurs in early life stages (in freshwater, estuarine, and nearshore ocean habitats). A general analysis of impacts on Columbia River ESUs suggests that harvest and hydropower impacts and potential improvements affect the 12 listed ESUs differentially.

Development of Demographic Criteria for ESA Listing Decisions – the Marine Mammal Experience

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The Endangered Species Act (ESA) requires a determination of whether a species should be listed based on five specific factors. While this requires that "objective, measurable criteria" be developed to evaluate the five factors, separate demographic criteria are not explicitly required under the ESA. In practice, demographic criteria are the key to a listing determination, but the ESA only describes an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range," and a threatened species as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of the range." The only guidance from the Act seems to be that federal agencies need to consider risk and extinction when making a determination.

Seven large whale, manatee, and two seal species were listed prior to the passage of the ESA in 1973, with only three species listed since then. While the early marine mammal listing decisions were based on the status (abundance and trends) for species as a whole, these approaches generally only considered extinction in a qualitative fashion, and did not explicitly address risk. More recent decisions (e.g., North Atlantic harbor porpoise and Gulf Inlet beluga) have involved risk-based analyses. However, the approach has not been uniformly applied, and there is a need to develop a general strategy for de- or down-listing criteria to publish Recovery Plan updates or to change status. NMFS (F/PR) held a workshop in Seattle during February 2001 to design a framework for developing criteria with North Atlantic right and humpback whales as test cases.

Workshop participants determined that listing criteria should have the following characteristics: 1) be defined by the risk of extinction, 2) explicitly identify the acceptable risk and the time frame of consideration, 3) be probabilistic, 4) use a Population Viability Analysis (PVA) approach/philosophy, and 5) be developed and applied at the Distinct Population Segment (DPS) level. The workshop recommended that the generic criteria for large whales should be that they are "endangered" if the probability of becoming extinct is greater than or equal to 1% in 100 years, and "threatened" if the probability of becoming endangered was greater than or equal to 10% in ~20 years.

Rebuilding West Coast Groundfish Stocks: Long-Lived Species for Which Climate and Spawner-Recruitment Effects are Confounded

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Since 1998, eight west coast groundfish species have been declared to be below the overfished threshold, set at 25% of the unfished level of female spawning biomass. Major declines started during the 1980s as recruitment declined from historical levels just as levels of domestic harvest increased. During the 1990s, harvest rates were typically set at F35% for then-assessed species, but this rate, in retrospect, was not sufficiently low to halt the decline. Only one species, lingcod, shows sufficient productivity to rebuild in less than 10 years. The other overfished species are long-lived rockfishes (*Sebastes* spp): cowcod, canary, bocaccio, widow, darkblotched, Pacific ocean perch, yelloweye. Their mean generation times range from 12 to 37 years. Rebuilding analyses typically have estimated the unfished level from an early average recruitment level multiplied by the unfished spawner per recruit ratio. The probability and rate of rebuilding has been calculated by random resampling of either recent recruitment levels or recent recruit per spawner levels, whichever appeared to be more constant. Four of these species are below 10% of unfished levels. Five species are projected to take 20 to 60 years to have a 50% probability of rebuilding to the B_{MSY} proxy level (40% of unfished level) even in the absence of fishing mortality. These slow rates of rebuilding are due to low recent recruitment levels.

In some cases, recruitment has been barely above the replacement level with no fishing. A Beverton-Holt S-R steepness of only 0.33 was estimated for canary rockfish. The paper critiques the various rationales for using recruits versus recruits per spawner in the rebuilding projections and recommends greater use of fitted spawner-recruitment curves to forecast the central tendency of future recruitments. Although these declines in recruitment are linked to the decline in spawning biomass in the rebuilding analyses, the decline in recruitment for many of the overfished species started near climate regime shifts that have been identified in 1977 and 1989. There is no formal protocol to include rebuilding probabilities associated with a future regime shift to more productive levels, especially since there is no climatological ability to predict the onset, character, and duration of these regime shifts. However, the influence of climate regime shifts on natural long-term fluctuations in stock abundance, target levels of abundance, and potential rates of rebuilding should be investigated further.

Rebuilding of Major Groundfish Stocks on Georges Bank: Haddock and Yellowtail Take the Lead, Cod Lags Behind

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The Georges Bank groundfish complex historically supported a highly-productive fishery, until overall stock productivity was severely impaired by overfishing from the 1960s through the 1980s. Atlantic cod, haddock, and yellowtail flounder stocks represent a significant proportion of the overall groundfish biomass and have supported directed fisheries since 1600 (cod), 1900 (haddock), and 1930 (yellowtail flounder). The distant water fleets prior to 1976 and subsequent expansion of the USA fleets following the Magnuson Act caused all three stocks to decline to such an extent that they were declared collapsed in the early 1990s. A comprehensive fishery management plan, implemented in 1994, utilized area closures, effort limitations, increased mesh sizes, and a license buyback program to reduce fishing mortality in an effort to rebuild stocks. Restrictive management regulations including seasonal closures and quotas were implemented on the Canadian portion of Georges Bank concomitantly. Currently the Transboundry Resources Assessment Committee (TRAC), a joint USA-Canada committee charged with reviewing stock assessments for Georges Bank, provides stock status to both U.S. and Canadian managers.

U.S. rebuilding goals, defined by the Sustainable Fisheries Act, are being approached at a much faster pace for haddock and yellowtail flounder than for cod. This difference can be explained by both biological and management factors. Haddock and yellowtail flounder have benefited from the closed areas more than cod due to distribution and migratory patterns. The fishing mortality rate has been reduced more on haddock and yellowtail flounder than on cod, allowing an expanded age structure in these two stocks. This expanded age structure corresponds to average lengths that are close to the asymptotes for haddock and yellowtail flounder, but are still many years away for cod. In addition, due to the distribution of the three stocks relative to the Hague line, strict Canadian regulations have had a more pronounced effect on haddock and yellowtail flounder than on cod. TRAC assessments indicate that all three stocks exhibited increases in spawning stock biomass, but only haddock and yellowtail flounder have shown significant improvement in subsequent recruitment, which is required to potentially achieve rebuilding targets. Yellowtail flounder has increased from 9% in 1994 to 114% of the current rebuilding target in 2000, haddock has increased from 14% in 1994 to 61% of its biomass rebuilding target in 2000, while cod has only increased from 26% in 1994 to 36% of its biomass rebuilding target in 2000.

