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**.

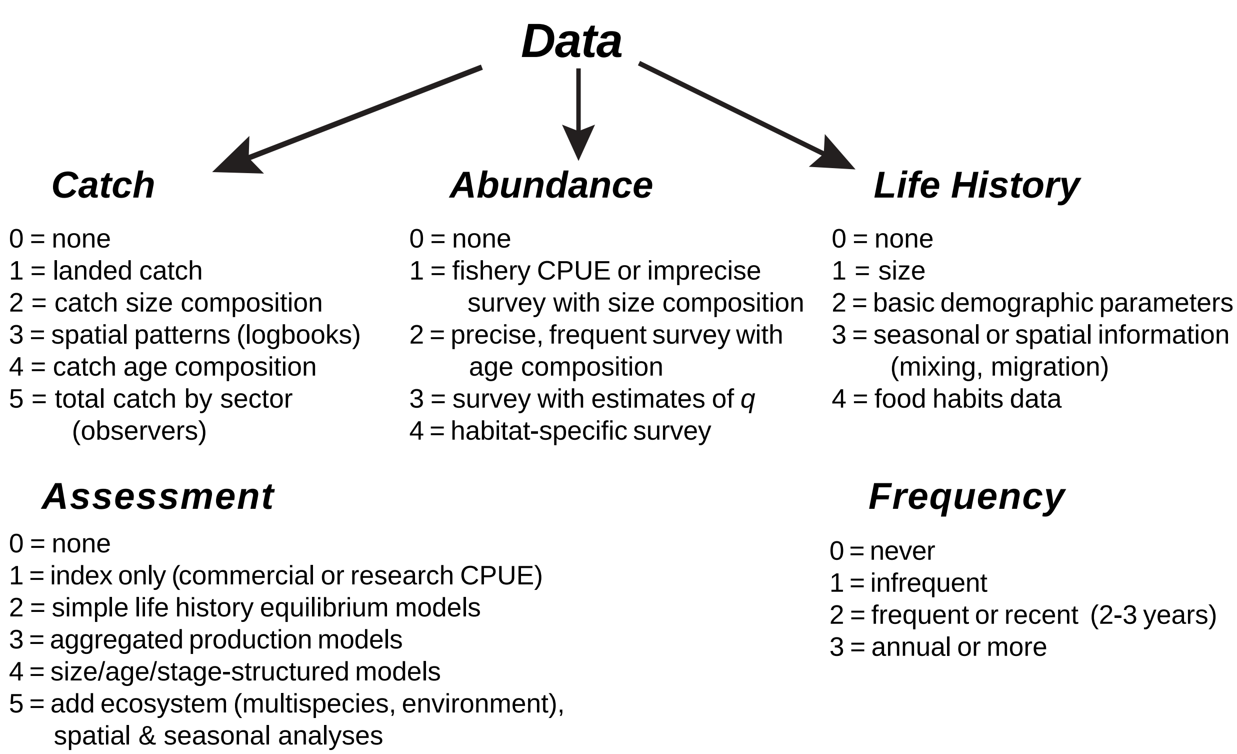
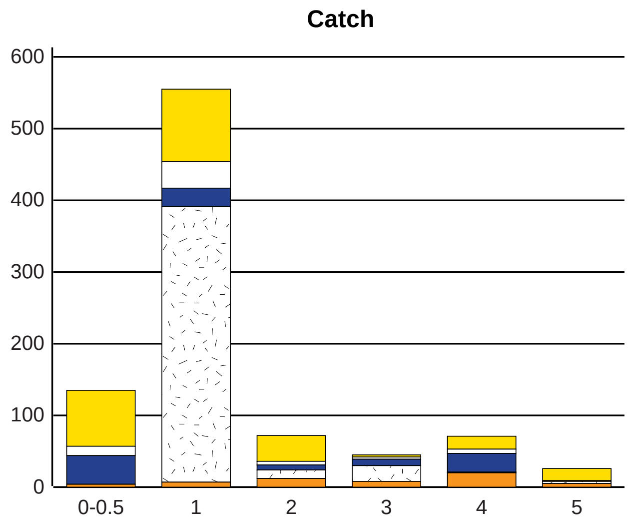
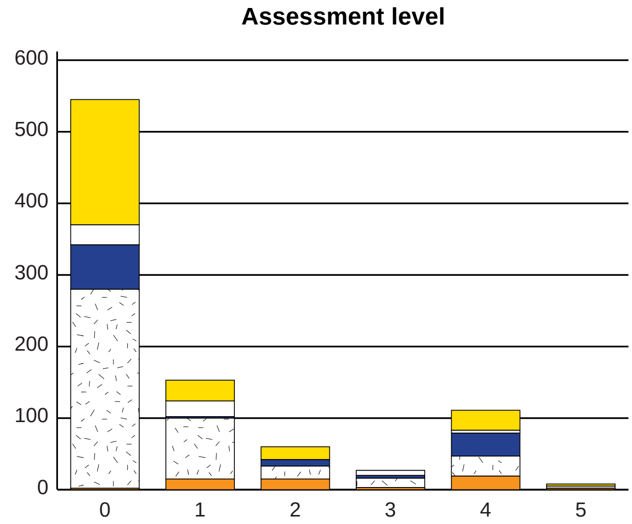


