Marine Fisheries
Stock Assessment Improvement Plan
Report of the National Marine Fisheries Service
National Task Force for Improving Fish Stock Assessments

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Preface

This report argues for greatly increased resources in terms of data collection facilities and staff to collect, process, and analyze the data, and to communicate the results, in order for NMFS to fulfill its mandate to conserve and manage marine resources. In fact, the authors of this report had great difficulty defining the "ideal" situation to which fisheries stock assessments and management should aspire. One of the primary objectives of fisheries management is to develop sustainable harvest policies that minimize the risks of overfishing both target species and associated species. This can be achieved in a wide spectrum of ways, ranging between the following two extremes. The first is to implement only simple management measures with correspondingly simple assessment demands, which will usually mean setting fishing mortality targets at relatively low levels in order to reduce the risk of unknowingly overfishing or driving ecosystems towards undesirable system states. The second is to expand existing data collection and analysis programs to provide an adequate knowledge base that can support higher fishing mortality targets while still ensuring low risk to target and associated species and ecosystems. However, defining "adequate" is difficult, especially when scientists have not even identified all marine species, and information on catches, abundances, and life histories of many target species, and most associated species, is sparse. Increasing calls from the public, stakeholders, and the scientific community to implement ecosystem-based stock assessment and management make it even more difficult to define "adequate," especially when "ecosystem-based management" is itself not well-defined. In attempting to describe the data collection and assessment needs for the latter, the authors took a pragmatic approach, rather than trying to estimate the resources required to develop a knowledge base about the fine-scale detailed distributions, abundances, and associations of all marine species. Thus, the specified resource requirements will not meet the expectations of some stakeholders. In addition, the Stock Assessment Improvement Plan is designed to be complementary to other related plans, and therefore does not duplicate the resource requirements detailed in those plans, except as otherwise noted.

Executive Summary

- The Stock Assessment Improvement Plan is the report of the National Marine Fisheries Service (NMFS) National Task Force for Improving Fish Stock Assessments, and is a component of the Science Quality Assurance Program. The Task Force consisted of one representative from NMFS Headquarters and 1-2 representatives from each of the five NMFS Science Centers. The report also addresses recommendations made in the National Research Council study on Improving Fish Stock Assessments (NRC 1998a).

- Improvements in stock assessments are required for several reasons, including: that management entities are "managing at the edge" for many species, and therefore require the most accurate and precise stock assessments possible; it is no longer permissible to overfish; and there are currently increased demands for adopting a "precautionary approach" and incorporating "ecosystem considerations" into stock assessments and fisheries management. This reports discusses these and other factors that define NMFS' stock assessment mandate.

- Although the NRC study on Improving Fish Stock Assessments (NRC 1998a) focused on improving assessment methodology, the Task Force agreed that the greatest impediment to producing accurate, precise, and credible stock assessments is the lack of adequate input data, in terms of the quantity, quality, and type of data available.

- For most stocks, there is at least basic information on landed catch and the size frequency of the catch. However, for more than 40% of the 904 stocks listed in the 1999 Report to Congress on the Status of Fisheries of the United States (NMFS 1999a), there is no fishery-independent or fishery-dependent index of abundance, which makes it extremely difficult to conduct a meaningful assessment. Other factors, such as the need to prioritize the stocks to be assessed, result in a total of about 60% of the stocks (545 stocks) lacking assessments sufficient to evaluate stock status relative to overfishing. On the other hand, although there are relatively few stocks with comprehensive input data, a total of 119 stocks are routinely assessed using state-of-the-art age or size structured models, some of which may also incorporate spatial and oceanographic effects. With a few exceptions, all of the high-valued, high-volume, or high-profile species are routinely assessed, while most of the unassessed species contribute little or nothing to total landings.

- Stock assessments conducted by NMFS are rarely, if ever, the product of a single individual, and peer review is an integral part of the processes related to provision of scientific advice in support of fisheries management that are carried out by fisheries scientists from within and outside of NMFS. All five Science Centers have systems in place for peer review of stock assessments.

- The most important programmatic needs vary by region, and even by species groups within regions. Overall, the two most important needs are research vessel surveys designed to produce fishery-independent indices of abundance and to collect related information on spatial and temporal distributions, associated species, habitat, and oceanographic variables; and observer programs that provide information on species composition, amounts of each species kept and discarded, and fishing effort.

- Assessment scientists are faced with many demands. Within a given year, an individual assessment scientist may be expected to: (i) participate in fishery-independent surveys or other field work, (ii) provide input and advice on sampling designs for research surveys and other fishery-independent data collection activities, (iii) spend time on commercial or recreational fishing vessels, (iv) provide input and advice on the development of data collection objectives and protocols for observer programs and other fishery-dependent data collection activities, (v) conduct quality control or other preprocessing of data, (vi) conduct stock assessments, (vii) conduct research into stock assessment methods, (viii) present assessment results to peer review panels and constituent groups, (ix) participate on peer review panels, (x) participate in fishery management plan development or evaluation teams, (xi) defend a stock assessment in a court of law, (xii) research and write scientific papers for primary publication, (xiii) attend colleagues' seminars and offer critical review, (xiv) conduct formal, written peer reviews of articles submitted for publication in scientific journals, (xv) participate on committees to advance approaches to stock assessment and fisheries management, (xvi) undertake training to stay abreast of new methodologies, (xvii) run courses or workshops to train others, (xviii) participate in national and international meetings and conferences to enhance professional development, and (xix) undertake a variable amount of administrative duties depending on supervisory level. With limited exceptions, there is insufficient scope for individual scientists to focus on just one or a few of these activities due to an overall shortage of assessment scientists. A sur-

vey of assessment scientists indicated that there is insufficient time to devote to important activities such as research to improve the basis for assessments, professional development, and interactions and cooperative research with national and international peers. The same is likely to be true for individuals involved in data collection, data processing, and data management.

- In fact, staffing needs associated with the production of stock assessments go well beyond stock assessment scientists *per se*, who represent only the "tip of the iceberg." Far greater numbers of staff are needed for deployment in critical data collection activities, such as commercial or recreational catch and effort data, port sampling for biological data, observer programs, and fishery-independent resource surveys. Additional staff are also required to process biological samples (e.g. to determine fish ages from hard structures, construct age-length keys, develop growth curves, construct maturity ogives, and possibly to identify and count eggs and larval fish from ichthyoplankton surveys, and to examine stomach contents), and to enter, audit, integrate, and preprocess data from the myriad of data collection activities.

- The Task Force defined three Tiers of Assessment Excellence, which can be summarized as:

Tier 1 — Improve stock assessments using existing data

(a) for core species, conduct assessments that are more comprehensive, more thorough, more timely, better quality-controlled, and better communicated;

(b) for species of currently "unknown" status, mine existing databases of research vessel survey data and/or commercial and recreational statistics for archival information for new analyses to evaluate status determination criteria.

Tier 2 — Elevate stock assessments to new national standards of excellence

(a) upgrade assessments for core species to at least Level 3 [the Task Force defined six levels at which assessments are conducted, ranging from 0 to 5; Level 3 assessments comprise analytical models in which ages or species are aggregated];

(b) conduct adequate baseline monitoring for all federally-managed species (including rare species).

Tier 3 — Next generation assessments

(a) assess all federally-managed species or species groups at a minimum level of 3, and all core species at a level of 4 or 5 [size, age or stage-structured models, possibly including spatial and seasonal considerations, species associations, and oceanographic effects];

(b) explicitly incorporate ecosystem considerations such as multispecies interactions and environmental effects, fisheries oceanography, and spatial and seasonal analyses.

- A large part of the report specifies region-by-region program and staffing requirements needed to meet the three Tiers of Assessment Excellence. These are summarized in **Table 8** of the report, which is reproduced here.

- Among other things, the Task Force recommends that NMFS should aggressively pursue a course of action focusing on new budget and staffing initiatives to modern-

Table 8. Total Full-Time Equivalents (FTEs) required to meet the three Tiers of Assessment Excellence for each Science Center and all Centers combined. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national, and international commissions. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*	*All Tiers*
NEFSC	123	49	16	18	43	**61**	25	86
SEFSC	71	30	46	14	42	**56**	39	95
SWFSC	80	15	26+	27	60	**87**	66	153
NWFSC	18	33	59	13	74	**87**	39	126
AFSC	154	122	54	31	66	**97**	51	148
Summed FTEs	**446**	**249**	**201**	**103**	**285**	**388**	**220**	**608**
$ $ (FTE x $150K)				**$15,450K**	**$42,750K**	**$58,200K**	**$33,000K**	**$91,200K**

ize its data collection and assessment capabilities. At the minimum, NMFS should attempt to bring stock assessment science to at least Tier 2, and should initiate dialog both within house and with the public to determine how far-reaching and comprehensive Tier 3 should be. This will require hiring or contracting considerable numbers of additional qualified staff for data collection, data processing, data management, stock assessments, and evaluations of alternative management strategies, to ensure adequate data and analyses on which to base conservation and management decisions, now and into the future.

- It is also recommended that in order to develop more comprehensive and integrated future budget initiatives geared towards modernizing fisheries assessments and management, NMFS should prepare an umbrella plan that integrates all relevant existing documents on these themes; for example, the current Stock Assessment Improvement Plan, the NOAA Fisheries Data Acquisition Plan (**Appendix 3**), the NMFS Strategic Plan for Fisheries Research (NMFS 2001b**)**, the Proposed Implementation of a Fishing Vessel Registration and Fisheries Information Management System (**Appendix 8**), the NMFS Bycatch Plan (**Appendix 9**), the National Observer Program (**Appendix 10**), the Social Sciences Plan (**Appendix 11**), the Advanced Technologies Working Group (**Appendix 12**), and relevant fisheries oceanography initiatives (e.g. **Appendix 13**).

- In order to make substantial progress towards collecting the data needed to improve stock assessments, particularly next generation assessments, it is essential that NMFS continue to foster partnerships and cooperative research programs with other federal agencies, state agencies, private foundations, universities, commercial and recreational fishing organizations and individuals, environmental groups, and others with a vested interest in collecting similar types of data, although often for different purposes. Programs involving cooperative research with the fishing industry should continue to be developed and expanded as mechanisms for providing data relevant to improving the quality of stock assessments.

I. Introduction

The Stock Assessment Improvement Plan (SAIP) is the report of the National Marine Fisheries Service (NMFS) National Task Force for Improving Fish Stock Assessments. It consists of a main document with 8 tables and 15 figures, an Appendix table summarizing the level of completeness of data collection and stock assessments for each federally managed stock (**Appendix 1**), and an additional 24 appendices (**Appendices 2-25**) summarizing other relevant programs, plans and reviews. The Stock Assessment Improvement Plan is a component of the Science Quality Assurance Program (**Appendix 2**), which consists of several other elements including the NOAA Fisheries Data Acquisition Plan (**Appendix 3**), the Stock Assessment Toolbox (**Appendix 4**), the Center for Independent Experts (**Appendix 5**), and the NMFS-Sea Grant Joint Graduate Fellowship Program (**Appendix 6)**. The Task Force consisted of one representative from NMFS Headquarters and 1-2 representatives from each of the five NMFS Science Centers. Additional input from the Science Centers was obtained via questionnaires administered to stock assessment scientists and managers of stock assessment programs. Science Centers were also given the opportunity to review the contents of the Plan.

This report also draws on the analyses and recommendations of the National Research Council (NRC) study on Improving Fish Stock Assessments (NRC 1998a). In order to determine which avenues should be explored to improve stock assessments, NMFS requested in 1995 that the NRC undertake a review of the agency's current stock assessment methods and models and make recommendations for alternative approaches. The objective of the review was to produce an authoritative report that documented the strengths and limitations of stock assessment methods relative to the diversity of available data and types of fisheries management systems. The resulting review (**Appendix 7**) contained ten recommendations in seven categories for improving stock assessments; these are numbered and presented in summary form below for easy reference through the remainder of the current report.

Recommendation #1: *How should assessments be conducted and by whom?*
Recommendation #2: *Development of at least one reliable abundance index for each stock.*
Recommendation #3: *Collection of auxiliary biological data such as natural mortality.*
Recommendation #4: *More realistic assessments of uncertainty.*
Recommendation #5: *Analysis of alternative harvest strategies.*
Recommendation #6: *Development of rigorous evaluation systems including simulation models.*
Recommendation #7: *Development of new techniques for stock assessment.*
Recommendation #8: *More peer reviews*.
Recommendation #9: *Standardized data collection protocols for commercial fisheries.*
Recommendation #10: *Education and training of assessment scientists.*

Improvements in stock assessments are required for several reasons, including (a) that management entities are "managing at the edge" for many species, and therefore require the most accurate and precise stock assessments possible; (b) it is no longer permissible to overfish; and (c) there are currently increased demands for adopting a "precautionary approach" and incorporating "ecosystem considerations" into stock assessments and fisheries management. These issues are addressed in detail in **Section II**, along with other factors that define NMFS' stock assessment mandate. **Section III** provides background information on requirements for conducting assessments and for evaluating alternative fisheries management strategies. **Section IV** contains detailed information on qualitative and quantitative resource requirements for each of the five Science Centers, relative to three Tiers of Assessment Excellence. As such, it represents the core part of the report. Recommendations based on the preceding sections of the report are summarized in **Section V**. Assessment-related information is tabulated in **Appendix 1**, and an additional 24 Appendices contain information on other relevant plans, reports, and background documents. It is anticipated that the current report will provide a foundation for future initiatives, including budget initiatives, to improve the quality and quantity of NMFS' stock assessments.

Scope of the Stock Assessment Improvement Plan

The Stock Assessment Improvement Plan (SAIP) is the latest of a series of plans for enhancing and modernizing NMFS programs for data collection, information technology, data management, stock assessments, scientific research, and fisheries management. Although the SAIP is specifically geared towards stock assessments, when ac-

count is taken of the diverse data needs of stock assessment models and the expectation of more comprehensive ecosystem-based science and management in the future, there is considerable scope for overlap or duplication between several plans. With this in mind, the SAIP was designed to complement plans already completed at its inception, or otherwise to acknowledge duplication, and to avoid contradiction. The key complementary plan is the NOAA Fisheries Data Acquisition Plan (**Appendix 3**), which details the need for purpose-built fishery research vessels and chartered days-at-sea to satisfy immediate fishery-independent data collection needs. Thus, the SAIP does not include the capital and operating costs of the research vessels, nor chartering costs, nor the permanent vessel crews, but it does include the scientific staff that would participate in research surveys. Another important complementary plan is the Proposed Implementation of a Fishing Vessel Registration and Fisheries Information Management System (**Appendix 8**), which will provide much more accurate, complete, and timely information on commercial fisheries statistics. The core costs of this program are not considered in the SAIP, but the in-house or contract staff required to collect, manage, and process the data are included. The NMFS Bycatch Plan (**Appendix 9**), which includes monitoring, data collection, and research, overlaps to a degree with the SAIP but, since the Bycatch Plan did not develop specific staff and other resource requirements, duplication should not be a problem.

One plan with which there is considerable potential for overlap and duplication is the National Observer Program (**Appendix 10**), which was initiated subsequent to the commencement of the SAIP. As is evident in **Section IV** of this report, the most important overall need for improving stock assessments is for in-house and contract staff for observer programs for collecting data of relevance to stock assessments, in both the short- and the long-term. The National Observer Program examines observer needs from a slightly different perspective. First, it considers needs for monitoring both commercially-exploited fish species and protected and endangered species such as marine mammals and sea turtles, whereas the SAIP only considers that portion of existing and potential observer programs that could be attributed to obtaining data of direct relevance to commercially-exploited fisheries stock assessments. Second, it outlines a five-year plan, whereas the SAIP is much longer-term. Thus, there is some degree of overlap between the SAIP and the National Observer Program. The overlap will be quantified and controlled for as necessary in future budget initiatives.

The SAIP focuses on field biologists who collect data; laboratory technicians who process biological samples; computer scientists who audit, manage, and analyze data; and quantitative stock assessment scientists who develop and run stock assessment models. Another important fisheries profession not represented in the SAIP is that of social science (economists, sociologists, and anthropologists). The need for additional social scientists is detailed in the NMFS Social Sciences Plan and Budget Initiative (**Appendix 11**).

Capital costs for the purchase of advanced technologies and operating costs for research and field trials is another activity that is covered elsewhere (**Appendix 12**), and therefore excluded from explicit consideration in the SAIP. Also excluded are major infrastructure associated with increased staffing, particularly new workspace and buildings that may be required.

In order to further limit the scope of the SAIP and to reduce overlap with other plans and initiatives, it was also decided not to explicitly include resource requirements for fisheries oceanography (e.g. **Appendix 13**), stock assessments and related activities for marine mammals and sea turtles (**Appendix 14**), habitat-related research and conservation (**Appendix 15**), and stock assessments and related activities for Pacific salmon.

In order to develop a comprehensive ecosystem approach to fisheries stock assessments and management, and to estimate the actual costs of implementing ecosystem-based management (EBM), all of the above-mentioned plans, initiatives, and activities should be merged into an umbrella plan.

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 $1/5^{th}$ 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 Man-

agement 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 "bellwether" 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 tradeoffs). 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. Reallocation 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.

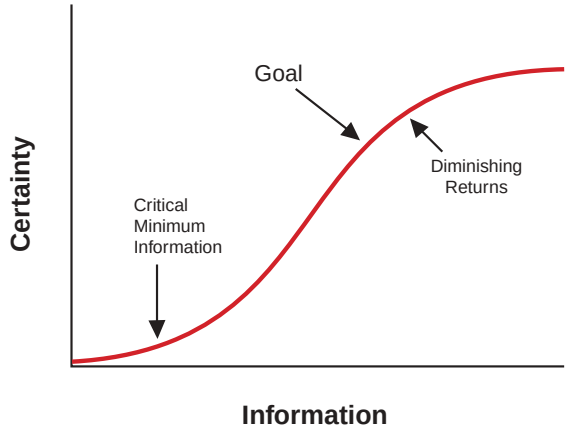

Figure 1.

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

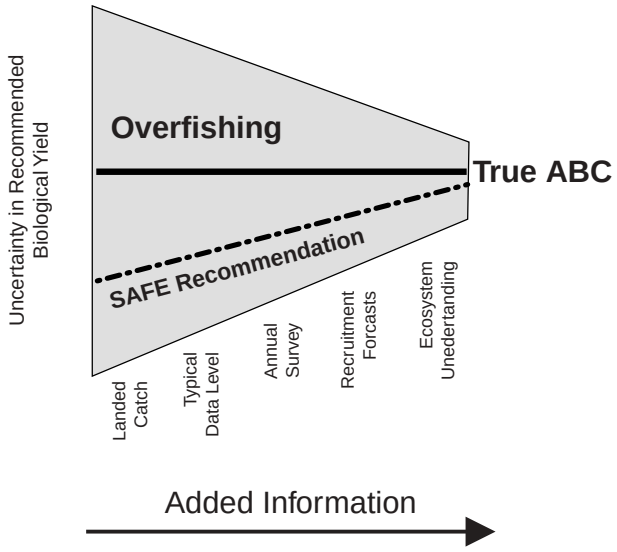

Figure 2.

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-diversity, 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.

III. Assessment and Management Strategy Evaluation Needs

This section provides background information on requirements for conducting assessments and for evaluating alternative fisheries management strategies. Topics covered include input data, stock assessment models, assessment frequency, adequacy of technology and infrastructure, peer review processes, translation of stock assessment advice into management action, communication of assessment results and analyses of alternative management strategies, and staffing issues.

A. Input Data

Calibration of stock assessment models requires three essential categories of data: catch, abundance, and life history characteristics. These data come from fishery-dependent and fishery-independent sources. The role of 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. Total catch is determined from monitoring by port samplers and observers, and mandatory or voluntary reporting systems. The most reliable indicators of changes in population abundance are fishery-independent resource surveys (NRC 1998a). In some cases, it is possible to conduct tagging studies, depletion experiments, or absolutely calibrated surveys that result in an absolute estimate of stock abundance rather than a relative index which must be tracked over time. Fishery-dependent data (e.g. logbook data) can also be used to develop indices of changes in abundance; however, validation that these fishery-dependent indices are truly proportional to changes in stock size usually requires comparing the fishery-dependent index to a fishery-independent survey index. Life history data (stock structure, growth, reproduction, and natural mortality rates) indicate the geographic limits of the stock and its inherent productivity. Inclusion of life history data in stock assessment models helps assure biologically realistic results which properly separate fishing mortality from natural changes. With incomplete data on catch, abundance, or life history characteristics, the results of assessment models will be less precise because of uncertainty in the assumptions used in place of the missing data.

The need for improving the collection, management and use of fisheries data was recognized in a recent report entitled, "Improving the Collection, Management, and Use of Marine Fisheries Data" (NRC 2000; **Appendix 20**).

(i) Fishery-dependent data needs

Fishery-dependent data include the landed catch, at-sea discards, biological characteristics (age and size composition, sex ratio, maturity stage) of the catch, fishing effort, and spatial distribution of catch and effort. Accurate stock assessments require that the total removals (landed plus discarded catch) be known for all significant commercial and recreational fishery segments. The primary methods to obtain these total catch data vary regionally and are strongly influenced by the scale of typical fishing operations and by the degree of historical development of federal and state reporting systems. Methods to track large volume landings by trawl vessels at a few locations may be ill-suited to estimating total landings by large numbers of commercial or recreational hook and line fishers individually landing small amounts of fish at many locations. For example, mandatory reporting of landed commercial catch by the west coast states provides a census of total commercial landings. Off Alaska, mandatory observer programs determine total catch for major species. For recreational fisheries, statistical sampling procedures are used to estimate total recreational catch and effort from samples of anglers nationwide. However, throughout the nation there are gaps in coverage for particular fishery segments, concerns about under-reporting of total catch or misreporting of species and the areas in which they were caught, low levels of sampling coverage, and insufficient statistical and database capabilities to ensure timely access to well-audited data.

Information on the size and age composition of the catch is needed to accurately estimate the fishing mortality caused by that catch. These data are typically obtained by samplers in the fishing ports and by observers on board fishing vessels. When comparable data are available for each fishery segment, evaluation of the biological impacts of different allocations among the segments is facilitated. Furthermore, size and age data from the fishery contribute information on variability in recruitment.

Collection of commercial and recreational fishery data faces significant logistic hurdles due to the need to implement sound statistical sampling procedures. The potential for bias and inefficiency exists in current procedures, and the NRC review of stock assessment methods recommends that a standardized and formalized data collection protocol be established:

NRC Recommendation #9: "The Committee recommends that a standardized and formalized data collection protocol be established for commercial fisheries data nationwide. The Committee further recommends that a complete review of methods for collection of data from commercial fisheries be conducted by an independent panel of experts."

One step that has been taken towards addressing this recommendation is the recent NMFS Report to Congress on a "Proposed Implementation of a Fishing Vessel Registration and Fisheries Information Management System" (**Appendix 8**), as required under the 1996 reauthorization of the MSFCMA. The report lays out a plan for implementing a Fisheries Information System (FIS) by integrating and expanding on the current regional fisheries cooperative statistics activities in three major areas: data collection, information management, and institutional arrangements. However, the plan is to integrate existing activities, rather than to overhaul the system completely and develop protocols to be used nationwide. The plan has been submitted to Congress as required, but to date, it has not been funded.

(ii) Fishery-independent data needs

Fishery-independent data include information on the distribution, abundance, and biology of the species being assessed. A suitable fishery-independent survey method must either be calibrated to measure absolute fish abundance, or it must be directly proportional to fish abundance so that relative trends can be tracked. When the time series of a survey is short, there is greater value in calibrating the survey for absolute abundance; however, such estimates are critically dependent on obtaining good estimates of catchability. As the time series gets longer, the trend information becomes more useful.

