NOAA Technical Memorandum NMFS

DEPARTMENT OF COMMERCE
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JUNE 1981

STOCK ASSESSMENT ACTIVITIES WITHIN THE NATIONAL MARINE FISHERIES SERVICE

NOAA-TM-NMFS-SWFC-12

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS

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The National Marine Fisheries Service (NMFS) provides the United States with an integrated program of management, research, and services concerned about the protection and rational use of living marine resources for their aesthetic, economic, and recreational value. NMFS determines the consequences of the naturally varying environment and human activities on living marine resources. NMFS provides knowledge and services to foster the efficient and judicious use of those resources. NMFS provides for domestic and for international management and conservation of these living resources of the sea.

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Who wrote? — Debbie - I think Gary Stauffer now of Alaska Fish. Center wrote it with a committee. check with him Dave M.

NOAA Technical Memorandum NMFS

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Dr. John V. Byrne, Administrator

National Marine Fisheries Service
William H. Stevenson, Acting Assistant Administrator for Fisheries

STOCK ASSESSMENT ACTIVITIES WITHIN

THE NATIONAL MARINE FISHERIES SERVICE

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STOCK ASSESSMENT ACTIVITIES WITHIN THE NATIONAL MARINE FISHERIES SERVICE

EXECUTIVE SUMMARY

The purpose of this report is to present results of the Stock Assessment Task Force investigation into the nature and scope of the existing stock assessment studies within National Marine Fisheries Service (NMFS). The Task Force focused its review on fishery and marine mammal populations as this work provides information to resource managers. The traditional fisheries definition of the term "stock assessment" is the collection and analysis of biological and statistical information to determine the changes in abundance or relative abundance of living resource populations in response to fishing. This report describes current stock assessment methodology used within NMFS, with examples and evaluation of adequacy for each method.

These methods include collecting fishery statistics and conducting fishery-independent surveys, such as trawl surveys, aerial surveys, marine mammal counts, fish egg and larva surveys, acoustical assessment, and environmental indices. The application of fishery analysis models for stock assessment then draws on the results of fishery and survey data collection projects. From its review, the Task Force concluded that stock assessment methodologies are not perfect. Each method has a particular set of biological and physical conditions under which it works best. Each method has a specific set of assumptions and associated costs. Existing methods are not completely interchangeable; each measures a slightly different aspect of stock abundance. As a result, no single approach or technique is suitable for all species or areas.

One hundred and fifty different fish and marine mammal stocks are currently being assessed by NMFS research centers. These assessments are not one-time endeavors but require continued updating because of the dynamic nature of the stocks involved. Of the total national funds available for fishery research in FY79, 59% supported traditional stock assessment research by NMFS centers and regions. Approximately 54% of the 788 fulltime research positions were involved in stock assessments. A total of 3,070 sea days of vessel time was required. The assessments for many of the minor fisheries or fish stocks that occur as by-catches in targeted fisheries, while based on the best scientific information available, are adequate only in the context of the pro forma requirements of the legislative acts. Stock assessments for most of the important stocks do provide estimates of stock size (absolute or relative) and information on trends in population abundance.

The Task Force concluded that there is a need to accelerate technological developments for stock assessment. Methods to evaluate the accuracy of traditional sampling approaches are of particular importance. In addition, advances in survey technology are needed for stocks for which adequate and cost effective survey technologies do not exist.

The Task Force also concluded that significant improvement in stock assessment will come from investigations of biotic and abiotic aspects of recruitment and inter-specific relations, i.e., causal mechanism of recruitment, and from ecosystem studies. Furthermore, the Task Force strongly emphasized the importance of improving the quality and timeliness of fishery statistics. This improvement will directly affect the quality of the assessments.

The advent of conservation and environmental legislation over the past decade has created an urgent need to improve the quality and timeliness of stock assessment information. Stock assessment studies have been significantly extended to provide information on the U.S. resources harvested by the domestic fisheries which have increasing need for data on a large variety of fish, shellfish, and marine mammals.

The increased need for timely, and in many cases urgent, stock assessment results requires that the quality of communications on stock assessment conclusions as they relate to resource management information be substantially improved. Preparation of stock assessment reports for various management bodies leaves little time for scientists to write manuscripts for scientific publication. As a result, peer review is often lacking.

Within NMFS, stock assessment research is guided by mandates of federal legislation such as the Magnuson Fishery Conservation and Management Act, Marine Mammal Protection Act, and Endangered Species Act, and of international treaties such as the International Convention for Conservation of Atlantic Tuna. For resources where stock assessment is not mandated by legislation, research is guided by NMFS scientific missions to understand the population dynamics and to monitor important fish stocks. The question of proper mix of NMFS research can be addressed at three levels: stock assessment work versus other fisheries-related research; balance of stock assessment research among fishery resources under the Center's purview; and level of stock assessment analysis for a particular resource with respect to frequency, precision, and combination of methodologies.

These various research studies currently under way throughout NMFS ultimately affect the status of the fishery resources and the resulting stock assessments. A fundamental knowledge of the impact of natural changes in the environment and its resources on the survival and growth of fish populations is needed to understand population trends and interactions of the population with other biota in the ecosystem. Hence, future stock assessment must be seen in a much more holistic manner and current research activities should be designed to understand the processes and events in the inanimate and biological environment.

The Task Force, recognizing that research demands and management needs vary among regions and fisheries, recommends that NMFS act to:

1) enhance the timely collection and processing of improved or new fisheries data to meet the needs of resource managers and researchers;

2) expand the concept of a multidisciplinary (ecosystem) approach to stock assessment, integrating information from environmental, ocean variability, and fisheries impact studies;

3) improve knowledge of both biotic and abiotic aspects of the recruitment function and inter-specific relations, so that resource managers may evaluate the potential of regulatory measures which affect resource productivity;

4) advance the theoretical and technical bases for stock assessment;

5) communicate with and inform user groups in order to increase their understanding of the strengths and weaknesses of assessment techniques, and the implications of these techniques to management decisions;

6) recognize that new information demands for management have eroded the peer review process, and to explore methods to improve such peer review.

