

## II. Defining NMFS' Stock Assessment Mandate

The central importance of stock assessments to NMFS is clear. The NOAA Fisheries Strategic Plan (NMFS 1997a) describes the agency's mission as:

*“stewardship of living marine resources for the benefit of the Nation through their science-based conservation and management and promotion of the health of their environment”*

That document then outlines five “foundations for stewardship,” the first of which is: “Science, which is of the highest quality, and which advances our ability to make living marine resource management decisions.” The goals and objectives of the Strategic Plan are reiterated and expanded in the NMFS Strategic Plan for Fisheries Research (1998c, 2001b). Those which are at least partially addressed by the current plan are reproduced below. To facilitate cross reference, the corresponding Fisheries Strategic Plan (FSP) strategy or foundation number follows each fishery research objective.

### **GOAL 1: Provide scientifically sound information and data to support fishery conservation and management. (Ongoing)**

Objective 1.1: Periodically assess stocks to ascertain whether changes in their status due to natural or human-related causes have occurred. These stock assessments require adequate fishery monitoring and resource surveys. (FSP Strategy 1.1.1)

Objective 1.2: Use stock assessments to predict future trends in stock status. Forecasts will take into account projected biological productivity, climatic information, economic markets, and other social forces that will affect levels of fishing effort. (FSP Strategy 1.1.2)

Objective 1.3: Determine and reduce the level of uncertainty associated with stock assessments through improved data collection and advanced analytical techniques. (FSP Strategy 1.2.1)

Objective 1.4: Use stock assessment workshops, peer reviews, and other fora to ensure that our information and advice are developed through an open and collaborative process. (FSP Strategy 1.2.2)

Objective 1.5: Communicate our scientific information and advice, along with the associated uncertainties, to

the Councils, other management authorities, and the public. (FSP Strategy 1.1.3)

Objective 1.6: Collaborate with the Councils and other management authorities to explore and develop fishery management regimes and alternative governance systems that will effectively control exploitation and promote sustainability. (FSP Strategy 1.1.4)

Objective 1.7: Provide guidelines to assist the Councils in assessing and specifying maximum sustainable yield (MSY) for managed fisheries. (FSP Strategy 1.1.5)

Objective 1.8: Work with the Councils to develop objective and measurable criteria for each managed stock to determine if the stock is overfished or approaching an overfished condition. (FSP Strategy 2.1.1)

Objective 1.9: For each stock which is overfished or approaching an overfished condition, we will develop, in collaboration with the Councils, measures to eliminate or prevent the overfishing. (FSP Strategy 2.1.2)

Objective 1.12: Support recommendations provided by the National Research Council [NRC 1999] and the Report to Congress [NMFS 1999b] by establishing criteria to define and delineate marine, estuarine, and riverine ecosystems for management purposes, and identify indicators for assessing the status and detecting changes in the health of such ecosystems. (FSP Strategy 7.3.2)

Objective 1.14: Incorporate assessments or indices of climate variability into stock assessments.

Objective 1.15: Monitor climate change on inter-annual, decadal, and centennial scales and its impact on currently sustainable fisheries.

### **GOAL 5: Improve the effectiveness of external partnerships with fishers, managers, scientists, conservationists, and other interested groups. (Ongoing)**

Objective 5.1: Promote a cooperative network of partners in the coordination of fisheries research.

Objective 5.2: Develop infrastructure for long-term, continuous working relationships with partners to address fisheries research issues.

As reported in the first four annual Reports to Congress on the Status of Fisheries of the United States (NMFS 1997b, 1998b, 1999a, 2001a), the status relative to overfishing of the majority of the fish stocks covered by federal Fisheries Management Plans (FMPs) is unknown. In contrast to the first three reports, the NMFS (2001a) report broke stocks out into “major” or “minor” categories based on landings. Thus, even though the Stock Assessment Improvement Plan is mainly based on information up to January 2000, the following statements are based on the NMFS (2001a) report, which tabulated information on 905 stocks (as compared to a slightly different mix of 904 stocks in the 1999 report). In the 2001 report, 623 of the 905 stocks were recorded as having unknown status. Although it is often overlooked, most of the 905 stocks tabulated can be classified as “minor” stocks: 618/905 or 68.3% have recent landings less than 90.74 metric tons (200,000 pounds) annually. In total, “minor” stocks have accounted for only about 0.11% of total landings in recent years. However, it should be noted that “minor” stocks are often not landed or identified to species, and discarded catches may not be recorded, particularly where observer programs are lacking. Whether or not actual removals constitute a risk to the long-term viability of these species is unknown. Of the 287 “major” stocks, 35.2% are of unknown or undefined status relative to threshold fishing mortality levels that define “overfishing,” while 41.8% are of unknown or undefined status relative to threshold stock sizes that define whether a stock is “overfished.” While the costs of determining the status of all 623 stocks in the unknown category may be prohibitive, additional efforts to obtain the information necessary to assess the major stocks with unknown status is certainly warranted. In addition, major stocks of “known” status also require special and vigilant attention because many of them (25.3%) are experiencing overfishing and many (36.5%) are overfished or approaching an overfished condition. The need to elevate the level of knowledge of many of the unknown species, even those of “minor” importance, will escalate as fisheries management progresses towards ecosystem-based management (EBM). Thus, there is a need to constantly improve both the quality and quantity of stock assessments.