A common survey approach is to use carefully standardized sampling gear (e.g. trawls, hooks, or pots) to collect hundreds of samples distributed over the expected range of the stock. Such a resource assessment survey provides information on distribution and abundance, and provides specimens for age, growth, genetic stock structure, food habits, maturity, and other biological studies. However, such methods can be difficult to standardize completely because fish behavior and gear performance may vary with habitat and environmental conditions. Other methods are valuable for directly calibrating such surveys, providing information from habitats not accessible to the primary sampling tool, and providing alternative measures of fish abundance. Acoustic methods have been developed to provide calibrated information on distribution and abundance, but must be coupled with other sampling tools to collect biological specimens. Egg and larval methods have been developed to provide measurements of abundance (spawning biomass) that are not susceptible to the same types of sampling problems that may affect trawl surveys. Imaging systems (visual, laser) are an appropriate tool in high relief nearshore habitats and have been useful in understanding the interaction between fish and other sampling tools. Mark-recapture methods, like egg and larval methods, can provide a direct estimate of absolute abundance but must rely on other tools to measure distribution and to collect biological specimens. More generally, a single survey method may not be suitable for the entire age range; for example, a separate survey may be necessary to provide an index of recruitment. In many instances, it is likely that at least two survey methods may need to be deployed in order to provide appropriate input for stock assessments and projections.

The NRC (1998a) evaluation of stock assessment methods recommended that each stock assessment contain at least one reliable index of relative stock abundance, preferably from fishery-independent surveys because incompletely calibrated fishery-dependent indices can lead to biased stock assessment results:

NRC Recommendation #2: "At the minimum, at least one reliable abundance index should be available for each stock. Fishery-independent surveys offer the best choice for achieving a reliable index if designed well with respect to location, timing, sampling gear, and other statistical survey design considerations."

Attempts to satisfy this type of recommendation have played a key role in NMFS' research planning for several decades. The most recent document directed specifically at this type of recommendation is the NOAA Fisheries Data Acquisition Plan (NMFS 1998a; **Appendix 3**), which calls for a combination of purpose-built fishery research vessels and chartered days-at-sea to satisfy immediate fishery-independent data collection needs.

Reliable fishery-independent indices are already available for several key stocks, primarily in the northeastern United States and Alaska which have long time series of research survey data. Such indices will become even more widely available as NMFS and partnering agencies and institutions acquire additional research platforms, including dedicated research vessels. But, even with additional resources for research, some important variables will always be difficult to estimate; for example, natural mortality, which is a key assessment variable singled out for attention by NRC (1998a):

NRC Recommendation #3 (in part): "...Greater attention should also be devoted to including independent estimates of natural mortality in assessment models."

To obtain reliable independent estimates of natural mortality, the types of fishery-independent research required are likely to involve extensive mark-recapture studies and/or collection and analysis of food habitats data from large numbers of potential predators covering extensive spatial and temporal scales.

B. Input Data: Minimal and Optimal Requirements

The great diversity of data available for the world's fisheries has fostered the development of a wide range of stock assessment modeling methods that can take advantage of these data. As the scope of the data and their quality and quantity improves, several improvements in stock assessment results will accrue. As data become more precise and as the time series of data become longer, the precision of stock assessment results should improve, and there should be greater stability in resulting recommendations on the status and potential yield from the stock. As more types of data become available, it will be possible to test and validate model assumptions and reduce the possibility that model results are biased because of inappropriate assumptions about the data. Appropriate data are also needed to reliably forecast likely future conditions of a stock, in addition to obtaining a retrospective view of a stock's history. It has sometimes been argued in the scientific literature that well-calibrated fishery catch per unit effort (CPUE) data is an adequate measure of relative stock abundance, and that useful stock assessments can be based solely on simple models tuned to such data. While this may be true for some fisheries, there are many case studies demonstrating that the assumption that commercial CPUE is directly proportional to resource abundance may lead to large biases in results, and that such bias is often detected too late and only when additional sources of data are obtained and included in the assessment.

In each of three major categories of information required as input to stock assessments; viz, catch, abundance, and life history, the Task Force defined 5-6 progressively more complete levels of data availability (**Figure 3**). Such a progression will fit no fishery perfectly, but gives a general guide to the progression of information improvement that should be the goal of comprehensive stock monitoring programs. A balanced development in these three categories of input data is also beneficial; generally, a stock assessment model will not be able to fully utilize detailed catch data if there is an inadequate survey index and lack of key biological data.

Levels of catch data

0 — No catch data.

1 — Landed catch provides a minimum estimate of fishery removals and is typically obtained from mandatory landing receipts. In some cases, particularly recreational fisheries, a statistical sampling program is used to expand estimates of sampled catch up to the total angling population.

2 — Catch size composition provides a measure of the sizes of fish being impacted by the fishery, and when tracked over time can provide an index of recruitment to the fishery and total mortality rates.

3 — Spatial data on catch from logbooks can provide information on range extensions and contractions, and other changes in stock or fleet distribution.

4 — Catch age composition requires the development of age determination techniques and an investment in the collection and processing of appropriate samples. The result is much greater stock assessment accuracy than can be obtained with size composition data alone.

5 — Accurate and complete data on total removals (including landed catch, discards, bycatch in other fisheries, and cryptic mortality induced by fishing gear contact) will contribute to accurate stock assessment results. An at-sea observer program can monitor total removals, cross-check logbook data, and collect site-specific biological samples. In many fisheries, the relative merits of observer programs for collecting data on total removals and/or age composition data may warrant consideration before or instead of investing in a fishery logbook program.

Levels of abundance data

0 — No abundance data.

1 — Relative abundance index from fishery catch per unit effort or an imprecise, infrequent survey. Another Level 1 situation would be a single survey from which an estimate of absolute abundance has been made. At this low level of information there will only be a limited ability to track changes in stock abundance because of uncertainties in the calibration of the index, or a high level of noise in the data relative to the magnitude of the expected changes in stock abundance.

2— Precise, frequent surveys with age composition will provide more accurate tracking of changes in stock abundance and the associated age composition data will enable better estimation of historical and current levels of recruitment.
3— Research surveys with known or estimated catchability, acoustic surveys with known or estimated target strengths, and statistically-designed tagging studies can provide estimates of absolute abundance. This is especially valuable when the time series of the survey is so short that no trend is detectable.
4— Habitat-specific surveys refine the concept of stratified random surveys so that survey results are more closely associated with particular habitats. The result is improved knowledge of the relationship between fish assemblages and habitat features. In addition, these surveys use alternative methodologies to extend survey coverage into all relevant habitats.

Levels of life history data

0— No life history data.
1— The size composition of harvested fish provides a simple index of a stock's growth potential and vulnerability to overharvesting.
2— Basic demographic parameters such as age, growth, and maturity rates provide information on productivity and natural mortality.
3— Seasonal and spatial patterns of mixing, migration, and variability in life history characteristics, especially growth and maturity, provides improved understanding of how a population responds to its environment.
4— Food habits information defines the predator-prey and competitive relationships within the fish community, thus providing a first step towards direct estimation of natural mortality rates and ecologically-based harvest recommendations.

The availability of data at these various levels is tabulated in **Appendix 1** for each of the 904 stocks included in the NMFS (1999a) Report to Congress on the Status of Fisheries of the United States. The data are also summarized by individual and combined Science Centers in **Table 1** and **Figure 4** and discussed in **Section III D**.

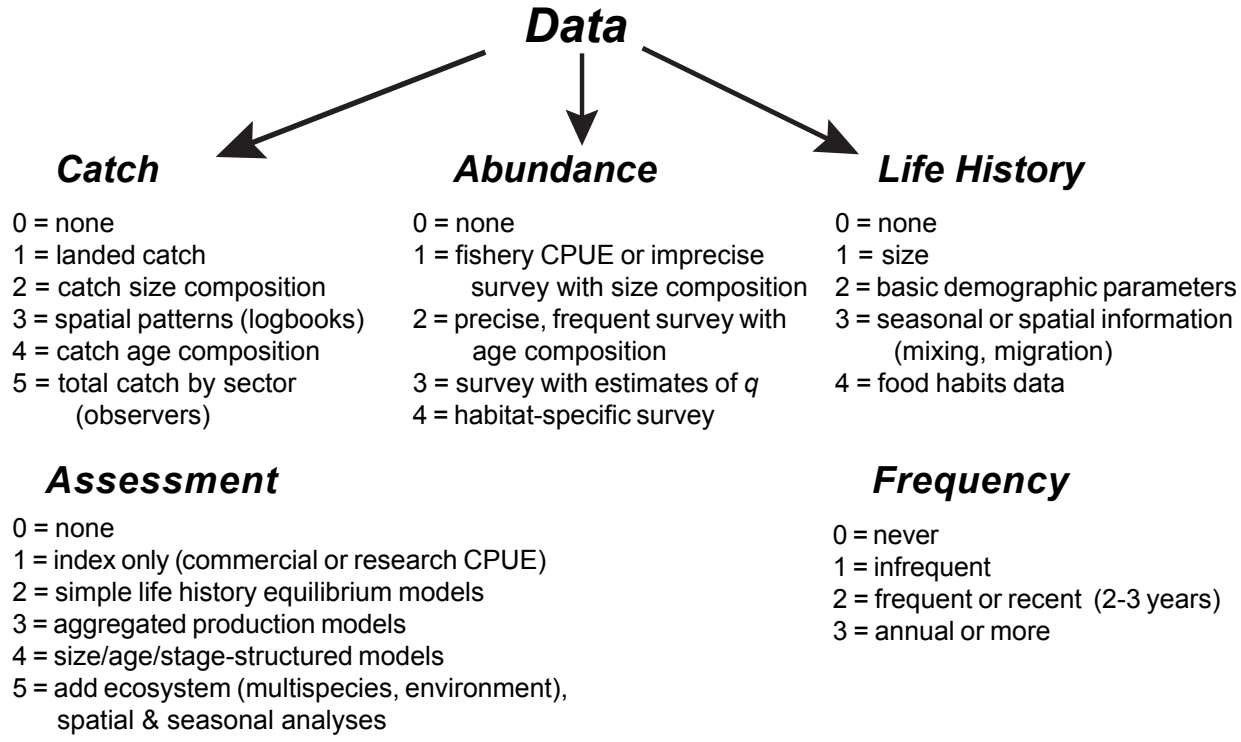

Figure 3. Factors used to classify stocks in terms of input data and assessment status.

LEVELS	Catch	Abundance	Life History	Assessment Level	Assessment Frequency
ALL REGIONS COMBINED					
0	95	374	96	545	443
0.5	40	14			
1	555	355	519	153	107
2	72	125	207	60	129
3	45	32	69	27	225
4	71	4	13	111	
5	26			8	
Sum	**904**	**904**	**904**	**904**	**904**
NEFMC, MAFMC & ASMFC					
0	4	1	0	2	7
0.5	0	0			
1	7	30	9	15	22
2	12	22	24	15	18
3	8	3	13	3	9
4	20	0	10	19	
5	5			2	
Sum	**56**	**56**	**56**	**56**	**56**
SAFMC, GMFMC, CFMC & Atlantic HMS					
0	0	285	49	278	312
0.5	0	0			
1	384	117	292	85	28
2	12	19	68	18	81
3	22	1	13	13	1
4	1	0	0	28	
5	3			0	
Sum	**422**	**422**	**422**	**422**	**422**
PFMC					
0	0	41	1	62	62
0.5	40	14			
1	26	34	59	2	14
2	7	0	27	9	14
3	9	18	19	4	19
4	26	2	3	32	
5	1			0	
Sum	**109**	**109**	**109**	**109**	**109**
WPFMC					
0	13	13	15	28	28
0.5	0	0			
1	37	41	0	22	12
2	5	3	37	0	6
3	3	6	12	7	18
4	6	1	0	4	
5	0			3	
Sum	**64**	**64**	**64**	**64**	**64**
NPFMC					
0	78	34	31	175	34
0.5	0	0			
1	101	133	159	29	31
2	36	81	51	18	10
3	3	4	12	0	178
4	18	1	0	28	
5	17			3	
Sum	**253**	**253**	**253**	**253**	**253**

Table 1. Numbers of stocks with different levels of input data (catch, abundance and life history parameters), assessment methodology and assessment frequency for the 904 stocks listed in the NMFS (1999a) Report to Congress on the Status of Fisheries of the United States. Zero indicates no information; otherwise, the higher the level, the better the information. See **Figure 3** and the text for a description of the levels, **Figure 4** for graphical comparisons, and **Appendix 1** for the stock-by-stock information.

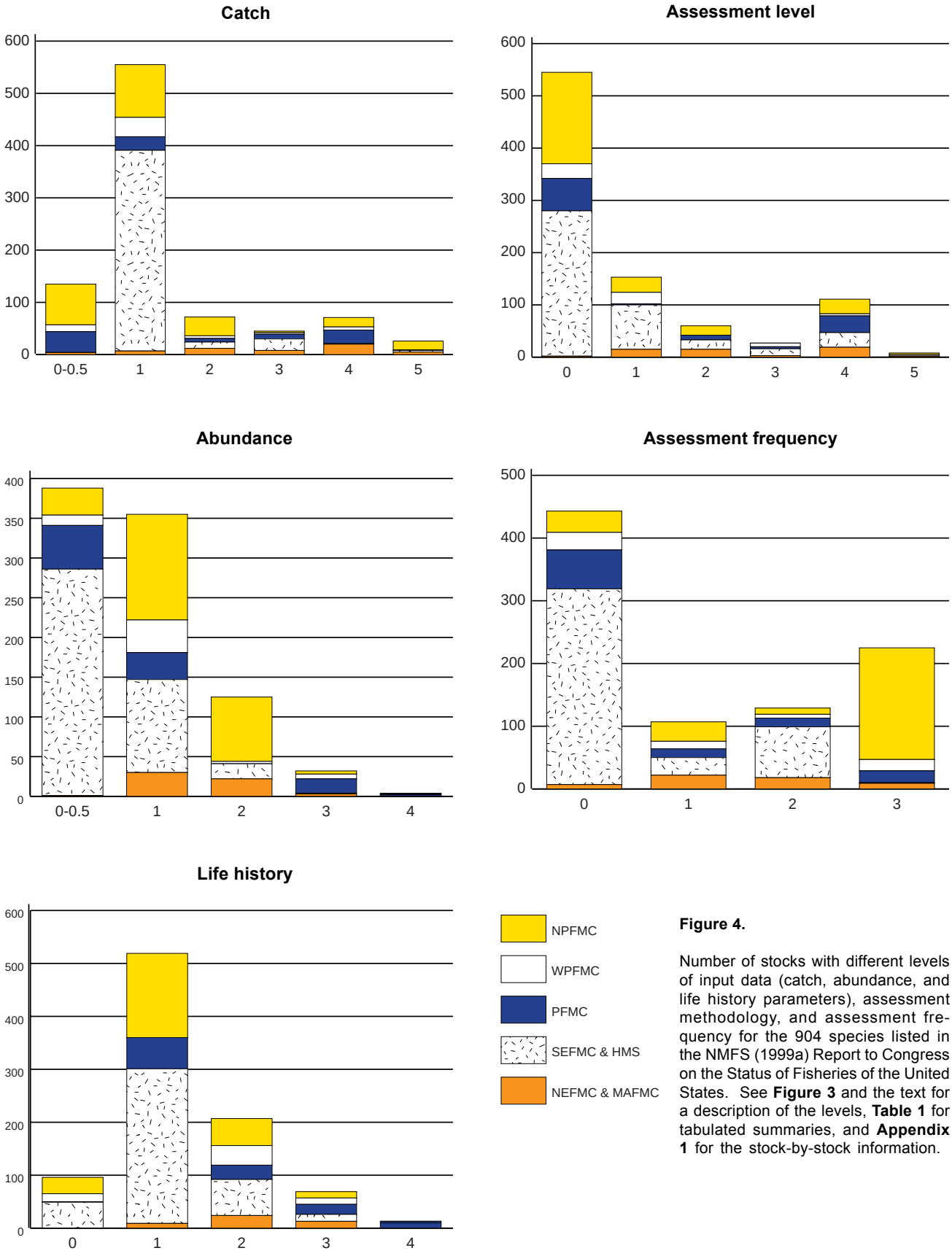

Figure 4.

Number of stocks with different levels of input data (catch, abundance, and life history parameters), assessment methodology, and assessment frequency for the 904 species listed in the NMFS (1999a) Report to Congress on the Status of Fisheries of the United States. See **Figure 3** and the text for a description of the levels, **Table 1** for tabulated summaries, and **Appendix 1** for the stock-by-stock information.

C. Stock Assessment Models

The complexity of assessment methods used for a given stock generally reflects the availability of data and the value or importance of the fishery. To indicate the current levels of analysis of the status of various stocks, two columns were added to **Appendix 1**, one giving a numerical code that roughly indicates the level of modeling effort/ complexity/ sophistication applied to each species in **Appendix 1** and the other giving the frequency with which stock assessments are conducted. To be classified as an assessment, an analysis must produce some measure of stock or fishery status relative to a benchmark such as a fishing target or an overfishing limit. The assessment level codes have the following meanings:

0 — Although some data may have been collected on this species, these data have not been examined beyond simple time series plots or tabulations of catch.

1 — Either:
a) a time series of a (potentially-imprecise) abundance index calculated as raw or standardized CPUE in commercial, recreational, or survey vessel data, or
b) a onetime estimation of absolute abundance made on the basis of tagging results, a depletion study, or some form of calibrated survey.

2 — Simple equilibrium models applied to life history information; for example, yield per recruit or spawner per recruit functions based on mortality, growth, and maturity schedules; catch curve analysis; survival analysis; or length-based cohort analysis.

3 — Equilibrium and non-equilibrium production models aggregated both spatially and over age and size; for example, the Schaefer model and the Pella-Tomlinson model.

4 — Size, stage, or age structured models such as cohort analysis and untuned and tuned VPA analyses, age-structured production models, CAGEAN, stock synthesis, size or age-structured Bayesian models, modified DeLury methods, and size or age-based mark-recapture models.

5 — Assessment models incorporating ecosystem considerations and spatial and seasonal analyses in addition to Levels 3 or 4. Ecosystem considerations include one or more of the following:
a) one or more time-varying parameters, either estimated as constrained series, or driven by environmental variables,
b) multiple target species as state variables in the model, or
c) living components of the ecosystem other than the target species included as state variables in the model.

According to the above scheme, an "assessment" is a data analysis at Level 1 or greater, provided that analysis allows statements about relative stock or fishery status to be made. The frequency column in **Appendix 1** give codes defined as follows:

0 — Never: an assessment has never been conducted.
1 — Infrequent: the most recent assessment was conducted more than three years ago.
2 — Frequent or recent: the most recent assessment was conducted within the last three years but is not conducted annually.
3 — Annual or more: assessments are conducted at least annually.

The assessment levels listed above were designed to represent a series of increasing analytical effort and sophistication. Lower levels are amenable to use of standardized software, but upper levels, particularly Level 5, probably require that models be tailored to deal with the particularities of each stock assessment or group of related assessments. Such newly crafted models will most likely require additional types of input data concerning oceanographic conditions, and/or biological features of various components of the ecosystem, and/or operational details of the fishing gear. Thus the progression of assessment levels implies a progression of increasing data needs. In addition, NRC (1998a) recommends that, where possible, more than one assessment model should be applied for a given data-set or fish stock:

> ***NRC Recommendation #3 (in part): "Because there are often problems with the data used in assessments, a variety of different assessment models should be applied to the same data; new methods may have to be developed to evaluate the results of such procedures. The different views provided by different models should improve the quality of assessment results..."***

Another NRC (1998a) recommendation is to develop new techniques for stock assessment:

> ***NRC Recommendation #7: "NMFS and other bodies responsible for fisheries management should support the development of new techniques for stock assessment that are robust to incomplete, ambiguous, and variable data and to the effects of environmental fluctuations in fisheries."***

Development of new computational and analytical techniques is most likely to take place at the upper end of the list of assessment levels where it will likely be necessary to craft a wide variety of new assessment models. However, because these new kinds of models may require new kinds of data, there may also be a need to develop new sampling or survey techniques, or to perform experiments. Models that can incorporate the effects of environmental fluctuations in fisheries are already under active development, but they suffer from a lack of understanding of the effects of major environmental regime shifts on individual species and species interactions. Thus, their predictability is currently limited. On the other hand, pursuit of this line of research is likely to be more fruitful than attempts to develop models that are robust to incomplete or ambiguous data – the extent to which models can compensate for data deficiencies is extremely limited.

NRC (1998a) also recommended the development of more realistic assessments of uncertainty:

> ***NRC Recommendation #4: "The Committee recommends that fish stock assessments include realistic measures of the uncertainty in the output variables whenever feasible. Although a simple model can be a useful management tool, more complex models are needed to better quantify all the unknown aspects of the system and to address the long-term consequences of specific decision rules adequately. The implementation of this recommendation could follow the methods discussed in Chapter 3 [of NRC 1998a]."***

While expression of uncertainty is not included in the above definitions of assessment levels, one would expect that increasing sophistication of assessment models would go hand in hand with increasing sophistication in calculating uncertainty, and one would hope that more sophisticated uncertainty assessments would also be more realistic. To the extent that more realistic uncertainty assessments incorporate more components of variation, there is the possibility that they would show wider confidence bounds. Thus the higher level assessments are not at all guaranteed to yield tighter uncertainty distributions and consequent high levels of allowable catch as promised elsewhere. Therefore, it is important that lower level assessments be accompanied by uncertainty calculations that are sophisticated and comprehensive enough to make them as realistic as they are for higher level assessments.

D. Inventory of the Status of Stock Assessments: Adequacy of Input Data, Assessment Level, and Frequency of Assessments

The status of input data and assessment analyses for the 904 stocks listed in the 1999 Report to Congress on the Status of Fisheries of the United States (NMFS 1999a) is tabulated in **Appendix 1** and summarized in **Table 1** and **Figure 4**. The first point to note is that for most stocks, there is at least basic information on landed catch and the size frequency of the catch. However, for more than 40% of the stocks, there is no fishery-independent or fishery-dependent index of abundance, which makes it extremely difficult to conduct a meaningful assessment. Other factors, such as the need to prioritize the stocks to be assessed, results in a total of about 60% of the stocks (545 stocks) lacking assessments sufficient to evaluate stock status relative to overfishing. Although there are relatively few stocks at the highest levels of each of the input data categories, a total of 119 stocks are routinely assessed at Level 4 or higher. Detailed examination of the information contained in **Appendix 1** shows that most of NMFS' data collection and assessment resources have been directed towards those species that dominate in the catch or have previously been deemed to be overfished. With a few exceptions, all of the high-valued, high-volume, or high-profile species are routinely assessed, while most of the stocks with few input data and analysis are bycatch species that contribute little or nothing to total landings. In other words, they are usually relatively unimportant from an economic perspective. Their importance from an ecological perspective and their biological status with respect to risk of reproductive failure is generally unknown.

E. Adequacy of Technology and Infrastructure

In some respects, the job expected of stock assessment scientists is impossible: to estimate the numbers and biomass of each harvested species in the ocean even though they cannot be seen; to determine demographic parameters such as growth and mortality even though such are affected by unobservable and complex interactions between species and with the environment; and to forecast catches and population responses ahead 1-10 or more years even though incoming recruitment is known to be highly variable and affected by environmental events that may not yet have occurred. The difficulty of these tasks necessitates high-technology solutions. Improved technologies are needed to sample, survey, or experiment with species of interest in situ, in order to decrease sampling error, increase sampling intensity, or increase the area or number of species cov-

ered. Such technologies, many of which are actively being developed at present (**Appendix 12**), include development of specialized sampling nets and other methods of direct sampling, multifrequency acoustics, multi-beam acoustics, LIDAR, laser line scan systems, remotely-operated vehicles equipped with underwater cameras, and electronic acoustic or satellite tags.

Improvements in fishery-dependent data sampling are also required to reduce the reporting burden on fishers, reduce reporting errors and mistranslation of information, and increase the timeliness of availability of such information. Vessel monitoring systems are already in use by several fishing fleets, but these are mainly used to record and monitor vessel location. Several prototype electronic logbook systems have been developed and tested and, if these can become part of the standard operating procedures of all major fisheries, they will have tremendous benefit to fishers, scientists and managers alike. Tools for remote monitoring of fishing behavior and catch quantity and composition are under development but complex problems remain to be solved.

The availability of hardware and software for processing the complex and voluminous data collected by some sampling tools is often a limiting factor in the implementation of innovative assessment methodologies. Lack of adequate computing power may also be an obstacle in the stock assessment and stock projection processes, particularly when realistic representations of uncertainty are attempted. For example, if uncertainties in assessment inputs are modeled such that probability distributions of current status are produced rather than point estimates, and then future stock or fishery status is projected from these distributions incorporating uncertainty in future events as well, the number of iterations required can quickly mount up and bog down existing computer systems. Thus, proposals for improving stock assessments need to be linked to advanced technology initiatives and information technology (IT) planning. In fact, it is now a requirement that IT staff be included in programmatic planning activities and the budget formulation process.