STOCK ASSESSMENT ACTIVITIES WITHIN THE NATIONAL MARINE FISHERIES SERVICE

1.0. INTRODUCTION

Considerable concern has been expressed by members of the Regional Fisheries Councils created under the Magnuson Fishery Conservation and Management Act of 1976, by members of the Marine Mammal Commission, by members of state fisheries and game agencies, and by academia, regarding the adequacy and emphasis of existing National Marine Fisheries Service (NMFS) stock assessment activities. Questions have been raised regarding the most effective technology in the conduct of such activities by NMFS and whether assessments are adequate in terms of the needs of the councils.

To respond to these inquiries, the Assistant Administrator for Fisheries of the National Oceanic and Atmospheric Administration (NOAA) in April 1979 established a Stock Assessment Task Force to investigate the nature and scope of existing stock assessment studies within NMFS. Dr. Dayton L. Alverson, Director of the Northwest and Alaska Fisheries Center, NMFS[1], was requested to chair the Task Force. Members included Dr. Brian Rothschild, Senior Scientist, NOAA[1]; and, from NMFS, Mr. Jack Gehringer, Deputy Assistant Administrator for Fisheries[1]; Dr. Lamarr Trott, Acting Director, Office of Science and Environment[1]; Dr. Robert Edwards, Director, Northeast Fisheries Center; Dr. William Fox, Jr., Director, Southeast Fisheries Center; and Dr. Izadore Barrett, Director, Southwest Fisheries Center. Upon Dr. Alverson's retirement in January 1980 from NMFS, Dr. Barrett assumed chairmanship of the Task Force.

The Task Force was requested to investigate and consider the following:

1) current stock assessment activities within NMFS--including methodology, assumptions, form of outputs, and accuracy and precision of findings;

2) relation of stock assessment and monitoring activities to more fundamental processes influencing the behavior, abundance, and population characteristics of fisheries resources;

3) potential of new technological and stock assessment activities; and;

4) questions of the best overall combination of different types of research which NMFS must and should consider.

A general outline was developed by the Task Force Chairman and agreed upon by its members. The material has been organized to provide information on the following major topics: Stock Assessment as a Concept, Stock Assessment

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[1]Position in April 1979.

Methods, Adequacy of Stock Assessment Methods, Allocation of Financial, Personnel, and Vessel Resources to Stock Assessment, Geographic Application to Stock Units or Marine Mammal Species, Communicating Results to User Groups, and Proper Mix of Science.

A discussion of some of the problems confronting NMFS in the conduct of stock assessment studies, and recommendations to the Assistant Administrator, are also included. A series of matrices is added as an Appendix, to point out, in a condensed form, the large volume of the work conducted by NMFS to carry out its management responsibilities.

This document was prepared by a Working Group of NMFS Scientists, including Miles Alton, Dayton L. Alverson, Murray Hayes, and Michael Tillman, NWAFC; Andrew Kemmerer, Joseph Powers, and James Zuboy, SEFC; Izadore Barrett, Tim Smith, and Gary Stauffer, SWFC; Emory Anderson, NEFC; and James Meehan and Lamar Trott, F/SR. Brian Rothschild, University of Maryland, also contributed to the document. Murray Hayes was chairman of the Working Group. Overall direction was provided by the Guidance Group made up of the NMFS Center Directors.

1.1. Stock Assessment as a Concept

The term "stock assessment" in fisheries science has been applied to the collection and analysis of biological and statistical information to determine the changes in sizes or relative sizes of living fishery resource populations (or stocks) in response to the effects of fishing and, in some instances, to predict future trend patterns. The process of stock assessment frequently leads to conclusions that equate large population sizes with the term "healthy" and small population sizes with the term "threatened" or "overfished." Stock assessment has seldom been approached from an ecosystem standpoint; that is, factors such as disease, adequacy of food, and viability of the individuals in the populations are frequently ignored. Hence, for the most part, stock assessment within NMFS has been traditionally concerned with abundance and distribution of stocks and their size, sex, and age composition. From such data, information is generated on the numbers surviving, numbers dying, growth rates of individuals and populations, and trends in population sizes, particularly in the presence of fishing. Finally, from these parameters, allowable biological harvests have been estimated in light of the goal of maximizing such yields.

There are many possible objectives for conducting stock assessments. For example, the stock assessment activity might be designed to estimate the growth rate of a particular species, or to determine the relation between catch and effort in the fishery of a single species or a group of species. Such a stock assessment might then be used to develop a model which interrelates biological and economic factors to determine a level of fishing effort that will maximize net revenue to fishermen. Ultimately, most stock assessment activities are conducted to develop fishery-management information.

The many possible objectives and techniques for stock assessment raise the following issues: 1) What are appropriate objectives for stock assessment? 2) Which of several techniques should be employed to satisfy a particular objective? and 3) Is the attainment of particular objectives impeded by a lack of techniques, or do certain available techniques require improvement?

Fisheries management objectives have changed considerably over the last decade. While earlier objectives were primarily oriented toward attainment of maximum catches, present fisheries management goals involve social and economic objectives within biological constraints. The biological (maximum catch) objectives of earlier management were relatively simple to define and could be measured directly in the magnitude of the catch. The social and economic objectives of later management, however, tend to be more diffuse and complex; they are with us, nevertheless, as indicated by recent marine-resource legislation.

The Marine Mammal Protection Act of 1972 (MMPA), for example, declares that stocks of marine mammals should not fall below a level "...which will result in the maximum productivity of the population or the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." The Magnuson Fishery Conservation and Management Act of 1976 (MFCMA) seeks to attain optimum yield for each stock of fish, which, among other things, "...is prescribed on the basis of the maximum sustainable yield...as modified by any relevant economic, social, or ecological factor." The Endangered Species Act of 1973 (ESA) implies that "...overutilization for commercial, sporting, scientific, or educational purposes" is a factor in determining whether a species is endangered or threatened. (If a species is endangered or threatened, there are specific sanctions with respect to their capture.)

It is clear that these laws provide us with responsibilities which fall into two management-related areas. The first area is conceptual and involves terms--such as maximum productivity; optimum carrying capacity; health of the ecosystem; optimum yield; relevant economic, social, or ecological factor; and overutilization--which are not simply nor easily defined. Many years may pass before scientifically valid definitions of these terms are agreed upon. These terms, each of which contains not only biological, but also social and economic implications, are very vague and considerable disagreement exists about their interpretation. Because stock assessment specialists are often called upon to advise whether stock abundance is above or below maximum productivity, or whether stocks are harvested at a level deemed overutilized, it is critical to isolate the complex issues raised by terminology and, by so doing, provide a basis for better future definitions.