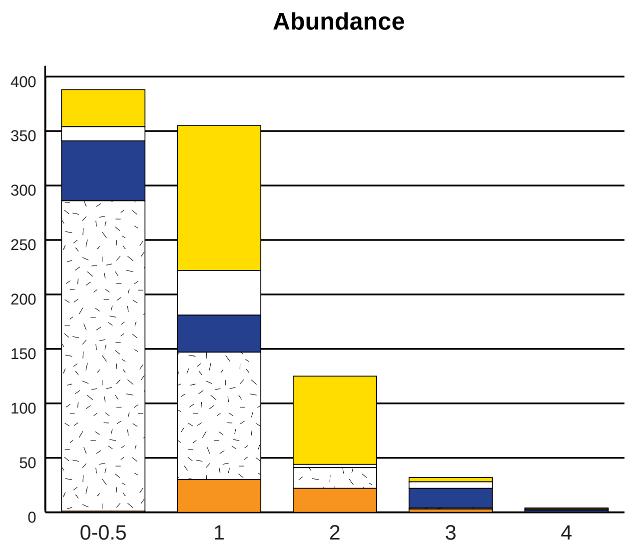
Figure 3. Factors used to classify stocks in terms of input data and assessment status.

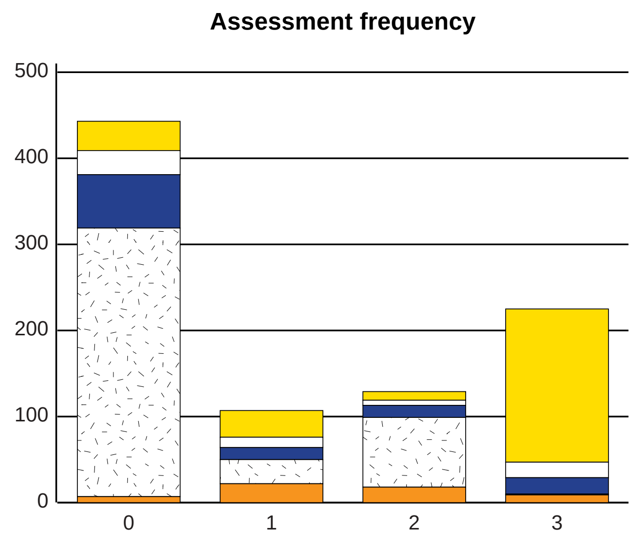
LEVELS	Catch	Abundance	Life History	Assessment Level	Assessment Frequency
ALL REGIONS COMBINED					
0	95	374	96	545	443
0.5	40	14			
1	555	355	519	153	107
2	72	125	207	60	129
3	45	32	69	27	225
4	71	4	13	111	
5	26			8	
Sum	**904**	**904**	**904**	**904**	**904**
NEFMC, MAFMC & ASMFC					
0	4	1	0	2	7
0.5	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**

