RESEARCH PLAN FOR WEST COAST GROUNDFISH

NATIONAL MARINE FISHERIES SERVICE

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INTRODUCTION

This research plan for west coast groundfish represents the results of discussions with many diverse organizations and people involved with this fishery and resource. The plan is a living document that will be reviewed and updated periodically to reflect progress and new issues.

The West Coast groundfish fishery contributes significantly to the economy of fishing communities, to valuable recreational fisheries all along the coast, and to a tribal fishery off Washington. Today, West Coast groundfish stocks and fisheries are in crisis and its commercial ex-vessel value has declined from its peak near $100M annually. The fishery is overcapitalized, and several groundfish stocks have been depleted by a combination of fishing and natural factors. Allowable catches for these stocks must be reduced to levels that cannot economically sustain present participation. For healthier fish stocks that are now fully exploited, there are concerns that we are not collecting enough information to guide fishery levels that will keep these stocks healthy. Concerns mount that our limited ability to forecast groundfish production from single species investigations is missing important natural and fishery-induced changes in the ecosystem and will not be able to forecast truly sustainable harvest policies.

This fishery occurs within the California Current marine ecosystem which contains a complex web of pelagic and demersal fish resources, marine mammals, birds, invertebrate resources and elements of the food chain which support these more visible and economically valuable resources. This ecosystem undergoes significant climate fluctuations that last from a couple of years to several decades. These climate cycles both increase and mask the human impacts. Understanding and protecting this system needs to be a high priority to assure long-term sustainability of all west coast fisheries, including groundfish. Today, there is a high level of interest in marine protected areas to diversify the tools used to protect the marine ecosystem and these important groundfish resources.

The problems of declining groundfish stocks, inadequate information and ecosystem change are interconnected, and a holistic solution is needed. Problems in West Coast groundfish fisheries will take years to resolve and will require a long-term commitment of agency resources. Management options are being explored today through the Pacific Fishery Management Council (PFMC) Strategic Planning Committee. The research program described here is designed to provide needed scientific information and advice for fishery management decisions.

BACKGROUND

The 82 groundfish species can be roughly broken into six assemblages (*Table 1*) based upon their adult habitat and co-occurrence in the fishery. This breakout will facilitate discussion of fishery monitoring and resource survey programs:

a. Midwater- These semipelagic schooling species include Pacific whiting and shortbelly rockfish. These species can be surveyed with acoustic methods, and whiting is surveyed triennially. Whiting are more than 10 fold more abundant than other groundfish and support a midwater trawl fishery with annual catch near 300,000 mt.

b. Deep slope includes primarily sablefish, dover sole, shortspine thornyhead, longspine thornyhead, and Pacific grenadier. They are found mostly on trawlable habitat on the shelf break and continental slope extending out to at least 1500m bottom depth. Most of these species recruit on the shelf and gradually move into deeper water as they age. This valuable assemblage supports a multispecies trawl fishery, and sablefish is a target of pot and hook and line fishermen. The slope trawl survey is their primary source of abundance data.

c. Shelf includes 30 rockfish species, lingcod, and Pacific cod. These species occur on the continental shelf. Many species are found over rocky habitat, and some species have significant off-bottom tendencies. The fishery is primarily trawl and hook and line, and the triennial bottom trawl survey is the major source of abundance information for these species.

d. Slope rockfish includes nine rockfish species found on the upper continental slope. The fishery is primarily trawl, and the triennial bottom trawl survey is the major source of abundance infomation for these species.

e. Nearshore rockfish includes 13 rockfish species and a few other species. They are found mostly in high relief habitat and are caught primarily by commercial and recreational hook and line gear. There are very little assessment data for these species, except for black rockfish off Oregon and Washington.

f. Nearshore flatfish includes 11 flatfish species that are found on trawlable, sand-mud habitat on the continental shelf. The triennial trawl survey provides limited abundance data for these species.

Over the past 20 years, a major component of the groundfish management program has been annual catch quotas intended to obtain optimum yield while tracking natural fluctuations in abundance and allowing each stock's abundance to be safely fished down to near 40% of its unfished level. These quotas are based upon scientific stock assessments which determine abundance and productivity[1]. Assessments have concentrated on commercially and recreationally important species. These species account for most of the historical catch and have been the targets of fishery monitoring and resource survey programs that provide the basic information for quantitative stock assessments, although not all these assessments have the same level of information and precision. Assessments are typically updated every 3 years.

These assessments indicate that some species are healthy but several have declined substantially below target levels. Of the 16 species that have enough assessment data to determine the status of the species (Table 1), 10 have abundances that are near or above the target level (35-40% of unfished level). One species is approaching the overfished level of 25% of unfished abundance. Five species are at depressed levels (abundance near 10% of unfished levels) and have already

[1]Productivity is used as a general term to represent the ability of a fish population to sustain itself while being subject to increased mortality due to fishing. "Basic productivity" will refer to the prey production by the food chain that supports the fish resources.

been declared overfished. Assessments for 10 additional species are listed as "partial" in *Table 1* because they did not have enough data to determine the status of the species abundance. However these assessments did determine that the level of catch for some of these species exceeds biologically acceptable levels. As assessments are conducted for more of the many rockfish species, there are preliminary findings of more species in the low to depressed state. Further, the Puget Sound populations of some groundfish species have experienced severe declines and currently are under review for listing under the Endangered Species Act (ESA).

For other species, there is generally insufficient information to determine whether or not the stocks are depleted and whether or not the current level of exploitation is overfishing. Some of these species are small-bodied and are not targeted by current fisheries, but other species are increasingly the target of developing fisheries, such as rockfish landed and marketed live. Catch limits on some groups of these "unknown status" species have been set somewhat below historical harvest levels, but there is no assurance that even these levels are sustainable.

There are three factors that contributed to the current situation:

First, the target harvest rate was an approximation of the unknown optimum rate. This harvest rate was reasonable from worldwide knowledge of other species' productivity, but there was little specific knowledge of the productivity of each West Coast groundfish species. Nor was there knowledge of how this productivity is linked to the California Current ecosystem or interactions between species. We now believe the exploitation rate was too high for many groundfishes, which collectively seem to be relatively unproductive. Actions by the PFMC to reduce the default harvest rate occurred during 1998-2000 and were too late to prevent the decline.

Second, there was insufficient resource survey information to estimate stock abundance with adequate precision, insufficient research to forecast the impact of declining recruitment, and no observer program to verify that the actual catch was at the intended level. This low level of assessment capability led to delays in knowledge of declining stocks and resulting delays in management actions. Thus, reductions in quotas during the decline were reactive to the decline and not sufficiently proactive. Further, the uncertainty could have inadvertently led to overfishing because target harvest rates were not set safely below "best estimate" levels.

Third, nearly coincident with the increase in groundfish harvest in the late 1970s was a long-term decline in the basic productivity of the California Current. It is likely that this decline contributed to the reduced recruitment of young groundfish for several species. However, the long lifespan (50-100 years) of many groundfish and the imprecise and infrequent stock assessments delayed detection of the persistent change in recruitment until several years later. Further, the role of predator-prey and other interactions between these and other species is largely unknown and could have contributed to this recruitment decline.

The West Coast groundfish fishery is in the midst of a major transition that will require a fundamental shift in our perception of resource productivity. In the past, annual harvests could be larger because they had a component from population surplus production plus an added component due to reduction in stock size, i.e., the fishery was living on the "interest" and some of the “principal.” A very limited number of stocks are still above their optimum levels, so the excess “principal” is largely gone. With the implementation of the Sustainable Fisheries Act of 1997 (SFA), however, there is a clear legal requirement that groundfish fisheries be managed to achieve optimum sustainable harvests. For stocks that are at their optimum abundance level, the “fishing up” bonus is no longer available and harvests have been reduced to sustainable levels based on current productivity only. In some cases, even more severe reductions in harvest are required to meet rebuilding requirements.

In addition to the biological crisis described above, socioeconomic factors are a major element in proposed management approaches. Although a limited entry system was established in 1994 for the major segments of the fishery, these segments were already overcapitalized, and new fishery sectors, such as the nearshore live rockfish fishery, continue to grow. The limited entry program initiated in 1994 also provided for the continued existence of an open-access fishery for many species, where the number of participating vessels remains uncontrolled. Although this fleet harvests a small percentage of all groundfish, it has been allocated more than a third of the commercial rockfish catch in California, based on historical landings. In the short-term, the socioeconomic impacts of harvest reductions needed to rebuild overfished stocks will be severe. A focus of this research plan will be improving understanding of these impacts so that they can be distributed more equitably, and to lead the groundfish fishery towards an economically viable future.

Other features of West Coast groundfish create additional assessment and management complexities. For example, the recreational harvest is a major component of the total catch for lingcod and several rockfishes; coastal tribes off Washington harvest sablefish, whiting, and some rockfish; and the distributions of several species span the borders with Canada and Mexico. Nearly all healthy stocks are fully utilized today, and increased domestic production can only come by rebuilding depleted stocks, increasing yield efficiency (full utilization) of capture fisheries, or by developing aquaculture.

Bycatch and discard concerns also face the west coast fishery. Year-round fishing and marketing opportunities are a goal of the groundfish fishery management plan. However, because the fishery is overcapitalized, vessel catch limits on each of several species have been imposed to slow the aggregate rate of catch and delay annual quota attainment until late in the year. These vessel limits cause economic inefficiency and indirect allocation among user groups. Further, they cause discard because a fisherman cannot precisely control the rate of catch of each species in this multi-species fishery. Historical estimates of this limit-induced discard were estimated to be near 16-20% of total catch for several species. Yet, without an ongoing, comprehensive observer program these dated estimates are still used for management purposes. Further, retention of Pacific halibut and salmon by groundfish fishermen is prohibited, so all of their bycatch is discarded. Uncertainty regarding the level of mortality of discarded bycatch further complicates the issue.

Protection of the marine habitat and ecosystem is another concern facing the west coast groundfish fishery. Fishing gear can have adverse impacts on benthic habitat and cause bycatch of non-target species. Identification of sensitive and important habitats and reduction of impacts from fishing gears are important goals. Marine protected areas are being considered as a tool to contribute to these and other stewardship goals.

PARTNERSHIPS

The National Marine Fisheries Service currently works in close collaboration with the state agencies, the Pacific States Marine Fisheries Commission (PSMFC), the Pacific Fishery Management Council (PFMC), universities, and constituent groups on groundfish. These partnerships have a long and successful history on the West Coast. The Pacific Fishery Information Network (PacFIN) Data Committee, the US-Canada Groundfish Technical Subcommittee, the PFMC's stock assessment review process, and other forums all provide opportunities for the several agencies to coordinate their research and monitoring programs. The PacFIN program that provides the coastwide comprehensive database of fishery statistics exemplifies the success of this partnership. Partnerships between the research agencies and participants in the groundfish fishery have been, and will continue to be, key to collecting information about these resources in order to guide a sustainable fishery.

The biennial report on Research and Data Needs prepared by the PFMC highlights the need for a comprehensive statement of what we are doing, and what are priority areas for further work. The "Working Together for West Coast Groundfish" forum in July 1998 and the "Rockfish Forum" in April 1999 add momentum and constituent support for such a planning effort. Each of these forums generated good new ideas and added support to some commonly identified ideas. The research plan described here benefits from all these past efforts.