The second area is operational and involves estimating whether a population is at a level below the defined "optimum" level. If an optimum level has been defined, an estimate of population abundance made, and the estimate falls below the optimal level, is the estimate below the optimal level real or is it due to a chance deviation? On what basis should resource harvesting be terminated?

Our new laws have created new demands on stock assessment activities. The results of stock assessment affect both the livelihood of those who harvest or process fishery resources and the sensibilities of those who feel that harvesting of some species should be terminated or greatly reduced. Developing a strategy for attaining the social and economic resource objectives therefore places considerable emphasis on the completeness, accuracy, and precision of stock assessment.

1.2. The Criteria of Relevance, Accuracy, and Precision

Stock assessment is a science-based activity oriented to provide information for management of fisheries, marine mammals, and their environment. Such information provides the biological boundaries and limits within which the socioeconomic bounds of man's use are set. Within the analytical process, the criteria of relevance, accuracy, and precision bear heavily on success; consequently, these criteria provide the benchmarks for evaluation of credibility.

The criterion of relevance is paramount in a mission-oriented agency, such as NMFS, which has multiple objectives. Work must be selected which will provide both immediate and long range information for various constituencies--fisheries managers, marine mammal managers, environmental managers, commercial and marine recreational fishermen, processors, consumers, and concerned laymen. The major problem is the selection of priorities. These decisions are properly influenced by the constituents themselves through the various institutions for public input. Agency "managers" are responsible for interpretation of such inputs and for setting priorities for relevant work.

Once the relevant work is selected, the criteria of accuracy and precision provide the measure of success. In most scientific undertakings such as stock assessment, the objective is to predict--that is, to attempt to develop information that reflects conditions which will be found in the real world. The degree to which such information conforms with reality is termed accuracy. Particularly in biological systems, variation occurs in application of a survey or sampling technique and results vary from one experiment to another. Theory suggests that variation is an inherent characteristic of a biological system, and the measure of that variation around the real (parameter) value is termed precision. While precision for a given level of effort may be improved by careful statistical design, the primary means to improve precision is increased sampling, which translates directly to costs.

2.0. STOCK ASSESSMENT METHODS

After the objectives of fisheries management are clearly understood, it is necessary to select the most appropriate stock assessment technique for meeting the particular objectives. How should one or several of the available techniques be chosen? Answering this question involves development of criteria for choosing among stock assessment techniques with respect to understanding the fishery.

The existence of new requirements affecting the nature and time frame in which stock assessment objectives are defined and the ensuing need to develop criteria to clarify the adequacy of stock assessment techniques set the stage for determining the state-of-the-art in stock assessment and for NOAA-NMFS to develop its programs. Particular objectives need to be identified; the techniques appropriate to their attainment need to be surveyed; the cost effectiveness of each technique needs to be developed; and recommendations need to be made.

NMFS currently utilizes a variety of techniques to acquire information on stock sizes and trends. Frequently, several of these techniques may be used to evaluate or assess the stock condition for a single species or species complex. Stock assessment usually begins with an evaluation of catch and effort data collected from a fishery or fisheries. Such data are frequently augmented by port sampling of landings designed to collect information on the biological attributes (size, age, sex, and reproductive condition) of the populations (stocks). Fisheries-independent data collected during biological surveys are used where fisheries statistics are inadequate or require complementing. Such surveys may take the form of aerial reconnaissance, direct sampling of populations with fishing gear, sampling of egg and larva forms with quantitative plankton nets, and remote sensing techniques. These data may subsequently be modified or interpreted in light of environmental indicators.

Although a variety of methods exist for stock assessment analyses, some may not be applicable to a particular species, species group, or geographic area; some cannot be employed because of the manner in which historical data have been collected from the fisheries. Hence, the variety of applicable information is limited due to species behavior, technological limitations, costs, etc.

These methodological constraints must be considered along with such factors as available manpower, financial resources, etc. Some fisheries are more valuable than others, and certain fisheries show a greater variability in abundance with time. The more valuable the fisheries, the more "leverage" is associated with a particular stock assessment. For example, a 10% underestimate of stock size has a considerably different implication for a fishery that exhibits a net benefit of $100,000 than for a fishery with a net benefit of $1,000,000. Greater sampling intensity or a more detailed examination of assessment methodology might be warranted for the more valuable fish. The more variable a fishery, the more observations need to be taken. Thus valuable, highly variable fisheries may warrant a different set of stock assessment strategies than low valued or low variability fisheries.

Another factor to be evaluated is the margin of return of information for the investment of research resources. Low value and low variability fisheries might be managed if sufficient research is undertaken. However, high variability fisheries, even if highly valued, may not be better managed, even with a considerable expenditure of resources.

Each NMFS Center must evaluate methodologies in terms of the above factors and select the most feasible approach within its financial and equipment resources. Stock assessment from egg and larval studies has, for example, been employed consistently in the California Current area and less frequently in the Gulf of Mexico; it has been more or less inapplicable in the northeast Pacific and northwest Atlantic. Direct sampling with commercial fishing gear has been, to a greater or lesser extent, a mainstay of the stock assessment studies conducted by the Northwest and Alaska Fisheries Center, the Southeast Fisheries Center, and the Northeast Fisheries Center. Remote sensing and aerial sensing have been used by both the Southwest and Southeast Fisheries Centers. All Centers make extensive use of routinely collected statistical data from foreign and domestic fisheries.

In this section on methodology, we will consider the sources of data--from the fishery itself, from fishery-independent surveys, and from the environment--and how these are integrated through fisheries analyses to produce stock assessments.