The final infrastructure-related concern voiced by the Task Force was the availability of space to house the additional staff required to improve stock assessments. Office space is already at a premium in most NMFS facilities. Any plan to increase on-site staff will also need to address this issue.

F. Peer Review of Assessments

Stock assessments conducted by NMFS are rarely, if ever, the product of a single individual. Peer review is an integral part of the process conducted by fisheries scientists from within and outside of NMFS. The NRC (1998a) recommended that:

> ***NRC Recommendation #8: "NMFS conduct (at reasonable intervals) in-depth, independent peer review of its fishery management methods to include (1) the survey sampling methods used in the collection of fishery and fishery-independent data, (2) stock assessment procedures, and (3) management and risk assessment strategies."***

With regards to the three classes of peer reviews listed by the NRC, NMFS routinely conducts peer reviews of stock assessments and stock assessment procedures, and occasionally conducts reviews of survey sampling methods, but rarely conducts reviews of management strategies. One of the problems that arises is in the interpretation of the word "independent." To some, it means non-government, or at least non-NMFS. A more liberal interpretation is simply a review conducted by experts who have not been directly involved in the work being evaluated. NMFS Science Centers frequently recruit scientists from other Science Centers, regional offices, or headquarters to participate in peer reviews. It is also common to invite state fisheries scientists, academics and non U.S. nationals to serve as reviewers, particularly now that the Center for Independent Experts (CIE) has been formed. The CIE (**Appendix 5**) provides a mechanism for accessing a worldwide pool of highly-qualified fisheries scientists, statisticians, and other experts.

All five Science Centers have systems in place for the peer review of stock assessments and sampling methods. These are described briefly below.

Northeast Fisheries Science Center

The current peer review forum for stock assessments conducted in the Northeast dates back to 1985. At that time a region-wide process was initiated to subject selected stock assessments to a two-level peer review. The goals of this process are to assure that scientists reviewing the assessments are not those responsible for the conduct of the work, and that experts independent of the process are included. Although the details of the structure have changed, the Stock Assessment Workshop (SAW) has been, and continues to be, the main vehicle for critical evaluation of stock assessment results and the crafting of management advice in the region.

The SAW consists of two parts: two week-long meetings of the Stock Assessment Review Committee (SARC), usu-

ally conducted in June and November each year, and formal SAW meetings with the New England and Mid-Atlantic Fishery Management Councils where results of the SARC are presented and feedback is solicited. Overseeing the process is the SAW Steering Committee, consisting of the Northeast Regional Administrator, the Science and Research Director of the Northeast Fisheries Science Center, and the executive directors of the New England and Mid-Atlantic FMCs and the Atlantic States Marine Fisheries Commission (ASMFC). The steering committee sets the schedule of which stock assessments will be reviewed at upcoming SARC meetings, and determines the specific "terms of reference" establishing assessment information requirements of managers. The SARC committee usually consists of about 10 members selected from the staffs of the Center, ASMFC (member states), the Councils, and designated outside experts from academia, state agencies, other NMFS Centers and foreign (usually Canadian) research institutes.

Stock assessments reviewed at the SARC are conducted by standing working groups (WGs) responsible for the various species: Northern Demersal WG, Southern Demersal WG, Coastal/Pelagic WG, Invertebrate WG. Stock assessment methods are addressed by the standing Methods WG. Currently the chairs of the WGs are NEFSC scientists, but membership consists of state and academic scientists as well. Some assessments are contributed to the SARC directly by ASMFC assessment committees. The chair of the SARC meetings has, in recent years, been selected by the Center for Independent Experts (CIE; **Appendix 5**), and has included individuals from Canada and Scotland in the past two years.

In addition to the SARC/SAW process, which primarily addresses assessments of state and national importance, stock assessments of transboundary (international) importance are peer reviewed in additional fora, including the TRAC (Transboundary Resource Assessment Committee), a joint U.S.-Canada committee responsible for cod, haddock and yellowtail flounder on Georges Bank, NAFO (the Northwest Atlantic Fisheries Organization), which is responsible for *Illex* squid and various other stocks, and NASCO (the North Atlantic Salmon Conservation Organization), which receives scientific advice from ICES (the International Council for the Exploration of the Sea) North Atlantic Salmon WG.

Southeast Fisheries Science Center

As the SEFSC provides quantitative stock assessment advice to three Fishery Management Councils plus the NMFS Atlantic Highly Migratory Species Management Division, there are a number of peer-review processes that are undertaken. Most typically, SEFSC assessments are conducted by a team of Center scientists. Assessment documents are prepared and distributed to Council review panel members in advance of review meetings. The Councils' stock assessment review panels, which are typically comprised of regional experts who have not been involved in the work being evaluated, comment on the adequacy of the assessment and provide management advice to each Council. In the case of many Atlantic HMS fisheries, assessments are conducted in an international assessment working group setting (through ICCAT), with subsequent additional peer review conducted by ICCAT's Standing Committee on Research and Statistics. Within ICCAT, it is not unusual for the U.S. scientific delegation to be comprised of scientific representatives of a wide array of interest groups. It is also common for the U.S. scientific delegation to be comprised of non-U.S. nationals. For other HMS species (e.g. coastal sharks), assessments are carried out in a workshop format in which state fisheries scientists, academics and non-U.S. nationals participate in the assessment. Further review of any of these assessments is also undertaken through the Center for Independent Experts (CIE; **Appendix 5**), if the assessment results appear to raise controversy.

Southwest Fisheries Science Center

The Southwest Fisheries Science Center provides peer review for all its stock assessments and uses a variety of mechanisms to do so. The choice of mechanism is often based on the customary approach for the forum receiving the assessment. For assessments produced by the SWFSC for the Pacific Fishery Management Council (PFMC) a Stock Assessment Review Panel (STAR Panel) is formed with members chosen from the Council's SSC and other nominated non-NMFS individuals to review and verify the assessment. For assessments produced by the SWFSC for the Western Pacific Fishery Management Council (WPFMC), peer review is accomplished using the Center for Independent Experts (CIE; **Appendix 5)**, currently coordinated through the University of Miami, or other designated panels. Protected resource stock assessments are peer reviewed by panels of external reviewers constituted by external organizations such as the Inter-American tropical Tuna Commission (IATTC), or the Marine Mammal Commission, or the SWFSC. For SWFSC assessments presented to international scientific bodies such as the Interim Scientific Committee for Tunas and Tuna-like Species in the North Pacific Ocean (ISC) or the Standing Committee on Tuna and Billfish (SCTB) of the Secretariat of the Pacific Community (SPC), either as finished assessments or as NMFS input for collaborative assessments, the receiving forum and its scientists provide the peer review.

Northwest Fisheries Science Center

The stock assessment review (STAR) process for groundfish assessments off the U.S. west coast has been developed as a shared responsibility of the National Marine Fisheries Service and the Pacific Fishery Management Council. The STAR process helps make groundfish stock assessments the "best available" scientific information and facilitates use of the information by the Council. The process operates under the direction of a NMFS Stock Assessment Coordinator and reports primarily through the Council's Scientific and Statistical Committee (SSC). The process has a detailed calendar, explicit responsibilities for all participants, and specified outcomes and reports. STAR panels meet in a public setting in which all interested parties are legitimate meeting participants. This increases understanding and acceptance of groundfish stock assessment and review work by all members of the Council family.

The STAR Panel's terms of reference concern technical aspects of stock assessment work. The Panel is expected to identify scenarios that are unlikely or have a flawed technical basis, while reporting information, discussions, and disagreements which reflect uncertainty in the assessment. The Panel operates by consensus and strives for a risk neutral approach in its reports and deliberations.

STAR Panels normally meet for one week to review two assessments. Typically 2-3 Panels meet each year, and Panels reviewing transboundary assessments are informally coordinated with the Canadian stock assessment review process. Each Panel normally includes a chair, at least one "external" member (i.e. outside the Council family and not involved in management or assessment of West Coast groundfish), and one SSC member. In addition to Panel members, STAR meetings will include representatives from Council technical and advisory committees with responsibilities laid out in their terms of reference. The STAR's SSC representative attends Council meetings where stock assessments are discussed to explain the reviews and provide other technical information and advice.

Alaska Fisheries Science Center

The AFSC provides stock assessment advice to the NPFMC on an annual basis. Stock assessments are reviewed internally for consistency and accuracy. External technical reviews are conducted by the NPFMC BSAI and GOA Plan Teams and the Scientific and Statistical Committee (SSC). The Plan Teams and SSC are composed of scientists who represent federal, state and academic institutions. The Plan Teams provides a detailed technical review of the assessment methods and analytical approaches. The SSC provides a similar level of technical advice and is responsible for establishing the Allowable Biological Catch (ABC) and Overfishing Level (OFL) for FMP species. Preliminary assessments are prepared for the September Council meeting and final assessment documents are completed in November for Council action in December. Preliminary assessment documents are required when assessment scientists introduce a new analytical method, or utilize a new data source in their model. The preliminary SAFE provides an opportunity for the analyst to incorporate comments and suggestions from the Plan Teams and Scientific and Statistical Committee in their final SAFE chapter. In November, the Plan Team meets to review the final SAFE documents. The Plan Teams prepare reports documenting their recommendations for ABCs and OFLs and they compile the SAFE document for distribution at the December Council meeting.

AFSC schedules detailed reviews of selected assessments on an annual or semiannual basis. Stock assessment experts are invited to conduct a thorough review of the methodology used. This review process provides time for the assessment expert(s) to work one on one with the assessment scientists. Reports derived from this process are presented to the NPFMC advisory bodies. This assessment review is similar in scope to the reviews now provided by the Center for Independent Experts (**Appendix 5**).

G. Translation of Stock Assessment Advice into Management Action

The translation of stock assessment advice to management action is where science and management interface and is an important but often controversial activity. Conflicts frequently arise over the "proper" roles of scientists and managers. At one extreme, it is argued that there should be greater separation of the science and the management, in order to ensure that the science is unbiased. Scientists would then provide information on stock status in a form such as graphs giving the probability that current or projected fishing mortalities will be above or below some benchmark (specified previously by the managers), and managers would decide what action to take on the basis of this information. At the other extreme, it is argued that there should be greater co-mingling of science and management with most if not all science being specifically focused on management-oriented questions, and the priorities for science being driven by management priorities. In reality, scientists provide information on stock status but, because they have the data, the quantitative skills, and the infrastructure, are subsequently asked to evaluate the likely outcomes of alternative management actions with respect to their effect on future stock status. Stock assessment scientists

are frequently members of Plan Development Teams and related groups that evaluate the effectiveness of alternative management tactics and strategies in meeting management goals. Assessment scientists often also evaluate and provide advice on management benchmarks.

Many of the problems addressed by Plan Development Teams and related groups are tactical; i.e. short-term measures to solve the immediate problems of reducing fishing mortality and/or rebuilding stock biomass. Tactics that are frequently evaluated include size limits, gear restrictions, closed areas, closed seasons, trip limits, total allowable catches, limited entry, and restricted days at sea. When fishing mortality and fishing capacity are under control, and the stock biomass is near long-term sustainable levels, it is appropriate to conduct strategic (long-term) analyses of "optimum" management strategies. Such strategies might include constant fishing mortality strategies at various levels of fishing mortality, constant escapement strategies, constant catch strategies, alternative strategies that have variable effects on the bycatch of protected species or nontarget species or nontarget sizes, pros and cons of permanent closed areas, and the social and economic implications of alternative fleet configurations. These types of analyses tend to be conducted only sporadically—typically at the beginning of development of a new management plan, during major overhaul of a plan, or as a research topic undertaken by one or more internal or external scientists on their own initiative.

The process of translating assessment advice to management action is also where conflicts arise over the "proper" amount of influence by, or interaction with, stakeholders such as the commercial, recreational and environmental sectors. The process set up by the MSFCMA theoretically involves public participation at every step. In general, however, there is relatively little public involvement in the assessment process itself, possibly because relatively few people have the training or interest in the technical aspects of the quantitative analyses conducted. There tends to be considerably greater involvement at the stage of formulating management actions to improve stock or fishery status. This mainly takes the form of attendance at Fishery Management Council meetings and public hearings and, increasingly, by challenging particular management actions or the stock assessment itself in courts of law. The problems addressed in these forums also tend to be mainly short-term and tactical.

It is likely that conflicts could be lessened considerably if more resources were to be devoted to improving this interface between science and management. First, more attention should be paid to analyzing the long-term implications of alternative management strategies, and a greater array of alternatives should be examined. The NRC (1998a) study recommended evaluation of a wide array of alternative management strategies in terms of their robustness to assessment and other errors.

> ***NRC Recommendation #5: "Precautionary management procedures should include management tools specific to the species managed, such as threshold biomass levels, size limits, gear restrictions, and area closures (for sedentary species)"***

Second, simulation models should be constructed to allow managers and other stakeholders to evaluate the implications of alternative actions and strategies themselves. Such models have been in existence for at least 25 years, but it takes considerable time to program them and to construct a user-friendly interface, particularly if a wide array of management alternatives is incorporated. In addition, they may need to be reprogrammed each time a new stock assessment is conducted. Third, models for analyzing assessment methods and harvesting strategies simultaneously, called management procedures simulation models, should be constructed for each major stock or fishery. The structure of management procedures simulation models varies but they generally include an operating model that provides a simulation of a "true" population, a procedure for sampling the true population, an assessment model that uses the sampled data to produce a "perceived" population, a management model that implements specific harvest rules, and performance statistics and feedback associated with each of these components. This is essentially the approach recommended by NRC (1998a).

> ***NRC Recommendation #6: "Assessment methods and harvesting strategies have to be evaluated simultaneously to determine their ability to achieve management goals. Ideally, this involves implementing them both in simulations of future stock trajectories. For complex assessment methods, this may prove to be very computationally intensive, and an alternative is to simulate only the decision rules while making realistic assumptions about the uncertainty of future assessments. Simulation models should be realistic and should encompass a wide range of possible stock responses to management and natural fluctuations consistent with historical experience. The performance of alternative methods and decision rules should be evaluated using several criteria, including the distribution of yield and the probabilities of exceeding management thresholds"***

This framework is particularly useful for investigating the robustness of various types of biological reference points and management actions, but it is extremely labor and computationally intensive.

H. Communication of Assessment Results and Follow-up Evaluations

Communication, or the perception of a lack of communication, may be one of the greatest threats to the credibility of stock assessment science. Translating complex technical information into formats that a wide array of constituents can identify with can be extremely time consuming and not all assessment scientists are equally adept at it. In addition, it is often not pleasant or rewarding to present assessment results and evaluations of alternative management strategies to a sometimes hostile audience with varying agendas and views about the future of the fishery. Scientists are often accused by one or more sectors (e.g. small-scale commercial fishers, large-scale commercial fisheries, for-hire recreational fishers, private recreational fishers, and environmentalists) of being biased in favor of one or more other sectors.

Another communication problem affecting the credibility of stock assessments is the disassociation between the generation and analysis of fishery-dependent data. A fisher filling out a logbook detailing the catch at a certain time and place may believe that the size of a particular catch was more a function of weather or oceanographic conditions or the way the gear was deployed, rather than actual abundance, but this information will probably not be conveyed to those analyzing the data. In addition, fishers may sometimes have an incentive to under- or over-report catches. And some fishers may provide incomplete data because, like most people, they simply dislike filling out forms. Fishers may distrust stock assessment results because (i) they are aware of the problems inherent in the generation of fishery-dependent data, and (ii) since fishers are adept at finding fish, they may have a more optimistic view of the state of the stock than is implied by the assessment. It is often stated that it is impossible for a scientist to produce a valid assessment unless s/he spends time out on the water observing fish and fleet behavior. However, since individual vessels tend to focus on "hot spots," a few days at sea would only give a very localized view of a fishery or stock. Scientists also need to spend time on statistically-designed fishery-independent surveys to develop a more holistic view of fish distribution and abundance.

Lack of time to communicate with other groups of constituents is not just a problem for scientists. All groups of constituents would probably benefit from participating more in each others activities, but this would take time away from their own specialty. Assessment scientists should, however, devote more time and attention to communications about data deficiencies, to cooperative research with constituents, to communication of assessment results, and to interactive analysis of the implications of alternative management tactics and strategies.

I. Staffing Issues

Education and training

NMFS employs the largest collection of world-renowned fisheries scientists of any agency, university, or other organization worldwide. In general, these scientists have strong backgrounds in both biology and either mathematics or statistics. However, biologists with solid quantitative skills, or quantitative experts with some biological background, are relatively rare and the pool of qualified applicants graduating from appropriate university courses is actually shrinking. This situation was recognized by NRC (1998a) who recommended that:

> ***NRC Recommendation #10: "NMFS and other bodies that conduct stock assessments should ensure a steady supply of well-trained stock assessment scientists to conduct actual assessments and to carry out associated research. NMFS should encourage partnerships among universities, government laboratories, and industry for their mutual benefit. This can be accomplished by exchanging personnel and ideas and by providing funding for continuing education at the graduate, postdoctoral, and professional levels, including elements such as cooperative research projects and specialized courses, workshops, and symposia."***

In fact, NMFS has numerous cooperative programs with academic institutions (see Data Acquisition Report, NMFS 1998; **Appendix 3**), provides funding for continuing education of employees, and frequently organizes topical workshops and specialized courses. However, the paucity of qualified applicants for advertised stock assessment scientist positions is evidence that insufficient people are being encouraged to enter this field and receive appropriate training. A relatively new program designed to alleviate this problem has been established jointly by NMFS and NOAA Sea Grant. Each year (beginning in 2000), this program will provide up to three years of funding, mentoring and summer employment for two Ph.D. candidates in quantitative assessment-related areas of research, up to a maximum of six students at any one time (**Appendix 6**).

In addition, NMFS does not have a comprehensive continuing education program for technical staff, although there have been several attempts to initiate such programs. As shown below, assessment scientists do not feel that they have sufficient opportunity to participate in professional development activities, including training.

Time and motion analysis

As detailed in **Sections III G and III H** and elsewhere in this report, it is evident that there are many other demands placed on assessment scientists aside from the basic requirement of a background in biology and mathematics. Within a given year, an individual assessment scientist may be expected to: (i) participate in fishery-independent surveys or other field work, (ii) provide input and advice on sampling designs for research surveys and other fishery-independent data collection activities, (iii) spend time on commercial or recreational fishing vessels, (iv) provide input and advice on the development of data collection objectives and protocols for observer programs and other fishery-dependent data collection activities, (v) conduct quality control or other preprocessing of data, (vi) conduct stock assessments, (vii) conduct research into stock assessment methods, (viii) present assessment results to peer review panels and constituent groups, (ix) participate on peer review panels, (x) participate in fishery management plan development or evaluation teams, (xi) defend a stock assessment in a court of law, (xii) research and write scientific papers for primary publication, (xiii) attend colleagues' seminars and offer critical review, (xiv) conduct formal, written peer reviews of articles submitted for publication in scientific journals, (xv) participate on committees to advance approaches to stock assessment and fisheries management, (xvi) undertake training to stay abreast of new methodologies, (xvii) run courses or workshops to train others, (xviii) participate in national and international meetings and conferences to enhance professional development, and (xix) undertake a variable amount of administrative duties depending on supervisory level. With limited exceptions, there is insufficient scope for individual scientists to focus on just one or a few of these activities due to an overall shortage of assessment scientists.

To better understand the allocation of NMFS' stock assessment scientists' time, and to determine whether there is a difference between the actual and optimal allocation, the Task Force prepared a questionnaire and administered it to working stock assessment scientists. Activities commonly undertaken by assessment scientists were divided into ten categories: (i) the mechanics of stock assessments, (ii) modeling research to improve stock assessment methodology, (iii) other (field or related) research to improve stock assessments, (iv) participation in data collection or data management activities, (v) provision of scientific advice to Fishery Management Councils and others, (vi) participation in FMP development, evaluation of the consequences of alternative management strategies, and other Council-related activities, (vii) other interactions with constituents, (viii) professional development including researching and writing scientific papers, reading scientific journals, attending conferences, and training, (ix) administrative duties, and (x) other. Assessment scientists were asked to estimate the percentage of their time roughly averaged over the previous two years spent in each of these activities, and also to estimate the ideal percentage allocation of time averaged across a group of stock assessment scientists, recognizing that there may be some degree of specialization between individuals. Results are summarized in **Figure 5** for all respondents combined and separately for each Science Center except the Northwest (due to a very small sample size). Overall, about 22% of an average assessment scientist's time is spent on the mechanics of conducting stock assessments, and this seems to be close to ideal, although there are notable differences between Centers. The other features of the summarized results that stand out are a desire to spend less time on data collection and data management activities, providing scientific advice, FMP development and, in particular, administrative duties; and more time on modeling and other research and professional development. This is an important result that supports the belief of the Task Force that assessment scientists are "stretched too thin." Production of an assessment and provision of advice are activities that usually have a critical time horizon associated with them, whereas research to improve the basis for assessments does not. Yet, such research is crucial to advance the discipline. Also, in the hectic world of stock assessments, professional development is almost perceived as a luxury when, in fact, it is essential for maintaining a workforce of high caliber, internationally renowned and respected assessment scientists. Interaction with peers both nationally and internationally is also essential given the small size of the profession and the need to have a critical mass to discuss and debate ideas.

Beyond assessment scientists

A wide diversity of staff is required to produce a stock assessment. In fact, stock assessment scientists just represent the "tip of the iceberg" (**Figure 6**). Far greater numbers of staff are deployed in critical data collection activities, such as commercial or recreational catch and effort data, port sampling for biological data, observer programs, and fishery-independent resource surveys. Additional staff are required to process biological samples (e.g. to determine fish ages from hard structures, construct age-length

Time & Motion Analysis

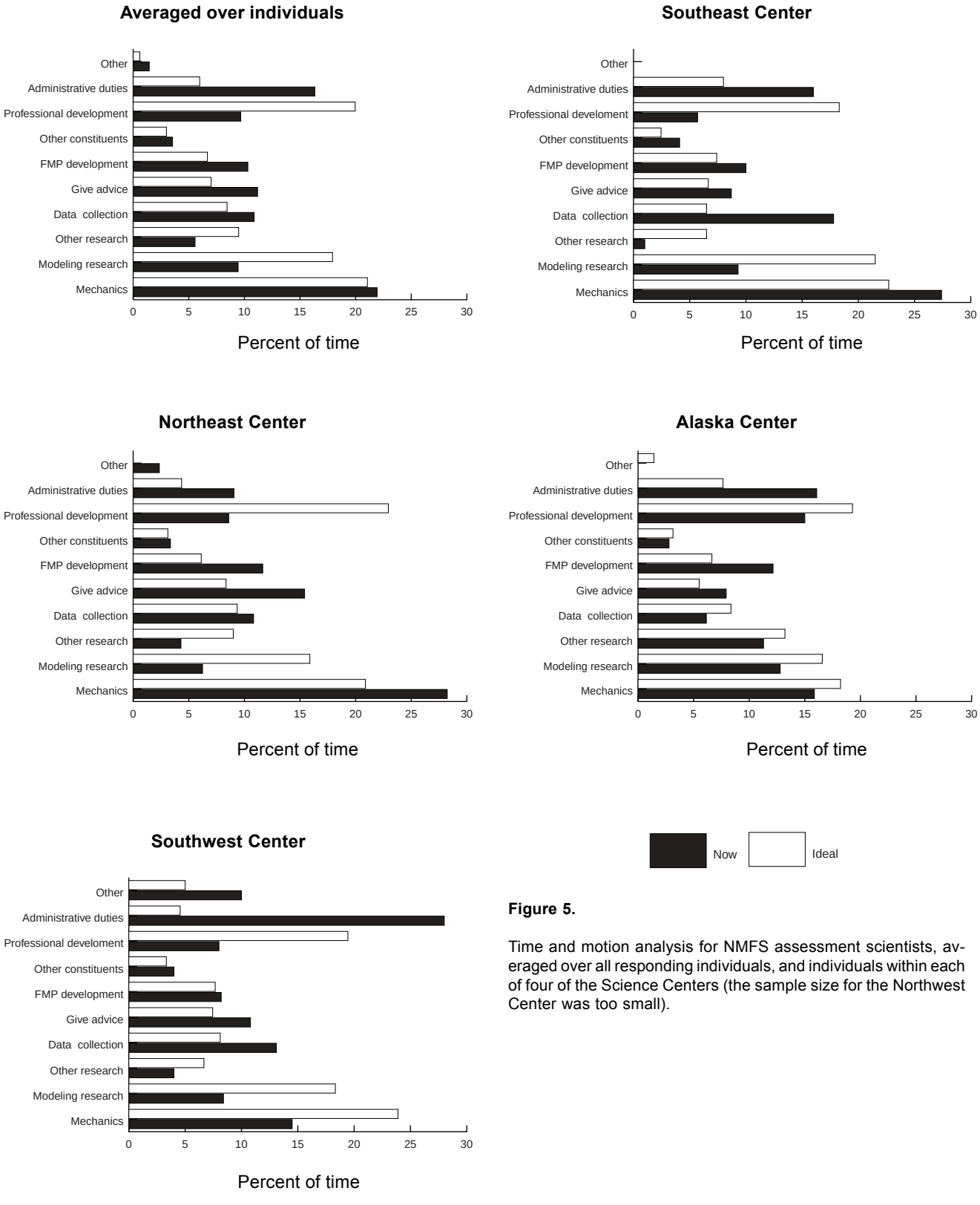

Figure 5.