The overall goal of this draft research plan is to serve as a framework for the entire suite of research needed for westcoast groundfish, to indicate the immediate high priority needs, and to stimulate discussion among agencies and constituents on how we can collectively achieve these goals. We present this report without much explicit reference to which agency is doing what today, nor to who should be doing it in the future. We must work together to make hard choices about priorities for future research and monitoring efforts.

GOALS

This research plan is designed to identify the scientific information and approach needed to achieve NMFS stewardship objectives for West Coast groundfish. These national objectives include:
1. Maintain healthy stocks important to commercial, recreational, and subsistence fisheries
2. Eliminate overfishing and rebuild overfished stocks important to fisheries
3. Increase long-term economic and social benefits to the nation from living marine resources
4. Promote the development of robust and environmentally sound aquaculture
5. Recover and maintain protected species populations
6. Reduce conflicts that involve protected species
7. Protect, conserve, and restore living marine resource habitat and biodiversity

In addition, NMFS recognizes important foundations for a successful research plan including:
1. Development of high quality science that provides basis for management decisions
2. Communication and collaboration with constituents
3. Strong and productive partnerships
4. Effectively conveying results to fishery management organizations.

This research plan is structured by research topic area, rather than the above management goals, because many of our research activities produce results that contribute to more than one of the agency goals. Successful achievement of these management goals is, however, the ultimate motivation for developing this plan. Simply stated, our goal is to provide the scientific basis for stewardship of living marine resources. Scientific knowledge is the key to balancing the attainment of optimum yield with the long-term protection of the resources.

PRIORITIZATION

A fundamental issue is determining how to prioritize our research and monitoring efforts among the many short-term and long-term research and monitoring needs. When prioritizing research plans, it is instructive to consider the linkage between information, certainty, and safe management. This is most clearly done in the context of management of fishery harvest levels, but the general precautionary approach has broader application. Simultaneous achievement of a high optimum yield and a low risk of overfishing is impossible without a high level of knowledge. As information improves, the level of certainty in assessment results will also improve (*Figure 1*). Scientific assessments for west coast groundfish has sought to deliver the best possible advice on fishery potential yield, even though all of these assessments have varying degrees of uncertainty. Unfortunately, whenever we make a "best estimate" of acceptable biological yield from a weak knowledge base, there is a high chance that we could accidently miss the true value by a wide margin, high or low.

The Sustainable Fisheries Act compels us to err on the side of safeguarding the resource. A precautionary approach (*Figure 2*) is to scale back the recommended harvest rate in relation to the level of uncertainty in the knowledge of potential yield. Then as the level of knowledge increases, an equal level of safety can be achieved without as large a precautionary adjustment. In order to implement such a precautionary approach, fishery scientists must deliver to fishery managers a description of this uncertainty and an assessment of the risks created by overfishing and other impacts on the stock. Some kinds of information will provide greater improvement than others. For example, developing a time series of fishery catch per effort or developing a rough estimate of fish abundance will let us determine if the current level of catch is in the right ballpark. An annual fishery-independent survey is expected to make a substantial improvement in the accuracy of that determination. Then adding a recruitment survey will add improved forecasting to that accurate assessment. Finally, adding the ecosystem considerations will allow us to adjust management strategies to incorporate knowledge of species interactions. Because full ecosystem understanding is unattainable without a tremendous research effort, each simpler element of fishery research must be attuned to ecosystem considerations and be viewed analyzed as a building block of ecosystem understanding.

We use a series of questions to guide decisions about which research has highest priority for funding and staffing in the West Coast groundfish research program. Although this has not been a formal process, we intend to implement a more rigorous process to prioritize research efforts. The questions below, which are not all of equal importance, outline this general approach to prioritization:

1. STATUS OF THE SPECIES/POPULATION (STOCK)
   a. Has the status of the stock ever been assessed?
   b. Is the stock listed as overfished, threatened, or endangered?
   c. Is the abundance level declining?
   d. Is there evidence that the status has changed since the most recent assessment?

2. MANAGEMENT NEED
   a. Does the information resulting from this project have direct applicability and significance to a priority management issue?
   b. Is there a critical management decision that requires this information?
   c. What is the magnitude of the need for this project to achieve overall management goals?

3. BENEFIT TO THE STOCK
   a. Will the research reduce risk to the stock?
   b. Will the research promote rebuilding?
   c. Will the research help maintain healthy status of the stock?
   d. Will the research make a real and significant contribution to the stewardship of living marine resources?

4. SCIENCE NEEDS
   a. Is there a critical science need that this project addresses?
   b. How much does the project reduce uncertainty in the information provided to management?
   c. What is the magnitude of the need for this project to achieve overall goal for species?
   d. Is there an emerging issue or science area that the project addresses?

5. SCIENTIFIC QUALITY
   a. Is the project feasible?
   b. Is the expertise to do the project available in the required time frame?
   c. Is the project well designed?
   d. Is the funding sufficient to achieve statistically valid results?
   e. Is the project state of the art science?
   f. Will the research result in high quality science?

6. FUNDING OPPORTUNITY
   a. Does the project increase our opportunity for new funding?
   b. Does the project increase our opportunity for leveraging or matching funding?

7. BROADENS EXPERTISE

a. Does the project develop expertise that will have other uses?

As we present the elements of a comprehensive research plan below, we will also identify two tiers of research and monitoring priorities. Selection of these broad priority areas is based upon considering the above questions. While we need to strive to achieve the first tier as soon as possible, we do not expect our work to be entirely sequential and linear among these tiers of information or other research areas. Other considerations include:

a. Species that are listed under the ESA will have more importance for research effort than a healthy species that has been fully assessed over a series of years;
b. If management identifies a particular area where information is urgently needed, that will be given high priority for research effort, if possible;
c. We are not at the same level of knowledge for all stocks of groundfish at this time. Some species need a recruitment survey in order to improve forecasts, whereas other species are in need of a first time assessment;
d. Some time series need to be initiated soon and linked to historical data in order to pay off in the future;
e. Some high priority work (like direct measurement of natural mortality) may not be feasible because of prohibitive expense, or lack of appropriate technology.
f. If the funding is inadequate to do a particular high priority project, then we may consider whether a lower level of funding will provide scientifically valid results or whether a lower priority project would be more cost effective and still provide important information for management decisions.
g. Stakeholders may be interested in investing in particular information, even though this information may not be the highest overall priority;
h. Alternative sources of funding may be interested in research topics that are not highest priority for groundfish.

RESEARCH PLAN

OVERVIEW

This research plan for West Coast groundfish is designed to provide scientific knowledge needed to achieve NMFS strategic objectives with respect to the West Coast groundfish fishery. We identify six areas of research: status of stocks, socioeconomics, manmade stress, ecosystem and climate, technological innovation, and management support (*Figure 3*). Appendix A lays out this long-term research plan in more detail, including information on the current programs and research areas where improvements are feasible.

Within each research area we identify topics that are of primary importance in dealing with the immediate problems of the groundfish fishery. These topics are classified into a top (first) or second tier priority level. In identifying these priority topics, we have focused on the immediate research needs to support a sustainable fishery, and we have estimated the approximate additional annual cost for conducting this work. If we are able to accomplish a significant fraction of this work in collaboration with other agencies and groups, everyone will have greater trust that west coast groundfish are being managed on the basis of good scientific information.

Even achieving these two tiers of priority work will leave unanswered questions. The detailed information in Appendix A is an attempt to lay out the fuller scope of work that could be done to more fully assure a sustainable valuable fishery with acceptable impact on the marine system.

In brief, the six areas of research are:

I. <u>Status of stocks</u> provides the basis for identifying overfished and threatened stocks, guiding and monitoring rebuilding of these stocks, and forecasting biologically sustainable harvest levels for healthy stocks. Stock assessments are conducted periodically to track changes in abundance and are supported by long-term fishery-dependent and fishery-independent monitoring, and life history studies.

> 1st Tier Priority - Conduct baseline assessments for all managed species, even those with weak databases, to determine which species are probably healthy, and which are at risk of being overfished or threatened.
>
> 1st Tier Priority - Improve certainty in assessments for priority species by improving frequency and extent of resource surveys, expanded biological investigations (stock structure, growth, natural mortality, etc.), and better knowledge of total fishing mortality.

II. <u>Socioeconomic</u> investigations determine the social and economic impacts of fishery management actions and harvest policy.

> 1st Tier Priority - Develop better understanding of socioeconomic issues for West Coast groundfish in order to guide development of an economically viable fishery.

III. <u>Manmade stress</u> includes gear impacts, bycatch, contaminants, habitat alteration, disease, and exotic species. These studies will identify potential risks to fish stocks, their habitat, or other components of the ecosystem. In addition to identifying risks, these studies also seek to develop tools to reduce adverse impacts.

2nd Tier Priority - Determine ecological effects of fishing, including bycatch, bycatch mortality and impacts on essential fish habitat. Evaluate potential role of marine protected areas.

IV. Ecosystem and climate studies seek to understand the physical and biological nature of the system in which the fishery occurs. Important goals include: (a) determining how natural fluctuations in this ecosystem affect fishery productivity; and (b) how the fishery affects ecosystem function through bycatch, changes in species abundance, and impact on essential fish habitat. Important studies will include monitoring ocean climate and predator-prey studies of important interacting species. There will be a strong interaction with status of stocks activities which track species' abundances and with studies to evaluate the ecological effects of fishing.

2nd Tier Priority - Improve understanding of decadal-scale ocean climate fluctuations on fish productivity. This will improve forecasts of available yield and forecasts of the time to rebuild overfished stocks.

V. Technological innovations such as electronic logbooks and underwater imaging systems offer potential for more cost-effective and accurate methods to accomplish research and monitoring objectives, but require extensive testing and practical evaluation. Other technology, such as artificial propagation, has the potential to broaden the range of groundfish management options, but such controversial options require substantial scientific research and evaluation before and during implementation to guard against unanticipated negative effects.

2nd Tier Priority - develop technological improvements in survey methods to make current surveys more cost-effective, and to evaluate potential new surveys for species found predominantly in untrawlable habitats.

VI. Management support--the status of stocks, manmade stress, and socioeconomic research areas provide a decision support system for sustainable fisheries. They provide technical guidance by describing and analyzing the current status and trend in fishery resources, their habitat, and fishery. The goal is to supply the best available scientific advice for management decisions, with associated uncertainty, on a timely basis.

2nd Tier Priority - evaluate long-term alternative management strategies

There is a strong interaction among these six areas of research. The first three research areas–Status of Stocks, Manmade Stress, and Socioeconomic–provide information for Management Support. Together, these areas of research are a decision support system with a primary orientation towards describing *what* is the current situation. Such an approach is a necessary component of an overall program, but the limited scope of such investigations may not be sufficient to assure long-term sustainability of valuable fisheries. There is a need for additional investigations that will provide better answers to resource management problems in the future. Investigation of Manmade Stress and Ecosystem&Climate will provide a fundamental understanding of *why* changes have occurred in the resource and its fishery. Research on Technological Innovations will provide new options on *how* we can have sustainable, valuable fisheries while preventing damage to the ecosystem. There will be a two-way interaction between these additional investigations and the core decision support system. The expanded work will rely upon the core program for extensive monitoring of the system and validation of new research results. It will return to the core program a set of new technologies and understanding that will improve the long-term performance of the core program.