2.1. Information from the Fisheries

A primary source of information for stock assessment is the fisheries themselves. The mechanisms for collection of such information vary among fisheries, areas, and agencies. For example, landings data from the commercial fisheries are generally collected by federal agents on the east and Gulf coasts and by state agents on the west coast. Recreational catch statistics, on the other hand, are usually collected by creel census techniques applied on a random sampling basis. Fishing effort and location data may be collected by mandatory logbooks in some fisheries and by interview data in others. These data collected from the fisheries, however, may be organized in functional groups as follows:

1) traditional fisheries statistics on participation, catch, effort, and fish products;

2) catch sampling data for species, sex, size, and age composition, and for food habits and reproduction;

3) logbook, interview, or survey data for detailed area of catch, effort, and socioeconomic descriptors; and

4) tagging studies to identify origin of stocks, migrations, growth, and rate of exploitation.

2.1.1. Fisheries Statistics

Fisheries statistics are a primary source of information on the status of fish stocks. These statistics include routine scientific data collected from samples of the fishery catch but do not include data collected during resource surveys carried out by scientific organizations.

To be of most value, catch data should be reported by species or stock and by area and time; associated effort data should be reported on the most refined basis possible, e.g., trawl hours as opposed to number of days absent from port.

Landings data are generally collected on a per trip basis, which last one day to several months. Trip data can be reported on individual sales transaction records (also called weigh-out slips or fish tickets) which are filled out by the purchasing dealer in cooperation with the vessel captain. Alternatively, the information on the fishing trip may be collected through interviews by a port agent with a vessel captain at the conclusion of a trip. Data collected on fish tickets include weight and price of catch by species, and date of sale; sometimes area of capture, fishing effort, and gear type is also included. The individual vessel is generally identified so that effort can be standardized among vessels.

Summary landings data are reported at periodic intervals (usually monthly) by wholesale dealers. These reports give total landings, value, and price ranges, but provide little useful data on fishing effort or location. Summary landings data may be sufficient for stock assessment when only total catch information is required and there is an independent measure of fishing effort. Generally, however, more detailed information is needed.

Landings data are usually collected by census techniques, i.e., 100% sampling, but may sometimes be collected for a portion of the fishery only, e.g., the commercial fishery in contrast to the recreational fishery, or commercial landings sold to leading wholesale dealers. In such cases, landings data for these portions of the fishery are used as an index. Statistical sample design theory, therefore, needs to be developed to improve the accuracy of the estimates of total landings and to increase cost effectiveness. Although it would be possible theoretically to estimate total landings based on sampling, uncertainties about the fishery universe and its sampling variability have precluded most attempts at estimation.

Special methods are generally required to estimate recreational catch. Recreational catch does not flow through a number of channels, which would permit data gathering; therefore, survey problems are often difficult. Creel census techniques are applied on a random sampling basis. Two-stage sampling may also be used, which combines creel census (intercept survey) to determine catch-per-unit effort and telephone or mail surveys to estimate total effort. The National Recreational Fishing Survey is designed to provide estimates of catch by species on a bimonthly basis. Results from the first survey year are now being evaluated.

Fishery statistics for stock assessment are collected by federal and state governments. The division of responsibility is by local arrangement.

On the west coast, the states often collect comprehensive fishery statistics while the federal government has a limited role. On the east and Gulf coasts, the federal government operates regional statistical data collection systems, with input from the states. In some cases, integrated data collection systems have developed through a partnership approach implemented by specific state-federal agreements on collection of statistics.

Fishery statistics are the heart of fishery information systems used by economists, biologists, and managers. Such systems provide summary information to economists on the economic status of fisheries, specific data to biologists for stock assessment, and data to managers for management analysis. For example, fishery statistics often include price and product flow data, which are of little use for stock assessment but are important to economists and to analytical models of total fishery systems. Because of a need to serve many users, fishery statistical systems have developed somewhat independently of, rather than as a result of, the requirements for stock assessment. Consequently, biologists have sometimes developed independent data files for analysis. Managers are often unable to use these detailed statistical data files unless they have adequate data management support to redesign existing operational systems.

2.1.2. Effort Sampling

While fishery statistics collected by fish tickets or port agents provide nominal data on effort per trip, more detailed records of individual fishing activities are collected by interviews or logbooks. These techniques provide detailed records of individual fishing operations, such as the number of sets or hauls by gear type, or a summary of a day's fishing activities. Data usually include estimated weight of catch by haul, date, time, and location, which, when combined with data on physical characteristics of the individual fishing vessel, can be used to standardize fishing effort among vessels to obtain essential fishing mortality estimates.

Logbook or interview data are generally collected by state agencies on the west coast[1] and by federal port agents or state-federal programs on the east and Gulf coasts. Such arrangements rely on the confidence that exists between the fisherman and the data collection agent or biologist. The recent decision to separate such data from enforcement use will do much to improve acceptance of the data.

A difference of opinion exists as to the desirability of mandatory versus voluntary participation in logbook and interview programs. Advocates of mandatory programs point to successful use by the International Pacific Halibut Commission (IPHC) and certain states, and to the legal leverage at hand. Advocates of voluntary programs point to other successes and suggest that willing participation provides "better data." The results, however, are

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[1]Exceptions are the international arrangements for collecting information on halibut (IPHC) and on yellowfin tuna and skipjack (International Convention for Conservation of Atlantic Tuna (ICCAT)).

the significant factors, and they will ultimately be governed by local custom and social confidence in the management institution.

In addition to effort data, logbook and interview programs provide contacts with the fisheries that yield ancillary data on "conditions" of the target species, interrelationships among elements of the catch, and estimates of such factors as discards at sea. Examples of logbook and interview programs follow.