It is also important to keep in mind that NMFS’ mandate is actually a dual one of both sustainability and exploitation, which can often create conflict. The fact that our science is used for regulation means that stock assessments will often be challenged. Thus, as stated in the NMFS Strategic Plan for Fisheries Research, “all of the agency’s information must be comprehensive, objective, credible, and effectively communicated.”

## **A. What is a “Stock Assessment?”**

The term “stock assessment” is used to describe the processes of collecting, analyzing, and reporting demographic information for the purpose of determining the effects of fishing on fish populations. The production of stock assessments requires quantitative information on the relative or absolute magnitude of a fish population, estimates of the total removals due to human activities (due to fishery landings, discarded bycatch, and cryptic mortality due to encounters with fishing gear), life history data including rates of growth, average age of the onset of sexual maturity, maximum longevity, and the proportion of each age group dying each year due to natural causes, and other factors that affect stock productivity. These data are combined using simple or complex mathematical models (NRC 1998a) to derive “best” estimates of vital statistics such as historical and recent trends in the number and biomass of the resource, recruitment levels (number of small fish entering the fishery each year), and the fishing mortality rate or the fraction of the stock alive at the beginning of the year that are killed by fishing (commonly referred to as the exploitation rate).

The results of stock assessment calculations provide information necessary to estimate the current abundance and exploitation rates of resources in relation to predefined goals for these two attributes, also termed “status determination criteria.” If the biomass is determined to be significantly below a minimum threshold, the stock is in an “overfished condition.” If the current exploitation rate is significantly higher than a maximum exploitation rate threshold, overfishing is deemed to be occurring. The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) mandates that if stocks are in an overfished condition or if overfishing is occurring, managers must implement measures to rebuild the stock and/or to eliminate overfishing. In addition, assessment results provide the technical basis for setting the level of biologically acceptable yield for healthy stocks, and the expected rate of rebuilding for depleted stocks.

The stock assessment evaluation is thus a key element of the fishery management process since it is used to determine whether additional regulations are necessary, or if greater fishing opportunities can be allowed consistent with the objective of sustainable fishing. In addition to enabling determination of overfishing, stock assessment results have three additional important purposes: (1) for each managed stock, a history of estimates of catches, stock sizes and exploitation rates is used to establish reference levels for the two status determination criteria; (2) assessment results (biomass, recruitment levels and exploitation rates) are combined to provide short- (1-2 year),

medium- (3-10 year) and sometimes long-term (10+ year) projections of how fish populations and catches will change over time; and (3) stock assessment results are typically combined with other research results or assumptions to evaluate various alternative sets of management measures proposed by managers to attain specified objectives. The latter analyses are termed “alternative management strategy analyses” and are important because there are often many different types of measures that can be used to manage fisheries (e.g. regulating the characteristics of the gear such as minimum mesh size, or regulating the amount of effort by fleet sector, area, or season). The selection of the “preferred” set of management measures is often complex and requires quantitative evaluation since even if one or several options allow a stock to rebuild to optimal levels, they may have dramatically different implications for the profitability of fisheries and the allocation of benefits among competing harvest sectors. Quantitative stock assessments provide the essential information necessary for the analyses required in the fishery management process.

The quality of a particular stock assessment (i.e. the accuracy and precision of stock size and exploitation rate estimates) is directly related to the quality and completeness of the input data used for the assessment. No stock assessment is perfect because the information used is derived from a modest number of observations that are assumed to be statistically representative of the population as a whole. Elsewhere in this document (**Sections IIA, IIB**), information on the quality of data on catches, abundance measures and life history data supporting stock assessments for all managed or assessed fishery stocks occurring in EEZ waters is provided. In most cases, the sophistication of the stock assessment model used to estimate stock size and the accuracy and precision of the results is directly related to the quality of the assessment data. It cannot be overemphasized that *improving the quality of fish stock assessments (consistent with the focus of the NRC report) primarily involves improving the quality of basic input data on catches, abundance and life history, and that these improvements will lead to a progression through Tiers of Assessment Excellence.*

The goal of improving fish stock assessments is to allow society to extract maximum benefits from fish stocks while minimizing the risk that stocks will become overfished. As assessments are improved, the types of questions posed by managers will increasingly emphasize multispecies aspects (technological and biological interactions among stocks and fisheries), and will require greater temporal and spatial detail to evaluate fine-scale time/area components of management measures. Thus, the requirements for the next generation of fish stock assessments will necessitate continued improvements to data and refinements to models.