However, the apparent rapid rebuilding of yellowtail flounder may be due to underestimation of the rebuilding target. A 70-year time series of catch at age data and associated assessment results for the Georges Bank haddock stock provides a long context including a 30 year period of relatively stable landings and recruitment on which to base stock rebuilding targets. For the cod and yellowtail flounder stocks, shorter assessment time series (< 30 years) associated with highly exploited stock sizes may result in an underestimation of potential stock productivity and associated stock rebuilding targets. As these stocks rebuild and potential stock productivity is achieved, revisions to stock rebuilding targets may be required.

Standardization of the Spanish Baitboat CPUE for Eastern Atlantic Bluefin Tuna: A Combined Analysis of Fleet Characteristics and Oceanographic Conditions (poster)

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The Spanish baitboat fishery operating in the Bay of Biscay since 1975 constitutes a specialized fishery targeting mainly young bluefin tuna. Using live bait, bluefin schools are attracted to the side of the boat where water curtains and live bait start a feeding frenzy. Individual or pair rods are used to catch the fish at the surface. The fleet operates almost exclusively from one port, Fuenterrabia (Spain), and has remained rather constant in terms of the number of boats. However, changes in fishing technology and replacement of all wooden boats with new larger steel boats have apparently increased the fishing power of this fleet. In the 1998 stock assessment, the SCRS-ICCAT working group recommended standardization of the Spanish baitboat CPUE series. In preparation, data on fleet evolution and characterizes, detailed catch information by trip collected from logbooks, and environmental and oceanographically correlated data were gathered and revised during 2000 and 2001.

Relative indices of abundance by age-class were estimated using generalized linear mixed models (GLMM). During the 1975-2000 period, four strong cohorts were detected with a periodicity of five to six years, which corresponds to the cohorts of 1975, 1982, 1987, and 1994, the last of these standing out as an exceptionally large year class. The new standardized CPUE of bluefin tuna at age was evaluated by re-calibrating the last Virtual Population Analysis (VPA) and performing a retrospective analysis. Results were compared with the most recent assessments. The standardized baitboat indices have a large influence on recent perceptions of the stock, in particular for the younger ages, which are the main target of the fishery. The retrospective bias analysis indicated that standardized indices of abundance for the younger age-classes are more reliable.

The Sustainability of Western Atlantic Bluefin Tuna: A Warm-Blooded Fish in a Hot-Blooded Fishery

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The Atlantic bluefin tuna (*Thunnus thynnus*) is one of the most valuable animals in the world. Weighing as much as 700 kg and able to swim at over 90 km h^{-1}, it is regarded by many as the consummate game fish. It is also highly prized among connoisseurs of sashimi, particularly in Japan where one 200-kg specimen recently commanded almost $174,000. Not surprisingly, the bluefin tuna population in the West Atlantic has plunged to a fifth of its former biomass, yet the fisheries for it remain lucrative. Some see this as a recipe for disaster reminiscent of elephant ivory and rhinoceros horns—but others see only a resilient species temporarily stymied by poor environmental conditions. Still others say the bluefin caught in the West Atlantic are part of a much larger pan-Atlantic stock and that the real problem is unregulated fishing in the East Atlantic. This paper discusses these and other perplexing issues that govern the "sustainability" of West Atlantic bluefin tuna in today's unquenchable markets. It also examines how cutting-edge technologies are being used to unveil the mysteries that for decades have enshrouded bluefin management policies in controversy.

Trends in Zooplankton Abundance off the U.S. West Coast and Implications for Recruitment of Sablefish

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There is increasing evidence suggesting that the northeast Pacific has recently undergone a climatic regime shift from a warm, low productivity period to a period of cool, high productivity. Trends in west coast sablefish (*Anoplopoma fimbria*) recruitment appear to be correlated with this regime shift. The 1970s and 1980s were also a time of relatively high sablefish recruitment with the 1977 year class being well above average. The 1990s were characterized by seven years of below average sablefish recruitment, the lowest estimated recruitments since the start of the time series in 1971. In 1999, there was an abrupt increase in sablefish recruitment, despite the lower estimated spawning stock biomass. The spring and summer months of 1970s and 1980s were characterized by copepod assemblages dominated by boreal (subarctic) species, such as *Pseudocalanus mimus* and *Calanus marshallae.*

Starting in 1990 the copepod species assemblage began to shift. The spring-summer abundance of the boreal copepod species declined off both central Oregon and southwestern British Columbia, while subtropical neritic and transitional zone species increased, indicative of a warm, low-productive environment. This trend to a more southerly copepod species assemblage reversed quite suddenly in 1999 as the system reverted back to the patterns seen in the 1970s and 1980s, with boreal neritic species dominating the copepod assemblage and southern subtropical neritics being common only during winter months. It is not known if the link between copepod species assemblage and sablefish recruitment is direct or indirect; however, copepod species assemblages may offer a predictive tool for future sablefish year class strength.

Scales of Physical Variability Impacting Marine Resources

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It is now generally accepted that environmental variability is an important contributor to ecosystem structure and changes in the biomass and distribution of marine populations. The challenge is to understand the critical factors of this variability that impact ecosystems, and use this understanding to assist in the management of fish stocks. A number of recent and historical changes in the biomass of marine fish stocks have been observed on interannual to decadal (10-50 year) time scales. Many of these are closely linked to changes in their physical environment. In some cases, the observed population changes led investigators to note corresponding physical changes. Evidence that geographically separate stocks fluctuate synchronously suggests that planetary-scale climate change may drive ecosystem changes in a number of ocean locations.

The atmosphere and ocean vary on a number of dominant time scales. In addition to the seasonal cycle, conditions change interannually (most notably with El Niño and La Niña events). They also vary considerably on decadal scales. Some of this climate variability can be described as a gradual evolution, over several years to decades, from one physical state to another. Other decadal changes appear as a sharp, rapid (i.e., within one to a few years) transition from one relatively stable state to another. These are referred to as climate regime shifts. These temporal fluctuations all appear to some degree as changes in marine populations and ecosystem structure.

The upper ocean appears to have two or more preferred, recurring states. For example, the present state of the north Pacific Ocean is quite similar to that observed during previous La Niña events. Upper ocean temperatures are relatively warm in central north Pacific and cool in the Gulf of Alaska and California Current System (CCS). These patterns can persist for decades, in a pattern called the Pacific Decadal Oscillation. The present, cool state (relative to the CCS) has existed since late 1998. It developed previously in the 1940s, coinciding with the collapse of the California sardine fishery, and persisted until about 1976. This cool state is also linked to higher production of Pacific Northwest salmon stocks and a number of baitfish species. The warm state, which is observed during El Niño, and after 1976, is more favorable for Alaska salmon production. There is additional evidence that the carrying capacity and species dominance of marine ecosystems change according to the ocean state.