Example 1.--Guianas Shrimp Logbook Program

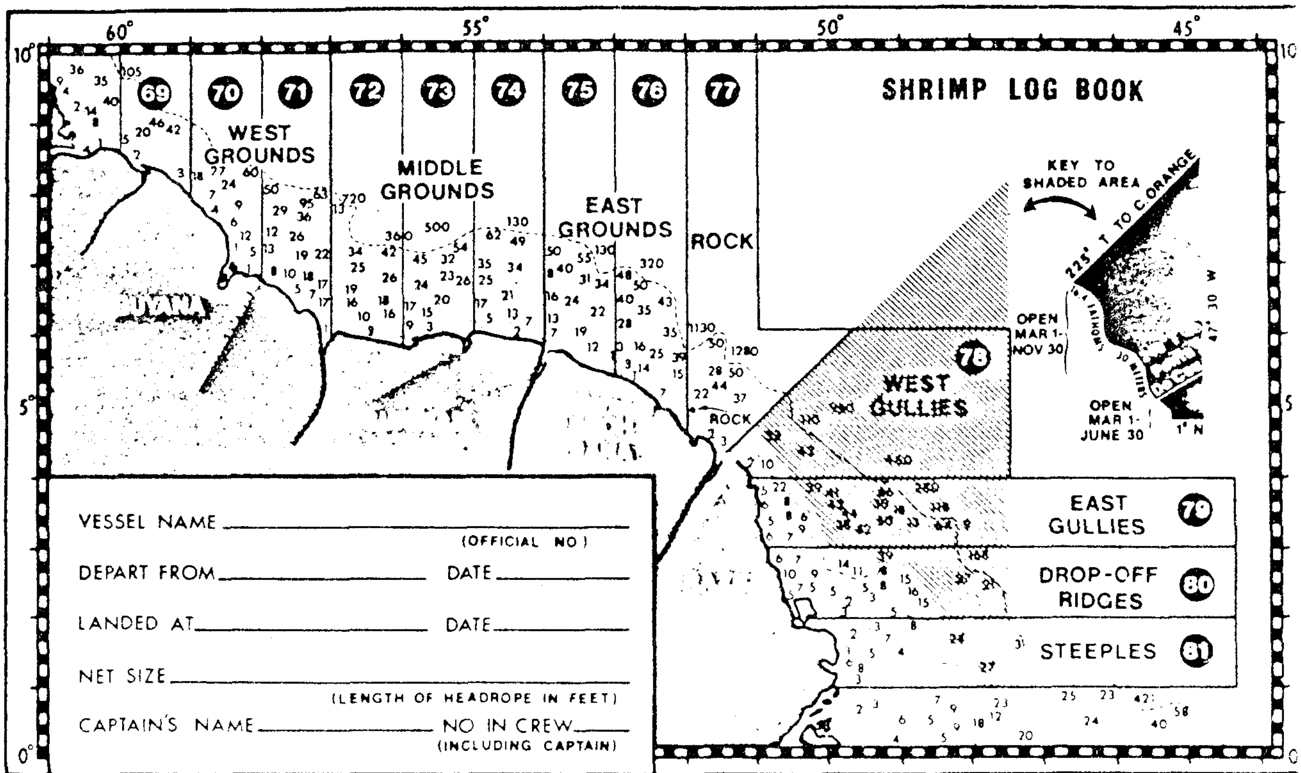
In 1972, the Southeast Fisheries Center established a system for collecting information on catch and fishing effort for the Guianas-Brazil shrimp fishery as part of its responsibility under the U.S.- Brazil Agreement. The Agreement requires that vessel skippers keep records of their fishing activity. A logbook form was designed after consultation with fleet operators, plant processors, and representatives of the Brazilian fisheries department (Fig. 1). The form provides a record of information on fishing time, area, and catch for each trip. To aid the skipper in describing his fishing area, the logbook form includes a chart of the fishing grounds marked with grid zone numbers and depths. Fishing time is recorded as number of drags made and number of hours fished each day, and separate entries are made for day and night fishing. Catch is given as total pounds (heads-off weight) caught each day, and the fisherman is asked to indicate the species and the predominant size category.

The Agreement requires that logbook records be kept for fishing in the Area of Agreement off Brazil. The U.S. industry, however, realizing the importance of this information, has taken a far-sighted step by volunteering to record and submit these data for the entire area of the fishery. In addition to the logbook reports, each processing plant reports the size composition of each vessel's landings. It is important to point out that, although NMFS provides the logbook forms and processes and analyzes the statistical data, the U.S. industry collects and submits the information. The collection of raw data is the most important part of any fishery statistics system and represents a significant input of time and effort by industry members--the vessel captains and the fleet managers--to provide the basic information necessary to understand and manage this fishery.

The information from the logbook reports is tabulated and made available in summary form. The summary, prepared by computer print-out on a monthly or quarterly basis, shows the catch in pounds and the fishing effort in number of drags made and number of hours fished for each fishing zone and depth range. This information is further used to study the unit of fishing effort which will best describe the fluctuations in the stocks.

Example 2.--Shrimp Trip Interview Program

The shrimp trip interview is conducted by Southeast Fisheries Center Fishery Reporting Specialists (FRS). Each FRS randomly samples approximately 30% of the total shrimp vessel trips in his assigned area. Data are collected on a field work sheet (Fig. 2) and include the following: vessel name, date of landing, dealer, size and number of shrimp trawls, catch by species,



VESSEL NAME ______________________________
(OFFICIAL NO)

DEPART FROM ____________________ DATE __________

LANDED AT ____________________ DATE __________

NET SIZE ______________________________
(LENGTH OF HEADROPE IN FEET)

CAPTAIN'S NAME ____________________ NO IN CREW ______
(INCLUDING CAPTAIN)

DATE	FISHING AREA			FISHING TIME			SHRIMP CATCH							REMARKS
							TOTAL POUNDS	KIND					SIZE OF SHRIMP	
MONTH DAY	GROUNDS	ZONE NO	DEPTH (fms)	DAY OR NIGHT	NO. OF DRAGS	TOTAL HOURS FISHED	(heads off)	PINK	HOPPER	BROWN	WHITE	MIXED		

Figure 1.--Logbook form used in shrimp fishery in South American waters.

NOAA FORM 88-20 (3-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

FORM APPROVED
OMB NO. 41-R2590

VESSEL NAME	DATE OF LANDING MO. DAY YR.	DEALER
SIZE OF TRAWLS	NUMBER OF TRAWLS	TOTAL CATCH

ITEM		FISHING ACTIVITY BY GROUNDS		
		GROUNDS	GROUNDS	GROUNDS
FATHOMS				
EFFORT	NIGHT ONLY	# Hrs.	# Hrs.	
	DAY ONLY	# Hrs.	# Hrs.	
	DAY AND NIGHT			
CATCH	BROWN SHRIMP			
	PINK SHRIMP			
	WHITE SHRIMP			
	SEA BOBS			

CONDITION LANDED

☐ HEADS-ON	☐ POUNDS	☐ BOXES
☐ HEADS-OFF	☐ BARRELS	☐ BASKETS

REMARKS

NOAA FORM 88-20

Figure 2.--Field work sheet - shrimp trip interview.

grounds and depths fished, effort in hours by day and night, and condition landed. The FRS also interviews the dealer and obtains total catch by species and size category for all vessels landing on a given day (Fig. 3). An estimate of the total effort can be obtained.by combining all of this information.