I. STATUS OF STOCKS

The goal of research on status of stocks is to determine the health (status) of harvested stocks, and to forecast the potential fishery yield from a long-term harvest policy. Knowledge of the abundance and productivity of these key species is an important building block to understanding the functioning of the ecosystem, which in turn should modify the single species perspective on potential productivity. Harvest recommendations involve balancing a sufficiently high harvest rate that will approach maximum sustainable yield against the probability of overfishing and causing a depletion of the resource or other harm to the ecosystem. When faced with uncertain information on stock productivity, a precautionary approach compels some reduction in harvest to reduce probability of overfishing. The Sustainable Fisheries Act established formal requirements to identify overfished stocks and to establish rebuilding plans for these depleted stocks. Further, for species that exhibit extreme levels of depletion, the Endangered Species Act established a process for determining if there is a threat of extinction for any distinct population segment of the species.

Stock assessment models are at the core of the scientific basis for determining the status of fish stocks and estimating optimal harvest levels. These models of harvested fish stocks generally require three essential categories of data: abundance, fishery catch, and life history (*Figure 4*). These data come from fishery dependent and fishery independent sources. Models of the future will seek to incorporate more information on habitat, climate, and species interactions.

<u>Abundance:</u> The most reliable indicators of stock abundance are carefully standardized fishery independent resource surveys that track changes in abundance over many years. The best surveys have no bias (so their results are proportional to stock abundance), high precision (i.e., low sampling variability) in each year's survey result, and high frequency (i.e., annual) so that rapid changes in stock abundance can be tracked in a timely manner. In some cases, it is possible to conduct tagging studies, depletion experiments, or absolutely calibrated surveys such that the result is a direct estimate of population abundance, rather than just the trend in abundance. Surveys should provide age-specific results, and some survey methods may better track the adults, while other methods may better track young fish (recruitment).

Surveys can be conducted from fishery research vessels (FRV) and from chartered fishing and university vessels. In order to meet the many survey demands of a comprehensive program, NMFS plans to use both dedicated FRVs and chartered vessels. Chartered fishing vessels are able to effectively deploy fishing-type gear over a wide geographic areas, especially when several vessels operate at the same time. With a high level of attention to standardization of methods and measurement of gear performance, chartered fishing vessels can carry out many types of basic resource surveys. FRVs provide an even higher level of standardization and are designed specifically for multi-disciplinary fishery missions. They are acoustically quiet, nearly all-weather, can carry large scientific parties to collect maximum information from each sample, and can deploy several fishery, biological, and oceanographic samplers to accomplish ecosystem research objectives.

Fishery logbook data record catch and effort and, in some circumstances, can be analyzed to produce an indicator of changes in abundance. Logbook results can be precise because of the large number of tows made each year. However, it is difficult to assure accurate standardization so that results will be proportional to stock abundance changes, especially during periods of changing fishery regulations. Even if the logbook data cannot be standardized into an index of changes in abundance, these data still are extremely valuable for tracking changes in the locations of fishing activities and catch. Electronic logbooks can assist in collecting data to achieve better standardization.

Catch - Total catch from commercial and recreational fisheries is determined from fishery dependent monitoring including mandatory reporting systems, shoreside samplers and interviewers, and at-sea observers. Increased use of electronic reporting systems will improve system accuracy, timeliness, and accessibility. The role of total catch data in stock assessment models is to indicate the magnitude of fishery removals during the time period in which the surveys have measured a change in abundance. Age-specific catch data allow age-structured population modeling, thus improving accuracy of calculated fishery impacts and estimates of recruitment to the stock.

Life history - These data on stock structure, growth, reproduction and natural mortality rates indicate the geographic limits of the population and the inherent productivity of each fish recruited to this population. Inclusion of life history data in stock assessment models helps assure biologically realistic results that properly separate fishing mortality from natural changes.

1st Tier Priority Research: Evaluate the Status of All Managed Groundfish Stocks
Although the Pacific Fishery Management Council's Groundfish Fishery Management Plan (FMP) has been in effect for 18 years, only 26 of the 82 species in the groundfish FMP have been assessed, and only 16 of these assessments have been backed by sufficient information to fully evaluate the stock status. Although several groundfish species are healthy, five of the quantitatively assessed species are overfished (bocaccio, Pacific ocean perch, canary rockfish, cowcod and lingcod), so there is a reasonable likelihood that some unassessed species are also overfished. The law requires that the status of all groundfish species in the FMP be evaluated to ascertain the condition of these stocks.

To accomplish this goal it is essential to recognize that the fishery data, life history information, and survey statistics needed to conduct detailed quantitative stock assessments are not available for all 82 groundfish species. Nor will those data be available in the foreseeable future. This shortage of information means that different approaches to evaluating stock condition will have to be developed and implemented on a stock by stock basis. In addition, holistic models, including assemblage, ecosystem, and meta-analyses, can be used to make inferences about the status of data-poor stocks using the information that is available from data-rich stocks. More stock assessment scientists will need to focus their attention on the groundfish fishery, and those scientists will need to devise new ways of quantitatively evaluating stock status (and its uncertainty) in data-poor situations.

1st Tier Priority Research: Reduce Uncertainties in Assessment of Managed Species
Reduced uncertainty in assessment of managed species means that we will be able to more confidently determine the status of the species with respect to overfishing criteria, and we will be

able to recommend levels of harvest that can obtain a large fraction of the potential yield while confidently avoiding overfishing and harm to the ecosystem. When there is high uncertainty, larger precautionary adjustments in optimum yield are necessary to confidently avoid overfishing. Improvement in assessment certainty will come from improved quantity and accuracy of abundance, fishery catch, and life history information.

Some short-term, relatively low-cost improvements to stock assessments can be made. Improved assessment models can better characterize the uncertainty, and the sources of this uncertainty, so that it is clear where the greatest improvements can be made. Better information on the stock structure can lead to more accurate assessments through better alignment of the assessment data areas with actual stock boundaries. Incremental improvements in the collection of biological (age and growth) data from the fishery and surveys will improve assessment precision. Better standardization of existing fishery catch-per-effort data is another means to quickly improve our assessments.

Medium-term improvements in data are likely to lead to major improvements in assessment precision within 5 to10 years. These include large efforts such as annual resource assessment surveys, more comprehensive fishery logbook programs and at-sea monitoring of total catch, evaluation of fish association with particular habitats, and environmental monitoring. Not all of these survey and fishery studies should go into routine monitoring. Some of the survey effort needs to go into studies of factors that may influence survey standardization. New recruitment surveys can directly forecast changes in fish abundance. There also is a need to develop survey technologies to extend coverage to more species found predominantly in untrawlable habitats. Some of the fishery studies need to be in investigation of bycatch mortality. Many of these medium-term efforts are large scale and expensive, but have the greatest likelihood of significantly improving the precision of the assessments.

Longer-term improvements in assessments will require new kinds of information, particularly from the ecosystem and climate research area described below. In particular, studies of climate regime patterns will improve longer-term projection of average recruitment levels.

Plan for Priority Research

At the current funding levels we would conduct the following activities during the next three to five years, under the expectation of future program growth as described in Appendix A. To some degree these status quo activities are modeled after much more data-rich programs and they can be successful only if significant program growth is achieved. If program growth appears unlikely, we must reevaluate and redirect these activities accordingly. The status quo effort includes:

a. Maintaining current schedule of trawl, acoustic, plankton and other surveys. Although a longer time series of these surveys will gradually improve the level of certainty in historical levels of exploitation, the current scope and frequency of surveys will not improve the basis for management decisions in the near future. Research listed later under technological innovations will seek to improve the accuracy of current surveys.

b. Improving ability to monitor the implementation of the rebuilding plans. We will work with states to review and adjust fishery sampling procedures to more accurately measure the low incidental catches of overfished species under rebuilding plans.

c. Analyzing and evaluating past fishery observer data to guide planning for a future observer program.

d. Conducting and reviewing approximately six to eight stock assessments per year. Competing demands for these assessments include: the required biennial evaluation of progress towards rebuilding of overfished stocks; updated assessments and optimum yield levels for healthy, previously assessed stocks; and first-time assessments for more of the species with "unknown" status. In addition, some stock assessment expertise is needed to conduct status reviews of species petitioned for listing under the Endangered Species Act. At this rate, it will require many years to conduct an assessment for each groundfish species. To accelerate the assessment of all groundfish species and to set priorities for these assessments, we will: (a) assemble summaries of existing information for all species; (b) develop consistent, simple assessment approaches that can quickly be applied to many data-poor species; (c) and examine groupings (assemblages) of species that would provide an orderly and timely approach, for example a six-year plan that would rotate assessment effort among north-south, and nearshore-shelf-slope species groupings.

e. Filling some critical gaps in biological knowledge needed for accurate stock assessments. Priorities include developing ageing methodology for more species, particularly shortspine thornyheads, and determining the stock boundaries and structure for more species.

f. Improving assessment models to make the most complete use of available data and to communicate assessment results, with associated uncertainties, to managers and constituents. Efforts will include developing a simple approach for data-poor situations, a standardized approach to evaluating rebuilding time frames, and an approach to describing and communicating assessment uncertainty.

<u>Expanded Fishery Monitoring</u> - Improved fishery monitoring is necessary to provide needed information on total fishing mortality and rebuilding of overfished stocks. Major research needs are: observer programs, logbooks for more of the gear groups, improved recreational fishery monitoring, electronic logbooks, increased port sampling, and more comprehensive database integration. Fishery monitoring is staff-intensive and costly (Table 2). Efforts to use electronic logbooks and other technological innovations to efficiently collect better data at lower cost will be pursued.

<u>Expanded Resource Surveys</u> - Greatly improved resource survey coverage and frequency is absolutely necessary if there is to be improved accuracy in monitoring the rebuilding of depleted stocks and if we are to ensure a sustainable harvest of healthy stocks. The mandatory biennial evaluation of rebuilding progress cannot be adequately conducted with only a triennial survey. A key element of this improved resource survey coverage is acquisition of a Fisheries Research

Vessel to partner with chartered fishing and university vessels to conduct these surveys and other field investigations. The research that is needed (Table 2) includes:

a. Annual bottom trawl survey covering shelf and slope trawlable habitats. This is critical to monitor rebuilding of lingcod, bocaccio, canary rockfish, and Pacific ocean perch, as well as provide for accurate harvest recommendations for other species.

b. Expanded use of alternative survey methods, such as egg and larval surveys, particularly for species that are not accessible to the bottom trawl survey (nearshore rockfish and species south of Point Conception).

c. Annual hydroacoustic survey for whiting.

d. Recruitment surveys for key species, particularly whiting, sablefish, and major rockfish species.

Expanded Stock Assessments - We require expanded biological investigations, analysis staff and infrastructure to turn these increased fishery and survey data into timely stock assessments.

a. Life history and stock structure investigations to assure biologically valid assessments.

b. Improved frequency, timeliness, and comprehensiveness of the groundfish assessments, and improved communication of assessment methods and results.

II. SOCIOECONOMICS

Socioeconomic information and analysis is necessary to guide development of management actions that have fair and equitable impacts across all user groups and that obtain the greatest benefits from the use of marine resources. Besides satisfying statutory mandates, this socioeconomic information and analysis is necessary to guide development of management actions that have fair and equitable impacts across all fishery stakeholders and that obtain the greatest benefits from the use of marine resources. Allocation of available biological yield among user groups will continue to be a contentious issue, as will efforts to reduce the degree of overcapitalization in the harvesting and processing sectors. Additional longer-term work will be needed to develop an ability to predict how fishery participation or costs would change if there were major changes in the approach to fishery management or to changes in the long-term harvest policy

1st Tier Priority Research: Improve Socioeconomic Data Collection and Analysis

At present levels of funding and staffing, NMFS will make no significant progress on improvements in socioeconomic analyses for West Coast groundfish. Existing socioeconomic information and analytical capabilities of NMFS and the PFMC are barely able to respond to Magnuson-Stevens Act mandates and other regulatory impact analytical requirements.