Time and motion analysis for NMFS assessment scientists, averaged over all responding individuals, and individuals within each of four of the Science Centers (the sample size for the Northwest Center was too small).

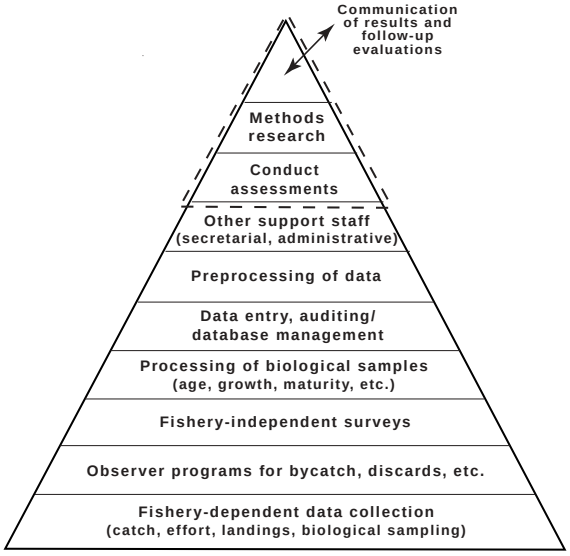

Figure 6.

Schematic showing relative staffing requirements in support of providing scientific advice for fisheries management. Staff requirements for conducting stock assessments, developing new stock assessment methods, and communication of results and management strategy evaluations represent just the tip of the iceberg.

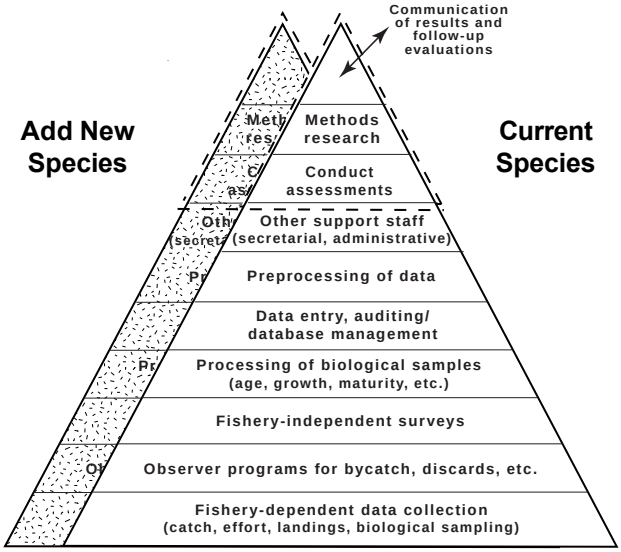

Figure 7.

Schematic showing the relative costs of adding new species to be assessed. Often the existing infrastructure can be used to collect the basic data. However, the higher up the pyramid, the less the ability of the existing infrastructure to absorb new responsibilities.

keys, develop growth curves, construct maturity ogives, and possibly to identify and count eggs and larval fish from ichthyoplankton surveys and examine stomach contents), and to enter, audit, integrate, and preprocess data from the myriad of data collection activities. Support staff such as secretaries, administrators, and human resource personnel are required to support the data collection and stock assessment staff and their activities. Assessment scientists themselves are involved in three primary assessment-related activities: conducting assessments (using assessment models), methods research (developing assessment models), and analyzing management alternatives and providing advice to managers and constituents based on assessment results (management strategy evaluations). Relative staffing requirements for assessment-related responsibilities can be roughly represented by a pyramid, with data collection activities forming the base of the pyramid, and the assessments themselves at the apex using information from all lower levels (**Figure 6**).

Thus, when a new species needs to be assessed, the entire pyramid of activities needs to be considered. If the existing infrastructure can be used to collect the basic data for the new species (or basic data are already being collected but have never been processed), it may only be necessary to expand slightly on data collection and data management activities. However, the higher up the pyramid, the less the ability of the existing infrastructure to absorb new responsibilities (**Figure 7**). If an entirely new program or infrastructure is needed to provide the basic data for the new species, one or more levels of the pyramid may require substantial expansion.

Current assessment-related staffing requirements by type of activity are detailed below using the northeast region as a case study.

Northeast case study

A careful inventory was conducted for staffing levels expressed as Full Time Equivalents (FTEs) for all major data collection, research, and modeling activities of direct relevance to northeast stock assessments. It should be noted that these analyses apply only to staffing levels and other resources contributed on the federal side; however, for many of the region's resources, data collection and analyses are undertaken by staff in state marine fisheries organizations. Totals FTEs by category are summarized in **Figure 8**.

Commercial Catch and Biological Sampling:
(**49 FTEs**; 30 in-house, 19 contract)

Commercial landings data are primarily collected through a network of NMFS "port agents" stationed in major fishing ports throughout the region, and mandatory dealer and fisher-supplied data. Dealer records are required for most major regulated species. Port agents assure that dealer data are entered into computer files and audited. Individual fishers are required to submit vessel trip reports (VTRs or logbooks), which are entered into computer files through a central processing facility located at the Northeast Regional Office in Gloucester, Massachusetts. In addition to basic data on fishery landings (lbs.), VTRs are also used to allocate landings to water area fished, which is an important element when more than one stock of a particular species is assessed and managed, and for analyses of management strategies involving measures such as closed fishing areas. Discard data are requested in VTRs, but the data provided in these self-reported documents are generally considered unreliable for stock assessment purposes (although the data have been used in some limited circumstances). These data collection programs generate information for activities other than stock assessment (e.g. compliance monitoring, economics, and management), but without such data, monitoring of the effects of fishing on the stocks would not be possible.

Biological sampling of landings (length sampling, collection of structures for subsequent ageing) is also carried out by port agents and additional sampling staff allocated to the ports. Sampling priorities are developed by stock assessment scientists, and port agents attempt to fulfill minimum sample sizes for length and age sampling.

Recreational Catch and Biological Sampling:
*(**50 FTEs**; 3 in-house, 47 contract)*

Recreational fisheries in the Northeast are an important source of fishing mortality on regulated species such as striped bass, bluefish, Atlantic cod, winter flounder, scup and black sea bass. Data on the magnitude of the recreational catch (numbers of fish caught) are derived from the Marine Recreational Fishery Statistical Survey (MRFSS) conducted by NMFS. This nationwide survey employs a contractor who deploys field personnel in a two-phase sampling scheme. The phone survey element of the program identifies the number of households participating in recreational fisheries in the region. The intercept portion of the survey estimates catch numbers and species composition of fishing trips by anglers. The data are combined to generate estimates of recreational landings and discards, by species.

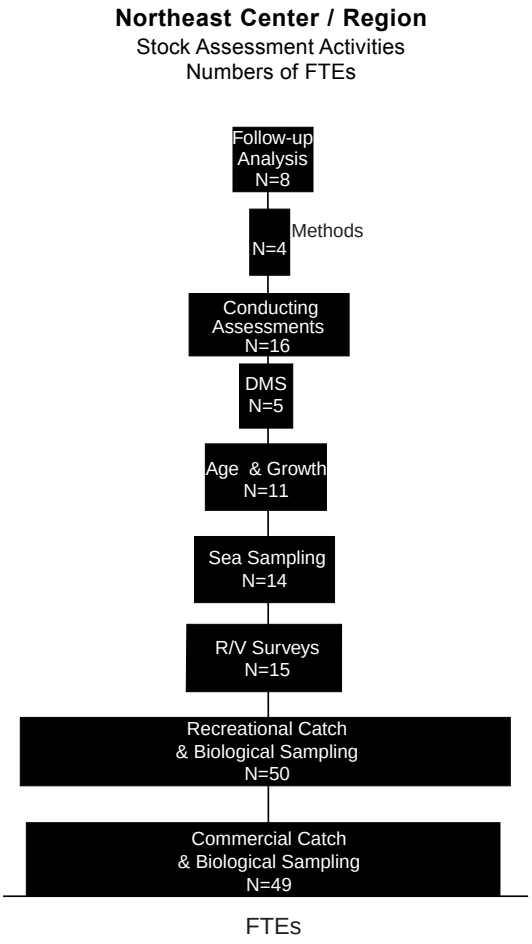

Figure 8.

Assessment-related staffing levels by type of activity for the Northeast Fisheries Science Center. DMS = Data Management Services; R/V = Research Vessel.

Biological sampling of recreational catches is currently limited to length composition and individual weight data. In several states, the basic sampling scheme is augmented (increased sample sizes) in order to provide more precise catch estimates for important species.

In the Northeast region, the contractor utilizes 47 FTEs for the phone survey and intercept portions of the survey. An additional three FTEs are required to administer the program and provide statistical oversight and management.

Research Vessel Surveys:
*(**15 FTEs**; 8 in-house, 7 contract or volunteers)*

Standardized research vessel surveys provide the backbone for stock assessment activities in the region, and have done

so for nearly 40 years. The primary survey activities include spring and autumn bottom trawl survey series (broad-based multispecies trawling surveys), a winter bottom trawl survey in the Middle Atlantic and Southern New England region (primarily providing data for stocks such as summer flounder, scup, squids, dogfish, and skates), a sea scallop dredge survey, an hydraulic dredge survey for surfclam and ocean quahog, and a trawling survey for northern shrimp. These surveys require scientific personnel equivalent to about 10 person-years to collect data in the field. Currently this requirement is fulfilled by assigned personnel, volunteers from various agencies and universities, and stock assessment staff. In addition to field data collection personnel, about 5 FTEs are required for data entry and auditing.

Additional research vessel survey data are provided by some states (and by Canada for transboundary resources). More recently, cooperative NMFS-fishing industry surveys have been undertaken to increase the spatial resolution of surveys for sedentary resources (scallop and surfclam), and to develop approaches to real-time management (squid). These activities have significantly increased the requirement for at-sea personnel and for analysts to design the surveys and analyze the results.

Sea Sampling:
***(14 FTEs**; 3 in-house, 11 contract)*

Most sea sampling (fishery observer) activities in the Northeast Region are directed to assessing the impacts of fisheries on marine mammal populations of the region, including harbor porpoise in relation to sink gill net fishing. The total sea sampling program includes about 56 FTEs; however, the majority of the program is focused on monitoring fisheries interactions with protected species, including marine mammals and sea turtles. About 25% of the sea sampling program is devoted to sampling for fishery-related problems (e.g. stock assessment and compliance monitoring for fished resources). The magnitude of the program is not sufficient to provide reliable estimates of fishery catches and discards for all the region's fisheries. Consequently, the limited resources of the fisheries-portion of the sea sampling program have been focused on several high priority problems: (1) discards of summer flounder in the Middle Atlantic and Southern New England trawl fishery, (2) estimates of fishery catches and size composition and bycatches of the sea scallop dredge fisheries, (3) estimates of finfish bycatches in the northern shrimp trawl fishery, and (4) monitoring of finfish bycatches in the sea scallop dredge fishery in an area recently reopened to fishing on Georges Bank.

Age and Growth:
***(11 FTEs**; 8 in-house, 3 contract)*

Analyses of year class strength and projections of stock abundance require measurements of the age-length and age-weight relationships of fishery resources. Because of high interannual variation in recruitment survival, the abundance and growth rates of adjacent year classes may differ greatly. Accordingly, where age-based stock assessments are performed, age information must be collected each year from the fisheries and from research vessel abundance surveys.

The NEFSC currently ages about 50,000 individual fish and invertebrates per year. These ageing studies support priority age-based stock assessments, depending on which stock assessments need to be updated. In addition to ageing work, biological studies supporting stock assessments include validation of ageing structures (e.g. fish otoliths or scales, clam shells) and factors controlling the rate of growth and onset of sexual maturity.

Data Management Services:
***(5 FTEs**; 4 in-house, 1 contract)*

Data management activities (data entry, data auditing, database maintenance, custom programming for high priority tasks, and support of data processing activities such as geographical information systems) requires about five FTEs.

Stock Assessment Scientists:
***(28 FTEs**; 23 in-house, 5 contract)*

Stock assessment staff include individuals involved in data assembly and quality control (technical functions), as well as stock assessment model execution, development of new analytical approaches to stock assessment methodology, computer programming of models, the provision of management advice, and peer review of assessment science. These tasks can be divided into three broad categories describing the general functions of stock assessment research: (1) conducting stock assessments, (2) developing and implementing stock assessment methods, and (3) assessment follow-up activities including analysis of the implications of alternative management strategies and other scientific input into the management process. Within the Northeast Region, approximately 16 FTE are involved in the conduct of stock assessments, four in methods-related research, and eight in communicating assessment results and evaluating alternative management strategies. In all cases, no single individual exclusively performs one of these tasks; rather, individuals may function in all three areas during part of an assessment cycle.

Apart from scientists at the NEFSC, other stock assessment professionals from several states, ASMFC, the two regional Fishery Management Councils, Canada, and various academic institutions all contribute to the stock assessment and peer review processes in the Northeast Region.

*Total (**172 FTEs**)*

Based on the above, there is a minimum of 172 FTEs involved in various data collection, data management, data analysis, and communication functions related to the provision of scientific advice for 59 species or stocks of fishery resources in the Northeast. On average, this represents about three staff per assessed species or stock, so that the minimum additional staffing needed to assess a new species using existing infrastructure is at least three. However, if entirely new major programs are required (e.g. a new logbook reporting system, a new port sampling program, a new observer program, a new type of resource survey), the Task Force estimated that as many as 20 new staff may need to be added. These estimates also do not include administrative support staff.

IV. Resource Requirements

A. Programmatic Needs: Responses to questionnaires

In preparation for addressing the question of resource requirements for improving stock assessments, the Task Force prepared a questionnaire and administered it to working stock assessment scientists and to managers of stock assessment programs. Not surprisingly, programmatic needs varied by program with, for example, some assessment groups having reasonable fishery-independent data but poor fishery-dependent data, and others the reverse. Thus, on average, all types of data commonly required as input to assessment models are lacking (**Figure 9**).

Overall, the need for fishery-independent indices of relative abundance is the greatest of all, although less so in the Northeast Center. Information on target catch appears to be relatively the least problematic except that the Northeast Center identifies it as its most important programmatic need (**Figure 9**). Similarly, the lack of a reliable fishery-independent index is the greatest impediment to producing high-quality stock assessments, particularly in the southeast, although less so in the northeast (**Figure 10**).

On average, lack of adequate data seemed to be only slightly more of an impediment than staffing levels to the quality of assessments but again this varies considerably by program. Data and research needs for recreational fisheries were low in Alaska where such fisheries are relatively much less important (**Figure 10**). Overall, observer programs and analyses of biological samples were identified as the two most important fishery-dependent data needs, with improved information on recreational catch monitoring and commercial fishing effort being relatively the least important, although still in need of substantial improvement (**Figure 11**). Overall, tagging programs and staff to process biological samples were identified as the two most important fishery-independent data needs, with training in species identification and improved understanding of benthic habitat associations being relatively the least important (**Figure 12**).

The general conclusion from these questionnaire summaries is that, overall, no single activity stands out as being disproportionately deficient; however, it is equally true that none of the inputs to stock assessments approach the ideal situation of "no real need for improvement."

Figures 9-12 give a qualitative indication of the variation in data and staffing needs between Science Centers, but the raw data (not included with this report, but available on request) indicate that there is greater variability in data and staffing needs between programs than there is between Centers.

B. Three Tiers of Assessment Excellence

The Task Force developed three scenarios to consider in the analysis of the resources required to improve stock assessments. These are detailed below and summarized in **Figure 13**.

Tier 1 – Improve stock assessments using existing data

> *(a) for core species, conduct assessments that are more comprehensive, more thorough, more timely, better quality controlled, and better communicated;*
>
> *(b) for species of currently "unknown" status, mine existing databases of research vessel survey data and/or commercial and recreational statistics for archival information for new analyses to evaluate status determination criteria.*

Tier 1 essentially addresses the question of what improvements in stock assessments can be made without initiating new data collection programs. Although the Task Force agreed that new and/or expanded data collection programs are of paramount importance to the improvement of stock assessments, it was concluded that a certain limited amount could be accomplished even in the absence of new programs. Although most data collected by NMFS are analyzed in a timely manner, there are many databases that have not been examined exhaustively. In particular, there may be considerable unanalyzed data for "minor" or non-target species. In some cases, there may even be historical data that has never been computerized, thus necessitating "data-rescue" operations. One reason that some data have been left unedited or unanalyzed is simply a lack of technical and quantitative staff to do the work. Inadequate staffing levels have also compromised the timeliness, quality and thoroughness of assessments conducted to date. Thus, the main requirements for Tier 1 are increased staffing levels, particularly database managers, statisticians, technicians, and assessment scientists.

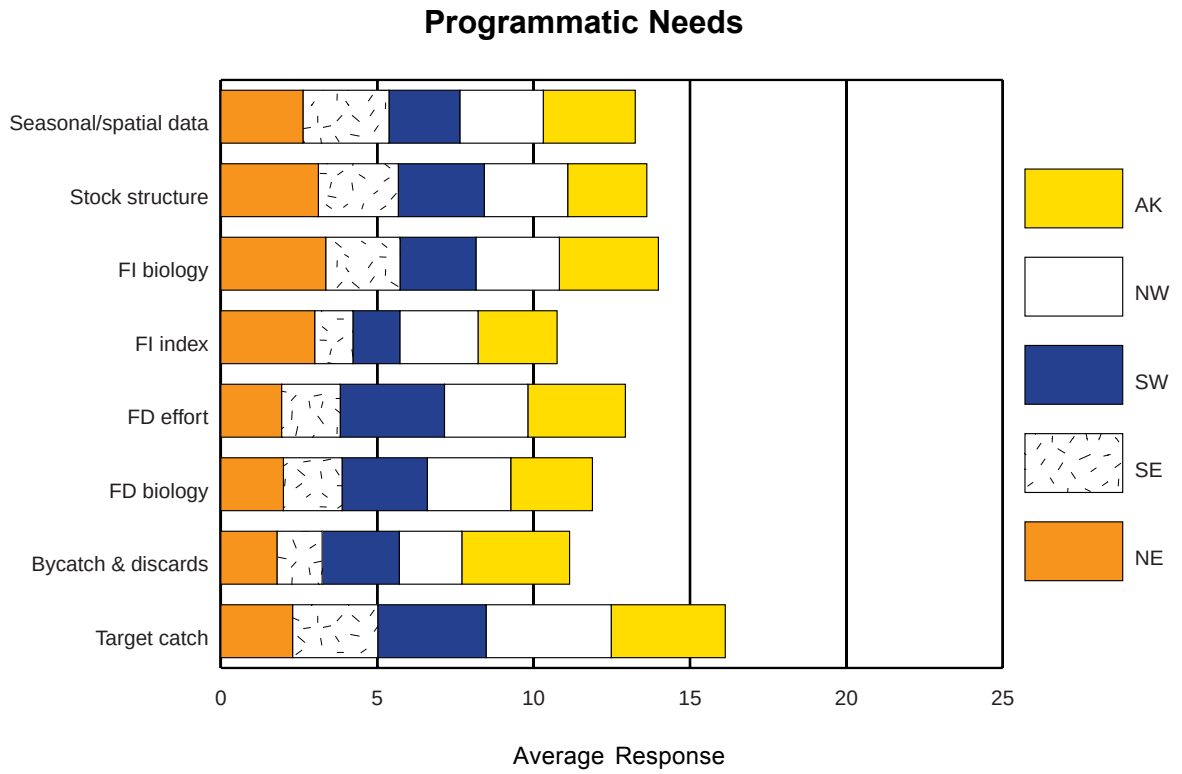

Figure 9.

Programmatic needs averaged over responses from assessment scientists within each Science Center. An average response of 1 for a given Science Center indicates that the lack of a given program is a major impediment to producing credible assessments and has high priority for improvement; 2 indicates a major impediment, but not amongst the highest priorities; 3 indicates adequate for accuracy but not for sample size; 4 indicates that relatively fine tuning is needed; and 5 indicates that the current program is adequate with no real need for improvement. Thus, for the five stacked histograms combined, a total of five would represent the greatest need and 25 would indicate the least need. The difference between 25 and the summed histograms is an overall indication of the need for improving the specified programs. FI=Fishery-independent; FD=Fishery-dependent.

Tier 2 – Elevate stock assessments to new national standards of excellence

(a) upgrade assessments for core species to at least Level 3;

(b) conduct adequate baseline monitoring for all federally-managed species (including rare species)

The focus for Tier 2 is new or expanded data collection and research initiatives. The task of upgrading assessments for core species to at least Level 3 would likely be relatively simple if there were adequate baseline monitoring for all federally-managed species. A key question is, "what is 'adequate'?" The definition of "adequate" will differ by species or stocks and will depend on their geographic range, extent of migration, and magnitude of inter-annual variations in stock size and recruitment. The Task Force agreed, however, that in most cases adequate coverage would require sampling throughout the range of a species or stock at least every 1-3 years, and preferably at least every 1-2 years. For most species, fishery-independent research surveys are the method of choice; for some species, tagging experiments may be more practical; and where neither of these are possible, fishery-dependent surveys may suffice. There are currently very few stocks that can be characterized as having adequate baseline monitoring (**Appendix 1** and **Table 1**). In addition, a minimal requirement for conducting ecosystem-based management and for fully satisfying the standards set forth in the Sustainable Fisheries Act (e.g. standards associated with bycatch issues) is that there be adequate baseline monitoring of all commercial and recreational species and also all associated species, not just federally-managed species.

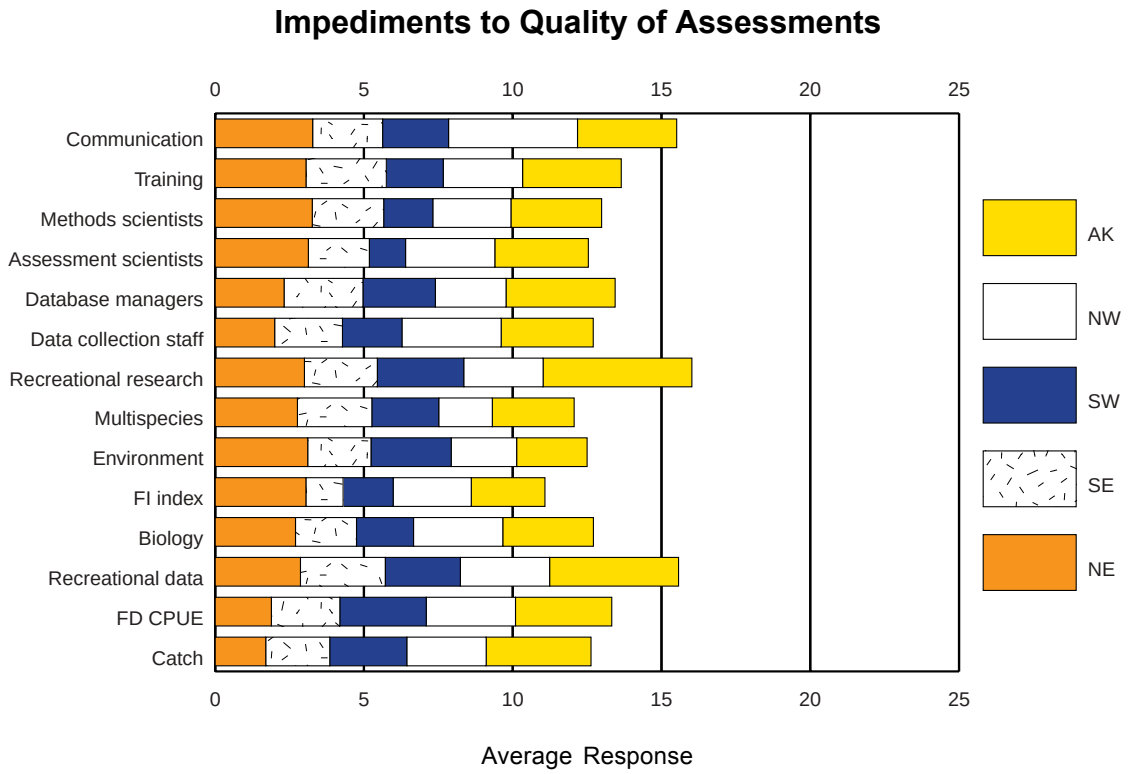

Figure 10.