In addition to requiring fishery data and selection of appropriate mathematical models, the process of producing stock assessment, as practiced by NMFS, involves explicit and intensive QC/QA through a process known as “peer review.” Owing to the implications of stock assessment results for the ecosystem and the economy, the public must be assured that data and procedures used by NMFS and its cooperators meet accepted standards for the production of such analyses. Assessments undertaken by all of the NMFS Science Centers include an element of peer review, which involves review of data and calculations by experts independent of the people responsible for the work being reviewed. In many cases peer reviews have involved academic researchers, inter-Center exchanges of personnel, experts hired by fishery industry groups, and international scientists. An increasing and serious impediment to the improvement of stock assessments nationwide is the difficulty of providing for adequate peer review under the burden of increasing numbers of stock assessments with higher levels of complexity being produced more frequently, in combination with a relatively small pool of experts in this specialized area.

## **B. The Quality of NMFS’ Assessments**

The stock assessment activities within the National Marine Fisheries Service have produced strengths and accomplishments that are globally recognized. The strength of the national assessment activities lies in the development of periodic stock-wide status determinations for major species; i.e. those species which are economically most important and which comprise the majority of the fisheries biomass. The accomplishments of NMFS scientists in this regard compare favorably with any national effort worldwide. These assessments have allowed these important stocks to be monitored effectively. The precision and accuracy of these assessments has proven to be extremely helpful in management. These results have also formed the basis for much of the understanding of fishery population dynamics and the historical trends of these species.

However, NMFS assessment efforts have been less effective in several other areas. Specifically, there are many species that are not assessed even though in many instances some relevant data may exist. While these species are not economically dominant and do not comprise a high proportion of the biomass, they often interact ecologically with the economically important species and they may be significant keystones in the functioning of the ecosystem. At the present time we have little understanding of the role of these species either in the ecosystem or in local economies. There has been a lack of resources to obtain sufficient data to evaluate these species.

Another limitation to present assessment efforts is the understanding of the spatial and temporal dynamics of the species. Under what conditions do fish move into alternative areas of their range and what are the stimuli? These questions have become important as managers attempt to provide for the diversity of users of the resources.

### C. Changing Demands

The demand for stock assessments has shifted both quantitatively and qualitatively throughout the Nation. Fisheries have expanded to target heretofore lightly exploited resources, as traditional stocks have been fully exploited or over exploited, leading to needs for increased numbers of stocks to be assessed. More detailed and complex regulatory mechanisms are being devised to distribute the limited resources equitably between fishing sectors, commercial, recreational, and bycatch users. In order to evaluate these alternative mechanisms, spatial and temporal projections of management scenarios are required, taxing the limits of the available data and the number of assessment scientists. The MSFCMA has imposed new management requirements that have increased both the detail and the number of assessments that are to be conducted. These general changes have manifested themselves in the Nation's fisheries in a variety of ways which are described below for each of the NMFS Science Centers.

#### ***Northeast Fisheries Science Center***

The Northeast Fisheries Science Center (NEFSC) typically produces stock assessments, in one form or another, for about 51 managed species/stocks (**Appendix 1**). Not all of these stocks are managed under Federal FMPs (e.g. some are managed by the Atlantic States Marine Fisheries Commission, ASMFC, or individual states, or under international agreements). These assessments run the gamut from index-level assessments using trawl survey information, to stage-based analytical assessments incorporating multiple abundance indices and catches. During the past 15 years, stock assessments have been peer-reviewed under the jurisdiction of the Northeast Stock Assessment Workshop (SAW) process. Typically, the SAW has reviewed about dozen high priority stock assessments per year, six each in spring and autumn SAW meetings.

The demand for more timely and comprehensive stock assessments has increased greatly, primarily as a result of the need to respond to information needs associated with the MSFCMA. The exploitation history of most of the economically-important stocks of the region has necessitated stringent rebuilding plans, and managers are requesting more frequent assessment updates on a wider array of species, and are considering more complex types of indirect

controls on fishing mortality, including manipulating the temporal and spatial patterns of fishing.

A major new demand on the assessment process is to increase the precision of estimates of exploitation rates and stock sizes. For many resources, fishing rates historically have greatly exceeded standard biological reference points and stock sizes were considerably below those considered optimal for sustainable fisheries. Thus, even imprecise assessments were considered useful enough to give clear advice about the direction of fishery management and rough indications of the magnitude of fishing effort reductions required (e.g. in many cases fishing mortality rates were five times the target levels, and stock biomasses were 1/5<sup>th</sup> of the biomasses generating MSY). Management programs instituted in the mid-1990s have resulted in reduced harvest rates for species such as haddock, yellowtail flounder, sea scallop, and other economically-important resources. As a result of these changes, managers require more precise information to determine the probabilities of attaining fishing mortality rate targets associated with the harvest control rules they have adopted. Additionally, because so many of the region's resources were determined to be overfished, 10-year rebuilding programs are now in effect. Consequently, management requires medium-term projections to determine which exploitation strategies will allow attainment of biomass targets with a specific probability.

In addition to the increased demand for precision of analyses, the requirement for estimates of biomasses and fishing mortality rates or proxies associated with MSY for all managed species necessitates that the *level* of many stock assessments be increased from monitoring of indices of abundance to greater levels of analytic complexity. This means that the demands for biological sampling of fishery catches and abundance indices will increase (e.g. more routine age determinations for managed stocks). Likewise, managers require more specific information on all components of fishery catches, and especially fishery discards, which have historically not been sampled adequately in the Northeast fisheries. Thus, in addition to increased needs for more stocks to be assessed, increased quality of assessments means significantly augmented data collections and biological information to support improved assessments.