A significantly expanded socioeconomic program is needed to guide development of options for achieving an economically viable fishery. Elements of this expanded program will include:

c. Improved data collection programs to cover the commercial, recreational and tribal fishery sectors, the processing and wholesaling sector, and fishing-dependent communities. Data needs include: processor and harvester cost, revenue, effort, and labor opportunity cost data; charter boat revenues, costs, labor expenditures and vessel characteristics data; fishing community jobs, household income, tax revenues, public services, infrastructure; fishing port geographic and physical descriptions; habitat-related economic data; and recreational expenditure and value (consumer surplus data).
d. Better policy evaluation through cost-benefit analysis, social impact assessment, bio-economic models, input/output impact analysis, nonmarket valuation, system behavior analysis including predicting fishery participation, and risk and trade-off analysis. These models will help understand the current year-round fishery and its trip limit regime, describe the socioeconomic impacts of alternative plans for rebuilding depleted fish stocks, and evaluate approaches and targets for capacity reduction.
e. Longer-term evaluation of market-based fishery management tools such as individual quotas, incentive/disincentive programs to manage bycatch, and other alternative tools of fishery management.

III. MANMADE STRESS

The goal of this line of investigation is to identify, understand and seek means to reduce manmade risks to fish stocks, their essential habitat, or other components of the ecosystem. Such investigations have a strong role in developing our ability to evaluate impacts on Essential Fish Habitat (EFH). These risks include all factors other than the direct effect of fishery catch, which is studied under the Status of Stocks topic. There will be significant interaction between study of these risk factors and the Ecosystem topic. In addition to identifying risks, these studies will also seek to develop methods to reduce adverse impacts. Manmade stress factors include:

a. bycatch of non-harvested species - Many nontarget species, ranging from benthic invertebrates to seabirds, are taken in fishing gear. An assessment of the levels of this take and its effects needs to be undertaken to assure that harmful impacts are not occurring.
b. fishing gear impacts on benthic habitat - Fishing can produce changes in both the biotic and abiotic components of benthic marine habitats and communities.
c. other habitat alterations - Other human activities, such as mineral exploration, kelp harvesting, dredging, etc. can adversely affect the habitat and its ability to support historical levels of fish production. Global climate change is, in principle, a manmade habitat alteration, although its possible effects are presently indistinguishable from natural patterns in climate variability.
d. genetic and other nonlethal effects of fishing on fish populations - There are also population level consequences of fishing that may result from selective removal of large and fast growing or behaviorally dominant members of the population, e.g., reduction in genetic growth potential and overall genetic heterogeneity and delayed sexual maturation.
e. contaminant effects on fish health and other biota - Contaminants can directly affect the health of fish and other biota, and increase their susceptibility to disease and predation.
f. disease - The occurrence of die-offs in the ocean is not well documented, but the finding of diseased fish in heavily impacted estuaries suggest that fish disease needs further study, especially in habitats impacted by contaminants.
g. exotic species - Introduction of exotic species into our coastal waters upsets the natural biotic community and may have extreme impacts on some native species. Although an impact on groundfish species has not yet been identified, this is a growing threat, especially for species that utilize major estuaries.

2nd Tier Priority Research: Ecological Effects of Fishing

Of the many potential manmade threats to groundfish, the greatest current concern is from the ecological effects of fishing, including disturbance of the benthic habitat and bycatch of non-groundfish species. Both of these effects can impact the health and bio-diversity of the marine ecosystem and affect the ability of the system to support production of groundfish.

Fishing can produce changes in both the biotic and abiotic components of benthic marine habitats and communities. For example, fishing gear may alter the three dimensional habitat space available to benthic fishes and macro invertebrates by disturbing the substratum and/or removing or damaging macro invertebrates that constitute the habitat. The removal of both target and nontarget species undoubtedly alters benthic community structure and trophic dynamics. There are also population level consequences of fishing that may result from selective removal of large and fast growing or behaviorally dominant members of the population, e.g., reduction in genetic growth potential and overall genetic heterogeneity and delayed sexual maturation. These potential impacts of fishing have presently unknown and/or unquantified effects on fishery ecosystems that must be understood to manage exploited stocks and conserve ecosystem function and productivity. Marine protected areas are under consideration and evaluation as a potential tool to protect a portion of groundfish habitat from such impacts.

We need to determine which habitats are most susceptible to these impacts, and whether significant impacts are already occurring in some areas. Understanding ecological effects of fishing will lead to determination of means to reduce adverse impacts to acceptable levels. Expanding such research is currently a second tier priority behind the top tier stock assessment and socioeconomic issues. With present research efforts we will be able to:

a. Analyze existing data on fish distribution and benthic habitats, especially high resolution sea floor imaging data where available. These analyses would provide indications of changes in species distribution and abundance, community structure and benthic habitats over the last 10 to 20 years. These analyses would also identify habitat areas that are of particular importance to some of the species.
b. Begin preliminary investigation of the effects of fishing on the biotic and abiotic components of the habitat, using comparisons of lightly and heavily fished sites and other methods.

With an expanded program, we will:

a. Identify areas where fishing impacts may be the greatest. Include improved mapping of benthic habitats, improved mapping of fishing locations by all gear types, and improved mapping of fish distributions from fishery and survey data. These studies will leverage from improvements in survey coverage, development of a precise electronic logbook system, and emerging (e.g. electro-optics) technologies to rapidly image the seafloor and associated biota.
b. Conduct surveys in unfished reference habitats to compare to distribution and abundance, and community structure in fished habitat areas. Evaluate need for new research reserves in order to fully evaluate effects of fishing.
c. Conduct experimental fishing with current and modified gear to determine and reduce fishing gear impacts on the biotic and abiotic components of the habitat, and reduce the mortality of discarded bycatch.

IV. ECOSYSTEM AND CLIMATE INVESTIGATIONS

We need to be able to track natural and manmade changes in the ecosystem, predict their effect on fisheries, and adjust fishery management approaches to take these ecosystem factors into account. Ignoring these ecosystem factors may lead us to misjudge the cumulative effects of single-species management efforts. Some of these ecosystem changes are direct, such as the impact of habitat degradation on productivity of particular species. Other ecosystem changes are indirect and are caused by the predator-prey and competitive interactions between species, so will be much more difficult to predict. For example, we should know if the fishery-caused reduction in harvested fish abundance to near 40% of unfished levels (a single-species harvest policy) will cause major shifts in ecosystem function and its ability to support all groundfish fisheries in the future.

Ecosystem investigations need to take into account natural fluctuations in the climate that affect the ecosystem and groundfish productivity. In particular, decadal-scale shifts in the ocean climate appear to have dramatic effects on the productivity of fish stocks. Climate studies will: improve stock assessment accuracy by distinguishing historical fishing from natural causes in fish abundance; improve short-term forecasts of fishery potential yield by developing more timely estimates of fish recruitment; improve projections of timescales for fish stock rebuilding by taking into account decadal-scale cycles in productivity; and improve resource survey and fishery efficiency by predicting changes in fish distribution.

Ecosystem considerations also include improved knowledge of the various specific habitats used by the progressive egg-larval-juvenile-adult-spawner life stages. This knowledge of the spatial-temporal diversity of the ecosystem will assist in identifying the importance of particular habitats for groundfish production. This knowledge will be instrumental in evaluating whether marine reserves are a viable tool to assist in safeguarding fish stocks. Some of these habitat-specific ecosystem studies will have a high cross-over with studies under Manmade Stress - Ecological Effects of Fishing.

2nd Tier Priority Research: Identify and Forecast Decadal Changes in Stock Productivity

The most immediate need for ecosystem and climate research is to improve our ability to understand and predict ecological consequences of decadal scale shifts in the climate. These shifts occur rapidly as the components of the climate system realign themselves, moving from one state, or regime, to another in a period of months. The classic fisheries assessment and forecasting paradigm views recruitment as varying randomly about a single, long-term level. This paradigm is not consistent with the emerging view that there may be several, very different, mean recruitment levels, each one persisting for a decade or two followed by a rapid transition to another level. Improved forecasts of the time needed to rebuild overfished stocks require a better understanding of the effect of these regime shifts on fish productivity. NMFS' stewardship mission requires us to understand the relative role of past regime shifts on the decline of some groundfish, to forecast the effect of future regime shifts on rebuilding of these stocks, and to develop long-term harvest policies that take into account the expected effect of climate regime fluctuations.

At minimum, NMFS scientists must work with other NOAA scientists and our academic partners to develop diagnostic physical/biological ecosystem models to identify principal modes of ecosystem variation and, most importantly, to develop indicators of future regime shifts and their consequences. Development of such models requires analysis of historical time series data (fishery-independent surveys, cooperative ecosystem surveys, catch, port sampling, atmospheric and sea-surface temperature, oceanographic buoys, shore station data, satellite information, output from complex ocean circulation models, etc.).

With our current capabilities, we will

a. Prepare a review of North Pacific climate patterns and California Current productivity related to groundfish.
b. Evaluate possibility of using recent climate information to refine estimates of rebuilding rates for overfished stocks.

An expanded program is needed to develop greater predictive ability by coupling increased environmental measurement with retrospective analyses and modeling. The accuracy and timeliness of predictions of regime changes, based on biophysical models, depends upon on the verification using a strong observational program and direct measurement of variables that can provide advanced warning of change. Thus in the optimal program, retrospective analysis and modeling would be coupled with an observational program consisting of both physical and biological measurements from moored instruments and bio-physical ocean surveys.
An expanded ecosystem and climate program will be able to:

a. Develop and calibrate relationships between physical climate information and historical patterns of fish recruitment.
b. Augment oceanographic monitoring programs to assure timely access to data relevant to forecasting fish recruitment and survival levels.
c. Conduct field studies to assure that the statistical relationships are based upon ecological information.

V. TECHNOLOGICAL INNOVATIONS

In addition to providing a better understanding of the system in which fisheries occur, we also need to take a lead role in developing technologies and knowledge to obtain the maximum benefits for fishing communities and the nation, and for cost-effective monitoring of this fishery and the affected stocks and ecosystem. Some of this new technology should go into improved methods for gathering and using data for Status of Stocks, Manmade Stress, and Ecosystem/Climate Investigations. Other aspects of this new technology will go into improving the value of the fishery. Some potential technologies to evaluate include:

a. Advanced technologies offer opportunities to conduct new resource surveys in currently unsurveyed habitats and to improve the standardization of existing survey technologies;
b. Timely and efficient fishery monitoring tools such as electronic logbooks and electronic fish tickets will improve the timeliness and accuracy of fishery data, thus reducing the possibility of over- or under-shooting harvest targets;
c. Improvements in fishing gear and methods to reduce bycatch and the mortality of bycatch;
d. The fishery may obtain greater benefits from a limited supply of fish if they can make more complete and value-added use of these fish. Relevant studies will include development and demonstration of technologies to more fully utilize the entire carcass of harvested fish, to utilize smaller fish caught along with larger targeted fish, to develop methods to produce safer and more valuable fish products;
e. New technologies for artificial propagation and culture of marine fish. Successful development of cost-effective and environmentally safe methods will enable expansion of aquaculture, enhancement of overfished and threatened wild stocks, and fuller understanding of the life history characteristics (e.g. feeding, growth, maturation, behavior) of target species.