These oceanic climate states are reflected in atmospheric circulation. In the northeast Pacific, the cool state occurs during a period when winds are favorable for enhanced coastal and open ocean upwelling. A characteristic relationship between global atmospheric and oceanic physical features has some persistence and a tendency toward repeatable patterns over time. This gives hope that forecasting future ocean conditions that affect ecosystem structure is attainable. Because the ocean generally remains in a particular state for years to decades, particularly in the mid-latitudes where the US EEZs are located, we may only need to recognize that the physical environment has changed to anticipate a corresponding population change. However we are still at the "proxy" stage of linking environmental and fishery variability. Future research must focus on identifying the mechanisms by which changes in the physical climate state of the ocean leads to ecosystem change.

Recovery of Atlantic Striped Bass: Now What Do We Do?

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Over the past 20 years, Atlantic coastal striped bass stocks have varied markedly in abundance, from very low to very high levels of abundance. The reasons for recovery in recent years include improved habitat and water quality and perhaps most importantly, aggressive fisheries management by State and Federal agencies. Managers are now faced with managing rebuilt populations to address multiple objectives among different user groups.

The historical record indicates that striped bass have undergone several periods of severe population declines, particularly during the late 1800s-1920s and again in the 1970s-1980s. In the latter case, the imposition of stringent management regulations reduced fishing mortality substantially, fostering increases in abundance and spawning stock biomass. Subsequently, recruitment increased and record high year classes were produced in 1993 and 1996. The fishery re-opened in 1990 and fishing mortality has since been at or below the target fishing mortality.

A new amendment is being developed to the Atlantic Striped Bass Fishery Management Plan. During the Amendment scoping process, a number of issues have surfaced reflecting conflicting objectives among four broad categories of users (i.e., coastal commercial; producer area [bays] commercial; coastal recreational; and producer area recreational). These groups target different size groups of bass and therefore resource allocation is a contentious issue.

Future management of striped bass will need to contend with emerging ecological and social issues associated with managing the resource at abundance levels not previously experienced.

Decision-Theoretic Estimation of the Optimal Catch Using a Stock Assessment Model Structured with Respect to Age, Season, and Area

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A stock assessment model is proposed in which both the age structure and spatial structure of the stock are modeled on intra-annual as well as annual time scales. The system state at each time step is modeled as a linear function of the system state at the previous time step, modified by random process error. Observations of the system state at each time step are modeled as a linear function of the true system state, modified by random measurement error. The Kalman filter is used to form the likelihood function. Other features of the new model include the following: 1) selectivity, weight, and maturity at age are described by functional forms that assure a smooth transition between individually modeled age groups and the "age-plus" group, and 2) fish movement between areas is modeled as a trendless random walk, thus eliminating the need to estimate a matrix of migration rates. In principle, the spatio-temporal scale of the model can be arbitrarily fine, potentially allowing assessment results to be presented on scales useful to studies of the dynamics of predator species such as the Steller sea lion.

The model is used to illustrate a simple answer to the familiar question, "What should single-species fishery management be trying to maximize?" or, stated somewhat differently, "What is the appropriate tradeoff between the mean and variance of yield?" For example, if the stationary distribution of relative yield y (i.e., sustainable yield scaled relative to MSY) is normal, then the distribution of antilog relative yield ARY is lognormal, and the following table helps to illustrate the answer:

attitude toward risk	quantity to maximize	equivalent to maximizing
risk averse	harmonic mean ARY	mean(y)-variance(y)/2
risk neutral	geometric mean ARY	mean(y)
risk prone	arithmetic mean ARY	mean(y)+variance(y)/2

Although the third column in the above table is dependent on the assumption that the stationary distribution of relative yield is normal, the second column depends only on the choice of a particular family of utility curves. Three sources of uncertainty are sequentially incorporated: uncertainty due to random variability ("process error"), uncertainty due to imprecision in estimates of the current state, and uncertainty due to imprecision in estimates of parameters. In the risk-neutral approach, incorporation of uncertainty does not alter the optimal fishing mortality rate. However, in the risk-averse approach, incorporation of each additional source of uncertainty results in a lower optimal fishing mortality rate.

A Synopsis of Fish Harvesting Capacity Concepts, Definitions, Qualitative and Quantitative Estimates, and Implications

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Fish harvesting capacity has been identified as the primary cause of overfishing in domestic and global fisheries. Numerous empirical studies can be cited to indicate the level of excess capacity presently existing in international fisheries, its continued rate of growth over time, and the concern this has engendered in fisheries managers. In fact, an assessment of federally managed fisheries in the U.S. identified that fifty-five percent of those surveyed had qualitative indications of excess capacity. Preliminary quantitative assessments of excess capacity developed by NMFS indicated exceptionally low capacity utilizations rates in two regions and for highly migratory species; i.e., excessive fish harvesting capacity levels. These assessments resulted from a NMFS program to define and measure fish harvesting capacity in domestic fisheries required to satisfy the Build Sustainable Fisheries budget initiative and the FAO International Plan of Action for the Management of Fishing Capacity. Relative to other industries in the United States, most fisheries have unique characteristics requiring that a distinction be made between excess capacity and overcapacity in terms of their implications for fishery management. This distinction needs to be reflected in the definitions of capacity and, as a result, in methods of capacity measurement to ensure that accurate capacity assessments are made and interpreted. This synopsis of the NMFS capacity program clarifies the concepts of excess and overcapacity, and presents capacity definitions, measurement techniques, and estimates of capacity as they exist at this point in time.

DISCUSSION GROUP REPORTS

TOPIC 1: DEFINING "ECOSYSTEM OVERFISHING"

Discussion Leaders & Rapporteurs: ***Jason Link (NEFSC) and Jon Brodziak (NEFSC)***

Suggested trigger questions:

1. Are there ecosystem analogs to single-species overfishing reference points?
2. Which metrics are useful for evaluating ecosystem status?
3. How can we evaluate the relative desirability of alternative ecosystem states?
4. What are reasonable objectives for a fisheries ecosystem plan?

Round 1

It was noted that the group consisted primarily of individuals who work in higher latitude ecosystems. Additionally, the majority of the group was from the west coast. It was recognized that the experiences of all the individuals involved and their perceptions of the major ecosystem processes from different ecosystems would likely influence the discussion.