The frequency of stock assessment updates has increased primarily as a result of the many changes recently incorporated in many of the region's FMPs. Because of reductions in fishing effort, the closure of large areas of productive fishing grounds, trip limits and other measures, managers want to know the incremental effect of these measures on attaining required fishing mortality and biomass targets. Thus, for example, the New England Fishery Management

Council has requested detailed assessment updates on all managed stocks well in advance of each new fishing year, so as to determine the suite of new measures necessary to meet the requirements of the law. This is in strong contrast to recent history when a small group of important species (e.g. cod, haddock, yellowtail flounder) were used as “bell-wether” indicators of the exploitation of the status of a complex of about 25 managed stocks. Additionally, the MSFCMA requires that stocks that were historically “written-off” as virtually commercially extinct, be rehabilitated towards sustainable stock levels (e.g. Atlantic halibut, redfish). Thus, new stock assessments are required to determine the feasibility and impacts of efforts to do so. Even stocks for which no commercial uses exist are subject to increased demand for assessments when their status may be impacted as a result of fishery bycatch (e.g. barndoor skates).

Management advice based on analytic stock assessments is also increasingly required to support complex measures accounting for technological interactions among the region’s stocks (which are generally significant) and the increased demand for finer spatial and temporal scale information supporting area rotation strategies, and other complex management approaches. Supporting these scales of management will require improvements in basic information collected from fishers (e.g. logbook-type data and observer data) and dealers. There is an important new demand for integration of single species assessment information to support assemblage management (stock trade-offs). Managers are also increasingly concerned with the trophic implications of attempting to increase all managed stocks to  $B_{MSY}$  simultaneously, necessitating more research on biological interactions.

### ***Southeast Fisheries Science Center***

The fisheries under the research jurisdiction of the Southeast Fisheries Science Center (SEFSC) are diverse in both the species being exploited and the fishing sectors prosecuting these fisheries. The fisheries include a large number of snapper-grouper fisheries, mackerel fisheries, croakers, shrimp and other invertebrates, sharks, and Atlantic-wide tunas and billfish. Characteristically, these fisheries involve large recreational sectors along with the usual commercial sector (in some instances the recreational sector takes the majority of the catch). Additionally, there is a large bycatch sector; i.e. bycatch of commercially and recreationally important species occurs in large numbers in some fisheries. Interactions between these sectors have manifested themselves in numerous allocation conflicts.

Another characteristic of southeastern U.S. fisheries is that the productivity of many of the species being exploited is

low, supporting relatively small catches (there are over 400 species within Southeast FMPs or international conventions). However, some of the species are extremely valuable and many are very important to local communities. Also, in aggregate the species catches are significant and the fisheries often have the capability to exploit a variety of species, switching target species as conditions change. These characteristics create unique dynamics which affect the research and management of these resources.

The Southeast Fisheries Science Center has conducted assessments for the most important stocks for the last two decades. These assessments have been reviewed through Stock Assessment Panels of the Councils and through international scientific working groups within the International Commission for the Conservation of Atlantic Tunas. Through these scientific groups the assessment information is integrated into the scientific advice on Allowable Biological Catch (ABC).

However, there are a number of recent events that have altered the assessment landscape in the Southeast. First and foremost, several important stocks have been severely depleted leading to very restrictive limitations on catch. As the stocks begin to recover, more detailed regulations such as trip limits, area closures, minimum sizes and bag limits are being devised to distribute quotas more equitably. Evaluation of these alternatives require an order of magnitude greater spatial and temporal details. The evaluation activities require an increasingly larger proportion of the assessment scientists’ time. Additionally, as fishers look for new alternatives to replace depleted stocks, they have begun to target stocks that traditionally have not been exploited. In many cases, detailed assessments have not been conducted for these stocks but as fishing pressure has increased, there has been an increased need to evaluate their status. The ability to do this is limited by both the available data and the human analytical resources.

Finally, the MSFCMA has shifted the focus of management from limiting fishing mortality rates under the 602 Guidelines to limiting both the maximum allowable fishing mortality rate and the minimum allowable stock abundance. Scientifically, it is easier to estimate the reference fishing rates than to determine appropriate reference abundance criteria, especially when data are limited and the species are numerous. The MSFCMA requirements have shifted the focus to determining abundance criteria. This requires examination of each stock individually. It is unclear whether the Southeast Fisheries Science Center has the data or human resources available to address these issues for all 400+ species in the southeast and Caribbean.

### ***Southwest Fisheries Science Center***

On the Pacific coast and in Hawaii demands on the Southwest Fisheries Science Center (SWFSC) stock assessment scientists have been increasing significantly due to new FMPs, increasing lawsuits and other pressure from industry and environmental groups, and new demands to manage international fisheries for which little data are available. At the same time, SWFSC resources for this research have diminished and little funding beyond basic salaries is available.