Impediments to the quality of assessments averaged over responses from assessment scientists within each Science Center. An average response of 1 for a given Science Center indicates that the quantity or quality of data and staff resources is a major impediment to producing credible assessments and has high priority for improvement; 2 indicates a major impediment, but not amongst the highest priorities; 3 indicates adequate for accuracy but not for sample size; 4 indicates that relatively fine tuning is needed; and 5 indicates that the current program is adequate with no real need for improvement. Thus, for the five stacked histograms combined, a total of five would represent the greatest need and 25 would indicate the least need. The difference between 25 and the summed histograms is an overall indication of the need for improving the specified data collection programs or staffing levels. FI=Fishery-independent; FD=Fishery-dependent.

Tier 3 – Next generation assessments

> *(a) assess all federally-managed species or species groups at a minimum Level of 3, and all core species at a Level of 4 or 5;*
>
> *(b) explicitly incorporate ecosystem considerations such as multispecies interactions and environmental effects, fisheries oceanography, and spatial and seasonal analyses*

The Task Force struggled to define reasonable limits to Tier 3. The most recent Report to Congress on the Status of Fisheries of the United States (NMFS 2001a) lists 905 federally-managed stocks, most of which are not routinely monitored, and many of which may not even be identified to species in commercial or recreational landings. The number of data collection activities and staff resources required to enable 900+ assessments of stock status to be undertaken on a regular (e.g. annual) basis is enormous. Additionally, if associated species and other ecosystem considerations were to be taken into account, the task is mind boggling. It then becomes necessary to ask the question, what would be the utility of having 900+ annual assessments; is this a reasonable long-term objective? Would this substantially enhance fisheries management, or are there simpler ways of achieving a similar result? Certainly, it is hard to imagine that 900+ catch quotas would therefore be set, monitored and enforced simultaneously.

From a management perspective, a more realistic aim would be to manage only the primary (core) species by catch quotas, effort controls, or similar high maintenance management methods, and to manage other species using closed areas (e.g. marine protected areas, MPAs), closed seasons, gear restrictions and other indirect management measures. From a stock assessment perspective, a more realistic aim would be to assess groups of species from within the same fishery or geographic area in an aggregate Level 3 assessment, but to also have separate fishery-in-

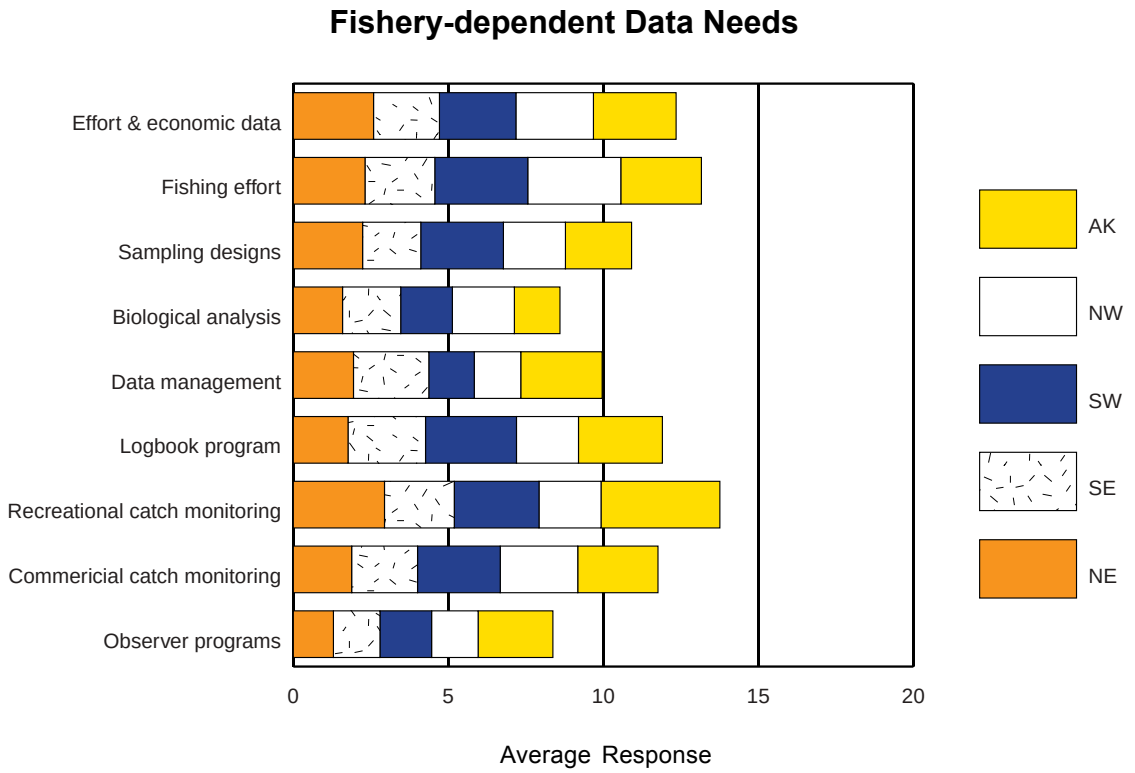

Figure 11.

Fishery-dependent data needs averaged over responses from assessment scientists within each Science Center. An average response of 1 for a given Science Center indicates that a new or greatly expanded data collection program of the specified type would greatly enhance the ability to produce accurate, precise, and timely assessments; 2 indicates that the program would help moderately; 3 indicates that the program would only help marginally; and 4 indicates that the program would not help or is irrelevant. Thus, for the five stacked histograms combined, a total of four would represent the greatest need and 20 would indicate the least need. The difference between 20 and the summed histograms is an overall indication of the need for improving the specified data collection programs or staffing levels.

dependent indices of relative abundance that could be monitored over time to make sure that no individual species was becoming severely depleted. Nevertheless, it is obvious that any reasonable attempt to even partially satisfy the objective of assessing all federally-managed species at a level of 3-5 will require substantial new or expanded data collection and research initiatives, and staff to collect, manage, process, and analyze the data, and to communicate the results.

In essence, Level 4 assessments can be considered "state-of-the-art," while Level 5 assessments are "next generation assessments." Level 4 stock assessments are the standard to which NMFS Science Centers currently strive for the stocks of primary importance. Level 4 assessments comprise analytical age, size, or stage-based calculations that provide relatively precise time series of stock abundance estimates, estimates of exploitation rates and the distribution of the exploitation across size or age groups. From such analyses, short- and medium-term stock and fishery projections and detailed analyses of alternative management scenarios can ensue.

One goal of the Stock Assessment Improvement Plan is to increase the proportion of stocks that can be evaluated with Level 4 stock assessments. This step alone will require a major commitment of resources to enhance data collection activities and analysis functions. However, it is important to consider enhancements beyond high quality single species stock assessments, recognizing longer-term needs of fishery management and emerging issues related to management of species assemblages, communities and ecosystems. Clearly, there is increasing demand for information to allow finer scales of management in space (geographic distribution) and time (seasonally, monthly, and even weekly) than are typically provided in Level 4 assessments. In many cases, these needs are immediate, as managers attempt to manipulate the spatial and temporal pattern of fishing effort to change exploitation rates and patterns on individual stocks, to harmonize the man-

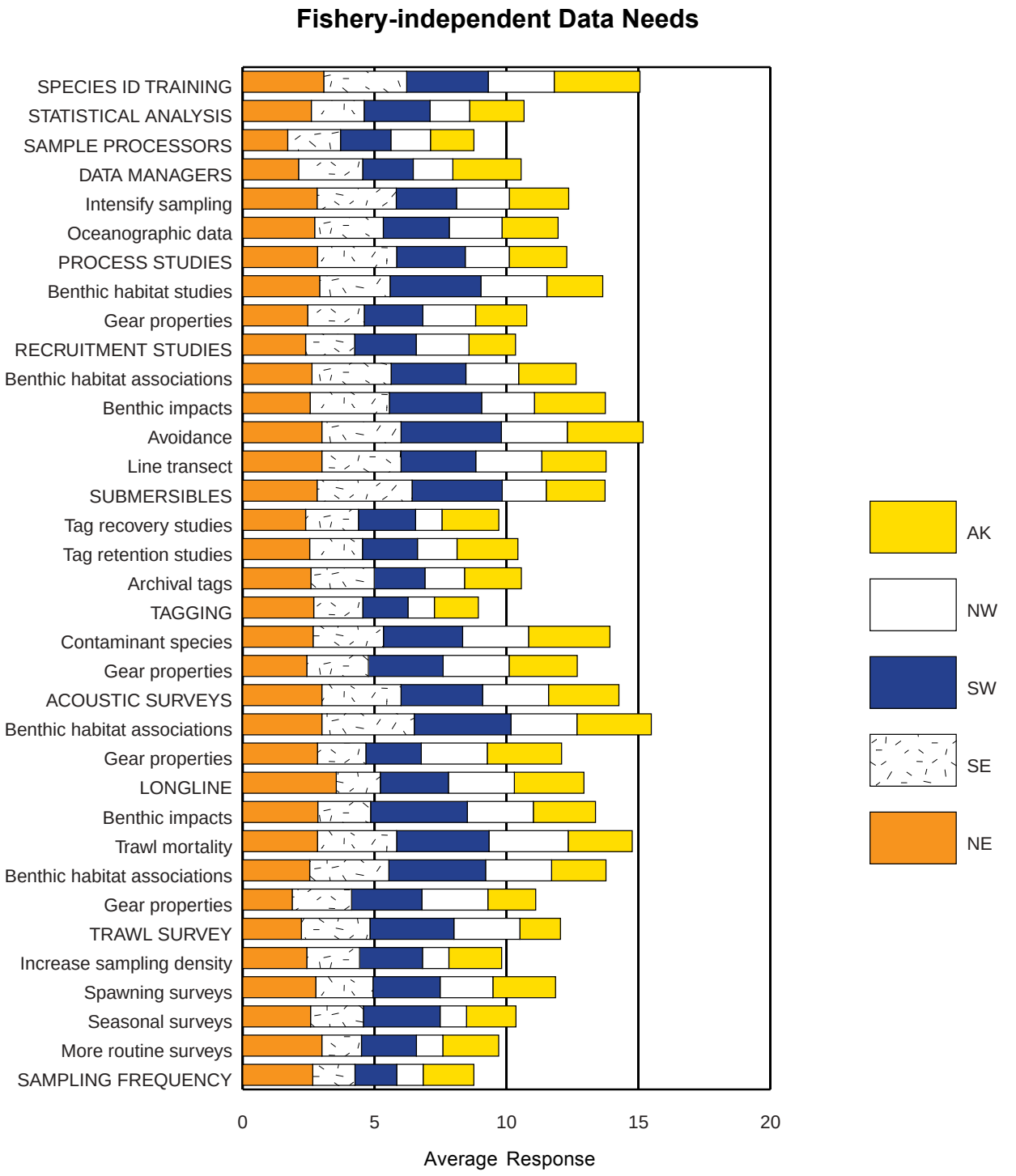

Figure 12.

Fishery-independent data needs averaged over responses from assessment scientists within each Science Center. An average response of 1 for a given Science Center indicates that a new or greatly expanded data collection program of the specified type would greatly enhance the ability to produce accurate, precise, and timely assessments; 2 indicates that the program would help moderately; 3 indicates that the program would only help marginally; and 4 indicates that the program would not help or is irrelevant. Thus, for the five stacked histograms combined, a total of four would represent the greatest need and 20 would indicate the least need. The difference between 20 and the summed histograms is an overall indication of the need for improving the specified data collection programs or staffing levels. To group main headings (upper case labels) and subheadings (lower case), it is necessary to read from bottom to top on the y-axis.

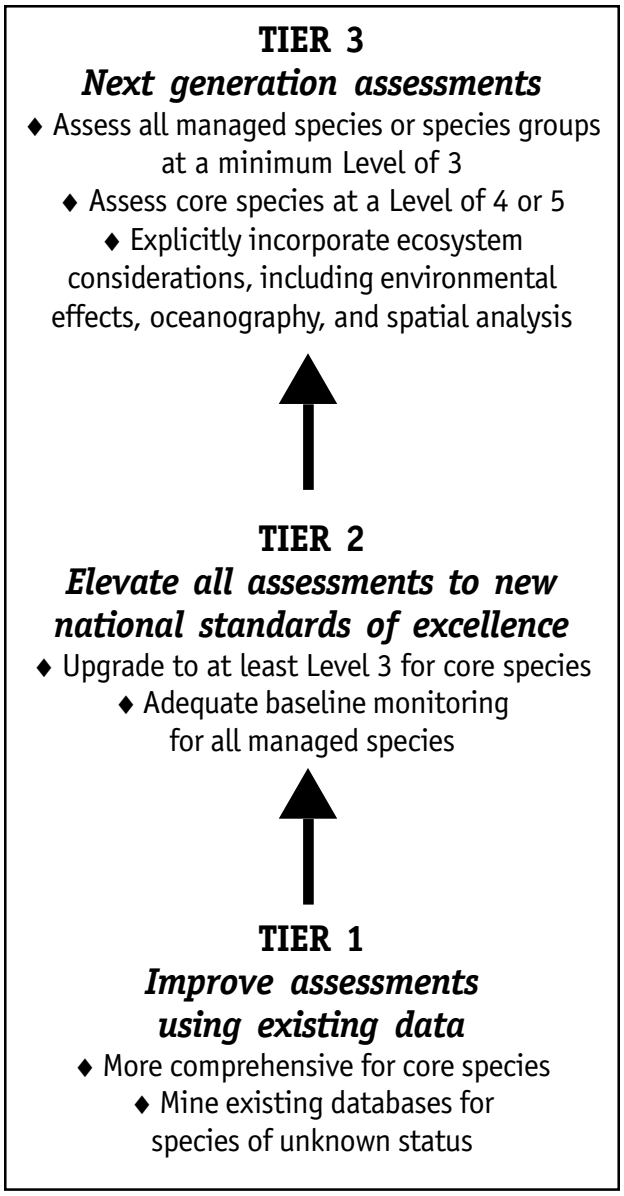

Figure 13. Summary of the key features of the three Tiers of Assessment Excellence.

agement of co-occurring stocks, and to deal with allocation issues. There is also growing interest and need for quantitative information on predator-prey and competitive interactions among managed stocks and associated species. Assessments incorporating biological interactions will become increasingly important because of the requirements of the Sustainable Fisheries Act to maintain all managed stocks near or above biomass levels that can support MSY. The feasibility of achieving this simultaneously for all stocks warrants further investigation, as do the trade-offs between fishery yields and stock sizes that will accrue due to manipulation of the abundances of interacting species. Such models are now available in limited situations, primarily as research tools, but the next generation of assessment models will be required to allow more detailed management scenario analyses of such trade-offs for a wider diversity of situations.

Next-generation assessments are also envisaged as providing the foundation for ecosystem-based management. While considerable work on incorporating ecosystem considerations into assessment models and management advice is currently underway, both within and outside of NMFS, ecosystem science is still in its infancy. Ecosystem research is also prohibitively expensive and labor-intensive. The U.S. Global Ocean Ecosystem Dynamics (GLOBEC) program on Georges Bank serves as an example. Planning for this program was initiated in 1991 with preliminary studies in 1993, and a full program including broad-scale monitoring of physical and biological variables and fine-scale process-oriented studies was conducted over the period 1994-99. During this period, research vessels were deployed on Georges Bank for about 250 vessel-days per year, with data collection and analysis involving about 70 scientists, plus support staff, at an overall cost of about $5 million per year. It is projected to take at least another four years to process all of the ichthyoplankton samples, analyze the data, and synthesize the results. Although this program went well beyond simple monitoring of species and collected considerable physical oceanographic data as well as investing in new technologies, for practical and logistic reasons, the program focused only on a few target species: cod and haddock (primarily only at the egg and larval stages), and two species of calanoid copepods. Even accounting for the transferability of knowledge gained from the process-oriented studies and technological spin-off benefits, a data collection program of this intensity would hardly be practical if the targeted species included all species inhabiting Georges Bank.

Thus, the goal of performing frequent individual assessments for all 900+ FMP species, incorporating ecosystem considerations for as many stocks as possible, and considering the effects on associated non-FMP species, is probably not realistic. It is highly likely that the cost of conducting this amount of research would far exceed the landed value of the fisheries. This would not necessarily mean that the overall benefit of such research was negative because research on marine ecosystems has utility beyond simply providing advice on optimal harvest levels. However, there are many competing priorities for government spending. Even if this stock assessment improvement plan and related initiatives are aggressively pursued and actively supported by stakeholders, it is unlikely that NMFS will ever have sufficient data collection and analysis capabilities to conduct more than double the number of assessments currently undertaken per annum, meaning that

some species will probably always be assessed either infrequently or as part of a larger group. However, with sufficient resources, it will be possible to also conduct better assessments for the core species. In particular, it may be feasible to anticipate conducting Level 5 assessments (incorporating some but not necessarily all elements listed under Level 5) for as many as 4-8 core species per region. Ecosystem-based research is also likely to yield useful ancillary information about associated species, as well as improving our understanding of the dynamics of marine ecosystems.

Another important future consideration for next-generation stock assessment models is that people and groups influenced by the results of such models (commercial fishers, recreational fishers, environmental groups, and managers) will increasingly request greater access to the data and models themselves, and greater participation in data collection and analysis functions. In the next generation, user-friendly models to analyze the implications of alternative management strategies (e.g. stock projection models simulating the biological and economic consequences of various patterns of future catches or exploitation rates) should be developed and made available to the public so that affected parties can conduct their own analyses of alternative management scenarios. While all of this is possible with current technology and agency expertise, the resources required to develop the necessary interfaces with the public at large are not inconsequential. Greater flexibility in analysis options should be one of the hallmarks of next-generation assessment models, as should access to data and models over distributed computer networks. An important element of improving NMFS' stock assessments is planning for and moving forward with the next-generation of stock assessments immediately, consistent with these considerations.

In conclusion, models addressing more species, and more detailed spatial, temporal, environmental and species interactions questions will require significantly more precise, timely and comprehensive fishery-dependent and fishery-independent data. Next generation models will be extremely data-intensive, requiring much-augmented, comprehensive monitoring data. Gathering and analyzing such data will require even greater cooperation from harvesters, fish dealers, and others, more agency staff and funding, and more partnerships and cooperative research programs with other federal and state government agencies, academic institutions, private foundations, fishers, and environmental groups with a vested interest in similar or related data. Many such partnerships already exist (**Appendix 21**), but many more are needed. Recent initiatives to develop cooperative research programs with the fishing industry (**Appendix 22**) are showing considerable promise as a mechanism for augmenting existing programs to collect data of relevance to stock assessments, and a National Cooperative Research Program is now being developed. It may also be fruitful to pursue participation in broad-scale programs such as NOAA's Ocean Exploration Program (**Appendix 23**), the Census of Marine Life (**Appendix 24**), and other initiatives involving science policy, data collection and scientific research (**Appendix 25**).

C. Timeframes and Relationships Between the Tiers

Attainment of the three Tiers of Assessment Excellence involves both short and long-term horizons which, in turn, are dependent upon other complementary programs and initiatives being put in place, and the ability to recruit qualified personnel for the various tasks at hand.

Tier 1: With adequate additional trained staff, most useful work based on existing data will probably have been completed within 3-4 years, by which time new data from Tiers 2 and 3 would hopefully be beginning to become available for additional species. Tier 1 benefits will be almost immediately obvious as data on species of currently "unknown" stock status are analyzed; however, moving certain species from "unknown" to "known" status may not be the highest priority. For example, improved analysis of major target stocks, currently overfished stocks, or new or expanded data collection programs for such species may take precedence.

Tier 2: Contingent on initiation of needed new data collection programs and appropriate additional staff, benefits would become obvious within 5-10 years as time series develop to sufficient length to be of use in stock assessment models. There are also likely to be some immediate benefits; e.g. immediate improvements in the knowledge of the fine-scale distribution of some species and assemblages which could improve management decisions.

Tier 3: Next generation assessments represent a long-term (10+ years) objective and investment because considerable research and development is required and because new time series of consistent data collection must be initiated. In addition, Tier 3 is dependent upon an adequate, purpose-built fleet of dedicated research vessels, continued development of advanced technology that will facilitate sampling of marine organisms, and development of partnerships and cooperative research programs with other federal agencies, state agencies, private foundations, universities, commercial and recreational fishing organizations and individuals, environmental groups, and others with a vested interest in collecting similar types of data, although often for different purposes.

D. Region-Specific Needs to Achieve the Three Tiers of Assessment Excellence

The number of species covered by FMPs differs substantially between regions. This is less a reflection of regional differences in species diversity or fishing intensity than it is of regional differences in the philosophy of which species to include in FMPs. For example, the Gulf of Alaska groundfish plan includes 100 species, but most of the landings are comprised of only a dozen or so species; in contrast, in the New England and Mid-Atlantic regions, less than two dozen of the nearly 200 shelf species are explicitly included in FMPs. For the purposes of reporting on the status of U.S. fisheries, tracking progress in conserving or restoring resources, and comparing region-specific needs and achievements, it would be useful to have greater consistency. However, for the purposes of this plan, the authors all approached the question of region-specific needs in a similar way, regardless of differences in regional philosophies about the degree of inclusiveness. Core species are those with the highest value, highest volume, or highest profile. Minor species are those that contribute little or nothing to landings, but need to be considered in some way in an ecosystem context, regardless of whether or not they are explicitly included in FMPs.

Unless otherwise specified, the current and required resources detailed in this section apply as of January 2000. In some cases, there have been several staff hired or contracted to perform assessment-related activities subsequently. These are highlighted in the appropriate sections.

Northeast Fisheries Science Center

The following two sections contain an analysis of the current staffing and status of assessments in the northeast region relative to defined assessment levels, and an analysis of the staffing resources necessary to meet the three Tiers of Assessment Excellence based on data and resources currently used in the region. It should be noted that these analyses apply only to staffing levels and other resources contributed on the federal side; however, for many of the region's resources, data and analyses are undertaken by staff in state marine fisheries organizations. Thus, existing and required staffing resources should be considered minimum.

NEFSC current situation

A total of approximately 172 staff involved in stock assessment related activities within the Northeast region (**Section III, part I** and **Figure 8**) currently provide advice on 59 managed or otherwise important species/stocks (**Figure 14**).

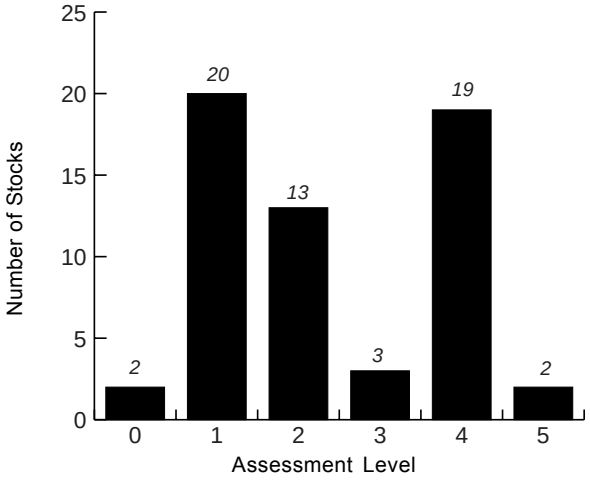

Figure 14.

Number of stocks (N=59) assessed by assessment level at the Northeast Fisheries Science Center.