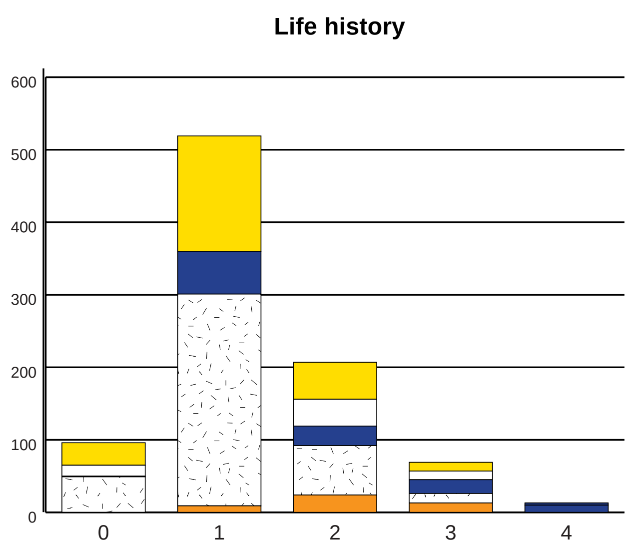
Table 1. Numbers of stocks with different levels of input data (catch, abundance and life history parameters), assessment methodology and assessment frequency for the 904 stocks listed in the NMFS (1999a) Report to Congress on the Status of Fisheries of the United States. Zero indicates no information; 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.











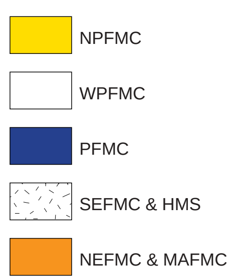


Figure 4.

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 covered. 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, multibeam 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), usually 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

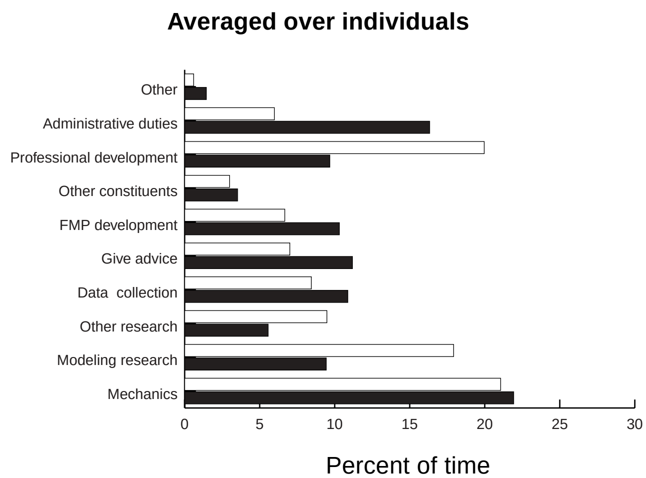
As detailed in **Sections III G and III H** and elsewhere in this report, it is evident that there are many other demands placed on assessment scientists aside from the basic requirement of a background in biology and mathematics. Within a given year, an individual assessment scientist may be expected 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.

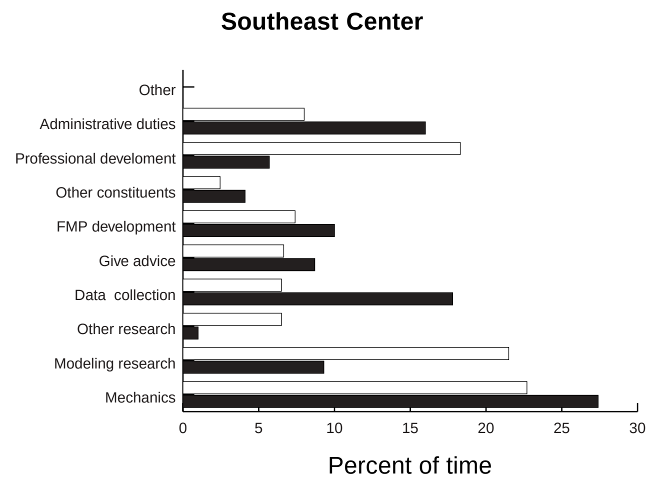
To better understand the allocation of NMFS' stock assessment scientists' time, and to determine whether there is a difference between the actual and optimal allocation, the Task Force prepared a questionnaire and administered it to working stock assessment scientists. Activities commonly undertaken 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.