New FMPs are in place or being developed for coastal pelagic species and highly migratory species, and increased attention is being demanded for stock assessments of squid, marlins, swordfish, albacore, groundfish, sharks, marlins and tropical tunas. Environmental groups are pressing for increased research on sharks, monk seals, turtles and rockfish. Marine mammal stock assessments are partially completed for the 38 west-coast species but have not been started for Hawaiian or other U.S. Pacific waters. A new fishery has developed for near shore rockfish; coral fisheries are resuming; and California salmon issues are highly controversial.

A new international agreement on western Pacific Highly Migratory Species is being developed that will demand a huge and complex stock assessment effort by the U.S. in collaboration with other fishing nations. Also, new legislation requires that research be strengthened on the major international fisheries in which U.S. fishers participate, harvesting swordfish, tropical tunas, albacore, plus incidentals such as marlins, mahimahi, opah, wahoo, and others.

### ***Northwest Fisheries Science Center***

The Northwest Fisheries Science Center (NWFSC) engages in assessments of west coast groundfish and salmon. The demands for accurate assessments for both groups of species are high and increasing. For groundfish, only 26 of the 82 species have been quantitatively assessed. Of these 26 species, several have experienced severe declines because of overly optimistic historical harvest rates during a 20-year regime of poor ocean productivity with inadequate stock assessment information to adequately monitor and forecast the declines. As of 2001, rebuilding plans are being developed for seven groundfish species that have declines below the overfished threshold, and there are concerns that others of the 60+ species with unknown status may also be in danger. For salmon, the status of Pacific salmon species on the west coast has been reviewed under provisions of the Endangered Species Act and 26 of the populations (Evolutionarily Significant Units) have been listed as threatened or endangered. A tremendous effort is

being mounted by the NWFSC to develop salmon recovery plans that incorporate all aspects of human and natural risks to salmon.

Groundfish and salmon are managed according to Fishery Management Plans developed by the Pacific Fishery Management Council. Although the NWFSC has the lead role in coordinating assessment information for both FMPs, there are major contributions by other NMFS Science Centers and by the state fishery agencies of California, Oregon and Washington. For salmon, nearly all of the escapement monitoring and run forecasting is based on inriver information and is done by the state agencies. This information is used by the Salmon Technical Team of the PFMC to develop harvest options for consideration by the PFMC. The Scientific and Statistical Committee of the PFMC provides reviews of methodology for this work. For groundfish, shoreside catch monitoring is done by the state agencies with coordination through the Pacific States Marine Fisheries Commission (PSMFC) which maintains a centralized database of fisheries data (PacFIN). In 2001, a coastwide observer program was implemented by NMFS in collaboration with PSMFC and the states. Most resource surveys are conducted by NMFS, with the triennial bottom trawl and hydroacoustic surveys providing a major source of data for most assessments. Approximately six groundfish stock assessments are conducted each year by NMFS, state agencies and others. The NWFSC coordinates a stock assessment review process in conjunction with the PFMC's SSC, that involves external peer-reviewers and public input. These groundfish assessments have been controversial. The west coast groundfish industry seeks an increasing role in gathering of relevant stock assessment information, and in participating in the stock assessment process.

Passage of the Sustainable Fisheries Act strengthens the mandate to improve the west coast stock assessment capability. Assessments need to be conducted for more of the groundfish species. The level of uncertainty in groundfish assessments and the current information indicating low productivity for these species needs to be combined in an adequately precautionary approach to managing these species. Rebuilding plans, which are expected to have time horizons longer than 10 years, need to be developed and subsequently monitored for several long-lived species. All of these tasks will be extraordinarily difficult given the lack of a dedicated research vessel for surveying these resources and the low level of current resource survey efforts. Further, increased stock assessment effort will primarily result in increased knowledge about what changes the fish populations have undergone, but knowing what is only the first step. In order to develop a better understanding of why changes are occurring, programs need to be developed to investigate the role of decadal scale changes in ocean climate,

and the role of ecosystem shifts such as the major increase in pinniped abundance that has occurred off the west coast.

### ***Alaska Fisheries Science Center***

The Alaska Fisheries Science Center (AFSC) stock assessment staff have experienced increased demands stemming primarily from requests for information regarding the impacts of fishing on marine ecosystems. These requests require added activities including (1) development of new assessments for minor species, (2) development of models that address predator-prey interactions, and (3) development of models that incorporate environmental forcing on stock production.

The AFSC produces stock assessments for fish and shellfish in the Eastern Bering Sea, Aleutians and Gulf of Alaska (**Appendix 1**). These stocks are managed under Federal Fisheries Management Plans (FMP) or under international agreements. The North Pacific Fisheries Management Council (NPFMC) FMP covers 100 species/stocks in the GOA and 127 species/stocks in the Bering Sea Aleutian Islands. In some circumstances (e.g. Pacific salmon and crab), fish stocks are assessed jointly between federal and state fishery scientists. The NPFMC has a long tradition of conservative management of Alaskan fishery resources that includes bycatch limits to protect weak stocks or prohibited species.