The distribution of these stocks is bimodal with respect to "assessment level," with 24 stocks assessed at Level 3 and above, and 35 stocks at Level 2 and below. This mix of assessment quality and completeness is primarily a function of historical interest in various species (e.g. groundfish, summer flounder, and surfclams), an increasing need for higher-level assessments to support management programs, and new legal requirements for population biology data. The situation is not static, with managers increasingly requesting more frequent assessment updates, with more extensive "terms of reference."

In particular, stock assessments are now often required to incorporate discussion and evaluation of "control rules" used by management to meet the requirements of the MSFCMA. These control rules provide managers with a formulaic approach to scientific advice, pre-specifying the relationship of target fishing mortality rates to biomass conditions in the stocks. The construction and testing of control rules makes use of absolute biomass and fishing mortality rate estimates, or proxies for these quantities, if adequate approaches can be developed. As part of this effort, medium term simulations of the performance of control rules in recovering and maintaining stocks are required so as to evaluate the efficacy of a proposed control rule in meeting the 10-year or one generation time constraints imposed by the MSFCMA. Center stock assessment scientists have been involved in developing proposed control rule strategies for various species, and in scientific research for providing realistic simulations of the performance of stocks in relation to control rule management (e.g. simulating population status in the medium term using various approaches for determining recruitment re-

Table 2.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for the Northeast Fisheries Science Center. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*
Commercial Catch & Biological Sampling	30	19			10	**10**	
Recreational Catch & Biological Sampling	47	3			5	**5**	
Observer Programs	3	11			13	**13**	
Fishery-independent Surveys	8	7	10		5	**5**	2
Process Biological Samples (age, growth, maturity, etc.)	8	3	3	5	5	**10**	5
Data Management & Preprocessing of Data	4	1		7	2	**9**	5
Conduct Assessments	13	4	3	2	1	**3**	5
Assessment Methods Research	3			2	1	**3**	5
Communication of Results & Follow-up Evaluations	7	1		2	1	**3**	3
Subtotal (Assessment scientists)	***23***	***5***	***3***	***6***	***3***	***9***	***13***
Subtotal (0thers)	***100***	***44***	***13***	***12***	***40***	***52***	***12***
Total	**123**	**49**	**16**	**18**	**43**	**61**	**25**

sponses). As the need for more complex stock assessments has been increasing, so has the need to upgrade index-level assessments to assessments incorporating age/size structure to support sophisticated simulations of control rule performance.

NEFSC programs and staffing required to meet the three tiers of excellence

Based on the current distribution of stock assessment levels, data and technical limitations, and staffing in data collection and analytical tasks, the following represents an analysis of augmented staffing levels required to meet the three Tiers of Assessment Excellence for Northeast stock assessments (staffing increases by activity are summarized in **Table 2**).

Tier 1: Improve stock assessments using existing data

The intent of upgrading assessments of Tier 1 is to more fully utilize existing information, to upgrade the synthesis of available data and to provide information to users on a more timely basis. In order to meet Tier 1 requirements for Northeast stocks, additional FTEs are required primarily in data management and synthesis activities (**Table 2**). Data on species age and growth have been collected and archived, but not analyzed, for many stocks currently assessed in the "index level" category. A total of five additional FTEs in the Age and Growth activity will allow more complete biological data for assessments of some of these stocks. Additionally, this would enable more timely production of age data.

Improving Tier 1 assessments will also require additional staff to better archive and extract sea sampling information, and biological sampling data collected from commercial fisheries. Data management support is needed to maintain databases and improve access to a wider array of users. A modest increment in stock assessment and support staff is required to produce more frequent and improved assessments under this tier.

Tier 2: Elevate stock assessments to new national standards

The major increment in FTEs required under the stock assessment improvement plan occurs when moving to Tier 2 requirements to upgrade assessments for core species to at least Level 3 and for providing adequate baseline assessments for all managed species. In order to meet these

requirements, there needs to be major improvements in the quality and timeliness of commercial and recreational fisheries data and required biological sampling. Currently, biological sampling of catches is concentrated on a few core stocks, and sampling levels are barely adequate in many other cases. Improvements in the collection, management, and synthesis of fishery dependent data are needed. Ageing structures are not currently collected from recreational catches and this needs to be rectified. Likewise there is no universal sea sampling program providing routine estimates of discards and bycatch from the region's fisheries, and this needs to be improved. Increased biological sampling under these programs will require the processing of greater numbers of ageing structures, and data entry and manipulation. For some stocks not currently indexed by research vessel survey programs (e.g. tilefish, deep water fisheries and components too deep for surveying in current programs) additional types of fishery-independent data are required and will need to be developed. Additional stock assessment scientists are required to produce higher quality and more frequent assessments called for under this requirement.

Tier 3: Next generation assessments

Next generation assessments are intended to provide more explicit accounting for biological and technological interactions, longer-range predictions and integration of biological and environmental data. A major component of these assessments will be the incorporation of feeding data into routine stock assessments and modeling and spatial dynamic models and data to examine the fine-scale implications of alternative management strategies. In order to support such requirements, additional data collections for biological analyses (e.g. stomach sampling) are required, as well as fishery oceanographic data bases, geographical information systems, and data management necessary to support these activities.

Southeast Fisheries Science Center

The fisheries under the research jurisdiction of the Southeast Fisheries Science Center are diverse in both the species being exploited and the fishing sectors prosecuting these fisheries, including large recreational sectors and bycatch sectors, as well as commercial fisheries. In some fisheries, 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 result in unique research and management requirements.

SEFSC current situation

The Southeast Fisheries Science Center has unique resource requirements to achieve each of the three Tiers of Assessment Excellence. This results largely from the diversity of fishery resources occurring within the Region. Current stock assessment efforts have focused on a small number of core species (those of greatest public interest and often of greatest political importance due to conflict between constituents). Thus, detailed assessments are conducted on 10-15 stocks, annually. However, there are a large number of stocks upon which little assessment work is done other than to monitor catches. The catches of any individual one of these unassessed stocks is often small and of small socioeconomic significance; however, in aggregate they are an important part of the fisheries economic sector and fishing communities.

Fisheries of the southeast are managed by the South Atlantic Fishery Management Council, the Gulf of Mexico Fishery Management Council and the Caribbean Fishery Management Council through fishery management plans on shrimp, reeffish, snapper-grouper, spiny lobsters, coastal pelagics, red drum, stone crabs, corals and others. The number of FMPs requiring stock assessment data is increasing. Data collection in support of assessment of these species comes through the SEFSC efforts and through joint agreements with the individual states (plus Puerto Rico and the U.S. Virgin Islands) and with the Atlantic and Gulf States Marine Fisheries Commissions. Additionally, since the recreational sector is large in many fisheries (in some cases larger than the commercial sector), several joint agreements have been made to obtain recreational catch data from various survey mechanisms.

A major issue that impacts stock assessments in the southeast United States is bycatch, particularly discarded bycatch resulting from Gulf of Mexico shrimp trawlers. The mortality resulting from this activity impacts stocks of fish for which there are directed fisheries, therefore limiting the production from those fisheries. There are also major concerns with the impacts of gill-net fisheries on marine mammals, and hook and release mortality in the substantial recreational fisheries that exist in the region. Incorporating bycatch estimates into stock assessments requires a new level of commitment to data collection through observer programs. Initial *ad hoc* projects have been conducted to obtain estimates of bycatch, but the precision is lacking.

The Southeast Fisheries Science Center has the responsibility for providing the United States scientific support for assessing stocks of Atlantic tunas, swordfish and billfish in conjunction with the International Commission for the Conservation of Atlantic Tunas (ICCAT) of which the United States is a signatory nation. Assessments of the tuna, swordfish and billfish stocks are conducted jointly with scientists from various nations. The Southeast Fisheries Science Center has the responsibility for monitoring catch and scientific data from throughout the U.S. Atlantic coast and report these to ICCAT. The U.S. scientists, also, take a lead role in the joint assessment working groups within ICCAT's scientific committee.

SEFSC programs and staffing required to meet the three tiers of excellence

Tier 1: Improve stock assessments using existing data

The first Tier of Assessment Excellence is a goal of improving assessments with existing data for both core stocks and those stocks whose status is largely unknown. The core stocks for which detailed assessments are currently being conducted can be improved, even with existing data. Improvements can be achieved largely through more comprehensive characterization of the uncertainty associated with various management parameters arising from the assessment. Characterizing the uncertainty requires stochastic modeling activities which are time consuming both in their development and in the actual running of the models. Uncertainty characterization also requires extended interaction with managers and constituents in order to appropriately formulate the statistical questions.

The first Tier can be achieved for the "non-core" stocks by developing and organizing the data bases necessary for first pass assessments for these species. This will require statistical determinations of catch by size and other relevant strata, the collation of biological data and the analysis of appropriate survey and catch-effort trend data. In many cases some data exist within Federal, State and academic institute data bases on each of these aspects. But it remains to integrate the information and make "first-pass"assessments. These initial assessments are important for management, as they will allow initial overfishing/overfished determinations to be made; additionally, the results will be extremely useful in guiding further scientific prioritization of data collection activities for these stocks. Due to the large number of these stocks within the purview of the SEFSC, this will require increased monitoring by assessment scientists.

Tier 2: Elevate stock assessments to new national standards

The second Tier of Assessment Excellence expresses the goal of upgrading assessments of core species to a level in which dynamic changes in stock abundance are estimated and monitored over time; and that there should be a baseline monitoring of all managed species. To achieve this Tier, expanded data collection activities and extensive monitoring activities by assessment scientists will be required. Of particular importance is the need for fisheries-independent data. As noted above, catches for many stocks are relatively small; therefore, assessments with adequate levels of precision will require monitoring of appropriate abundance indices. SEFSC scientists indicate the high importance of developing fishery-independent indices within their responses to the questionnaire (**Section IV (A)**). The scientists' responses also placed emphasis on observer programs to address important issues of bycatch, discards, collection of biological data, and collection of better effort data. Thus, Tier 2 efforts should focus on developing and improving data collection mechanisms. Fishery independent efforts require extended ship time which is addressed in other initiatives. However, improvements will require more than simply conducting more trawl surveys. Extensive research is needed to explore avenues for monitoring stocks and life stages of stocks that are not conducive to trawl surveys; for example, mackerels and other coastal pelagics; billfishes and tunas; and reef dwelling species. This will require creative interaction between assessment scientists, survey statisticians, ecologists and gear-specialists in order to design appropriate survey strategies. Additionally, second Tier goals will also require improved characterization of bycatch, discards and other fisheries and biological data. Observer programs are essential for these activities. Management of statistically useful observer programs will require the close cooperation of biologists, assessment scientists, data managers and program management with the constituents.

Tier 3: Next generation assessments

The third Tier of Assessment Excellence expresses a goal of having minimal assessment levels (dynamic monitoring of abundance - production modeling) for ALL stocks with all core stocks being addressed by size, age, sex-structured assessments with possible inclusion of ecosystem factors. As noted above, the diversity of fishery stocks under SEFSC purview indicates the importance of ecosystem considerations. What effect are major ecosystem perturbations such as bycatch or environmental changes likely to have on species distributions? Can species shifts be predicted even in a probabilistic sense? Can management strategies be devised to avoid chances of deleterious

socioeconomic consequences of species shifts? Can management strategies be devised to achieve short term local objectives of the fishers? These questions pose important research goals. Steps to achieve these goals require extensive research, monitoring and data collection activities. In particular, spatial and temporal scales of data collection will need to be improved. This will require finer scale information on catches, survey abundances and oceanographic variability. Additionally, the monitoring of a large number of stocks (the components of the ecosystem) is needed to discern patterns of variability.

Specific resource requirements are outlined in **Table 3**. Note that resource requirements are additive; i.e., requirements for Tier 2 are additive to those in Tier 1.

Southwest Fisheries Science Center

The NOAA Fisheries Southwest Fisheries Science Center's area of responsibility encompasses a vast expanse of open ocean and international waters, including the coastal waters of California, parts of the Antarctic, and the Hawaiian Islands, and the U.S. Territories of Guam and American Samoa. The SWFSC is responsible for the research and management of some of the nation's most intriguing species, and is a major force in the nation's effort to build international cooperation for the stewardship of these species. Research extends over an area of more than 64.2 million square miles of open ocean – greater than 18 times the size of the U.S. land mass – including 1.8 million square miles of EEZ. The Southwest Region is home to over 72 protected marine species, and 153 fishery stocks, of which the status of 101 remains unknown. In addition to the complexity of the marine ecosystems in this region, the international and domestic mix of culturally diverse fishing communities present complex challenges for managing species, conducting research, and collecting data necessary to ensure sustainable fishing practices. The collective value of tuna, swordfish, sharks, and billfish from U.S. Pacific water fisheries exceeds $1.5 billion annually. Near shore

Table 3.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for the Southeast Fisheries Science Center. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*
Commercial Catch & Biological Sampling	10	2	15		2	**2**	3
Recreational Catch & Biological Sampling	10	3	25		2	**2**	3
Observer Programs	4	10	4		22	**22**	11
Fishery-independent Surveys	8	7			2	**2**	6
Process Biological Samples (age, growth, maturity, etc.)	15	7		1	3	**4**	5
Data Management & Preprocessing of Data	9	1		7	4	**11**	1
Conduct Assessments	8		2	4	3	**7**	3
Assessment Methods Research	1			1	2	**3**	6
Communication of Results & Follow-up Evaluations	6			1	2	**3**	1
Subtotal (Assessment scientists)	***15***	***0***	***2***	***6***	***7***	***13***	***10***
Subtotal (0thers)	***56***	***30***	***44***	***8***	***35***	***43***	***29***
Total	**71**	**30**	**46**	**14**	**42**	**56**	**39**

Note that the above table specifies the labor resources (FTEs) needed to address the three Tiers of Assessment Excellence for stock assessment responsibilities. The labor resources have an associated cost which is not addressed in the table. However, in addition to the labor costs there will be additional resources needed to conduct experiments to achieve Tiers 2 and 3. Vessel time on research vessels will, of course, be important, but this is discussed elsewhere. Activities which would likely be prominent in achieving Tiers 2 and 3 are archival tag experiments, stock identification sampling (mtDNA and microconstituents) and other activities.

landings of sardines, mackerel, tuna, rockfish, and flatfish in California and Hawaii totaled 370 million pounds in 1998 and were valued at $173 million. During the same year, aquaculture in the Southwest Region produced 30 million pounds of fish and shellfish worth $55.6 million to growers. From the recreational perspective, a quarter of a million saltwater anglers, 40 annual fishing tournaments, and prized game fish like marlin, tuna, wahoo, and mahimahi place Hawaii among the top 10 states adding significantly to the economy from sport fishing. California, with over a million recreational anglers, ranked second in the U.S. catching about 23 million pounds of fish.

The SWFSC supports two fishery management councils. The Western Pacific Fishery Management Council (WPFMC), located in Honolulu, Hawaii, manages the insular resources in the central and western Pacific. The Pacific Fishery Management Council (PFMC), located in Portland, Oregon, manages fishery resources along the U.S. west coast. Both councils manage highly migratory species.

SWFSC current situation – central and western Pacific

The SWFSC has assessment responsibility for 56 species listed in the FMPs under the jurisdiction of the WPFMC. In terms of domestic and international market value, "core" species include the large pelagic fishes (tunas and billfish), and in terms of political interest blue sharks are added to the list. These species readily migrate far beyond the U.S. EEZ and into waters where they may be caught by fleets of other countries. Assessments of these stocks cannot be based solely on catch data within U.S. territorial waters from U.S. domestic fleets. Stock assessment work must be conducted in an international context, taking account of all catches that affect the population being assessed. The two Atlantic coast science centers face a prospect somewhat similar to the SWFSC in this respect, although assessment-related procedures in the Atlantic have long been defined by participation in well-established international agencies, such as ICCAT, that orchestrate collection of data and workshops involving scientists from member countries who conduct comprehensive stock assessments. To date there are no comparable fishery management agencies in the temperate and tropical Pacific beyond that covered by the Inter-American Tropical Tuna Commission (IATTC) in the eastern tropical Pacific.

In the absence of such management agencies in the central and western Pacific, it has been necessary for SWFSC scientists to forge their own cooperative arrangements with fishery scientists in other parts of that region. This takes considerable time and effort. Various international cooperative arrangements have operated on a relatively informal basis for the purpose of assembling fishery data from disparate sources and conducting stock assessments. Foremost of late is the Standing Committee on Tunas and Billfish (SCTB) of the Secretariat of the Pacific Community (SPC) which for core tuna species has been fostering fishery data collection and high level stock assessments, with the participation of an international cadre of fishery scientists.

In the past few years, two prongs of diplomatic effort have been undertaken in the Pacific to formalize comprehensive, international management agencies for the region or a portion thereof. One, the Interim Scientific Committee (ISC), has met several times and established several subcommittees to promote assessment of various species and to establish a comprehensive fishery data base. The other effort, dubbed the Multilateral High Level Conference (MHLC), has met five times, is considerably more comprehensive in its membership than the ISC, and has the ambitious goal of establishing a fishery monitoring and management agency by June 2000.

At present, for most of the major fleets harvesting tuna species in the central and western Pacific (including U.S. fleets), catch and effort data are available to NMFS (or other) scientists for the purpose of conducting stock assessments thanks to the work of the SCTB and similar informal cooperative arrangements. The resolution in time and space is not always as fine as desired and there are some holes in the data, particularly catch at size data. Fortunately, good tag return data exist for the four major tuna species (skipjack, yellowfin, bigeye, and albacore) which in conjunction with the fishery data have enabled the high level stock assessments mentioned above. However, as sophisticated as the assessments have been, they have not had the benefit of regular survey data or other types of fishery independent abundance indices because no regular scientific surveys are conducted for pelagic fisheries in the region. Though scientific observer coverage has been very poor, it is improving with the observer requirements of the South Pacific Forum Fisheries Agency (FFA). Observer coverage on U.S. purse seine vessels in the region is 23%, and coverage of the Hawaii longline fleet is less than 5%.

For domestic insular fisheries for demersal fishes and crustaceans, the data coverage is mixed. Regular abundance index surveys for lobsters have been conducted in conjunction with release of tagged lobsters. In addition, there has been occasional observer coverage of the lobster fleet. Commercial catch/effort data for demersal fish are collected by the state of Hawaii, but data for significant amounts of "recreational" catch (much of it sold at roadside stands) are not collected.

The Honolulu Laboratory has seven stock assessment scientists, including those involved in conducting assessments, methods research, and follow-up activities such as input to plan development, for the 56 species in the WPFMC FMPs. These scientists are additionally charged with investigating the magnitude and gravity of interactions between domestic fisheries and protected species of turtles and sea birds. Assessment duties for tunas, blue marlin, swordfish, and blue shark are shared with scientists from other countries and agencies around the region, but many of the other pelagic species are neglected through necessity.

SWFSC current situation – west coast

The SWFSC has assessment responsibilities for four FMPs under the jurisdiction of the Pacific Fishery Management Council (PFMC). Under the Groundfish FMP, the SWFSC shares assessment responsibilities with the NWFSC. The SWFSC produces the assessments and the NWFSC provides data collection and overall coordination for 82 groundfish species, including over 40 species of rockfish distributed from Southern California to Canada. Only 26 of the 82 groundfish species have been assessed, and almost none from central California southward. Five species have been quantitatively assessed as overfished. This has caused a crisis due to severely reduced catch allocations. Many unassessed species are thought to be overfished as well, and there is at least one case where an unassessed stock may be threatened or endangered.

Under the Salmon FMP, the SWFSC has sole responsibility for assessing and developing recovery plans for 10 endangered salmon and steelhead runs from California affecting three species.

Under the Coastal Pelagics FMP, the SWFSC has sole responsibility for assessing sardine, Pacific and jack mackerel, northern anchovy, and market squid. This is done in cooperation with the State of California on an annual basis.

Under the Highly Migratory Species FMP currently being developed, the SWFSC will have sole responsibility for assessing six tuna and billfish species caught by fisheries originating from the U.S. west coast. This will be done using the same agreements and mechanisms described

Table 4.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for the Southwest Fisheries Science Center. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*
Commercial Catch & Biological Sampling	1	6	5		4	**4**	2
Recreational Catch & Biological Sampling			2		2	**2**	1
Observer Programs	7				7	**7**	7
Fishery-independent Surveys	8	1	2		11	**11**	9
Process Biological Samples (age, growth, maturity, etc.)	21	2	2	6	11	**17**	14
Data Management & Preprocessing of Data	19	6	3	8	10	**18**	15
Conduct Assessments	12		10+*	6	8	**14**	10
Assessment Methods Research	3		2	2	3	**5**	5
Communication of Results & Follow-up Evaluations	9			5	4	**9**	3
Subtotal (Assessment scientists)	***24***	***0***	***12+***	***13***	***15***	***28***	***18***
Subtotal (0thers)	***56***	***15***	***14***	***14***	***45***	***59***	***48***
Total	**80**	**15**	**26+**	**27**	**60**	**87**	**66**

* A loosely determined number of collaborating assessment scientists at SPC, CSIRO, NRIFSF and elsewhere.

above in the section on central and western Pacific and will include Mexico. Additionally, this FMP will include four pelagic shark species. None of these have been assessed. The complexities of coordinating international assessments are similar to those discussed for the central and western Pacific.

The SWFSC is currently assessing the white abalone population which has been petitioned to be listed as endangered under the Endangered Species Act. This species needs to be assessed throughout its range, which requires cooperation with Mexico.

The California recreational fishery bridges FMPs and complicates management, research and assessment efforts. This fishery is composed of both commercial passenger fishing vessels and private fishers and generates effort in millions of days annually. It targets many of the same species as commercial fleets, and is highly significant economically.

SWFSC programs and staffing required to meet the three tiers of excellence

The SWFSC currently has 24 assessment scientists with a total of 80 staff in the assessment processes (**Table 4**). The SWFSC is aided in commercial catch, recreational catch and biological sampling by various state agencies which independently or by contract conduct sampling. The jump to Tier 1 requires a large increase in stock assessment scientists, necessitated by the current low staffing of assessment personnel at the SWFSC. Movement to Tiers 2 and 3 is highlighted by the need for increases in methods research along with additional assessment capacity.

Tier 1: Improve stock assessments using existing data

Moving to the first Tier of Assessment Excellence, improving assessments with existing data, could be readily achieved by additional SWFSC scientists for many species. Current data collections, including indices of abundance and key biological data exist with various sources – state, federal, and international – and could be prepared for assessment use in relatively short order. In the Southwest Region, considerable numbers of species have not yet been assessed or have been inadequately assessed. These include some high profile species currently fished such as striped and blue marlins, all of the pelagic sharks caught in the Pacific coast HMS fisheries, and several tuna species such as skipjack and bigeye tunas. The rockfishes in central and southern California have large numbers of unassessed species including some mainstays of the recreational fishery such as Pacific bonito, vermillion rockfish and black abalone which are expected to be declared overfished once Tier 1 assessment are completed, or, as in the case of the white abalone move directly from unassessed to endangered. The jump to Tier 1 requires appreciable increases in database managers and analysts to retrieve, audit and preprocess the data; biological technicians to process archived samples; and stock assessment scientists to conduct assessments, explore new methodologies appropriate to data-poor situations, and communicate the results (**Table 4**).

Tier 2: Elevate stock assessments to new national standards

Moving or upgrading assessments to Tier 2 where dynamic changes in stock abundance can be assessed and monitored for core species and all managed species are monitored will require expanded data collection as well as extensive monitoring by assessment scientists (**Table 4**). SWFSC scientists are engaged in developing advanced technology survey methodologies including, for example, ROV strip census, advanced acoustics, LIDAR strip census and integrated acoustic and net surveys for krill-sized organisms. These methods, as well as more established methods, will form the core for fishery-independent data monitoring. Considerable effort will be focused on providing the basic biological parameters needed to move assessments to age and size based methods from current Tier 1 efforts. Genetics will play an important role in developing early life stage indices from fishery-independent survey methods such as continuous underway egg and larval sampling for biomass, which was pioneered at the SWFSC. Coordination of creative interactions between the various stock assessment specialities will require careful management.