Initial discussions noted that there are no formal agency guidelines or objectives for implementing ecosystem-based fishery management (perhaps a point of future work to be recommended by this group). Questions like "what do we want the system to look like" or "what do we want to maximize" immediately came up. This led into a lengthy discussion about competing and/or conflicting ecosystem goals (partially addressing trigger question #4 in the agenda - *What are reasonable objectives for a fisheries ecosystem plan?*). Example lists from last year's NSAW (6th) were noted as possible recommendations. No major consensus was made as to what ecosystem goals might look like or what should be chosen in terms of specific objective functions. Yet, general issues of sustainability (of a system state or specified benefits), considering biomass and economic yields, minimizing "deleterious" changes to ecosystem structure and processes, and robustness (being able to adapt) to different "regimes" should be key elements to be considered. There was lengthy discussion about how these goals should be constrained or conditioned (to protect protected and non-target species, to account for environmental regime shifts, to set aside areal or biomass reserves, etc.). Although a clear consensus on specific goals was not reached, the group did reach consensus that to adequately do ecosystem-based fishery management, we need to have ecosystem goals, and that to obtain them will likely require an iterative (and painful) process involving multiple stakeholders with a wide range of values.

This led the discussion into the broad question of "What can we do now?" that explicitly addressed trigger question #1 in the agenda (*Are there ecosystem analogs to single-species overfishing reference points?*). The group agreed that there are several possibilities for ecosystem level reference points (or points of reference). This quickly led into trigger question #2 from the agenda (*Which metrics are useful for evaluating ecosystem status?*). The group agreed that there are multiple metrics that exist and are useful to assess the status of an ecosystem. There are numerous indicators, "canary populations," aggregate/system models, and multivariate approaches that can be used now. The specific metrics for assessing ecosystem status will vary from ecosystem to ecosystem, but should be indicative of the dominant processes in a particular ecosystem.

Other items that we can do now (and would recommend) are: to do single species management well (there was discussion that this approach alone may not adequately/entirely address all ecosystem issues), to incorporate more holistic considerations (e.g., predation and environment) into single species models, to more broadly use multispecies (and ecosystem) models, and to simply communicate the status of an ecosystem to its stakeholders.

However, the issue of thresholds, limits, targets, and/or control rules remained elusive. There was some discussion about possible examples of setting thresholds for non-target species or aggregate/guild/trophic level yields or diversity, but the difficulties of these approaches were also discussed. There was a general consensus that we really don't have ecosystem analogs to single species controls rules at this point, which posed the next question- "Is defining 'ecosystem overfishing' even appropriate or feasible?" That is, can we define ecosystem overfishing? It was noted that ecosystem change does not necessarily equate with ecosystem overfishing. This remains a key question. A recommendation to have a national working group to establish national guidelines and standards for ecosystem-based fisheries management evolved from this discussion.

This left us at the point of asking, "what do we do next?" The group discussed and agreed that developing Fishery Ecosystem Plans (FEPs) is a major next step of what the agency needs to do to address broader ecosystem issues. The group noted that the FEP concept is still in a developmental stage and that operationalizing the concept would be region- and ecosystem-specific. Much discussion occurred regarding the specific contents of FEPs and referred to the Ecosystem Principles Advisory Panel (EPAP) report. Many of the issues discussed regarding ecosystem goals were revisited in this context. Key elements that should be included in FEPs are: 1) an assessment of the environmental (i.e., abiotic factors) state now and in the near future; 2) knowledge of predator-prey interactions (and other trophic interactions such as competition); 3) an understanding of the direction and magnitude of natural disturbances; 4) an assessment of the sustainability of biotic communities before and after disturbances (both human and natural); and 5) an understanding of the effects of fishing on non-targeted species and habitats.

The group noted that, in general, FEPs should provide an umbrella for single species FMPs that would account for species interactions and essential fish habitat issues across FMPs. The consensus was that FEPs may be difficult, but we need to and can start developing them, or parts thereof, now. There was no consensus on what should be specifically included for a particular ecosystem (other than the generalities listed above), but there was agreement that we can begin assessing the various ecosystems (and appropriate data needs) that the agency oversees. Again, the need for a national working group to develop national standards and guidelines was an extension of this discussion.

The whole issue of our limited knowledge regarding how ecosystems function was repeatedly discussed. The call to develop national standards for ecosystem control rules was a clear recommendation, but similarly our lack of knowledge was a clear concern. This may represent a possibility for a new NMFS research initiative – understanding marine ecosystem dynamics. Yet the group agreed that our limited knowledge and understanding of all ecosystem processes should not preclude us from providing advice, however precautionary that advice may be. Ecosystem-level advice, even if just directional, might be the ultimate product garnered from FEPs.

The final point of discussion addressed the current management system, particularly the perceived need of having "end-users" or stakeholders recognize the importance of ecosystem-based fisheries management as an operational concept. Currently, the scientific community is championing the issue, whereas the policy-makers, fishery managers, and assorted other stakeholders and constituents need to grasp how they can use the information provided by an ecosystem approach. If the end-users ultimately decide they want this type of information, then the appropriate resources and agency commitment might be more forthcoming. A primary mechanism to educate the various stakeholders on ecosystem considerations is to simply provide information to the general public about the status of the various ecosystems that the agency oversees.

Round 2

It was noted that this group consisted of individuals who work more in southern latitude ecosystems. Additionally, the majority of the group was from the east coast. It was recognized that the composition of this group might provide a notably different perspective than the previous group.

Even so, initial discussions reiterated and generally agreed with the conclusions from the first group. There was some discussion about ecosystem goals, yet it was recognized that to agree upon the desired ecosystem state is a broader process requiring the participation of a diverse set of stakeholders. This led to an even more interesting question – assuming we can agree on what we want from an ecosystem, can we even manage an ecosystem to a particular end? And, if so, what management advice can we give? These are key questions and it was recognized that we can only manage those things we can control (eliminating numerous abiotic factors).

The discussion then centered on the complexity of ecosystems, our lack of data, and our lack of a complete understanding of ecosystem processes. After some debate, the group discussed what we can actually accomplish. The group agreed that despite our limitations, we can assess the status of an ecosystem even if that includes noting knowledge gaps. There was also consensus that we need to do single species management well. The group also recommended to more broadly engage the ecosystem ecology scientific community, ultimately to produce simulations of model ecosystems that contrast the effects of different single species control rules and ecosystem objective functions (see 6th NSAW). This would allow us to compare outcomes of various ecosystem components (e.g., target and non-target species) resulting from the different management applications.

This led into a discussion of actually doing the simulations in the real world. In order to understand how we can maintain an ecosystem in a desired state, we need to examine empirical evidence from numerous ecosystems. The group recommended a retrospective review of example ecosystems that would: 1) characterize ecosystem state, 2) note what happened to the ecosystem (e.g., intensive fishing or climate change), 3) note how the ecosystem responded, and 4) note any general guidelines or commonalities from the various ecosystems examined. By conducting *ad hoc* large-scale experiments, we could simultaneously evaluate the effects of fishing in multiple ecosystems. This review study would help to establish "lines in the sand" denoting ecosystem overfishing.