The infrastructure supporting this type of management consists of complex fisheries-dependent and fishery-independent data collection programs as well as detailed assessments of core species. The NPFMC reviews stock assessments for groundfish and crab stocks or stock complexes on an annual basis. Stock assessments are peer-reviewed by the North Pacific Fisheries Management Council's (NPFMC) Plan Team and Scientific and Statistical Committee. In addition, AFSC solicits peer reviews of selected species by outside stock assessment experts. These review panels evaluate all aspects of the assessment from data collection to model formulations.

Passage of the MSFCMA in 1996 increased the need for comprehensive assessment of marine resources in Alaskan waters. The MSFCMA mandated adoption of overfishing definitions for exploited marine resources managed under Federal FMPs, and an evaluation of impacts of humans on essential fish habitat. These two mandates require increased data collection, data analysis, and impact review. Efforts are currently underway to increase the frequency and regional coverage of bottom trawl and Echo Integration Trawl surveys. For some species, new survey methods and fishery-dependent data collection programs are necessary to develop indices of stock abundance and

catch. Demands for data processing, data analysis and stock assessment modeling occur as these new sources of fishery-dependent or fishery-independent data become available.

There is a growing need for the development and implementation of complex assessment models. Recently, statistical assessment models (SAMs) have been modified to consider uncertainty stemming from process and measurement errors. SAMs have also been developed to explore the impact of temporal trends in predator abundance. These models are used to explore assumptions regarding predator satiation, natural mortality, and predator selectivity on uncertainty in estimating biomass.

In recent years, NMFS has experienced a number of challenges to regulatory decisions based on AFSC assessments. These challenges require assessment scientists to evaluate a number of alternative harvest strategies. For example, assessment scientists have been asked to develop ecosystem based harvest strategies that encompass impacts of fishing on the structure and function of marine communities. Recent declines in sea bird and marine mammal populations that share exploited resources with commercial fishers have triggered interest in designing harvest strategies for minimizing impacts of fishing on protected resources. These demands require analysis of marine mammal-fisheries interactions on finer spatial and temporal scales, and they require review of more complex management approaches.

### **D. The Credibility of NMFS' Science**

Assessment activities form the apex of the scientific support of management (see **Section III, I**). The assessment process integrates a wide array of scientific information and the results are directly communicated to managers and constituents by the assessment scientists. These activities are required to fulfill the Agency's dual role of maintaining conservation stewardship responsibilities and the promotion of optimum usage of resources. This dual role results in a natural tension between scientists and constituents. The scientific results are viewed as a constraint on allowable catch and allocation decisions. Indeed, in the short term they are. This has prompted several external reviews over the years; for example, the NRC Review of Northeast Fishery Stock Assessments (NRC 1998b; **Appendix 16**).

Criticism of the science occurs for a variety of reasons. At times, valid concerns are raised. However, much criticism stems from other causes, such as lack of understanding of science's role in the decision process by constituents, lack of understanding of scientific methods and issues by

constituents, poor communication of these methods and issues by the scientists, poor communication of the issues and methods by the managers to constituents, limited data resources to support the science, limited resources to support communication efforts, deliberate use of criticism of the science as a strategy or negotiation tactic to alter or hinder implementation of unfavorable management decisions, and the perception that scientists have a limited and unrealistic view of the status of fisheries resources.

Credibility with fishing constituents often is related to the data supporting the assessments: constituents argue that the data are of poor quality, that they are unrepresentative of their direct observations, and that the assessment scientists are not cognizant of these features. Hence, the constituents view the scientific opinions as unrealistic. This is a source of criticism against which scientists of NMFS must continually be on guard. New scientific perspectives on old problems must continually be integrated into the assessments. Mechanisms to do this are through regular, periodic peer-review and scientific program review processes which are discussed in **Section III F**. These reviews should make clear to managers and constituents, alike, appropriate interpretations of existing data *for the existing management questions being asked*, limitations of those data, and relative benefits to the decisions with improvement of the data.

Communication effects on credibility are a difficult problem. NMFS scientists are presently being asked to communicate and prepare documents in three arenas: to prepare documents with scientific details that will communicate to scientists and withstand scientific challenges; to prepare documents that will communicate to managers/politicians/lawyers to withstand legal challenges; and to prepare documents to communicate the nature of the biological and fisheries issues to lay constituents. Of these three arenas, NMFS scientists are required to put a disproportionate amount of effort into the second category. NMFS scientists, in general, probably get the most career fulfillment from the first and it is in that arena where NMFS scientist's activities overlap with academic scientists. The third category (preparing documents for lay constituencies) is admittedly lacking. Communication with constituencies is mostly spoken and often within the final decision-making process. That atmosphere does not promote dialog. But beyond that, the three activities require resources: people (or proportions of people's time) and travel. In addition, those individuals who actually conduct the science are not likely to have equally good skills in communication in all three arenas. Each arena poses different challenges, and also offers different degrees of career fulfillment. Real-

location of a scientist's time toward one activity will often be at the expense of other required activities of the individual.