2nd Tier Priority Research: Develop Cost-Effective Survey Technologies

A technological improvement that can make immediate improvements in west coast groundfish research and monitoring is the improved calibration of current survey methods and development of new methods. A variety of survey methods is needed for west coast groundfish. The most appropriate and cost-effective methodology for a particular groundfish species depends on many factors including life stage, habitat, susceptibility of the species to the gear, degree of control for environmental factors, etc. Some survey methods can provide only a measure of relative abundance; other methods are more amenable to direct calibration to absolute abundance. Some survey methods provide only a measure of the overall abundance of a stock, other methods also provide biological specimens to characterize the age and size composition of the population. Some methods provide only a measure of abundance for the total stock, other methods provide information on spatial distributions. Some methods cannot reach all habitats, while other methods can measure abundance across a full range of habitats. Some methods target a single species, others provide measurements for many species. Further, some methods require specialized vessels, while others can be adequately standardized for use on chartered vessels. Three categories of research are:

a. Understanding factors that affect the standardization of current survey methods. This includes everything that influences the degree to which the survey measurement is proportional to abundance of the targeted species. It includes study of fish behavior in different habitats and under different environmental conditions, and fish behavior in response to the sampling gear.

b. Development of new methods using advanced technologies. These include airborne and underwater imaging systems, acoustics, tagging studies with coded wire tags, and highly calibrated egg and larval methods.
c. Standardization of unconventional data sources such as power plant impingement, predator stomach contents, and other sources that could be used as an index of changes in fish abundance.

With current levels of effort, there is little opportunity to significantly improve our surveys methods. However, we can:

a. Evaluate statistical ability of current level of survey effort and proposed unconventional data sources to detect trends in abundance;
b. Improve interpretation of current surveys through comparison to habitat data, fishery logbook data, and alternative means of observation such as submersibles and remote-operated vehicles (ROVs);
c. Assess alternatives for more efficient coverage of the groundfish habitat among the existing trawl surveys.

With an expanded research effort on survey methods (Table 2), we will:

a. Develop visual and laser systems to directly measure abundance and distribution of groundfish, especially in untrawlable habitat;
b. Evaluate egg and larval methods;
c. Conduct studies of fish behavior in response to survey sampling gear.

VI. MANAGEMENT SUPPORT

The Status of Stocks, Manmade Stress, and Socioeconomic research areas provide a decision support system for sustainable fisheries. Their focus is on research and monitoring with the goal of providing the best available scientific advice for management decisions, with associated uncertainty, on a timely basis. A primary client for this scientific information is the Pacific Fishery Management Council and its advisory committees charged with development and evaluation of management options. Typical participants in this scientific support include economists and stock assessment scientists in the NMFS Science Centers and state agencies. Major functions of this decision support system include: conducting and reporting stock assessments; developing rebuilding plans; evaluating bio-socioeconomic impact of proposed fishery management measures; and assuring that best scientific advice has been used in these evaluations.

2nd Tier Priority Research: Evaluate Alternative Long-term Management Strategies

The current management paradigm used for West Coast groundfish is to establish a stock-specific Allowable Biological Catch (ABC) that is biologically-based and is derived from information on current stock size, the stock size at which Maximum Sustainable Yield (MSY) is obtained, and the exploitation rate that produces MSY. From that information an Optimum Yield (OY) is set by the PFMC to control total catch, and vessel limits are imposed and adjusted periodically with the goal of distributing the quota seasonally to achieve a year-round fishery. This particular system has become increasingly unwieldy, burdensome, and untenable over time due to a wide variety of factors, including: an inadequate base of existing information; rising and competing demands on data collections systems and stock assessment scientists; economic disruption to the fishery caused by continually reduced quotas/trip limits; escalated discards of marketable species; and heightened concern of widespread habitat degradation and adverse ecosystem effects.

Alternative strategies to manage and rebuild West Coast groundfish fisheries must be developed and evaluated if this situation is to improve. The PFMC is undertaking strategic planning to consider options to address the biological, economic, and sociological problems that plague the groundfish fishery. A number of different management approaches have generated interest from various groundfish constituents. These include, but are not limited to:

d. establishing a system of private harvest rights;
e. ending the open access policy, so all participants would be part of a limited license system;
f. reduced capitalization through permit/vessel buy-back programs;
g. seasonal closures that would reduce discard by ending the opportunity to fish year-round;
h. implementing no-take zones to protect a portion of stocks and habitat from fishery impacts;
i. stock enhancement programs to accelerate rebuilding; and,
j. social systems for co-management of the groundfish fishery.

Fishery science needs to take an anticipatory approach to development of new management options and scientific evaluation of any proposed options. In this way it assures that modifications to existing management procedures are, whenever possible, based on the best available science. Current socioeconomic capability that could contribute in this area will be saturated by providing critical technical support to the current management process. Under status quo, NMFS will continue to have to rotate its management support functions among existing staff, with little opportunity to engage in longer-range development. An expanded effort to develop and evaluate alternative approaches would look at a range of biological, technical, and economic possibilities. We would:

a. Hire bio-economic modelers to provide a broad examination of such possibilities;
b. Build more comprehensive decision-support models for use by technical teams preparing routine analyses, such as trip limit changes, for fishery managers.

CONCLUSION

This research plan for West Coast groundfish is designed to provide a framework for prioritization of research and monitoring activities. Six research areas are identified: Status of Stocks, Socioeconomics, Manmade Stress, Ecosystem and Climate, Technological Innovations, and Management Support. Within each research area, we identify priority topics where there is an immediate need for expanded research and monitoring. Such an expansion is critical if the West Coast groundfish fishery is to attain a valuable, sustainable status. Accurate scientific information is necessary on an ongoing basis to guide achievement of optimum yield levels without exerting an excessive risk of overfishing or other harm to the marine ecosystem. It must be recognized that this focus on immediate research needs is a reflection on the current low state of knowledge for most of these species and the ecosystem in which they occur. Many of these are critical building blocks for broad-scale understanding of the ecosystem in which this fishery occurs, and each will be undertaken with an ecosystem perspective.

This plan has been developed by the NMFS taking into account the results from several research planning efforts by the PFMC and constituent groups. We intend that the execution of this plan also be a collaborative effort among the several involved agencies and interested constituent groups. NMFS will take steps to facilitate this collaborative research effort.

Table 1 Species composition of groundfish assemblages, assessment information, status of population abundance, and landed commercial catch in 1998.

Common Name	Genus Species	Category	Assemblage	Assessment (1)	Status (2)	1998 CATCH (3)
Dover sole	Microstomus pacificus	Flatfish	deep slope	full	near	7982
longspine thornyhead	Sebastolobus altivelis	Rockfish	deep slope	full	above	2305
Pacific rattail	Coryphaenoides acrolepis	Misc.	deep slope	--	???	778
sablefish	Anoplopoma fimbria	Roundfish	deep slope	full	near	4362
shortspine thornyhead	Sebastolobus alascanus	Rockfish	deep slope	full	near	1225
Pacific whiting	Merluccius productus	Roundfish	midwater	full	near	227501
shortbelly rockfish	Sebastes jordani	Rockfish	midwater	partial	???	19
arrowtooth flounder	Atheresthes stomias	Flatfish	nearshore flatfish	partial	???	3169
butter sole	Isopsetta isolepis	Flatfish	nearshore flatfish	--	???	5
curlfin sole	Pleuronichthys decurrens	Flatfish	nearshore flatfish	--	???	2
English sole	Parophrys vetulus	Flatfish	nearshore flatfish	full	above	1138
flathead sole	Hippoglossoides elassodon	Flatfish	nearshore flatfish	--	???	3
Pacific sanddab	Citharichthys sordidus	Flatfish	nearshore flatfish	--	???	776
petrale sole	Eopsetta jordani	Flatfish	nearshore flatfish	full	near	1463
rex sole	Glyptocephalus zachirus	Flatfish	nearshore flatfish	--	???	636
rock sole	Lepidopsetta bilineata	Flatfish	nearshore flatfish	--	???	43
sand sole	Psettichthys melanostictus	Flatfish	nearshore flatfish	--	???	86
starry flounder	Platichthys stellatus	Flatfish	nearshore flatfish	--	???	98
other and unspecified flatfish						57
black and yellow rockfish	Sebastes chrysomelas	Rockfish	nearshore	--	???	11
black rockfish	Sebastes melanops	Rockfish	nearshore	full	above	290
blue rockfish	Sebastes mystinus	Rockfish	nearshore	--	???	57
brown rockfish	Sebastes auriculatus	Rockfish	nearshore	--	???	10
cabezon	Scorpaenichthys marmoratus	Roundfish	nearshore	--	???	196
calico rockfish	Sebastes dalli	Rockfish	nearshore	--	???	?
California scorpionfish	Scorpaena guttata	Rockfish	nearshore	--	???	?
China rockfish	Sebastes nebulosus	Rockfish	nearshore	--	???	12
copper rockfish	Sebastes caurinus	Rockfish	nearshore	--	???	33
grass rockfish	Sebastes rastrelliger	Rockfish	nearshore	--	???	42
kelp greenling	Hexagrammos decagrammus	Roundfish	nearshore	--	???	7
kelp rockfish	Sebastes atrovirens	Rockfish	nearshore	--	???	2
olive rockfish	Sebastes serranoides	Rockfish	nearshore	--	???	1
quillback rockfish	Sebastes maliger	Rockfish	nearshore	--	???	14
treefish	Sebastes serriceps	Rockfish	nearshore	--	???	0
aurora rockfish	Sebastes aurora	Rockfish	slope rockfish	--	???	42
bank rockfish	Sebastes rufus	Rockfish	slope rockfish	partial	???	458
blackgill rockfish	Sebastes melanostomus	Rockfish	slope rockfish	partial	???	221
darkblotched rockfish	Sebastes crameri	Rockfish	slope rockfish	partial	???	714
Pacific ocean perch	Sebastes alutus	Rockfish	slope rockfish	full	overfished	580
rougheye rockfish	Sebastes aleutianus	Rockfish	slope rockfish	--	???	176
sharpchin rockfish	Sebastes zacentrus	Rockfish	slope rockfish	partial	???	114
shortraker rockfish	Sebastes borealis	Rockfish	slope rockfish	--	???	58
splitnose rockfish	Sebastes diploproa	Rockfish	slope rockfish	partial	???	1322