The group then reiterated the need to establish national guidelines for ecosystem overfishing. These guidelines should definitely include model-based studies, but should also not dismiss statistical and comparative empirical approaches. The issue of revisiting two-tier quotas (setting limits at both the single species level and at a higher level such as all groundfish, or all piscivores, or all fish at trophic level 4, or all targeted species – with the sum of the single species limits (i.e., 1st tier sums) not to exceed the 2nd tier total) was also raised, and the group recommended further consideration of that concept.

Finally, the group reiterated the need to develop FEPs as umbrella documents. FEPs should link single species control rules such that individual species limits are constrained by broader ecosystem considerations (e.g., predator-prey interactions, bycatch concerns, EFH, and non target species) in the context of two tier quotas. The group recommended a rough outline of an FEP to: 1) characterize the ecosystem and assess ecosystem status, 2) serve as a repository of ecosystem information (or point to the location of such a repository), 3) note general principles of ecological (e.g., predation) and abiotic (e.g., climate) interactions, 4) list specific species and abiotic interactions of concern, 5) coordinate regional FMPs, and 6) "trump" single species FMPs and place constraints on both single species and aggregate (or trophic level or community or guild, whatever would be appropriate) harvest limits.

Topic 2: Considerations for Stock Rebuilding

Discussion Leaders & Rapporteurs: ***Alec MacCall (SWFSC) and Russell Brown (NEFSC)***

Suggested trigger questions:

1. Have stock rebuilding plans been successful: stock rebuilding in theory and in practice (including reports from each of the science centers)?
2. How can we incorporate multispecies and ecosystem considerations into stock rebuilding plans?
3. How have economic considerations been incorporated into stock rebuilding plans?
4. Can we develop alternative rebuilding strategies in data-poor situations?

Selection of Rebuilding Strategies and Consideration of Consequences

Most rebuilding plans have considered a range of rebuilding probabilities ranging from 50% up to a 70 or 80% chance of reaching the rebuilding target in the allowable time frame. Managers should establish desired levels of precaution and acceptable levels of risk in advance of stock- or fishery-specific decisions. Faster rebuilding provides a lower risk of recruitment collapse and possible ecosystem benefits by allowing less time for ecological restructuring. More prolonged rebuilding schedules provide less economic disruption (see following). The Sustainable Fisheries Act (SFA) preferred rebuilding time limit of 10 years does not allow for adequate consideration of risks and benefits.

There needs to be closer alignment between rebuilding plans and economic consequences. This issue involves both extremes of polices that are too strong and policies that are too weak. In both cases, management should plan strategically for biological, economic, and technological extraction patterns during rebuilding that tend to match or naturally accommodate corresponding patterns for the rebuilt resource. When policies are too strong, economic and social damage can result from unemployment and industrial collapse, with loss of the infrastructure that will be needed for a rebuilt fishery. When rebuilding policies are too weak, resumption of an economically healthy fishery is delayed, and excess capacity or suboptimal technologies may continue to pose management problems. NOAA Fisheries should consider policies that establish clear consequences for failure to rebuild within prescribed rebuilding periods (but those policies must also recognize that success is expressed as a probability rather than as a certainty).

Rebuilding Accountability

It is still too early to tell (the longest rebuilding programs under the SFA are only two years old), but the group voiced a concern that the effectiveness of the rebuilding programs in some cases is not being monitored adequately. Rebuilding plans should incorporate a cumulative accounting of catches, so that if catches exceed the rebuilding allowance in one year, following years' catch levels are reduced. Progress in rebuilding should be compared with the fishery simulations used to develop the plan, and discrepancies should be reconciled for the purpose of making mid-course corrections

What happens when estimates of reference points change?

Reference points can change due to a variety of reasons, and rebuilding targets and catch policies should be "frameworked" based on general biomass and fishing mortality parameters. Not only does this help to avoid a tedious plan amendment process, but also it makes the rebuilding plan more adaptable to future changes in fishery behavior.

Biomass targets should be estimated with associated confidence intervals, and once established should not be changed unless new estimates are appropriately reviewed and fall outside a pre-determined range in the existing confidence interval. Rebuilding catch rates are especially sensitive to changes in selectivity associated with changes in fleets and gears, especially when immature fish are taken. Use of a specified fishing rate (or even worse, a specified catch level) should be avoided in favor of a more flexible formula that accounts for changes in selectivity. Two possible metrics were proposed. One would be to specify a reference fishing rate in terms of a knife-edge selectivity at the age of maximum cohort productivity, and require that the effect of alternative selectivity patterns be accounted for. Another approach would be to specify an equilibrium value of spawning potential per recruit (SPR) so that any particular selectivity curve would have an associated fishing rate to achieve that SPR.

It is notable that the two separate breakout groups discussing the same issue differed strongly on the desirability of changing reference points in the course of rebuilding. The two points of view seemed to reflect different types of concerns in different regions of the country. At the risk of oversimplifying, scientists from regions with highly variable fish production (west coast) or variable selectivity patterns (Gulf coast) expressed a need for flexible rebuilding plans, whereas scientists from regions with perhaps more predictable fisheries but a history of political manipulation (east coast) preferred a more rigid approach.

Comments (of uncertain veracity) were heard that some Councils may have avoided the problem of shifting reference points by not updating the stock assessments. Rebuilding policies at the Council and at NMFS levels should be crafted so that there is a motivation to update stock assessments and a penalty for not doing so (i.e., a carrot-and-stick approach).

Specification of rebuilding targets: What happens once we "rebuild"?

Many stock rebuilding targets are based on aggregate biomass levels and do not specify the size structure or age structure of a rebuilt population. Consequently, one large yearclass could in some cases satisfy the rebuilding criteria even though the risk of re-entering a depleted condition is quite high. The group recommended that the rebuilding criteria should specify a target reproductive potential (in spawning biomass, or better yet, total egg production) rather than a simple target biomass. Alternatively, distributive properties of the size or age composition could be specified to assure that stock reproductive potential is adequately accounted for. Also, use of simulations to investigate post-rebuilding scenarios would help evaluate both rebuilding criteria and appropriate post-rebuilding management policies.