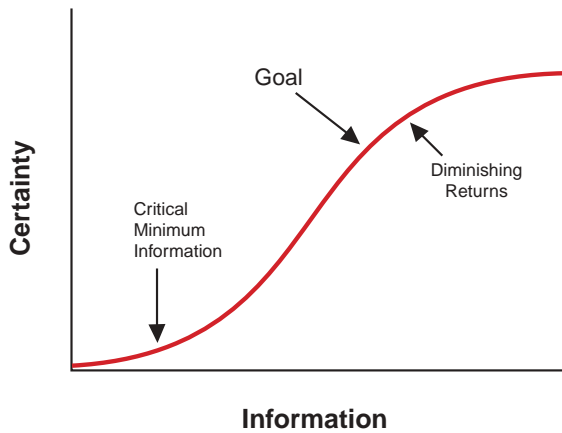
Another related credibility issue is that *within* NOAA. Unfortunately, credibility of NMFS science within NOAA is often filtered through constituent interactions rather than through NMFS scientific interactions. Also, since much of the assessment work results in regulations and limitations on the public users of fishery resources, it is hard to develop "good news" communications.

Perhaps the best solution to the perceived credibility and communication problems is a recognition that under existing management frameworks criticism will continue to exist; that communication to the lay public (including within NOAA) takes specialized skills and resources; that NMFS should develop new resources to achieve communication goals; and that these new resources should not be achieved at the detriment of the data and assessment bases of the scientific advice.

## **E. Implications of the Precautionary Approach**

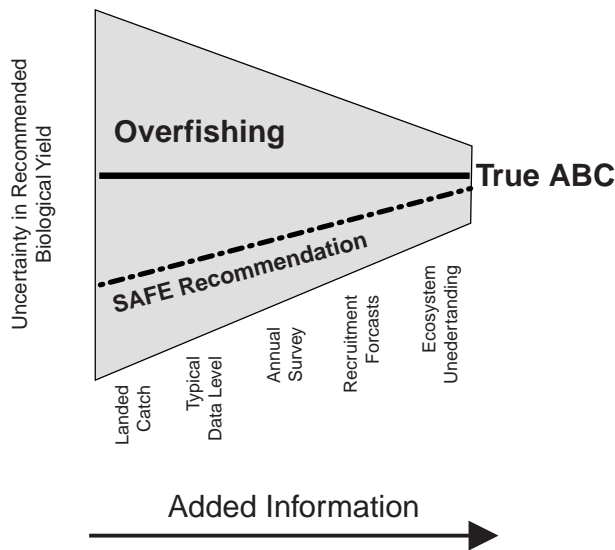
A major goal of fish stock assessments is to provide scientific advice on sustainable harvest strategies. In reality, this is a dual goal involving determination of the harvest strategy that will, on one hand, approach the maximum long-term average yield, yet, on the other hand, have a low probability of overfishing and causing depletion of the resource or other harm to the ecosystem. Maximizing long-term average yield while at the same time minimizing the risk of overfishing is impossible without a high level of knowledge about the abundance and productivity of the resource, especially when one considers the paucity of knowledge regarding the impact of climate, interactions with other species, and habitat changes (**Figure 1**). The precautionary approach is concerned with maintaining a balance between high yields and low risks of depletion in the face of uncertainty that is often substantial. In the past, it has been common to treat uncertainty as a reason to forestall implementation of restrictive management measures. Although the precautionary approach has many facets, one of the more important and universal features is that uncertainty is perceived as a reason to exercise caution by, for example, scaling back the recommended harvest rate in relation to the level of uncertainty in estimates of stock abundance and productivity (**Figure 2**) and to develop other methods, such as marine reserves, to contribute to safeguarding these resources. Greater uncertainty should result in greater caution in fishing activities.





**Figure 1.**

Initial levels of investment in information (e.g. catch monitoring) establish a baseline; intermediate levels of information (e.g. annual resource surveys) produce substantial gains; final levels of investment (e.g. ecosystem research) may have diminishing returns with respect to short-term recommendations, but can substantially affect long-term recommendations. Our goal is to obtain at least an intermediate level of information for the primary commercially or recreationally-exploited species.



**Figure 2.**

With a low level of information, there is a broad potential range of estimated biological yields. A precautionary approach in response to this uncertainty is to set recommendations safely below the “best estimate” to avoid accidentally exceeding the true value and overfishing. The progression towards reduced uncertainty is not as linear as indicated in this diagram. Some information, especially fishery-independent annual surveys, can greatly reduce uncertainty as long as it is combined with adequate information of other types (Figure 1).

Attempts to deal with uncertainty in the context of the precautionary approach have enlivened the development of limit reference points, target reference points, harvest control rules, and management procedures simulation models. Harvest control rules specify the management action (e.g. a specific fishing mortality) to be implemented depending on the status of the stock (e.g. the estimated biomass), and generally include target reference points (to be achieved on average) and limit reference points (to be avoided with high probability). The greater the degree of uncertainty in the assessment of stock status or in the ability to effectively implement management actions, the greater the difference between targets and limits should be. Models that include the entire system of observation-assessment-management with the attendant suite of errors (commonly called management procedures simulation models) deal with uncertainty in a more comprehensive way and enable evaluation of the robustness of alternative management strategies. A previous NMFS Working Group developed technical guidance on these and related topics as they relate to the development of definitions of overfishing (Restrepo et al. 1998; Appendix 17).