Common Name	Genus Species	Category	Assemblage	Assessment (1)	Status (2)	1998 CATCH (3)
bocaccio	Sebastes paucispinis	Rockfish	shelf	full	overfished	399
bronzespotted rockfish	Sebastes gilli	Rockfish	shelf	--	???	1
canary rockfish	Sebastes pinniger	Rockfish	shelf	full	overfished	1138
chilipepper	Sebastes goodei	Rockfish	shelf	full	above	1273
cowcod	Sebastes levis	Rockfish	shelf	full	overfished	19
dusty rockfish	Sebastes ciliatus	Rockfish	shelf	--	???	?
flag rockfish	Sebastes rubrivinctus	Rockfish	shelf	--	???	0
gopher rockfish	Sebastes carnatus	Rockfish	shelf	--	???	22
greenblotched rockfish	Sebastes rosenblatti	Rockfish	shelf	--	???	3
greenspotted rockfish	Sebastes chlorostictus	Rockfish	shelf	--	???	23
greenstriped rockfish	Sebastes elongatus	Rockfish	shelf	--	???	180
harlequin rockfish	Sebastes variegatus	Rockfish	shelf	--	???	?
honeycomb rockfish	Sebastes umbrosus	Rockfish	shelf	--	???	?
lingcod	Ophiodon elongatus	Roundfish	shelf	full	overfished	348
Mexican rockfish	Sebastes macdonaldi	Rockfish	shelf	--	???	?
Pacific cod	Gadus macrocephalus	Roundfish	shelf	--	???	413
pink rockfish	Sebastes eos	Rockfish	shelf	--	???	2
redbanded rockfish	Sebastes babcocki	Rockfish	shelf	--	???	46
redstripe rockfish	Sebastes proriger	Rockfish	shelf	partial	???	102
rosethorn rockfish	Sebastes helvomaculatus	Rockfish	shelf	--	???	24
rosy rockfish	Sebastes rosaceus	Rockfish	shelf	--	???	1
silvergray rockfish	Sebastes brevispinis	Rockfish	shelf	partial	???	275
speckled rockfish	Sebastes ovalis	Rockfish	shelf	--	???	4
squarespot rockfish	Sebastes hopkinsi	Rockfish	shelf	--	???	0
starry rockfish	Sebastes constellatus	Rockfish	shelf	--	???	6
stripetail rockfish	Sebastes saxicola	Rockfish	shelf	--	???	20
tiger rockfish	Sebastes nigrocinctus	Rockfish	shelf	--	???	1
vermilion rockfish	Sebastes miniatus	Rockfish	shelf	--	???	27
widow rockfish	Sebastes entomelas	Rockfish	shelf	full	below	3893
yelloweye rockfish	Sebastes ruberrimus	Rockfish	shelf	partial	???	110
yellowmouth rockfish	Sebastes reedi	Rockfish	shelf	--	???	54
yellowtail rockfish	Sebastes flavidus	Rockfish	shelf	full	near	2888
unspecified nearshore/shelf/slope rockfish						1699
finescale codling	Antimora microlepis	Misc.	misc	--	???	?
ratfish	Hydrolagus colliei	Misc.	misc	--	???	0
leopard shark	Triakis semifasciata	Shark	misc	--	???	14
soupfin shark	Galeorhinus zyopterus	Shark	misc	--	???	54
spiny dogfish	Squalus acanthias	Shark	misc	--	???	461
big skate	Raja binoculata	Skate	misc	--	???	?
California skate	Raja inornata	Skate	misc	--	???	?
longnose skate	Raja rhina	Skate	misc	--	???	?
unspecified skate						1175
miscellaneous groundfish						1397

Table 1 notes:

(1) Full assessments provide information on the abundance of the stock relative to historical and target levels, and provide information on current potential yield. Partial assessments do not have enough data to provide this full assessment. Within the range of full assessments, there is a wide range of data availability and resulting assessment certainty.

(2) Status of species is identified relative to target abundance levels, typically 35-40% of unfished levels. Overfished stocks are below 25% of unfished levels.

(3) Landed commercial catch in 1998 from PacFIN. For rockfish, the catch reported here is the sum of catch broken out to species from species composition samples plus recorded catch for species with required sorting. This leaves 1699 mtons of catch of unspecified rockfish species, primarily composed of the many species for which there is no stock assessment.

Table 2. Summary of priority research areas and costs of expanded programs[2]

HIGHEST PRIORITY

I. STATUS OF STOCKS	
Status Quo	
maintain current survey schedule	
minimal monitoring of rebuilding of overfished stocks	
analyze and evaluate past fishery observer data	
conduct and review 6-8 assessments per year	
fill critical gaps in biological knowledge for assessments	
improve communication of results from assessment models	
Additonal Critical Research	
Improved survey frequency and coverage	$3,500,000
Improved biological studies and stock assessments	$2,000,000
Enhanced fishery sampling and electronic data collection	$1,500,000
Fishery observer program	$4,700,000
II. SOCIOECONOMIC	
Status Quo	
Assist in mandatory Regulatory Flexibility Analyses	
Provide technical guidance for proposed management actions	
Additional Critical Research	
Collect economics data	$700,000
Build socioeconomic analysis capability	$500,000

[2]These costs are in addition to the current expenditures of near $6M in 1999 by NMFS and the PacFIN program. However, the $3.5M costs for the enhanced survey program has some overlap with current expenditures because this level of increased funding would allow the Alaska Fisheries Science Center to phase out of its current west coast survey activities.

SECOND LEVEL OF PRIORITY

III. MANMADE STRESS (ecological effects of fishing)

- Status Quo
  - Analyze existing data on benthic habitats and fish distribution
  - Determine habitat areas of particular concern
- Additional Research Need $1,000,000
  - Associate distribution of fish life stages with detailed maps of seafloor
  - Evaluate potential benefits of marine protected areas
  - Develop modified fishing methods to reduce bycatch mortality and habitat impact

IV. ECOSYSTEM AND CLIMATE

- Status Quo
  - Review climate patterns relevant to groundfish
  - Incorporate climate information, where possible, in rebuilding plans
- Additional Research Needs $1,000,000
  - Develop and calibrate relationships of climate and fish recruitment
  - Improve relevant monitoring of ocean climate
  - Validate statistical relationships through field studies of recruitment

V. TECHNOLOGICAL INNOVATIONS (improve survey methods)

- Status Quo
  - Review statistical accuracy of current survey coverage
  - Improve survey interpretation through incorporation of habitat and fishery data
  - Assess alternatives to trawl surveys for better coverage of all habitat
- Additional Research Needs $900,000
  - Develop visual and laser systems to measure abundance and distribution
  - Evaluate egg and larval methods

VI. MANAGEMENT SUPPORT

- Status Quo
  - Routine technical support for evaluation of management options
- Additional Research Needs $250,000
  - Bio-socio-economic examination of long-range management alternatives
  - User-friendly, comprehensive decision-support models for technical management teams.

APPENDIX A - ELEMENTS OF RESEARCH PLAN FOR WEST COAST GROUNDFISH

I. Status of Stocks

The goal of research on status of stocks is to determine the health (status) of harvested stocks, and to forecast the potential fishery yield from a long-term harvest policy. Harvest recommendations involve balancing a sufficiently high harvest rate that will approach maximum sustainable yield against the possibility of overfishing and causing a depletion of the resource or other harm to the ecosystem. The Sustainable Fisheries Act requires that a precautionary approach be taken to harvest management in the face of uncertainty on stock productivity, and the SFA established formal requirements to identify overfished stocks and to establish rebuilding plans for these depleted stocks. Further, for species that exhibit extreme levels of depletion, the Endangered Species Act established a process for determining if there is a threat of extinction for any distinct population segment of the species.

A. Life history and stock distribution

1. Objective: Provide biological data for accurate stock assessments and other fishery evaluations. This includes basic biological information such as stock structure, age composition, growth, and reproduction.
2. Current Program
    a. Stock distribution and movement information for egg, larval, juvenile, and adult life stages is determined from plankton surveys, fishery resource assessment surveys, fishery logbooks, and tagging studies.
    b. Genetic characteristics and species' population structure has been investigated for a few major groundfish species using mapping, genetics, morphology, parasites, microconstituents and other methods.
    c. Age, growth, maturation
        (1) "Production ageing" of fishery and survey specimens for major species in order to determine patterns in recruitment and enable age-based assessment methods.
        (2) Validation of ageing methods via radiometric, tag-recapture, other techniques.
        (3) CARE (US-Canada committee of age reading experts) provides interagency quality assurance on age determinations.
        (4) Where a good time series of age data exist, track changes in size-at-age (growth) potentially related to environmental or density-dependent factors.
3. Areas of Improvement

a. Collect data on age-specific growth and reproduction (maturity and fecundity) for more species.
b. Improve validation and precision of ageing methods.
c. Investigate new methods to estimate natural mortality rates.
d. Extend genetic examination of stock structure to more species that have a high probability of having separate distinct populations
e. Describe degree of mixing between and within populations using genetic, tagging, and other methods.
f. Investigate temporal and spatial trends in growth and maturation, and impact on assessments.
g. Expand life-history data collection to include additional measures of fish health and fitness (e.g., disease, parasite loads, bioenergetic indicators such as lipid and protein content).
h. Create an efficient access to information from all life history research projects, which are distributed among many agencies and academic institutions. This could include a centralized repository for summary information (website), a grant dedicated to academic studies of life history, and other approaches.

B. Fishery catch information

1. Objective: Document total fishery catch so that stock assessment models can correctly separate fishing from natural causes of changes in fish abundance, and so that the effectiveness of current regulations can be determined. A complete program should provide on an ongoing basis:
   a. Timely estimates of total commercial and recreational catch for each species by each gear, location, and time stratum.
   b. Information on bycatch, discards, and mortality of discarded bycatch.
   c. Biological characteristics (age and size composition) of the catch.
   d. Standardized measurement of fishing effort and catch-per-effort to complement fishery-independent resource survey data.
   e. Geographic distribution of catch and effort.
   f. Costs and other economic attributes of fishing and processing activities.

2. Current Program
   a. Landed commercial catch is monitored shoreside by the states and PSMFC with partial funding through the PacFIN grant, and coastwide data access through PacFIN data system. Basic program is based upon comprehensive mandatory

commercial landing receipts to determine landed catch, and biological samples by port biologists to determine species composition of each market category, and to collect size and age data.

b. The growing nearshore commercial groundfish fisheries, including the live rockfish fishery, are monitored by state programs, but the effectiveness of conventional fishery monitoring programs for this highly distributed fishery are in need of review. Washington has major efforts directed towards nearshore fisheries for lingcod and black rockfish.

c. Recreational fishery catch is estimated from interviews and other statistical sampling methods. There are state programs and the federal Marine Recreational Fisheries Statistics (MRFSS) program.

d. The catch made by or delivered to the at-sea whiting processors is monitored by the North Pacific observer program administered through the Alaska Fisheries Science Center (AFSC).

e. Logbooks

   (1) Trawl logbooks - coastwide trawl logbook program collects tow by tow data on trawl fishing effort and retained catch. Data from the three state programs are now mirrored into PacFIN. Statistical analyses to standardize fishing effort over time and between vessels have been conducted by NMFS and academic researchers.

   (2) Commercial Passenger Fishing Vessels (head boats) have a logbook program in California that has been used in some stock assessments.

   (3) Logbooks exist for some nontrawl commercial gears in some states, but no computerized database or concerted effort at standardization or compliance.

f. Observer program

   (1) At-sea program (observers) for the whiting midwater trawl fishery is administered by the AFSC. This program provides information on total whiting catch, bycatch of other species, and biological samples of whiting to determine age composition of catch for use in stock assessment models.

   (2) Pilot trawl observer program conducted primarily off Oregon in 1985-87 and 1996-98. Data from earlier study have been extrapolated and are basis of most current discard estimates. Data from later study are being analyzed.

3. Areas of Improvement

   a. Review port sampling priorities to provide most efficient use of samplers, and to define the potential gains from addition of more samplers.

b. Improve accuracy of recreational catch data by reviewing statistical design and implementation of MRFSS on West Coast. Seek cost-effective ways to reduce potential bias and improve precision of estimates of recreational catch.
c. Improve timeliness, accuracy, and integration of port sampling, fish tickets, logbooks, and observer data by deploying an electronic logbook within a comprehensively integrated data system.
d. Determine accurate information on total catch by deploying an at-sea observer program. Also see Bycatch section III-B.
e. Obtain more complete information on patterns of fishing activity and catch by developing a logbook program for nontrawl gears, including adequate outreach to assure good compliance and accuracy.
f. Investigate alternative methods to obtain catch data from small-scale, highly distributed nearshore fisheries (e.g. live rockfish fishery).