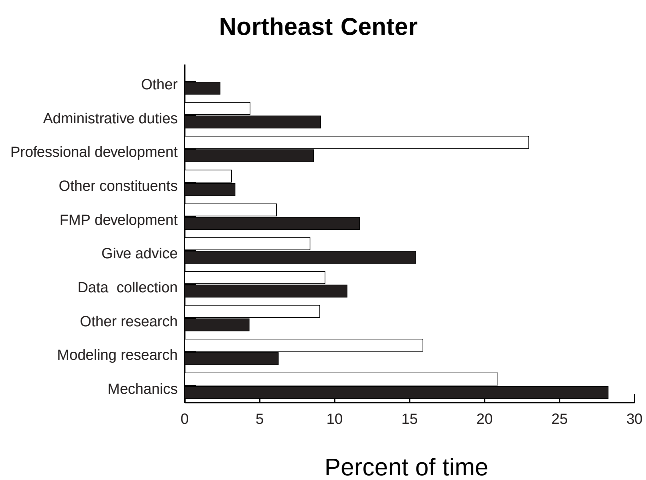
Beyond assessment scientists

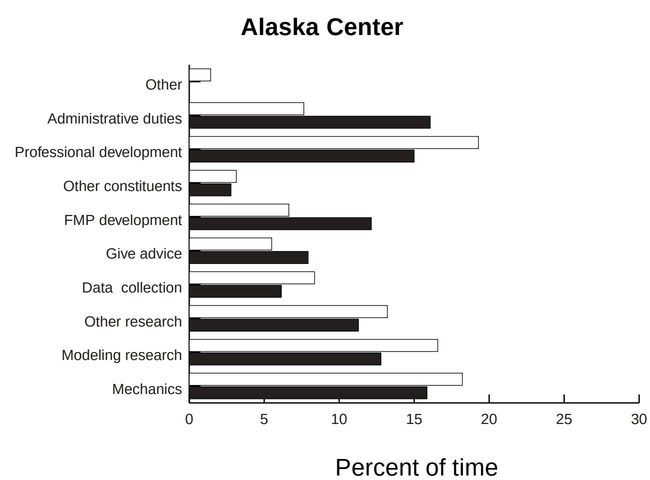
A wide diversity of staff is required to produce a stock assessment. In fact, stock assessment scientists just represent the "tip of the iceberg" (**Figure 6**). Far greater numbers of staff are deployed in critical data collection activities, such as commercial or recreational catch and effort data, 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

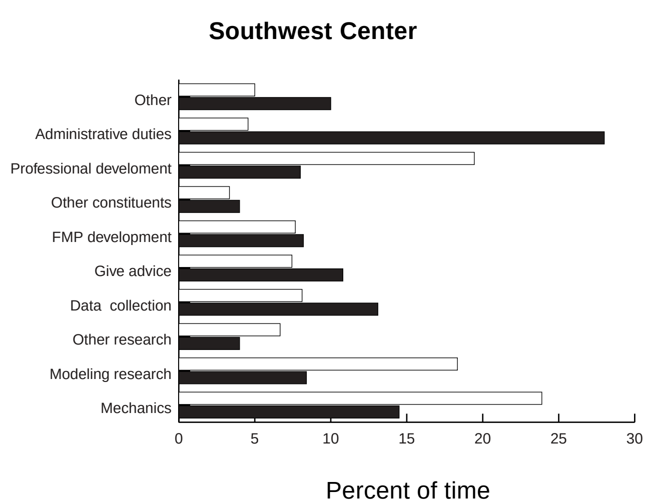
Time & Motion Analysis











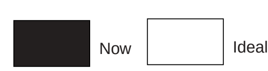


Figure 5.