The need to develop precautionary approaches, target and limit reference points, harvest control rules, management procedures simulation models, and related methods has added considerably to the duties of stock assessment scientists and, in many cases, has strained the limits of available data. In order to implement 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. It is not adequate to simply report the best estimate and describe its uncertainty. The analysis must be broadened to include evaluation of the possible consequences of alternative harvest strategies given the amount of uncertainty about current and projected stock status.

## F. Implications of the Need to Incorporate Ecosystem Considerations

Trends of increasing intensity and specialization of fisheries, and needs to more fully integrate fisheries and protected species management, argue for greater attention to ecosystem effects not addressed by traditional overfishing concepts and stock assessment models supporting them. Recent legal challenges to NMFS resource management decisions relative to the National Environmental Protection Act (NEPA), the Endangered Species Act (ESA) and the MSFCMA illustrate the growing need for NMFS to develop a comprehensive understanding of the effects of fishing on marine food webs and the effects of fishing on

marine habitats. In addition, there is currently considerable interest from the public, stakeholders and the scientific community to move towards more comprehensive ecosystem-based fisheries stock assessments and management. Several thorough studies on this topic have recently been completed, including an NRC report entitled “Sustaining Marine Fisheries” that focused on sustainability in an ecosystem context (NRC 1999; **Appendix 18**).

These issues necessitate the development of a new era in resource monitoring that requires collection of information on seasonal movements of fish, the response of fish to oceanographic factors, and trophic interactions. With added information regarding the functional relationships governing the spatial and temporal distribution of fish, ecosystem considerations could be incorporated into stock assessments by: (1) modifying existing single-species overfishing paradigms and stock assessment approaches to account for ecosystem attributes, (2) coupling fully mechanistic “bottom-up” models that incorporate the influence of trophic interactions and oceanographic factors on recruitment success to stage-based assessment models, and (3) developing aggregate system models to extract principal properties of marine ecosystems that can be utilized to develop single species harvest objectives. While NMFS is actively pursuing research in support of all three types of models, in the short term modification of existing single species models will be the most useful tool for providing management advice to our constituents. These models allow assessment scientists to modify concepts of growth and recruitment overfishing, maximum sustainable and economic yields and protected species management to account for ecosystem attributes such as technological and biological interactions among assemblages, restricted predator-prey communities, or shifts in carrying capacity due to decadal scale variability in ocean conditions.

As our understanding of the mechanisms controlling the productivity of marine communities improves, NMFS must strive to develop fishing strategies that ensure sustained community production. Ecosystem overfishing reference points, based on metrics of biodiversity, sustainability, and trophic considerations, have been proposed but not widely applied and typically fail to address the role of natural disturbance on shifts in community structure. While existing single species overfishing concepts and modifications have the advantage of a strong theoretical basis for evaluating choices between alternative management strategies (including risk assessment) and much practical use, they do not yet provide guidance on issues such as serial depletion of economically-valuable stocks, changes in bio-di-

versity, habitat-modifying effects of fishing methods, or some trophic impacts of fishing practices such as “fishing down the food chain.” On the other hand, measures that prevent overfishing of single species partially serve the objectives of multispecies management by ensuring that no stock is intentionally overfished. With adequate observer coverage, the bycatch can be closely monitored and target fisheries can be closed to protect bycatch species if necessary. The Ecosystem Principles Advisory Panel report on ecosystem-based fisheries management (**Appendix 19**) calls for the development of Fisheries Ecosystem Plans. A long-term goal would be the development of a theoretical basis for defining ecosystem overfishing. A short term activity in support of these goals would be to improve our documentation and monitoring of metrics of ecosystems such as diversity indices, slopes of size or diversity spectra, or average trophic level. The performance of these indices as predictors or heuristic reference points for management remains untested, but could be evaluated retrospectively for candidate situations of obvious ecosystem overfishing.

Regardless of approach, there appears to be a need to account for ecosystem implications in a more formal way when looking at the entirety of fishery management measures applied to systems. There is, then, a need to develop and implement more widely quantitative models to assist managers in accounting for ecosystem considerations explicitly when choosing between alternative management strategies. Nevertheless, resource management will, in all likelihood, always be driven by the real or perceived importance to society or the ecosystem of a subset of exploited and protected species. Rather than substituting for existing overfishing and assessment modeling concepts, ecosystem considerations will increasingly be used to evaluate and modify primary management guidance applied to the important species. In order for ecosystem overfishing definitions to assume a greater role in resource management, quantifiable, predictive, and unambiguous assessments of ecosystem states and fluxes must be developed and evaluated. This implies research focused on processes and interrelationships, complementing—rather than replacing—traditional stock assessment and monitoring activities supporting existing overfishing definitions. In all likelihood, advice resulting from the explicit incorporation of ecosystem effects will even further emphasize the need for conservative management of the fishing capacity of single- and multipurpose fleets, supported by refinements in the use of technical measures such as marine protected areas and gear restrictions.