Topic 3: Incorporating Oceanographic Factors into Stock Assessments and Rebuilding Plans

Discussion Leaders & Rapporteurs: ***Rick Methot (NWFSC) and Doug Vaughan (SEFSC)***

Round 1

The first group developed four trigger questions for subsequent consideration and discussion:

1. *Why/when is it necessary to incorporate oceanographic factors explicitly?*
2. *How much improvement can occur through inclusion of environmental information?*
3. *When do we know that a persistent environmental change has occurred?*
4. *Can we define status determination criteria that account for climate regime shifts?*

There are four areas where incorporation of environmental factors can improve stock assessments and forecasts. The first is consideration of the effect of the environment on assessment data. Recognition of environmental effects on survey catchability or availability can reduce variability of these primary assessment data. Second is incorporation of environmental effects on process factors, such as natural mortality and growth, that routinely are considered to be constant in assessment models. Third is accounting for environmental correlations with annual recruitment that routinely are estimated simply as random deviations from some long-term mean or spawner-recruitment curve. Accounting for environmental effects on annual recruitment can reduce potential confounding between historical environmental and spawner abundance, and can provide a tool to improve short-term stock forecasts. Finally, incorporation of time series patterns of environmental factors into long-term harvest policies can help buffer the stock and the fishery against unexpectedly large swings.

The time scales on which incorporation of environmental factors can help cover a wide range. Over this range, there is a trade-off between accuracy and timeliness. Currently, assessment models accurately detect changes in the stock after accumulation of a few years of adult abundance and age composition data. Addition of pre-recruitment survey data can improve the timeliness, but such surveys are typically imprecise. Addition of environmental correlations can provide an even more timely forecast of current and near-future recruitment, but the accuracy depends upon the strength of the correlation. Identification of climate regimes may provide an even longer forecast by narrowing, but perhaps only slightly, the likely range of recruitments over the next few years.

The nature of environmental effects is potentially quite complex. Not all species will respond similarly or at the same time. The environmental measurements we have are only proxies for the factors actually influencing the fish. The timing and nature of transitions between environmental states may be as important as the level of the environmental factors. Decadal regime shifts have been identified, but it is not known how many different regimes are potential "stable" states of nature. The age-structure of the stocks causes a time lag in the biological response, and there may be resonance or dampening due to the interaction of biological feedback and the dominant time scale of environmental forcing.

As potential environmental effects are identified, it is important to validate them to the extent possible before using them in revised management advice. Comparisons across species and ecosystems and identification of likely bio-physical mechanisms can help in this regard. Quantitative evaluation of both Type I and Type II errors is appropriate. Harvest control rules that incorporate environmental factors should consider several factors. There needs to be a clear understanding of the effect on catch variability versus the avoidance of stock depletion. A policy that tracks good and bad environmental conditions can have very high catch variability in order to avoid low stock levels. On the other hand, a policy that caps the harvest rate during good conditions could bank some fish to help maintain the fishery during short-term bad conditions. The age-structure time lag could create a need for a different response in a transition from good to bad versus bad to good conditions. The interaction between the autocorrelation of the environmental effects, including potential regime shifts, and the life span of the stock will affect the performance of a harvest control rule.

Overall, the group concluded that it is beneficial and technically feasible to include environmental factors in assessments and control rules. The challenge is in the research to identify appropriate environmental measurements that are good proxies for the factors affecting stocks.

Round 2

The second group revisited the four trigger questions developed by the first discussion group (see above) and identified the following research needs.

Research Needs:

- Addressing the first question, exploration of cause/effect relationships between the environment and fish populations can lead to reduced uncertainty in assessments and management.

- Because some commercial fishermen raise issues such as temperature effects on recruitment, why not collaborate with commercial fishermen to collect physical data (e.g., temperature sensors on gear).

- Environmental factors can have an effect on recruitment success through changes in early life history survival or through changes in maturity or fecundity resulting from modification to individual fish growth (e.g., declines in mean weight at age).

- There may be multi-species implications from changes in environmental factors, some of which may result from changing communities as related to variations in "good" habitat with environmental regimes. "Good" habitat for one assemblage will be different for another.

- Often we use proxies (e.g., ENSO, etc.) for the actual environmental factor/data needed. Research is needed to develop data more directly related to the underlying processes and mechanisms.

- Matching temporal and geographic scales of fish with environmental data is of concern.

- Importance of short-term environmental events versus annual means. In some cases, gradients in environmental variables (e.g., thermal and salinity gradients) can be extremely important. Furthermore, the steepness of these gradients may be important for some species.

- The scattershot approach to developing correlations among a realm of possible variables is not necessarily a bad thing. However, researchers must be cognizant of the increased risk of finding false positives, and await new data to test out these "potential" relationships.

- Under regime shifts and rebuilding plans, there is a need to fill out age structure, with the potential that second year and older spawners are needed to produce better quality eggs with improved survival. Larger age structure also may imply a more protracted spawning period (We should consider applying diversity indices based on age rather than species).

- Re-iterate the qualitative approach: high/low, wet/dry, to describe two states with different benchmarks and different expected recruitment.

- Re-iterate acceptance/rejection of environmental shifts: Prior to any acceptance of an environmental change, one should perform a Type I and Type II sensitivity analysis. That is, it is essential to explore the consequences on management "success" of not using the environmental relationship when true, or using this relationship when false. This can be examined as another source of uncertainty.

TOPIC 4: RESILIENCE, OVERFISHING AND RISK OF EXTINCTION OF MARINE SPECIES

Discussion Leaders & Rapporteurs: ***Pamela Mace (F/ST2) and Richard Merrick (NEFSC)***

Suggested trigger questions:

1. What are the most useful criteria for defining "endangered"?
2. Is overfishing generally reversible?
3. Are fish different from mammals in terms of this topic?
4. Which is more resilient: cod, scallops, herring, or sardines?

There was considerable overlap in the discussions of the two groups that met to discuss resilience, overfishing, and risk of extinction; therefore, the reports of the two groups are merged here. Several trigger questions were identified for further discussion. This report consists of these trigger questions, along with some of the more important points raised in response to each of them; and discussions on the relationship between the Endangered Species ESA, the Magnuson-Stevens Act (MSA), and the Marine Mammal Protection Act (MMPA).

1. Which approach is better: a threshold percent decline, threshold absolute numbers, a Population Viability Analysis (PVA), or something else?

No consensus was reached about which method is "best". It was generally felt that projection models should be developed when there are sufficient data, but that there would rarely be sufficient data. In addition, concern was expressed about the difficulties of modeling population dynamics at very low levels where they may never have been observed, but it is known from experience with other taxa that depensatory (Allee) effects can be influential. PVA models usually treat population dynamics near the origin as linear, but this may rarely be a good approximation. Also, the modeling results are very much dependent on what is assumed about reproductive potential and future levels of recruitment.