The total catch and total effort data are then utilized in production models to estimate sustainable yield for each species, and in summary tabulations for other biological and economic studies. studies.

2.1.3. Catch Sampling

Catch sampling provides critically important biological data for stock assessment, including data on species, sex, size, and age composition of catches, that are used to obtain growth and mortality information vital for fisheries analysis. Feeding habits and reproductive information are also obtained. Catch samples are normally taken by port samplers for domestic vessels or by observers aboard foreign fishing vessels, but efforts are being made to increase onboard sampling of the domestic fleet to improve information on discards at sea. Observers also collect data on the incidental capture of marine mammals in high seas fisheries for tuna and salmon. Frequently port sampling of catch is combined with log or interview data to further characterize individual catches and/or to extrapolate individual catch samples to the sampled universe. For these purposes, careful attention to random collection of samples and statistical design is essential to permit extrapolation of sample data to stock parameters. An example of a catch sampling program follows.

Port sampling of domestic catches, as with fisheries statistics and effort sampling, is generally conducted by state agencies on the west coast and through federal arrangements on the east and Gulf coasts. On both coasts, catch sampling data aboard foreign vessels are collected through the federal foreign fisheries observer program. Careful statistical design is required to combine such data from various sources.

Example 3.--Menhaden Catch Sampling

A prime example of catch sampling is that conducted by the Southeast Fisheries Center in the Gulf of Mexico and Atlantic menhaden fisheries. The program has been in effect for over 20 years and has contributed significantly to our biological knowledge of menhaden and to our ability to provide management advice on the fisheries.

The sampling program covers the entire coastline from Rhode Island to Louisiana. The port samplers take a ten-fish sample from each boat as it arrives at the processing plant, covering five to six boats per day, five days a week, for the entire season. It is possible to take such a seemingly small sample because of the slight variability found among individual fish from a given school. The length, weight, and a scale sample are taken for each fish. The vessel number and area of capture are also noted. The sample data, combined with the landing records of the processing plants, are used to estimate the number of fish landed weekly at each plant, and this information is then summed to estimate the total number harvested for the year. The

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PORT (1-2)	VESSEL NAME	OFFICIAL NO. (3-8)	DATE (15-20) MO. DAY YR.
TRIPS (32-37)	TYPE GRADING (38)	SCHEDULE NO. (65-68) S	DEALER NO (69-71)

(40-41)	AREA (21-24)	DEPTH (25-26)	AREA (21-24)	DEPTH (25-26)
	DAYS FISHED (27-31)		DAYS FISHED (27-31)	

SPECIES	SIZE (Heads–off)	CODE	POUNDS (Heads–off) (42-49)	POUNDS Heads–off) (42-49)
BROWN	UNDER 15	11		
	15–20	12		
	21–25	13		
	26–30	14		
	31–40	15		
	41–50	16		
	51–67	17		
	68 & OVER	18		
	PIECES	19		
PINK	UNDER 15	21		
	15–20	22		
	21–25	23		
	26–30	24		
	31–40	25		
	41–50	26		
	51–67	27		
	68 & OVER	28		
	PIECES	29		
WHITE	UNDER 15	31		
	15–20	32		
	21–25	33		
	26–30	34		
	31–40	35		
	41–50	36		
	51–67	37		
	68 & OVER	38		
	PIECES	39		
SEA BOBS	ALL	40		

NOAA FORM 88-20 B

Figure 3.--Shrimp trip interview form.

sample data are also used to construct life tables for estimating growth and mortality parameters.

Most of the menhaden vessels now carry logbooks for recording effort data as well as total catch. The data obtained by catch sampling will eventually be correlated with the logbook effort data to provide more viable management advice.

2.1.4. Tagging Studies

Tagging programs are designed to address stock origin, migration, growth, mortality, population size, or rate of exploitation; some have multiple purposes. These programs tend to be more closely associated with research programs than are other data collected from the fishery itself, although tags are commonly recovered in connection with catch sampling and interview programs. Example of a tagging program follows.

Example 4.--Shrimp and Groundfish Tagging Program

An example of one approach for acquisition of stock assessment information from tagging data is provided by the shrimp and groundfish program of the Southeast Fisheries Center. Tagging data are used in conjunction with catch and effort statistics collected from the commercial fisheries, to delineate shrimp stocks in the Gulf of Mexico, develop a yield-per-recruit model, and ultimately predict biological yield. Conventional fishery-independent trawling surveys are not relied on extensively to satisfy these objectives. Because shrimp are short-lived and population size varies greatly within seasons, months, and perhaps weeks, the shrimp cannot be aged, and the relationship between adult spawning populations and recruitment is not understood. Past offshore trawling surveys, however, have provided valuable information on species and size distribution patterns and some indications of the temporal and spatial characteristics of spawning. Additionally, estuarine trawling surveys are still used by state resource managers to provide data for controlling the opening and closing of shrimp fishing seasons.

The tagging program involves extensive cooperation among the States of Louisiana and Texas, universities, Sea Grant, Mexico, and commercial fishermen. In 1979, for example, over 113,000 shrimp were individually tagged and released in 16 geographically distinct areas (Fig. 4). Overall, approximately 7% of the tags were returned although, for selected areas, up to as many as 25% of the tags came back. Returns were primarily from commercial fishermen who were encouraged to participate in the program through various contests sponsored by universities in which cash prizes were awarded.