Tier 3: Next generation assessments

Tier 3 moves to the goal of providing basic assessments for all stocks with core stocks using age/size/sex structured methods and considering ecosystem effects. To reach this goal for core stocks, extended research to estimate key biological parameters will be needed. This will require substantially increased scientific effort (**Table 4**). The SWFSC at its Pacific Fisheries Environmental Laboratory is engaged in developing environmental data sets related to decadal climate shifts and shifts in ocean productivity, and researching methodologies for incorporating these effects into assessment models. Currently, SWFSC scientists have provided a management model to the Pacific Council which uses temperature as a forcing factor for determining harvest guidelines. Extension of these emerging methods for incorporating ecosystem effects will require interdisciplinary cooperation and facilitation between assessment scientists and other disciplines.

Northwest Fisheries Science Center

NWFSC current situation

The Northwest Fisheries Science Center has lead responsibility for assessment of west coast groundfish and evaluation of recovery options for Pacific salmon. The demands for accurate scientific investigations for both groups of species are high and increasing. Groundfish and salmon are managed according to Fishery Management Plans developed by the Pacific Fishery Management Council (PFMC). 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.

The status of Pacific salmon species on the west coast has been reviewed under provisions of the Endangered Species Act and 26 populations (Evolutionarily Significant Units) have been listed as threatened or endangered. A tremendous effort is being mounted by the NWFSC and the SWFSC to develop salmon recovery plans that incorporate all aspects of human and natural risks to salmon. Nearly all of the salmon escapement monitoring and run forecasting is based on in-river information and is done by the state and tribal agencies. These results are used by the Salmon Technical Team (STT) of the PFMC to develop harvest options for consideration by the PFMC. Because the assessments of salmon are primarily conducted by other agencies, and because the primary west coast salmon activity occurs under Protected Species, the salmon research and monitoring needs are not considered further in this document.

For groundfish, only 26 of the 82 species have ever been quantitatively assessed. Of these 26 species, several have experienced severe declines. Harvest rates, climate, and assessment precision all contributed to this decline. The default harvest rate during most of the 1990s (35% spawners per recruit), while conservative by global standards, was overly optimistic during what has become a 20-year regime of poor ocean productivity. The precision and frequency of stock assessments did not allow forecasting the magnitude or duration of the decline in recruitment until several stocks had already crossed into an overfished state. As of 2001, rebuilding plans are being developed for seven groundfish species. Even among the 26 assessed species, there are some for which there has not been sufficient information to adequately determine their status with respect to overfishing thresholds. There are concerns that others of the 60+ species with unknown status may be in danger of overfishing. Further, some populations of groundfish in Puget Sound have declined to such low levels that their status was reviewed in 2000 for potential listing under the ESA.

The majority of shoreside groundfish catch monitoring is done by the state agencies with coordination through the Pacific States Marine Fisheries Commission which maintains a centralized database of fisheries data (PacFIN). 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.

Passage of the MSFCMA strengthened 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 on low productivity for these species needs to be combined in a sound precautionary approach to managing these species. Rebuilding plans, which are expected to take more than 10 years, need to be developed and subsequently monitored for several of these long-lived species. All of these will be extraordinarily difficult given the lack of a dedicated research vessel for these resources and the low level of current resource survey efforts. Further, increased stock assessment effort will primarily tell us what is occurring to these species. Knowing what is only the first step. In order to develop a better understanding of why these 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.

NWFSC programs and staffing required to meet the three tiers of excellence

The great diversity of habitat, life history, and knowledge for west coast groundfish defies simple description of the data needs for improvement. The 82 species have a collective distribution which spans 1300 miles of coastline and from estuaries out to at least 1500 m bottom depth. Some species are schooling midwater, others are on the benthic continental slope, and others are associated with high-relief nearshore habitat. Species with the greatest accumulation of relevant stock assessment data tend to be those that have historically been targeted by the trawl fishery and are amenable to either trawl or hydroacoustic surveys. Species that have the greatest data needs tend to be those

that are associated with high relief habitat and are subject to growing commercial and recreational hook and line fisheries. Today, only 26 of the 82 groundfish species have ever been assessed, and many of these assessments have had insufficient data to allow adequate determination of the status of the species.

Tier 1: Improve stock assessments using existing data

Bringing all west coast groundfish species to a Tier 1 level will require additional stock assessment, data processing and ecological staff to make the best use of the limited existing data. Some groundfish assemblages have no fishery dependent or fishery independent index of abundance and limited biological sampling from the fisheries.

The Tier 1 focus of stock assessment modelers needs to be on developing a first-cut assessment for all species so that any overfishing can be identified and corrected. There are three general areas of improvements. One area will be in the development and application of relevant assessment methods for more of the species that do not have sufficient data to support current data-hungry quantitative assessment methods. This will require innovative use of stock assessment, biological and ecological data so that information from better known species can be used to develop proxies for poorly studied species. A second area of improvement is the development of assessment modeling protocols that better quantify and communicate the uncertainty in current assessments. Such improved models will structure implementation of a more formal precautionary approach to harvest management. A third area of improvement is in the spatial integration of fishery and survey databases, particularly through advances in linkage of fishery logbooks, landings data, and fishery biological samples.

Tier 2: Elevate stock assessments to new national standards

Medium-term improvements in major data sources can lead to substantial improvements in assessment precision within about 10 years. These include major programs such as periodic resource assessment surveys, more comprehensive fishery logbook programs and at-sea monitoring of total catch, collection of genetic stock structure data for more species, and evaluation of fish association with particular habitats. Beyond routine monitoring, survey effort also needs to be devoted to studies that will improve understanding of how environmental and other factors affect efforts to standardize surveys. Studies are needed to investigate bycatch mortality and gear impact studies. Many of these medium-term efforts are large scale and expensive, but have the greatest likelihood of significantly improving the accuracy of the assessments and our ability to conduct assessments for all assemblages of groundfish. Current efforts are far from meeting Tier 2 assessment needs because:

1. The NWFSC has no dedicated fishery research vessel to do standardized resource assessment surveys or other field research;

2. Surveys to assess most of the continental shelf rockfish and lingcod are conducted only triennially, yet several of these species are overfished and their rebuilding plan calls for a biennial assessment;

3. A small coastwide observer program to assess bycatch and total mortality of target species was not implemented until 2001, yet estimates of discard for some target species range up to 30%;

4. Fishery monitoring has historically focused on the trawl fleet. There are no fishery logbooks and insufficient fishery-dependent data for the hook&line fishery which accounts for the majority of many nearshore rockfish species catch. Further, there are few if any fishery-independent data from which to assess the status of these species.

Tier 3: Next generation assessments

Further improvements in assessments can be made by increasing the frequency and precision of fishery-independent surveys, and by increasing the number of species for which there is age composition data from the fishery and surveys. However, major improvements in our ability to forecast future stock conditions and to provide assurance of ecologically safe harvest strategies will require qualitatively different kinds of information. Among these longer term efforts are recruitment surveys that will directly forecast changes in fish abundance, climate studies to provide longer-term predictions of average recruitment levels, and ecosystem studies that will provide better understanding of the interactions among species and with their habitat. For west coast groundfish, recruitment surveys are particularly relevant for species such as whiting which have tremendous variation in recruitment and recruit to the fishery at a young age. With a recruitment survey, we can better adjust harvest levels to track these short-term natural fluctuations in abundance. Recruitment surveys are also relevant for the very long-lived species that have delayed recruitment to conventional surveys and the fishery. Here the recruitment surveys will provide advance notice of longer-term shifts in abundance

caused by shifts in average recruitment levels. Climate monitoring and fishery-oceanography investigations will help interpret these shifts in recruitment and further advance predictive capability. The result of these ecosystem studies will be a better assessment of the ecological impact of fishing, better understanding of the impact of factors such as the increased abundance of piscivorous pinnipeds, and potential adjustment of fishing strategies to obtain the best multispecies yields from the system.

Specific resource requirements for west coast groundfish are outlined in **Table 5**. The information labeled "current" in **Table 5** describes the situation in January 2000. A partial step towards meeting Tier 2 needs occurred in 2001 when the NWFSC received funding to establish a small west coast groundfish observer program and conduct coastwide trawl and hydroacoustic surveys.

Alaska Fisheries Science Center

The Alaska Fisheries Science Center is responsible for Gulf of Alaska, Bering Sea and Aleutian Island groundfish assessments. The Center conducts activities in support of these assessments that include fishery independent and fishery dependent data collection programs, and fisheries oceanographic studies. The Center is also responsible for conducting fishery independent surveys and research in support of Pacific salmon and Alaskan crab assessments.

Alaskan groundfish and crab are managed according to Fishery Management Plans developed by the North Pacific Fishery Management Council (NPFMC). For the Bering Sea / Aleutian Islands region, assessment scientists currently contribute to thirteen annual groundfish assessments: walleye pollock, Pacific cod, Atka mackerel, yellow-

Table 5.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for the Northwest Fisheries Science Center. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*
Commercial Catch & Biological Sampling			20		6	**6**	
Recreational Catch & Biological Sampling			7		6	**6**	
Observer Programs		25#			31*	**31***	12*
Fishery-independent Surveys	7	2			11	**11**	10
Process Biological Samples (age, growth, maturity, etc.)		3	5	1	5	**6**	8
Data Management & Preprocessing of Data	2	1	19	5	4	**9**	2
Conduct Assessments	6		5	4	4	**8**	4
Assessment Methods Research		1		1	2	**3**	2
Communication of Results & Follow-up Evaluations	3	1	3	2	5	**7**	1
Subtotal (Assessment scientists)	***9***	***2***	***8***	***7***	***11***	***18***	***7***
Subtotal (0thers)	***9***	***31***	***51***	***6***	***63***	***69***	***32***
Total	**18**	**33**	**59**	**13**	**74**	**87**	**39**

1. This table is limited to resources devoted to stock assessment of groundfish and other marine fish. Significant additional NMFS and state resources are devoted to work on salmonids.
2. "Partner" column contains minimum PSMFC and WA, OR, CA personnel working on groundfish. Many of these are supported through federal grants, including PacFIN.
3. The in house staff column represents the total number of positions as of January 2000. New funding in FY2001 is allowing development of an observer program and expansion in survey and assessment programs. Approximately 15-20 Tier 1+2 positions will be filled.
includes 25 observers and infrastructure hired in FY 2001
* excludes 25 observers hired in FY 2001; includes a proposed additional 30 contract observers (20 in Tier 2 and 10 in Tier 3)

fin sole, Greenland turbot, arrowtooth flounder, rock sole, flathead sole, other flatfish, Pacific ocean perch, other rockfish, sablefish and squid and other species. For the Gulf of Alaska region, 11 assessments are produced annually: walleye pollock, Pacific cod, Atka mackerel, thornyhead, slope rockfish, pelagic shelf rockfish, demersal shelf rockfish, arrowtooth flounder, other flatfish, sablefish and other species. AFSC staff assist in the development and review of stock assessments for Bering Sea crab stocks. Staff represent the Center on numerous technical and decision making boards including the NPFMC Groundfish Plan Teams and Scientific and Statistical Committee, the North Pacific Anadromous Commission, the North Pacific Halibut Commission, and international technical committees dealing with trans-boundary stocks such as Pacific hake and Bering Sea pollock.

Bycatch limits for several species have been imposed to ensure that individual species quotas are not exceeded. Species that are designated as prohibited species include Alaskan crab (e.g. Tanner crab, blue and red king crab and snow crab), Pacific halibut, and some stocks of Pacific salmon (chinook, pink, sockeye, chum, coho and steelhead). Retention for sale of prohibited species is prohibited to dissuade any targeting by groundfish fishers. Gulf of Alaska and Bering Sea Aleutian Islands groundfish fisheries also have some bycatch and discard of unmarketable species and small sized fish that is typical of any multispecies fishery. There is some discard of marketable fish caused by the NPFMC management system for the groundfish fishery. When bycatch limits are exceeded for a species, the species can no longer be retained to discourage further catch of this species.

In-season catch composition is monitored by a major fishery-dependent data collection program. Catch is monitored by an observer program and shoreside data collection. Roughly 30,000 observer days (equivalent to 114 FTEs) are expended annually to collect data from the North Pacific groundfish fishery. All vessels capable of hosting an observer may be required to do so at the vessel's expense. As currently implemented, vessels over 125 feet length overall (LOA) are required to have an observer on board at all times when ground-fishing, vessels of 60 to 124 feet LOA are required to have observers on-board 30% of the time, and vessels under 60 feet LOA are generally exempt from the requirements for observer coverage. Most of the fishing vessels operating in the Bering Sea and Aleutian Islands exceed the 125 foot limit, while most of the fishing vessels in the Gulf of Alaska are smaller than 125 feet. The recreational harvest of groundfish in Alaskan waters is a minor component of the total catch. Observers collect biological data such as otoliths, length frequencies, stomach samples and maturity stage for a variety of species.

Conducting fishery independent surveys in Alaskan waters requires a major investment of shiptime and personnel. The continental shelves off Alaska make up about 74% of the total area (2,900,785 km^2) of the United States continental shelf. The region is marked by adverse seasonal conditions that necessitate sophisticated equipment to ensure the safety of the crew and the accomplishment of the survey mission.

AFSC stock assessment scientists conduct research to improve the precision of their assessments, and provide technical support for the evaluation of potential impacts of proposed fishery management measures. Research activities are designed to improve the quality of stock assessments and to expand the scope of assessments to quantify the ecological impact of fishing on the Gulf of Alaska and Bering Sea ecosystems. Stock assessment scientists often serve a dual role acting as the scientific interface between the Alaska Fisheries Science Center and the North Pacific Fishery Management Council (NPFMC).

Numerous laws govern the implementation of fisheries in federal waters. AFSC staff often conduct research to evaluate the impact of fishing to comply with these legal requirements. The MSFCMA directs NMFS stock assessment scientists to provide annual status evaluations for all species managed under the NPFMC FMPs. AFSC stock assessment scientists also provide analytic assistance on many current fisheries management issues such as research activities leading to implementation of precautionary resource management, consultations and Biological Opinions regarding protected resources, and NEPA impact analyses regarding the effects of fishing on the marine environment.

The National Standard Guidelines for overfishing state that "If environmental changes affect the long-term productive capacity of the stock or stock complex, one or more components of the status determination criteria must be re-specified." This requirement necessitates new research on the mechanisms underlying shifts in production. Studies have demonstrated that several groundfish, crab and salmon stocks exhibit shifts in production that show marked similarity to the time scales of distant atmospheric forcing phenomena such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation. To determine whether shifts are due to human actions or environmentally induced shifts in the productive capacity of a stock or stock complex requires new research to investigate the mechanisms underlying the apparent response of key species to decadal scale changes in ocean climate.

Several species protected under the provisions of the Endangered Species Act are present in the region. Among

these, the western stock of Steller sea lion has been listed as endangered. A tremendous effort is being mounted by AFSC and the North Pacific Regional Office to develop a Steller sea lion recovery plan that incorporates all aspects of human and natural risks to this marine mammal population. Principal prey items in the sea lion diet include Atka mackerel, Pacific cod, and walleye pollock. These species are also targets of large commercial fisheries. Efforts are underway to explore methods to reduce the potential for competition between commercial fisheries and Steller sea lions at crucial times of the year.

Court challenges underscore the demands on AFSC staff to conduct new research surveys, process oriented research, and assessment activities to improve our understanding of the mechanisms underlying recent declines in the Steller sea lion population and the potential role of commercial fishing in limiting its recovery. These decisions also underscore the need for additional staff to evaluate management alternatives to provide reasonable and prudent alternatives to current fishing practices.

AFSC current situation – Gulf of Alaska groundfish

Among the 100 groundfish species covered by the GOA FMP of the NPFMC, 67 are assessed at a Level 1 or better (**Appendix 1**). These species have been the targets of fishery monitoring and resource survey programs that provide the basic information for quantitative stock assessments. Not all these assessments have the same level of information and precision. Of the 67 assessed species, only 8 are assessed using staged base models (Level 4 or above). In the case of 91 of the 100 species covered by the FMP, there is insufficient information to determine whether or not the stocks are overfished or approaching an overfished condition. Some of these species are targets of developing fisheries.

The 100 groundfish species can be roughly broken into four assemblages based upon their adult habitat and co-occurrence in the fishery. This breakout will facilitate discussion of fishery monitoring and resource survey programs:

1. Midwater schooling- Walleye pollock, eulachon and squid are amenable to acoustic survey methods. Walleye pollock supports a midwater trawl fishery with annual catch near 100,000 mt.

2. Deep slope (mostly trawlable habitat on shelf break and continental slope extending out to about 1500m bottom depth) includes primarily sablefish, dover sole, shortraker and rougheye rockfish, shortspine thornyheads, longspine thornyheads, Pacific grenadier. This assemblage supports a valuable trawl fishery, plus sablefish is a target of pot and hook&line fishers.

3. Demersal Shelf (mostly trawl caught species on continental shelf and upper slope, but many species occur over rocky habitat and some species have significant off-bottom tendencies). This assemblage includes rockfish species, flatfish, Atka mackerel and Pacific cod. The fishery is trawl for most species; however, Pacific cod is taken by hook&line and pot gear.

4. Pelagic shelf rockfish (mostly in high relief habitat) includes several of rockfish species.

AFSC current situation – Bering Sea / Aleutian Islands (BSAI)

Among the 145 groundfish species covered by the BSAI FMP of the NPFMC, 133 are assessed at a Level 1 or better (**Appendix 1**). These species exhibit great diversity in life history traits. Many have been the targets of fishery monitoring and resource survey programs that provide the basic information for quantitative stock assessments. Not all these assessments have the same level of information and precision. Of the 133 assessed species, only 15 are assessed using staged base models (Level 4 or above). In the case of 128 of the 145 species covered by the FMP, there is insufficient information to determine whether or not the stocks are overfished or approaching an overfished condition. Some of these species are the target of developing fisheries.

The 145 groundfish species can be roughly broken into four assemblages based upon their adult habitat and co-occurrence in the fishery. This breakout will facilitate discussion of fishery monitoring and resource survey programs:

1. Midwater schooling- Walleye pollock, eulachon and squid are amenable to acoustic survey methods. Walleye pollock supports a midwater trawl fishery with annual catch near 1,000,000 mt.

2. Deep slope (mostly trawlable habitat on shelf break and continental slope extending out to about 1500m bottom depth) includes primarily sablefish, Greenland turbot, shortraker and rougheye rockfish, and shortspine thornyheads. This assemblage supports a valuable trawl fishery, plus sablefish is a target of pot and hook&line fishers.

3. Demersal Shelf (mostly trawl caught species on continental shelf and upper slope, but many species occur over rocky habitat and some species have significant off-bottom tendencies). This assemblage includes rockfish, flat-

fish, Atka mackerel, crab and Pacific cod. The fishery for this assemblage is primarily trawl for most species however, Pacific cod are taken by hook&line and pot gear, and crab are taken with pot gear.

4. Pelagic shelf rockfish (mostly in high relief habitat) includes several of rockfish species.

Three crab stocks are currently listed as overfished: Bering Sea Tanner crab, Bering Sea snow crab and Saint Mathews Island Blue King Crab. Rebuilding plans need to be developed and subsequently monitored for these crab stocks. Building such plans will be difficult given the lack of life history and stage based information for these resources. Increased stock assessment effort will primarily elucidate the underlying factors contributing to recent declines in production.

AFSC programs and staffing required to meet the three tiers of excellence

Tier 1: Improve stock assessments using existing data

Bringing all Alaskan groundfish and crab species to a Tier 1 level will require additional stock assessment, data processing and ecological staff to make the best use of existing data. New personnel identified under Tier 1 (**Table 6**) would utilize existing fishery dependent and fishery independent data to facilitate the development of assessments for several new species and to improve existing assessments to the extent possible. To accomplish the first part of this objective, additional staff are needed to construct assessments for species where historical data is spotty or uncertain. AFSC scientists are exploring modeling approaches that draw on life history information from similar species to parameterize first generation assessments for poorly studied species. Additional assessment scien-

Table 6.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for the Alaska Fisheries Science Center. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*
Commercial Catch & Biological Sampling *			6				
Recreational Catch & Biological Sampling +							
Observer Programs	20	114			21	**21**	10
Fishery-independent Surveys	63.5	1	27		19	**19**	10
Process Biological Samples (age, growth, maturity, etc.)	21	3	7	7	8	**15**	21
Data Management & Preprocessing of Data	24.5	3	3	6		**6**	1
Conduct Assessments	10		3	10	10	**20**	2
Assessment Methods Research	8	1	3	3	3	**6**	4
Communication of Results & Follow-up Evaluations	7		5	5	5	**10**	3
Subtotal (Assessment scientists)	***25***	***1***	***11***	***18***	***18***	***36***	***9***
Subtotal (0thers)	***129***	***121***	***43***	***13***	***48***	***61***	***42***
Total	**154**	**122**	**54**	**31**	**66**	**97**	**51**

* Observer program includes shore-side samplers.
+ Recreational data not applicable.

tists could assist in developing overfishing criteria when information regarding the status of the stock is missing or intermittent. Assessment scientists and statisticians are needed to assist in reviewing the sampling design of proposed or existing fishery independent and fishery dependent sampling programs. This research effort would require a retrospective analysis of existing data to evaluate the efficiency of the current data collection program and to make recommendations for improvements in sampling design. Additional analytical staff could conduct research to better quantify and communicate the uncertainty in current assessments. Improved models will structure implementation of a more formal precautionary approach to harvest management. A final area of improvement is in the development of assessment models that fully utilize existing information on top down (predator/prey) influences on time trends in natural mortality, and bottom up on marine survival at early life stages in spatially explicit modes. AFSC is well positioned to advance this type of state-of-the-art stock assessment. The combination of a long history of data collection on the food habits of groundfish in the Eastern Bering Sea and Gulf of Alaska make the development of models that model top down forcing a realistic goal. Likewise, the long history of fisheries oceanographic process oriented research supported by the Fisheries Oceanography Coordinated Investigations provides the necessary knowledge of lower trophic level forcing required to implement a fully coupled model.

Tier 2: Elevate stock assessments to new national standards

Medium-term improvements in major data sources can lead to substantial improvements in assessment precision within about 10 years. These include major programs such as periodic resource assessment surveys, expanding and improving at-sea monitoring of total catch, collection of genetic stock structure data for more species, and evaluation of fish association with particular habitats. Beyond routine monitoring, research should be devoted to studies of factors that may influence survey standardization, and development of cost-effective survey technologies that are not susceptible to environmental influences on standardization.

Additional staff would be required to achieve a Tier 2 level of analysis for BSAI and GOA groundfish. Tier 2 envisions that assessments of core species would be upgraded at least Level 3 and would provide adequate baseline assessments for all managed species. Fishery dependent and fishery independent data collection are needed to achieve Tier 2. These staff members would be responsible for compiling and analyzing data for species currently managed as species groups (e.g. other flatfish, other rockfish and other species).

GOA assessment needs to achieve Tier 2

In the current implementation of the observer program, observers monitor catch and collect biological information on 70 of the 100 groundfish species in the Gulf of Alaska. Several minor species are classified into general categories. Skates are almost always recorded as "skate unidentified," with very few exceptions between 1990-1998. In the Gulf of Alaska, at least 80% of the recorded sculpin catch by year is recorded as "sculpin unidentified," with the remainder of the catch identified to the genus level. Only small amounts (<2%) of the sculpin catch each year were identified to species. Likewise, octopus and squid are generally not identified to species in the observer database. Octopus can only be recorded as "octopus unidentified," or "pelagic octopus unidentified." Eulachon and capelin are recorded to species more often than sculpins but in 1998, approximately 80% of their catch was recorded as "smelt unidentified." Monitoring the catch of these minor species would require additional staff to train and implement an expanded observer program.

Groundfish populations are routinely monitored by fishery independent surveys. A longline survey is conducted annually for sablefish. A gulf-wide trawl survey of the shelf areas of the Gulf of Alaska has been conducted on a triennial basis since 1984. Current operating plans call for future surveys to occur on a biennial basis. An acoustic survey of a major spawning concentration of walleye pollock in Shelikof Strait is conducted on an annual basis. These surveys provide a calibrated abundance measure (Level 2 or above) for only 4 species (**Appendix 1**). These surveys provide an index of abundance for 83 species (**Appendix 1**). To achieve Tier 2 level analysis additional effort should be devoted to obtaining and analyzing the life history of characteristics of species captured in the longline or trawl surveys (e.g. regional differences in growth, maturity, and habitat association).