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).

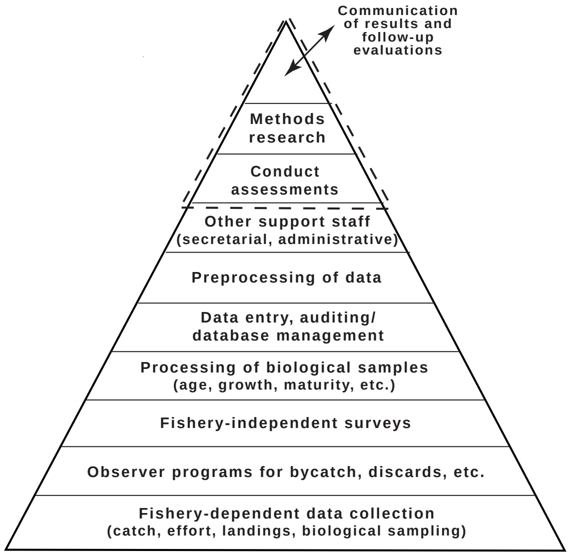


Figure 6.

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.

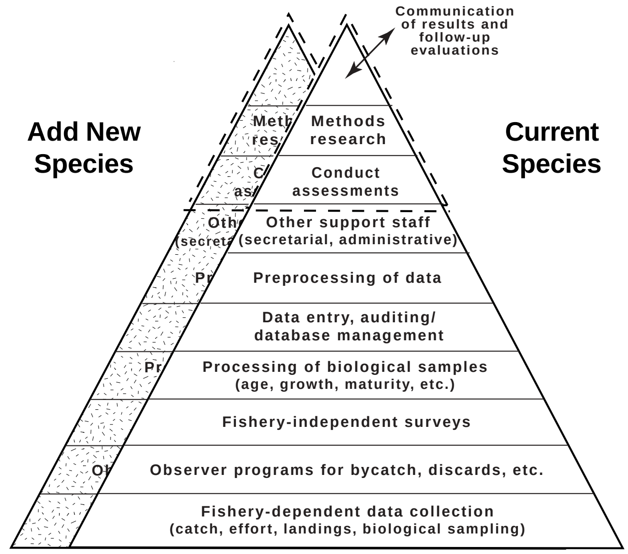


Figure 7.

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.

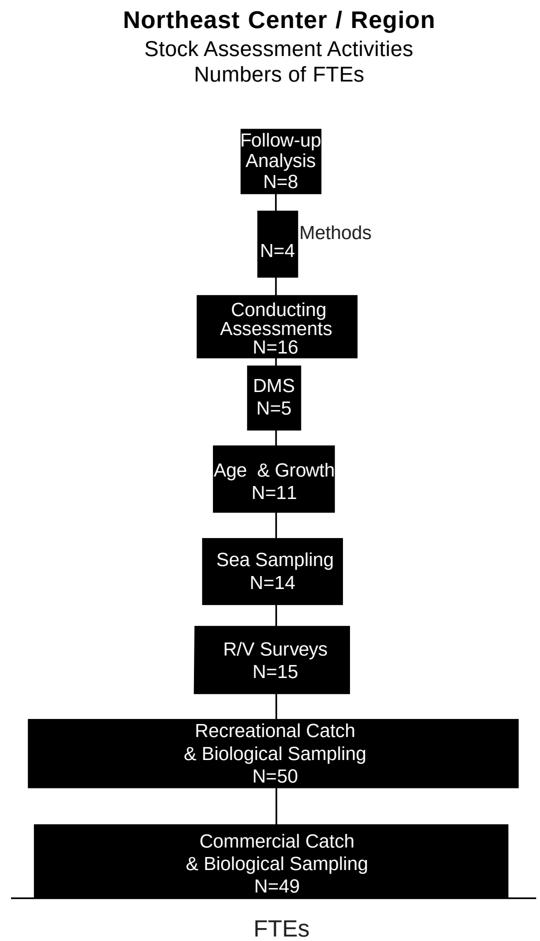


Figure 8.

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.