In contrast, threshold approaches based on the concept of depensation attempt to define an upper bound on the population size below which depensation might occur based on empirical observations. For the threshold approach, the group agreed that it was probably better to define ranges of numbers, rather than trying to apply a single absolute number across all taxa. A major research need to assist in providing guidance on depensatory thresholds is to conduct meta-analyses of observed levels from which stocks have rebounded.

2. What is an appropriate time frame for evaluation?

This trigger question relates to the use of generation times by IUCN, CITES, and AFS. In all three cases, it has been recommended that past declines be evaluated over a period of X years or Y generations, whichever is longer. This means that the evaluation period for, say, a sardine population might be only 10 years, but that for an elephant population might be closer to 90 years. Even though elephants have longer generation times, populations of sardines tend to have cycles with very long periodicities that definitely have relevance to the assessment of current population status. There was consensus within the group that analysts should never artificially restrict the time horizon over which population dynamics are examined. In other words, all available, credible data should be considered.

3. What is an "acceptable level of risk"?

The group agreed that determining an "acceptable level of risk" was more of a societal decision rather than a scientific decision. The large marine mammal group which met in February 2001 (see Merrick's abstract, this volume) used a risk level defined as the probability of extinction being greater than 1% in 100 years as a working definition of an "unacceptable" level. However, some discussants felt that 100 years was too long to make meaningful projections into the future, and that the 1% level may be too low to be statistically detectable.

4. Is population productivity a reasonable surrogate for resilience?

In the context of the current discussion, resilience was defined as the ability to rebound from a perturbation that has led to stock depletion. There was general agreement that productivity is probably the best measurable proxy for resilience, and that it is one for which considerable data for marine species exist.

5. How should baselines for determining stock status be defined?

If stock status is to be evaluated relative to some historical or potential baseline, and the carrying capacity of the environment has changed over time, how should this be taken into account? It was suggested that it is necessary to know the normal range of variability for a population in order to create a context for defining both baselines and current stock status relative to the baselines. The need to define baselines is probably the most problematic aspect of the threshold percent decline approach. A change in carrying capacity can be human-induced or environmentally-induced, and reversible or irreversible. If the change is irreversible, this needs to be taken into account in assessing the size to which a population can be restored; however, it is likely that there is some minimum carrying capacity below which the long-term viability of a population may be called into question.

6. Is it worthwhile to attempt to develop generic numeric criteria and guidelines?

The group did not reach agreement on this issue. Multiple criteria may be needed due to the different types and amounts of data available for different species. An alternative that was discussed was simply to develop a broad framework for risk analysis.

Relationship between MSA and ESA

The group also discussed the merits of linking the MSA to the ESA by automatically considering stocks classified as "overfished" under the MSA to be candidates for listing under ESA. Development of an effective rebuilding plan would then be sufficient to prevent the need for an ESA listing. However, there may still be utility in invoking the ESA if rebuilding is being impeded by some factor beyond the control authorized by the MSA. The group identified two problems associated with this idea. First, there was a general belief that the thresholds used to classify stocks as "overfished" are generally unlikely to be anywhere near any reasonable definition of an extinction threshold; in most, if not all, cases the extinction threshold will likely be well below the "overfished" threshold. Second, the unnecessary addition of "overfished" species for consideration as ESA candidates might overburden an already-burdened system. One aspect of this idea that might be worth following up on is the ability to use the ESA to assist in rebuilding stocks when factors other than fishing are impeding rebuilding. Although the group was unaware of any cases where the ESA might be able to assist in rebuilding in ways not possible under the MSA, such cases may well arise in the future.

Relationship between MMPA, MSA and ESA

The MMPA defines a "depleted" marine mammal population as a population that is below B_{MSY}, where B_{MSY} is given the default value of 60% of the unexploited population size. In contrast, the default for defining "overfished" under the MSA has evolved to become a value of ½ B_{MSY}, where B_{MSY} is usually calculated to be in the range of 30-40% of the unexploited stock size. Therefore, if the MSA definition of "overfished" is generally considered to be well above any reasonable definition of an "extinction threshold", the MMPA definition of "depleted" is likely to be even further above the "extinction threshold".

APPENDIX I: AGENDA

The 7th NMFS National Stock Assessment Workshop

(RE)BUILDING SUSTAINABLE FISHERIES AND MARINE ECOSYSTEMS

December 11-13, 2001
NMFS Santa Cruz Laboratory
110 Shaffer Road
Santa Cruz, CA
and
Long Marine Laboratory, Seymour Center
University of California, SC
Santa Cruz, CA
(200 yards from the NMFS laboratory)

(Please park at the NMFS lab and walk to the Seymour Center for the Plenary sessions)

Steering Committee: Pamela Mace (HQ), Alec MacCall (SWFSC), Rick Methot (NWFSC), Steve Murawski (NEFSC), Grant Thompson (AFSC), and Doug Vaughan (SEFSC).

A key focus of the 7th NSAW will be on discussion groups organized around the main theme and four related topics. Papers will be presented in Plenary sessions, primarily to set the stage for the discussion groups. The NSAW Steering Committee has purposely asked that the number of papers be restricted in order to maximize time for discussion and debate. Each of the four topic areas will be the focus of a plenary session with about 3-8 papers and two discussion groups. The agenda is structured so that each attendee can participate in discussion groups for two of the four topics over the course of the workshop. The discussion groups will produce recommendations to guide future agency research and budget initiatives.

AGENDA
(Revised 6 Dec 01)

Tuesday 11 December

8:30am *Introduction and objectives* – Pamela Mace (Office of Science and Technology)

Topic #1: Defining "ecosystem overfishing"

Discussion Leaders: Jason Link and Jon Brodziak

Suggested trigger questions:
- Are there ecosystem analogs to single-species overfishing reference points?
- Which metrics are useful for evaluating ecosystem status?
- How can we evaluate the relative desirability of alternative ecosystem states?
- What are reasonable objectives for a fisheries ecosystem plan?

8:50am *A framework for ecosystem-based fisheries management* – Jason Link (NEFSC).