Most of the tagging is done from NOAA research vessels. A 12.2-meter (40 ft.) standard shrimp trawl is used to collect shrimp for tagging. Tow time is less than 15 minutes to minimize injury to the animals. On board the vessel, the shrimp are quickly sorted from the catch and placed in large sea water tanks where they are held 30 to 45 minutes to isolate healthy shrimp from those injured by the trawl. The shrimp are then individually examined for species, sex, and tail length data; a narrow plastic ribbon tag is inserted through their tails with a needle coated with a broad sprectrum

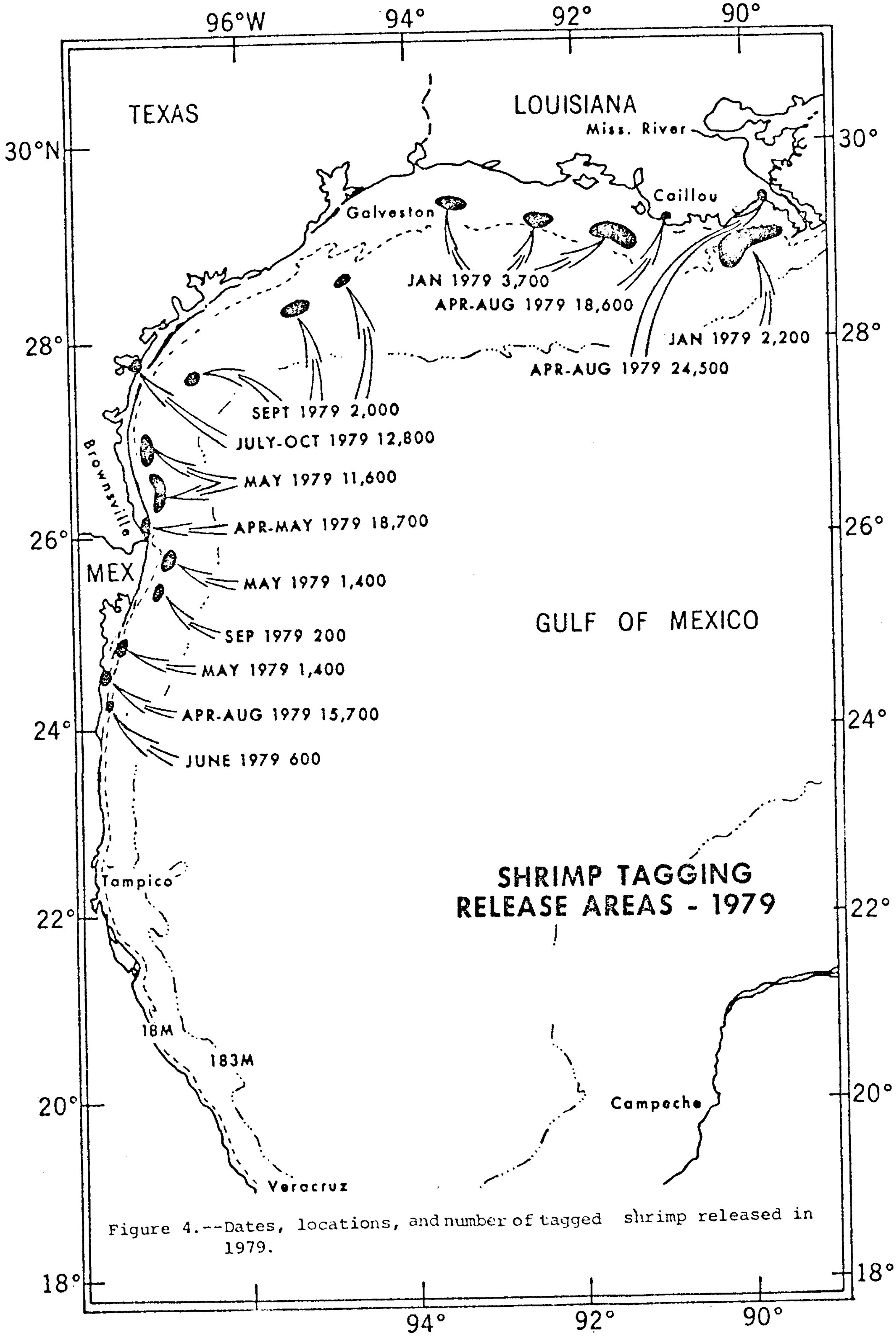


Figure 4.--Dates, locations, and number of tagged shrimp released in 1979.

antibiotic; tag numbers are recorded; and the tagged shrimp are placed back into large sea water tanks. After a period of 3 to 4 hours, the tagged shrimp are again examined to remove any which appear unhealthy. Selected numbers of the healthy tagged shrimp are then placed into disposable canisters for release on the bottom of the ocean. The canisters are equipped with spring-loaded ends held in place with a salt-block trigger. The canisters are dropped over the side of the vessel to fall to the bottom, where the ends break away after 10 minutes of soaking to release the shrimp.

Examples of the type of information already gained from the shrimp tagging program include verification that all three shallow-water shrimp species common from Texas to Mexico, i.e., brown (*Penaeus aztecus*), white (*P. setiferus*), and pink (*P. duorarum*) shrimp, are transboundary (Fig. 5), and that growth rates for both brown and white shrimp vary with season and environmental conditions. Information on shrimp movement and migration patterns, and on the contribution of specific estuarine systems to the offshore stocks, has also been gained, along with preliminary estimates of seasonal mortality rates.