For species such as small soft-bottom roundfishes (sculpins, poachers, eelpouts, and skates) the existing time series of trawl survey data is inconsistent because of differing levels of species identification. Starting in 1999 this problem was nearly eliminated because all survey vessels had new species identification guides that included photos of all known species. Species identification has therefore been greatly increased with very little cost. An existing problem for these species in the GOA, however, is that they are likely to have very low catchability by the survey trawls and it is uncertain how well research vessel CPUE tracks stock size. Assessment of these species could be improved using auxiliary trawl experiments to measure escapement under the footrope.

Many species of rockfish are not well sampled because they occur in areas that are too rough to be sampled with our usual survey nets and, additionally, some species (e.g. Pacific Ocean perch, northern rockfish, and dusky rockfish) are extremely patchy and not likely to be well sampled in the present bottom trawl survey. Considerable work has been done in attempt to develop a rockfish specific survey, but the best approach has yet to be developed. To improve the survey assessment of rockfish we need more research on gear design and sampling techniques. Once the appropriate technique is developed, it will undoubtedly require a distinctly different survey design than is now used and could not be incorporated into the current normal survey operations. Additional work will be required to develop appropriate techniques for the semi-pelagic species.

Fishery independent collections of age, length frequency and size at maturity are obtained for the core species (about 20 species, mostly rockfish and slope species, split between GOA, AI, and EBS). Expanding the age collections to include the remaining species would require collecting otoliths for additional species on surveys and could be accomplished without a large increase in money or manpower. However, additional staff would be needed to conduct the age determinations. Obtaining size at maturity information would require a considerable increase in research cruises to collect species at a time that is close enough to spawning so that mature or recently spent fish are easily recognized. Most survey or research cruises at the AFSC are currently conducted in the summer, after most species have completed spawning. In addition, a sampling strategy must be worked out so that a sufficient number of small and immature fish are collected.

Acoustic-trawl surveys in Alaska conducted by the Resource Assessment and Conservation Ecology Division (RACE) focus on walleye pollock as a target species. All aspects of survey design (e.g. area, timing, sampling intensity, etc.) are devised to assess the distribution and abundance of pollock. Pollock is ideally suited for acoustic assessment due to its semi-demersal nature, widespread distribution, and tendency to form monospecific aggregations. During RACE acoustic-trawl surveys, other pelagic fish species are encountered in very low numbers. Existing acoustic data could provide some information on eulachon occurrence observed during the 1980-1998 winter-spring Shelikof Strait surveys. Expanding the current acoustic program to routinely monitor eulachon would require a significant effort, including both staff and vessel time. Additional trawling would be needed and extended tracklines may be necessary.

Application of an acoustic-trawl survey approach to other FMP species (e.g. rockfish, capelin, squid, etc.) has been successful under certain circumstances, but would require a substantial amount of work (e.g. literature reviews and feasibility studies) merely to make a good guess of the resources required. A significant amount of preliminary research would be necessary to simply estimate the staff and funding necessary to fund each project.

Bering Sea / Aleutian Islands assessment needs to achieve Tier 2

Bering Sea and Aleutian Island groundfish populations are routinely monitored by fishery independent surveys. A longline survey for sablefish is conducted in alternate years in either the Bering Sea or the Aleutian Islands. Groundfish trawl surveys of the Eastern Bering Sea shelf have been conducted on an annual basis since 1979. Groundfish trawl surveys are conducted on a triennial basis in the Aleutian Islands region. Current operating plans call for future surveys of the Aleutian Islands region on a biennial basis. Acoustic surveys of major spawning concentrations of walleye pollock near Bogoslof Island are conducted on an annual basis. An acoustic survey of walleye pollock on the Eastern Bering Sea shelf has been conducted on a triennial basis since 1979. These surveys provide a calibrated abundance measure (Level 2 or above) for 76 species (**Appendix 1**). These surveys provide an index of abundance (Level 1) for an additional 47 species (**Appendix 1**).

As in the case of the Gulf of Alaska, the existing time series of trawl survey data for species such as small soft-bottom roundfishes (sculpins, poachers, eelpouts, and skates) may provide inconsistent results because of differing levels of species identification. This problem has been addressed through the addition of new species identification guides which included photos of all known species. However, as in the GOA, it is likely that these species have very low catchability by the survey trawls in the Aleutian Islands region. Assessment of these species could be improved using auxiliary trawl experiments to measure escapement under the footrope.

Many species of rockfish are not well sampled by the Aleutian Island trawl survey because they occur in areas that are too rough to be sampled with our usual survey nets and, additionally, some species (e.g. Pacific Ocean perch and northern rockfish) are extremely patchy and not likely to be well sampled in the present bottom trawl surveys. Nevertheless, the current Aleutian Island trawl survey does provide an index of abundance for several rockfish species, and rockfish age data are collected during the surveys. Additional research is needed to design a calibrated survey for rockfish.

Staffing needs to expand fishery independent collections of age, length frequency and size at maturity were discussed in the section on GOA fishery independent surveys.

During Midwater Assessment and Conservation Engineering (MACE) acoustic-trawl surveys, other pelagic fish species are encountered in very low numbers. Existing acoustic data could provide some information on eulachon occurrence observed during the 1980-1998 winter-spring Bogoslof Island surveys. Expanding the current acoustic program to routinely monitor eulachon would require a significant effort - including both staff and vessel time. Additional trawling would be needed and extended tracklines may be necessary.

Tier 3: Next generation assessments

A substantial increase in stock assessment staff would be required to achieve a Tier 3 level of analysis for BSAI and GOA groundfish. Tier 3 assessments would account for both biological and technological interactions and integration of biological and environmental data that may lead to more reliable long-range predictions. To accomplish this goal necessitates the implementation of fisheries oceanographic research programs for a broad spectrum of species. At the current time AFSC primarily supports fisheries oceanographic research on walleye pollock. Likewise, additional staff would be required to provide information on potential trophic interactions between species. Assessment scientists would be required to develop a broader spectrum of assessment modeling tools to address the complex interactions envisioned under Tier 3. In addition to the complex modeling activities envisioned for core species, additional stock assessment scientists would be required to conduct basic assessment functions for all species covered by the FMP.

E. Summary: National Resource Requirements

Current FTEs and FTEs required to achieve the objectives of the three Tiers of assessment Excellence are summarized by Science Center, Tiers of Assessment Excellence, and activity in **Figure 15**. Similar but more detailed summaries are provided in **Tables 7** and **8**. **Table 7** sums the FTE requirements for Tiers 1, 2 and 3 by major activity for all five NMFS Science Centers combined. Almost three times as many additional staff are needed to collect, manage and process data, as compared to additional staff needed to conduct and communicate stock assessments, to evaluate alternative management strategies, and to conduct research into assessment methods. By far the greatest overall need is for observers for Tier 2, particularly in the Southeast, Northwest and Alaska Science Centers. The second greatest overall need is for staff to participate in fishery-independent surveys (note, however, that this is contingent on the acquisition of adequate Fisheries Research Vessels, as outlined in the NOAA Fisheries Data Acquisition Plan, NMFS 1998c; **Appendix 3**).

Table 8 summarizes the total FTEs requirements for Tiers 1, 2 and 3 for each Science Center and all Centers combined. In terms of current in-house staff, contract employees, and others who provide assessment data (e.g. state government biologists, and employees or contractors associated with various regional , national and international Commissions), the Alaska Center is the largest with 330 FTEs, the Northeast Center is second with 188, the Southeast Center is third with 147, the Southwest Center is fourth with 121, and the Northwest Center has 110. (These numbers apply to the baseline of January 2000, except where otherwise noted in **Tables 2-6**; in particular, the Northwest Center total includes 25 observers hired in FY2001). Considering the sum of Tier 1 and 2 requirements, the Alaska, Northeast, and Southeast Centers require additions of about 30-40% to existing staff, whereas the Southwest Center requires an addition of about 70%, and the Northwest Center an addition of about 80%. To calculate the approximate costs of new FTEs to satisfy Tiers 1, 2 and 3, a multiplying factor of $150,000 per annum was used. This number takes into account salary and benefits, travel, training, equipment and individual Information Technology needs (although not the core systems needed for data management and communications); i.e. the multiplier covers everything except major infrastructure, particularly new workspace and buildings that may be required.

The numbers of additional staff indicated in **Tables 2-8** may seem staggering, but these numbers have been carefully thought through by the Task Force members. They simply represent the increasing demands being placed on NMFS to assess more stocks more frequently, and with greater accuracy, precision and timeliness; to incorporate associated non-target species and other ecosystem considerations into the analyses; and to evaluate a wider array of management options on increasingly finer temporal and spatial scales. In addition, as outlined in the Introduction, the FTE requirements detailed here are meant to complement other related NMFS plans such as the Data Acquisition Plan (NMFS 1998a; **Appendix 3**), which is primarily concerned with the costs of operating dedicated fishery research vessels and purchasing charter boat days at sea; the Stock Assessment Toolbox Plan (**Appendix 4**); the Center for Independent Experts Program (**Appendix 5**); the Pro-

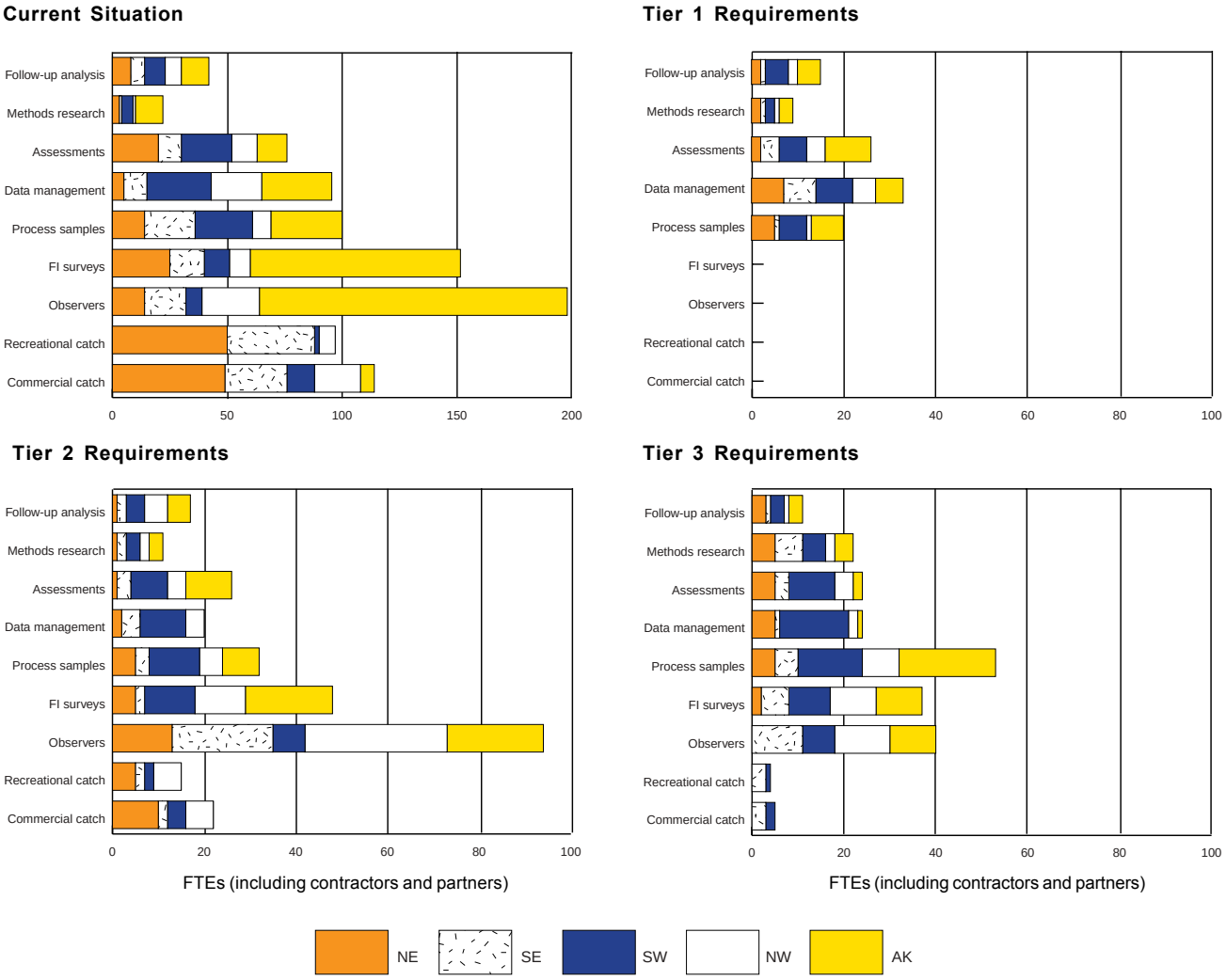

Figure 15.

Summary of FTE requirements by Science Center, Tiers of Assessment Excellence, and activity. FI=Fishery-independent.

posed Implementation of a Fishing Vessel Registration and Fisheries Information Management System (**Appendix 8**); the NMFS Bycatch Plan (**Appendix 9**); the National Observer Program (**Appendix 10**), the Social Sciences Plan (**Appendix 11**), the Advanced Technologies Working Group (**Appendix 12**), and relevant fisheries oceanography initiatives (e.g. **Appendix 13**). In order to develop a comprehensive ecosystem approach to fisheries stock assessments and management, and to estimate the actual costs of implementing ecosystem-based management (EBM), these and related plans, initiatives and activities should be merged into an umbrella plan.

F. The Benefits of Implementing the Stock Assessment Improvement Plan

The benefits of implementing the Stock Assessment Improvement Plan are numerous and diverse. With adequate additional trained staff, existing databases can be mined for material to improve analyses for major target stocks and for currently overfished stocks, and to develop new analyses for stocks of currently unknown status. The benefits arising from Tier 1 alone will, however, be limited because the most important need is for new and expanded data collection programs. Ultimately, these will lead to greater numbers of stocks being assessed with higher frequency, and greater accuracy, precision and timeliness.

Table 7.

FTEs required to meet the three Tiers of Assessment Excellence by type of activity for all NMFS Science Centers combined. Numbers of FTEs in each category do not necessarily reflect the actual number of individuals involved in these activities, in that some individuals may divide their time between several activities. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international Commissions. Follow-up evaluations include the production of additional assessment outputs, evaluations of alternative management strategies, and participation in plan development teams. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*	*All Tiers*
Commercial Catch & Biological Sampling	41	27	46		22	**22**	5	27
Recreational Catch & Biological Sampling	57	6	34		15	**15**	4	19
Observer Programs	34	160	4		94	**94**	40	134
Fishery-independent Surveys	94.5	18	39		48	**48**	37	85
Process Biological Samples (age, growth, maturity, etc.)	65	18	17	20	32	**52**	53	105
Data Management & Preprocessing of Data	58.5	12	25	33	20	**53**	24	77
Conduct Assessments	49	4	23+	26	26	**52**	24	76
Assessment Methods Research	15	2	5	9	11	**20**	22	42
Communication of Results & Follow-up Evaluations	32	2	8	15	17	**32**	11	43
Subtotal (Assessment scientists)	***96***	***8***	***36+***	***50***	***54***	***104***	***57***	***161***
Subtotal (0thers)	***350***	***241***	***165***	***53***	***231***	***284***	***163***	***447***
Total	**446**	**249**	**201**	**103**	**285**	**388**	**220**	**608**

Table 8.

Total Full-Time Equivalents (FTEs) required to meet the three Tiers of Assessment Excellence for each Science Center and all Centers combined. Estimated current FTEs include in-house staff, contractors such as observers, and "other," which includes state government biologists, and employees or contractors associated with various regional, national and international commissions. Numbers should be cumulated across tiers.

Activity	*Current In-house / Contract / Other*			*Tier 1*	*Tier 2*	*Tier 1+2*	*Tier 3*	*All Tiers*
NEFSC	123	49	16	18	43	**61**	25	86
SEFSC	71	30	46	14	42	**56**	39	95
SWFSC	80	15	26+	27	60	**87**	66	153
NWFSC	18	33	59	13	74	**87**	39	126
AFSC	154	122	54	31	66	**97**	51	148
Summed FTEs	**446**	**249**	**201**	**103**	**285**	**388**	**220**	**608**
$ $ (FTE x $150K)				**$15,450K**	**$42,750K**	**$58,200K**	**$33,000K**	**$91,200K**

Incorporation of ecosystem considerations into the analyses will facilitate analysis of trade-offs between harvesting target species and protecting non-target species such as marine mammals. The enhanced data collection and analysis activities proposed herein will also result in more accurate projections of future stock status under various alternative management strategies, and will enable evaluation of an increasingly wider array of management options on finer temporal and spatial scales, both of which will improve the basis for management decisions.

An improved knowledge base, improved ongoing data collection programs, and more comprehensive models should reduce the frequency of risk-prone management decisions, which have been common in many regions of the United States to date. This in turn will enable higher catches on average, at less risk to fisheries resources. The risk of non-target marine species becoming rare or extinct should also be considerably diminished, particularly in comparison to the current situation in which species could potentially be disappearing without us even being aware of it.

Overall, implementation of the Stock Assessment Improvement Plan will result in a greatly improved knowledge base for marine species, and a better basis for risk-averse management decisions which will result in fewer depleted or overfished stocks and greater stability and profitability in the fish harvesting sector. However, it should be noted that improved knowledge and enhanced stock assessment capability will not by themselves result in fewer overfished stocks and a more stable fishing industry; there must be a concomitant commitment to responsible fisheries management and fisheries policy development.

Another benefit of implementing the SAIP will be to improve relations between NMFS and other line offices within NOAA, other federal agencies, state agencies, academia, the commercial and recreational fishing industries, and environmental groups by promoting cooperative research and other types of partnerships. NMFS' own programs and those developed through such partnerships should also result in spin-offs in terms of monitoring information and research that can provide input into other programs; for example, risk and damage assessments. The resulting database of spatial and temporal distributions of marine species, associations between species, oceanographic variables, and habitat relationships will also be an invaluable source of raw material with which to develop and test hypotheses about population dynamics and ecosystem structure and function.

V. Recommendations

1. NMFS should aggressively pursue a course of action focusing on new budget and staffing initiatives to modernize its data collection and assessment capabilities. As a minimum, NMFS should attempt to bring stock assessment science to at least Tier 2 (**Section IVB**), and should initiate dialog both within house and with the public to determine how far-reaching and comprehensive Tier 3 should be. This will require hiring or contracting considerable numbers of additional qualified staff for data collection, data processing, data management, stock assessments, and evaluation of alternative management strategies, to ensure adequate data and analyses on which to base conservation and management decisions, now and into the future.

2. In order to improve the credibility of its stock assessment science, in addition to acquiring the resources needed to produce the best possible science, NMFS must improve its public image, both with constituents and within NOAA itself. There appears to be little awareness that NMFS employs the largest collection of world-renowned fisheries scientists of any agency, university, or other organization worldwide, and that fisheries science is a field where new and useful methodologies have mostly originated within government agencies (including those of foreign governments), rather than within academia.

3. NMFS also needs to make fishers, politicians, and the public aware of the benefits of truly precautionary management which will reduce the risks of overexploiting fisheries resources and associated species, and will ultimately lead to greater stability in the fishing industry.

4. Another avenue of public awareness which NMFS should pursue is to educate and discuss with interested parties (especially constituents and congressional aides) the implications of calls to incorporate ecosystem considerations into fisheries assessment and management. In particular, NMFS should request input on what different groups of people actually mean by "ecosystem considerations," and then jointly evaluate the costs and benefits of adopting such approaches. NMFS needs to work harder to align public expectation with reality.

5. NMFS needs to be more proactive in communicating the fact that the methodologies employed to conduct stock assessments are far less problematic than is the quality, quantity, and type of data available for analysis. NMFS needs to seek out and develop cooperative arrangements with stakeholders to improve the quality, quantity, and type of data provided.

6. In order to make substantial progress towards collecting the data needed to improve stock assessments, particularly next generation assessments, it is essential that NMFS develop further partnerships and cooperative research programs with other federal agencies, state agencies, private foundations, universities, commercial and recreational fishing organizations and individuals, environmental groups, and others with a vested interest in collecting similar types of data, although often for other purposes. Many such partnerships already exist (**Appendix 21**), but many more are needed. Programs involving cooperative research with the fishing industry (**Appendix 22**) should continue to be developed and expanded as mechanisms for providing data relevant to improving the quality of stock assessments.

7. In order to enhance progress in the development of new models and methodologies for conducting stock assessments, performing risk analyses and stock projections, and constructing multispecies and ecosystem models, NMFS must free up more time for existing quantitative staff to pursue such research and engage more fully in professional development activities which, in turn, implies the need to also hire or contract additional qualified quantitative staff.

8. In order to ensure a future supply of quantitative scientists to perform stock assessments and related activities, NMFS must augment existing programs that fund graduate study in appropriate fields.

9. In order to maintain the high caliber of current analytical staff, NMFS must develop a comprehensive training program to enhance the quantitative skills of in-house staff.

10. In order to develop more comprehensive and integrated future budget initiatives geared towards modernizing fisheries assessments and management, NMFS should prepare an umbrella plan that integrates all relevant existing documents on these themes; for example, the current Stock Assessment Improvement Plan, the NOAA Fisheries Data Acquisition Plan (**Appendix 3**), the NMFS Strategic Plan for Fisheries Research (NMFS 2001b), the Proposed Implementation of a Fishing Vessel Registration and Fisheries Information Management System (**Appendix 8**), the NMFS Bycatch Plan (**Appendix 9**), the National Observer Program (**Appendix 10**), the Social Sciences Plan (**Appendix 11**), the Advanced Technologies Working Group (**Appendix 12**), and relevant fisheries oceanography initiatives (e.g. **Appendix 13**).

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Acronyms

ABC – Allowable Biological Catch
AFSC – Alaska Fisheries Science Center
AI – Aleutian Islands
ASMFC – Atlantic States Marine Fisheries Commission
BSAI – Bering Sea and Aleutian Islands
CIE – Center for Independent Experts
CPUE – Catch Per Unit Effort
CSIRO – Commonwealth Scientific and Industrial Research Organization (Australia)
DAS – Days At Sea
EBM – Ecosystem-Based Management
EBS – Eastern Bering Sea
EEZ – Exclusive Economic Zone
ESA – Endangered Species Act
ESU – Evolutionarily Significant Units
FFA – South Pacific Forum Fisheries Agency
FIS – Fisheries Information System
FMC – Fishery Management Council
FMP – Fishery Management Plan
FRV – Fishery Research Vessel
FSP – Fisheries Strategic Plan
FTE – Full-Time Equivalent (applied to numbers of in-house staff or contractors)
FY – Fiscal Year
GLOBEC – GLOBal ocean ECosystem dynamics
GOA – Gulf of Alaska
GOM – Gulf of Mexico
HMS – Highly Migratory Species
IATTC – Inter-American Tropical Tuna Commission
ICCAT – International Commission for the Conservation of Atlantic Tunas
ICES – International Commission for the Exploration of the Sea
ISC – Interim Scientific Committee for Tunas and Tuna-like Species in the North Pacific Ocean
LOA – Length OverAll
MFCMA – Magnuson Fishery Conservation and Management Act
MHLC – Multi-lateral High Level Conference
MPA – Marine Protected Area
MRFSS – Marine Recreational Fisheries Statistics Survey
MSFCMA – Magnuson-Stevens Fishery Conservation and Management Act
MSY – Maximum Sustainable Yield
NASCO – North Atlantic Salmon Conservation Organization
NEFSC – Northeast Fisheries Science Center
NEPA – National Environmental Protection Act
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
NRC – National Research Council
NRIFSF – National Research Institute for Far Seas Fisheries
NWFSC – Northwest Fisheries Science Center
OFL – Overfishing Level
PDT – Plan Development Team
PSMFC – Pacific States Marine Fisheries Commission
ROV – Remotely Operated Vehicle
SAFE – Stock Assessment and Fishery Evaluation
SAM – Statistical Assessment Model
SARC – Stock Assessment Review Committee (NEFSC)
SAW – Stock Assessment Workshop (NEFSC)
SCTB – Standing Committee on Tuna and Billfish
SEFSC – Southeast Fisheries Science Center
SFA – Sustainable Fisheries Act (1996)
SPC – Secretariat of the Pacific Community
SQAP – Science Quality Assurance Program
SSC – Scientific and Statistical Committee
STAR – Stock Assessment Review Panel
SWFSC – Southwest Fisheries Science Center
TRAC – Transboundary Resource Assessment Committee
VTR – Vessel Trip Report
WG – Working Group