9:15am *An overview of metrics reflecting ecosystem status* – Jon Brodziak and Jason Link (NEFSC)

9:40am *Overfishing: single species and ecosystems* – Charles W. Fowler and Shannon M. McCluskey (AFSC)

10:05-10:30am – Break

10:30am *Comparative modeling approaches for exploited marine ecosystems in the Northeast Pacific* – John Field and Sarah Gaichas (AFSC)

10:55am *Fishing capacity as a metric for evaluating ecosystem status* – John Ward (Office of Science and Technology)

Topic #2: Considerations for stock rebuilding

Discussion Leaders: Alec MacCall and Russell Brown

Suggested trigger questions:
- Have stock rebuilding plans been successful: stock rebuilding in theory and in practice (including reports from each of the science centers)?
- How can we incorporate multispecies and ecosystem considerations into stock rebuilding plans?
- How have economic considerations been incorporated into stock rebuilding plans?
- Can we develop alternative rebuilding strategies in data-poor situations?

11:20am *Rebuilding of major groundfish stocks on Georges Bank: haddock and yellowtail take the lead, cod lags behind* – Loretta O'Brien, Christopher Legault, Russell Brown, and Steven Cadrin (NEFSC)

11:45am *Pacific sardine: a rebuilding success story but will the success continue? A test of management sticktoitivism under an environmentally-based control rule* – Ray Conser (SWFSC), Kevin Hill (CDFG), and Paul Crone (SWFSC)

12:10pm - 1:10pm – Catered Lunch

1:10pm *Rebuilding and management of sedentary stocks using area closures and rotational fishing: the Atlantic sea scallop example* – Dvora Hart and Paul Rago (NEFSC)

1:35pm *Recovery of Atlantic striped bass: now what do we do?* – Gary Shepherd (NEFSC), John Carmichael (North Carolina Division of Marine Fisheries), and Victor Vecchio (New York Department of Environmental Conservation)

2:00pm *Rebuilding west coast groundfish stocks; long-lived species for which climate and spawner-recruitment effects are confounded* – Rick Methot (NWFSC)

2:25pm *Rebuilding Atlantic swordfish: a ten year history* – Jean Cramer (SEFSC)

2:50pm *The sustainability of western Atlantic bluefin tuna: a warm-blooded fish in a hot-blooded fishery* – Clay Porch (SEFSC)

3:15-3:40pm – Break

Topic #3: Incorporating oceanographic factors into stock assessments and rebuilding plans

Discussion Leaders: Rick Methot and Doug Vaughan

Suggested trigger questions:
- Why/when is it necessary to incorporate oceanographic factors explicitly?
- Can we define status determination criteria that account for climate regime shifts?

3:40pm *Scales of physical variability impacting marine resources* – Frank Schwing (PFEL)

4:05pm *Trends in zooplankton abundance off the U.S. west coast and implications for recruitment of sablefish* – Michael Schirripa and William Peterson (NWFSC)

4:30pm *Incorporating environmental uncertainty (i.e., risk) into fisheries management policy* – Roy Mendelssohn (PFEL)

4:55pm Poster Session and reception at the NMFS laboratory

Wednesday 12 December

8:30am *Report on the ICCAT workshop on environment and tuna recruitment (Madrid, Spain, May 7-12, 2001)* – Craig Brown and Jerry Scott (SEFSC)

8:55am *The decline of spiny lobsters (*Panulirus marginatus*) in the Northwestern Hawaiian Islands: an alternative hypothesis using metapopulation theory* – Gerard DiNardo (SWFSC)

9:20am *Variations in growth of bigeye tuna (*Thunnus obesus*) in the equatorial western Pacific Ocean and ENSO* – Bert Kikkawa (SWFSC)

Topic #4: Resilience, overfishing, and risk of extinction of marine species

Discussion Leaders: Pamela Mace

Suggested trigger questions:
- What are the most useful criteria for defining "endangered"?
- Is overfishing generally reversible?
- Are fish different from mammals in terms of this topic?
- Which is more resilient: cod, scallops, herring, or sardines?

9:45am *A critique of the scientific basis for listing species on the IUCN Red List, CITES Appendices, and the AFS list of species at risk: we must be able to do better than this* – Pamela Mace (Office of Science and Technology)

10:10-10:35am – Break

10:35am *The impact of marine reserves on exploited stocks and fisheries: a review of modeling results* – Dennis Heinemann (SEFSC)

11:00am *Overfishing review of Queets River coho salmon: a case history* – Robert Kope (NWFSC)

11:25am *Salmon recovery planning: conservation and fisheries* – Michelle McClure (NWFSC)

11:50 - 1:00pm – Catered Lunch

1:00pm *A comparison between the requirements of ESA and MSFCMA for overfished stocks* – Alec MacCall (SWFSC)
1:25pm *Development of demographic criteria for ESA listing decisions -- the marine mammal experience* – Richard Merrick (NEFSC)

Open session: new or developing assessment methodologies

1:50pm *Multispecies Catch at Age Model (MSCAGEAN): incorporating predation interactions and statistical assumptions for a predator-prey system in the eastern Bering Sea* – Jesus Jurado-Molina and Patricia A. Livingston (AFSC)

2:15pm *Decision-theoretic estimation of the optimal catch using a stock assessment model structured with respect to age, season, and area* – Grant Thompson (AFSC)

2:40-3:05pm – Break

3:05 - 3:30pm Define objectives and products of Discussion Groups:
– What do we want to get out of the discussions and can we make recommendation and/or formulate guidelines that will further the Agency's science agenda?

3:30 - 5:00pm: ***Discussion Groups***

Topic #1: Defining "ecosystem overfishing" Jason Link and Jon Brodziak
Topic #2: Considerations for stock rebuilding Alec MacCall and Russell Brown
Topic #3: Incorporating oceanographic factors into stock assessments and rebuilding plans Rick Methot and Doug Vaughan
Topic #4: Resilience, overfishing, and risk of extinction of marine species Pamela Mace

Thursday 13 December
8:30 - 10:15am: *Discussion Groups continued*

10:15 - 10:35 – Break

10:35am - noon: Discussion Groups report to Plenary

12:00 - 1:00pm – Catered Lunch

1:00 - 3:20pm: *Second set of Discussion Groups*

3:20 - 3:40 – Break

3:40 - 4:55pm: Discussion Groups report to Plenary

4:55 - 5:00pm Closing remarks

5:00pm Adjourn

APPENDIX II: LIST OF PARTICIPANTS

Peter Adams (SWFSC)
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Russell Brown (NEFSC)
Ray Conser (SWFSC)
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Nancie Cummings (SEFSC)
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Robert Kope (NWFSC)
Chris Legault (SEFSC)
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AFSC – Alaska Fisheries Science Center
F/ST – Office of Science and Technology
NEFSC – Northeast Fisheries Science Center
NWFSC – Northwest Fisheries Science Center
SEFSC – Southeast Fisheries Science Center
SWFSC – Southwest Fisheries Science Center
USCS – University of California Santa Cruz
UW – University of Washington

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