C. Population abundance monitoring
1. Objective: Measure trends in abundance for groundfish species. Normally a resource survey is implemented as a long-term, ongoing index to track natural and anthropogenic changes in fish abundance. In some cases, a single survey or a short time series can be directly calibrated to absolute abundance. An annual survey will most closely track natural biological fluctuations and smooth out apparent fluctuations caused by environmental effects on catchability.

2. Current Program
a. Midwater - (Pacific whiting) acoustic and midwater trawl survey conducted triennially (1977-1998) with sufficient coastwise coverage using FRV *Miller Freeman*. Recent surveys have been coordinated with Canadian acoustic survey to assure adequate coverage in northern areas.
b. Shelf groundfish - bottom trawl survey conducted triennially (1977-1998) in midsummer, sufficient coastwise coverage for most target species but does not cover south of Point Conception; survey covers the 30-275 fathoms range of bottom depths using two large (125 foot) chartered vessels.
(1) also serves as triennial recruitment index for age 1 sablefish and whiting.
(2) incidental catch of nearshore flatfish serves as index of abundance for some of these species, but trawl footrope is not optimal for these species.
c. Slope species (sablefish, dover sole, thornyheads) - bottom trawl survey conducted near annual in mid-autumn, covers 100-700 fathom range of bottom

depth using the FRV *Miller Freeman*. Available days at sea have not been sufficient to achieve desired level of coverage. A pilot slope bottom trawl survey was started in 1998 and 1999. It covers same geographic and depth range as the FRV survey, but is done in summer from four medium-sized (65-85 foot) chartered vessels.

   d. Nearshore rockfish
      (1) SCUBA and hook&line surveys for various nearshore rockfish off California by California Department of Fish and Game (CDFG).
      (2) mark-recapture survey for black rockfish and lingcod by Washington Department of Fish and Wildlife (WDFW).
   e. Shelf rockfish recruitment - midwater trawl survey off Central California from FRV by Southwest Fisheries Science Center (SWFSC)-Tiburon for age 0 rockfish.
   f. Multi-species - multi-disciplinary oceanographic and egg and larvae survey off southern California (California Cooperative Oceanographic Fisheries Investigation (CalCOFI)). Currently is conducted quarterly using National Oceanic and Atmospheric Administration (NOAA) and University-National Oceanographic Laboratory System (UNOLS) vessels. May provide an index of spawning biomass for species that have a significant portion of their spawning in this area.
3. Areas of Improvement
   a. Develop and implement a survey method for each of the groundfish assemblages, and for each region of the coast. Particular needs are for all groundfish south of Point Conception, for nearshore flatfish, and for untrawlable habitats coastwide.
   b. Standard bottom trawl survey - Consider merits of combining the three current bottom trawl surveys (which differ in gear, vessel size, season, depth range, target species) into one or two surveys that will cover nearshore flatfish, shelf rockfish, and deep slope species.
   c. Determine potential improvement in survey accuracy by stratifying survey effort on finer habitat features.
   d. Evaluate alternative survey methodologies including egg and larval, mark-recapture, hook and line, visual. Particular need is to develop methods to apply in untrawlable habitats.
   e. Improve tracking of natural fluctuations in Pacific whiting abundance and US-Canada distribution by increasing frequency of whiting acoustic survey that currently is only triennial.
   f. Improve time series data on recruitment of groundfish species:

(1) Evaluate merits of recruitment (i.e., young fish) information that could be obtained from an annual standard bottom trawl survey. In particular for sablefish, whiting, and rockfish species.

(2) Evaluate merits of midwater trawl surveys to provide an index of recruitment for age 0 rockfish and whiting. Consider expanding the rockfish recruitment survey that is currently conducted only off central California and consider results of pilot studies by the Pacific Whiting Conservation Cooperative.

g. Determine relative value of alternative indexes of abundance, especially off southern California where sanitation district trawl surveys, power plant impingement data, and egg and larval surveys may have useful information for some groundfish.

h. Direct calibration of surveys.

(1) Target strength measurements for whiting.

(2) Direct observation of fish density using visual&laser methods.

(3) Investigate catchability characteristics of sampling methods, in particular fish behavior in response to sampling gear, and environmental effects on fish-gear interactions.

(4) Mark-recapture methods.

D. Stock assessment

1. Objective: Determine the status of each groundfish species. The primary goals are identifying overfished and threatened stocks, guiding and monitoring rebuilding of these stocks, and forecasting biologically sustainable harvest levels for healthy stocks. For species that exhibit extreme levels of depletion, determine whether there is a risk of extinction for any distinct population segment of the species.

2. Current program

a. Where there are sufficient data, stock assessments are conducted by using the life history data to build a biologically realistic model of the fish stock, and calibrating this model so that it reproduces the observed fishery and survey data as closely as possible. During the 1990s, most West Coast groundfish assessments were conducted using the stock synthesis model. Recently there has been development of similar, but more powerful, models using state-of-the-art software tools.

b. Approximately six assessments are conducted each year; 26 species have been assessed (with varying degrees of precision). Several species are assessed approximately every three to four years, some have been assessed only once, and only Pacific whiting is examined annually.

c. Assessments are conducted by scientists at the NWFSC, AKFSC, SWFSC, WDFW, ODFW, CDFW, Oregon State University, and University of Washington.

d. Approximately three STAR review panels each review approximately two assessments in week-long review sessions open to the public.
e. Assessment schedule and review process is coordinated by the NMFS Stock Assessment Coordinator in conjunction with the PFMC's Scientific and Statistical Committee.
f. Assessments and reviews are transmitted to the PFMC for use in determining acceptable biological catch for the assessed species.
g. Many species have never been assessed and lack the data necessary to conduct even a qualitative assessment (i.e., is trend up, down or stable?). The OY (optimum yield) for these "other rockfish" was recently reduced to 50% of historical catch in order to take a more precautionary approach to this lack of information. The OY for rockfish with less rigorous assessments were reduced to 75% of the estimated ABC (allowable biological catch).

3. Areas of Improvement
   a. Develop models to better quantify uncertainty and aid. communication/ implementation of precautionary approach.
   b. Develop models to specifically aid in the assessment of species with limited data.
   c. Improve standardization of assessment methods and conduct a formal review of these methods so that the subsequent review of each species' assessment can be shortened. This could allow more assessments to be reviewed each year.
   d. Develop models to better represent spatially-structured populations, e.g., populations with low rates of internal mixing or populations with ontogenetic patterns spanning a range of habitats.
   e. Develop a concise summary of the status of information for each groundfish species, even those that lack quantitative assessment data. Goal is to steer priorities to filling key gaps, and providing minimal information for precautionary management of each species. The results could be disseminated on an ongoing basis as a web-based information center with links to government databases and academic research projects.

E. Rebuilding plans

1. Objective - Rebuild depleted (e.g., overfished) stocks to levels that can support maximum sustainable yield within a specified time frame. Also see Management Support below.
2. Current program -
   a. determine expected effect of reduced fishery harvest on expected time frame for rebuilding to target level under prevailing environmental conditions and recruitment levels.
3. Areas of improvement
   a. Incorporate increased knowledge of cycles in ocean climate on the rebuilding target and the expected time frame to recovery
   b. Improve methods of characterizing uncertainty in analyzing alternative rebuilding strategies, and future biological and economic risks associated with alternatives.
   c. Determine and mitigate effect of degraded habitat on recovery.
   d. Evaluate artificial propagation methods to accelerate recovery, supplement depleted stocks, and increase production of valuable fishery products.

F. Stakeholder involvement
1. Objective - Improve design of data collection programs, correctly interpret currently available data, and develop means for stakeholders to invest in knowledge that will increase certainty that current harvest levels are safe and may allow higher harvest levels that are equally safe. Develop fair and equitable protocols to enable stakeholders to partner with NMFS to obtain scientifically valid information.
2. Potential mechanisms include:
   a. Better interpretation of fishery logbook data and other fishery data through good scientist-fisherman dialogue.
   b. Tracking changes in fish distribution and fishing effort through increased use of fishery logbook programs.
   c. Expanded collection of biological samples and environmental data through direct involvement of fishermen.
   d. Increased precision of resource surveys by increasing sample size with chartered fishing vessels. High cost-effectiveness if allocation of fishing rights can be used to compensate participating vessels.
   e. Other

II. Socioeconomic Issues

Goal - Guide development of management actions that have fair and equitable impacts across all fishery stakeholders, and that obtain the greatest benefits from use of living marine resources, including commercial harvest, recreational opportunities, nonconsumptive uses, and aquaculture.

A. Current Program

1. Analysis of potential economic effects of proposed fishery management actions.
2. Analysis of allocation among user groups.
3. Regulatory Flexibility Analyses and other mandated analyses for management actions.

B. Areas of Improvement

1. Improved understanding of the net economic value and income impacts generated by commercial and recreational fishing opportunities.
2. Improved benefit-cost analysis of management alternatives. A short-term need is evaluation of the benefits associated with the current vessel catch limit system used to achieve year-round fishing opportunities at the cost of induced discard.
3. Bio-economic analysis of long-term harvest policies.
4. Analysis of impact on fishing communities.
5. More complete Regulatory Flexibility Analyses for management actions.
6. Systems for market-based allocation of access to harvest rights.

III. **Manmade Stress on Groundfish and their Essential Habitat**

Goal - To identify, understand and seek means to reduce potential risks to fish stocks, their essential habitat, or other components of the ecosystem. Such investigations have a strong role in developing our ability to evaluate impacts on Essential Fish Habitat. These anthropogenic risks include all factors other than the direct effect of fishery catch, which is studied under the Status of Stocks topic. There will be significant interaction between study of these stress factors and the Ecosystem topic, which will include description of ecosystem functions and dependence of the ecosystem function on habitat. In addition to identifying risks, these studies will also seek to develop methods to reduce adverse impacts.

A. Gear impacts on habitat

1. Objective - Minimize, to the extent practicable, the negative impact of fishing gears on the marine habitat and biota, especially those habitats and prey species determined to be of particular importance to the productivity of groundfish.
2. Current Program
   a. Comparative studies of marine benthic habitat and biota characteristics in heavily versus lightly trawled habitats are being conducted off central California.
3. Areas for Improvement
   a. Determine extent and magnitude of impacts of all fishing gears on marine benthic habitat and biota. Consider using well-monitored research reserves to conduct such studies.
   b. Develop modified fishing gears and deployment methods that reduce adverse impacts of gear on the habitat.

B. Bycatch and discarded catch

1. Objective - Reduce impact of fisheries on nonretained, nontarget species (bycatch); accurately account for the total mortality attributable to fisheries, and reduce wastage associated with discard of potentially marketable fish products.
2. Current program
   a. Rough estimates of the levels of discard for major groundfish species, halibut and salmon have been made, primarily on the basis of limited trawl observer programs.
   b. Some knowledge of the factors affecting mortality of discarded halibut and sablefish have been obtained from field and laboratory studies.

c. Some knowledge of the size/age selectivity of fishing gear (especially trawl) through past directed studies and ongoing examination of the size/age composition of landed catch.

3. Areas for Improvement
   a. Improve knowledge of total fishery mortality by initiating more comprehensive observer programs.
   b. Improve knowledge of nonretained fishing mortality by conducting research on the mortality of discarded bycatch, and the mortality of fish that encounter fishing gear but are not taken.
   c. Evaluate technical means to reduce discard by improving selectivity of fishing gears and improving ability to forecast times and areas where bycatch will be lower.
   d. Develop methods for fuller utilization of current discards.
   e. Evaluate benefits and costs of technical discard reduction and utilization methods and possible socioeconomic incentives/ disincentives to discard reduction.

C. Impact of disease, contaminants, exotic species and other factors on fish health and productivity
   1. Objective: provide quantitative linkage between contaminant exposure and factors related to fish health and productivity that can be incorporated into stock assessments.
   2. Current Program - Substantial data available on tissue contaminant concentrations for a few groundfish species at selected locations, but little or no information for others. Linkage between contaminant exposure and productivity measures is available for a few species (e.g., English sole) but little data for most groundfish. Little information on disease/parasite loads for groundfish stocks and little information on correlation with survival, growth, or reproduction.
   3. Areas of Improvement
      a. Develop more sensitive indicators of fish fitness and incorporate into monitoring plans.
      b. Incorporate data collection on disease/parasite load into monitoring
      c. Incorporate monitoring of contaminant concentrations in tissues/environment, especially for those species that use nearshore sites as part of their critical habitat.
      d. Conduct exploratory research to better understand the role of chemical contaminants in degrading habitat resources critical to survival and productivity of fisheries (e.g., depletion or reduced quality of prey base due to contaminants; avoidance of contaminated habitat).

e. Conduct exploratory research to better understand how land-use practices and related activities (e.g., destruction of nursery areas, shoreline hardening, dredging practices) affect survival and productivity of fisheries.

D. Genetic diversity

1. Objective - Reduce the threat of human activities on the genetic traits of a species. Each species has evolved to have traits that are well suited to its environment. In most cases, a species harbors sufficient genetic variability to allow it to adapt to changing environmental conditions. In addition, a species often is not freely mixed throughout its range, so that populations in particular areas may differ genetically from populations in other areas. Human activities, particularly fisheries, can upset this balance by imposing "unnatural" predators (fishermen) that are skilled at selecting large (i.e., fast-growing) individuals of a species and skilled at concentrating that mortality on fish tending to aggregate. Further, the overall geographic distribution of human activities and fishing can concentrate impacts on particular sub-populations.
2. Current program
   a. Stock structure has been at least partially described for some species using tagging studies, and morphometric and genetic stock identification methods.
3. Areas for Improvement
   a. Identify stock structure of each species, including description of partially isolated meta-populations and estimating genetically effective population sizes.
   b. Identify risks to species' genetic composition created by localized impacts to essential fish habitat, including spatially concentrated fisheries.
   c. Identify heritable traits that are at risk from anthropogenic impacts, including size-selective fisheries.

IV. Ecosystem and climate studies

Goal - Determine whether the long-term health of the marine ecosystem is being sustained. The status of the ecosystem is susceptible to fluctuations caused by natural fluctuations in the ocean climate and by human influences. Some of these changes are direct, such as the impact of habitat degradation on productivity of particular species, or the impact of fisheries in reducing the average abundance of targeted species. Other changes are indirect and are caused by the predator-prey and competitory interactions between species; therefore they will be much more difficult to predict. Climate studies will improve stock assessment accuracy by distinguishing historical fishing from natural causes in fish abundance; improve short-term forecasts of fishery potential yield by developing more timely estimates of fish recruitment; improve projections of time scales for fish stock rebuilding by taking into account decadal scale cycles in productivity; and improve resource survey and fishery efficiency by predicting changes in fish abundance.

A. Ecosystem studies
   1. Extend monitoring programs in habitats essential to groundfish to detect changes in biodiversity and ecosystem function.
   2. Develop simple ecosystem scale food web models so that effects of fishery-induced changes in fish abundance can be more fully understood and predicted.
   3. Improve understanding of major predator-prey, and competitory interactions among species so that food web models can be improved.
   4. Understand feeding ecology of indicator species, how it is affected by environmental factors, and resulting impacts on growth, maturation, and fitness.
   5. Understand major host-parasite relations and disease prevalence in groundfish species so their influence on survival and productivity can be better quantified.
   6. Understand the linkage between habitat alteration/destruction and fisheries productivity so effects of anthropogenic activities can be more fully understood and predicted.

B. Ocean climate studies
   1. Current programs
      a. Ongoing ocean environmental monitoring.
         (1) Various NOAA, NASA, military agencies, including surface observations from ships of opportunity, collect oceanographic and meterological data. Coverage is not good in many areas and in subsurface waters. The NMFS Pacific Fishery Environmental Laboratory (PFEL) in Monterey assembles and analyzes much of this data with an explicit focus on fishery analysis.

(2) largest program directed towards fishery-oceanography understanding is the 50-year-old CalCOFI program that now works only south of Morro Bay.

b. Ongoing monitoring of fish recruitment

(1) Stock assessments that include age-structured data usually provide a 20-30 year time series of recruitment.

(2) Directed field program to measure recruitment of some rockfish species on an ongoing basis occurs only off central California.

c. Fishery-oceanography investigations

(1) NMFS West Coast programs studying the direct effect of ocean conditions on the physiology and survival of marine fish larvae and subsequent recruitment include: SWFSC-LaJolla program focusing on recruiting coastal pelagic species; NWFSC new program focusing largely on juvenile salmonids; the SWFSC-Tiburon program focusing on rockfishes.

(2) Correlation studies of time series of fish recruitment and time series of oceanographic data indicate some evidence for similar patterns for several species. For some species, there is evidence for reduced recruitment in El nino years, high recruitment immediately after an El nino, and reduced average recruitment since the climate regime shift in 1977.

2. Areas of Improvement

a. Monitor recruitment of more fish species to improve forecasting from stock assessments and to improve the understanding of the linkage between recruitment and ocean conditions.

b. Monitor the ocean climate to improve predictions in fish distribution, recruitment and productivity.

c. Develop understanding of the actual mechanisms by which the ocean climate affects fish recruitment, including predator distribution, prey availability, adverse transport patterns. Recent increases in the GLOBEC and PNCER programs will provide increased opportunities in this area.

C. Essential fish habitat (EFH)

1. Objective - Identify habitat essential to the productivity of groundfish.

2. Current program

a. Develop maps of geographic distribution for each life stage of each species.

b. Describe habitat.

c. Develop guidelines and process for consultation regarding potential impacts on EFH.

3. Areas of Improvement
    a. Improve understanding of fish assemblages and their association with particular habitats through examination of fishery and survey data, and dedicated studies using advanced imaging technologies. This has strong links to survey and life history program.
    b. Improve understanding of how conditions in each habitat influence fish productivity. What are the population level consequences of habitat alterations?
    c. Improve understanding of linkages between habitats and life stages. In particular, which habitat areas are sources of most successful reproductive output.

D. Marine reserves

1. Objective - Safeguard the marine environment and harvested species against excessive anthropogenic impact, and provide increased human benefits through access to areas that have minimal impact from fisheries and other activities. These benefits include non-consumptive uses and recreational fisheries for trophy-sized fish. The impacts that are reduced by marine reserves include: overfishing due to inadequate knowledge of optimum harvest levels; changes in marine habitat and biota caused by fishing gear impacts; risks to fish stocks caused by reducing old age groups in optimally fished populations; possible changes in the average growth rate of fished species due to the increased fishing mortality on fish that grow faster and enter the fishery at an earlier age; and possible changes in the schooling tendency of some species because of the fisheries' ability to target on fish aggregations.
2. Current program
    a. Modeling studies are being conducted to determine the effect of reserve size and location on the potential benefits, including evaluation of the effect of fish dispersal on the effectiveness of the reserve.
    b. Some small scale reserves have been implemented off California and in Puget Sound.
3. Areas of Improvement
    a. Establishing well-monitored research reserves to test potential effectiveness of larger scale implementation.
    b. Increased knowledge of fish mixing rates (from tagging studies, parasites, genetics, etc.) and location of productive source sites are needed to estimate biological effectiveness of various marine reserve sizes and siting schemes.

Socioeconomic studies are needed to determine impacts of marine reserve siting and to develop effective means for community acceptance and enforcement.

V. **Technological Innovation**

Goal - develop technologies and knowledge to obtain the maximum benefits for fishing communities and the nation, and for cost-effective investigation and monitoring of this fishery and the affected stocks and ecosystem.

A. Utilization
   1. Objective - Develop new technologies for fuller and more valuable utilization of fishery products, and develop alternatives to conventional harvest.
   2. Current Program -
      a. Develop processing technologies for fuller utilization of fish processing waste.
      b. Develop technologies for production of more valuable fish products from currently harvested species and under-utilized species.
   3. Areas of Improvement
      a. Continue to advance the technology for fuller utilization of fish processing waste, undersized fish, and currently undesirable species.

B. Fish Culture and Enhancement
   1. Objective - develop technologies for environmentally safe and valuable aquaculture, develop fish culture technologies for enhancing depleted wild stocks, develop fuller understanding of the life history characteristics (e.g. feeding, growth, maturation, behavior) of target species.
   2. Current Program
      a. Create captive broodstock for target species. Sablefish, lingcod, and several rockfish are among the species under investigation.
      b. Develop understanding of each species requirements for feeding, growth, maturation, behavior.
   3. Areas of Improvement
      a. Continue studies to improve rearing technology.
      b. Conduct studies of the potential ecological effects of marine aquaculture.
      c. Conduct studies of the potential ecological and genetic effects of marine enhancement programs.
      d. Conduct bio-economic studies of the potential benefits of enhancement programs.

C. Research and monitoring tools
   1. Objective - develop new methods for cost effective investigation and monitoring of the fishery and the affected stocks and ecosystem.
   2. Current Program -
      a. Development and prototyping of electronic fish catch logbook.

   b. Development of new egg and larvae based surveys.
   c. Development of new trawl survey gear monitoring tools such as bottom contact sensors.
3. Areas of Improvement (examples only)
   a. Development of advanced imaging technologies to augment and calibrate conventional surveys and investigate fish-habitat associations.
   b. Develop advanced fish tagging methods to improve study of movement patterns and abundance estimation.

VI. Management Support

The status of stocks, anthropogenic stress, and socioeconomic research areas provide a decision support system for sustainable fisheries. They provide an empirical approach to describing *what* are potential biological, social, and economic consequences of proposed management actions on fishery resources, their habitat, and fishery. The focus is on research and monitoring with the goal of providing the best available scientific advice for management decisions, with associated uncertainty, on a timely basis. A full management support system needs to look to the future also and develop technologies and knowledge that will enable consideration of new management alternatives.

A. Current Program
   1. Stock assessments and recommendations on annual quotas.
   2. Rebuilding plans.
   3. Consultations on essential fish habitat impacts, socioeconomic impact of fishery direct allocations, gear limitations, seasons, catch quotas, and individual limits, etc.
   4. Biological impacts of fishing gear regulations and bycatch reduction measures.
   5. Impacts of gear group allocations on the geographic distribution of catch.

B. Areas of Improvement
   1. Build standardized framework for community assessments and associated recommendations/uncertainty to fishery managers and constituents.
   2. Build a decision-support model for inseason management changes in trip limits.
   3. Improve biological, social, and economic analyses used in current program.
   4. Develop and evaluate alternative approaches to managing groundfish fisheries, rebuilding depleted groundfish resources, and protecting the marine ecosystem.