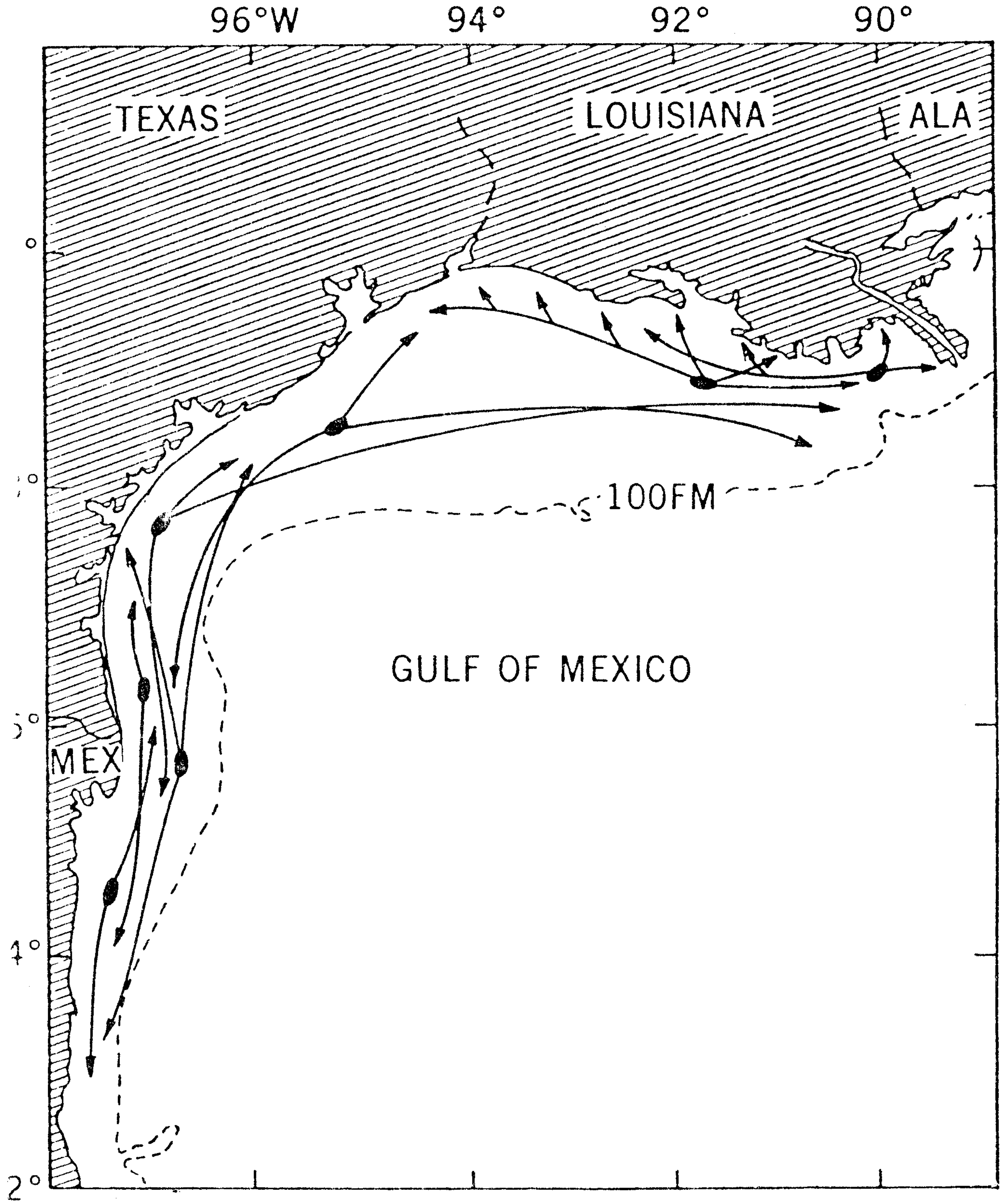


Figure 5.--Movement patterns of tagged shrimp released in 1979.

2.2. Information from Fisheries-Independent Surveys

Marine fishery resources display large temporal and spatial variability in abundance and distribution. Harvest statistics are frequently insufficient from which to develop unbiased estimates of the magnitude of biomass fluctuations in time or space for either a particular stock or a resource complex. Commercial or recreational fishing activities are generally directed toward maximizing profit or pleasure by adapting fishing strategies and harvest efficiency to market conditions, availability of fish, and the like. Accordingly, catch-effort data are often inadequate by themselves as a measure of abundance for individual stocks, despite adjustments to correct for these biases. Mixed fisheries exist in which landings and effort data are more a reflection of the behavior of fishermen (discarding and culling of selected species or sizes of fish, selective fishing, etc.) than of selected species or stock size. Even for those infrequent stocks for which fishery statistics are complete and largely unbiased, these data provide little or no information on pre-recruit abundance and distribution, growth and maturity rates, or species interactions (e.g., food habits).

To provide resource information independent from the fisheries, a number of field techniques are used. These include 1) fishing (trawl, longline, trap) surveys, 2) visual counting and enumeration of marine mammals and fishery resources with aerial, land-based, and underwater surveys, 3) fish egg and larva surveys, 4) acoustic and other remote sensing techniques, and 5) use of environmental indicators. A description of these basic methodologies and their analytical techniques is described in the sections which follow.

2.2.1. Fishing Surveys

2.2.1.1. Trawl Surveys

Perhaps the most important stock assessment activities involved with field surveys are those concerned with direct trawl surveys of pre-recruits and the exploitable portion of fish populations. Three examples of these types of surveys follow.

Example 5.--Bottom Trawl Survey Sampling Program

Beginning in 1963, the predecessor of the Northeast Fisheries Center (NEFC) initiated a bottom trawl survey sampling program in the continental shelf waters of the northwest Atlantic, designed to monitor fluctuations in the structure and size of fish populations independent of commercial fishery statistics, and to provide a quantitative index for the finfish biomass components of the northwest Atlantic ecosystem. The survey program was also established to facilitate estimation of fish production within the continental shelf region, and to provide basic ecological data (growth rates, maturity rates, feeding interrelationships, etc.) on a broad geographic scale so that causal relationships between the quantity and distribution of fish production and changes in environmental and biotic factors might be determined.

The first bottom trawl survey was conducted in the autumn of 1963. This and subsequent autumn surveys during 1964-66 sampled the continental shelf from western Nova Scotia to Hudson Canyon. In 1967, the survey was extended south to Cape Hatteras, North Carolina. Beginning in 1968, a spring survey was initiated covering the same area as the autumn survey.

In 1972 the surveys were expanded; previously the 26-meter (15-fathom) contour marked the innermost limits of the trawl sampling. To fill this gap in coverage, the Sandy Hook Laboratory in New Jersey began an inshore survey in waters of 26 meters (15 fathoms) to less than 9 meters (5-fathom contour). The first inshore survey in the fall of 1972 extended from Montauk Point, New York, to Charleston, South Carolina. At the same time, the Sandy Hook Laboratory initiated an offshore survey south of Cape Hatteras to Cape Canaveral, Florida. Coverage south of Cape Hatteras was assumed by South Carolina in 1973 with NMFS funding. Since then, semiannual or annual surveys have been conducted. One small gap remained in the coverage, between Cape Fear and Cape Hatteras, which has been sampled by routine autumn and spring surveys since the fall of 1978.

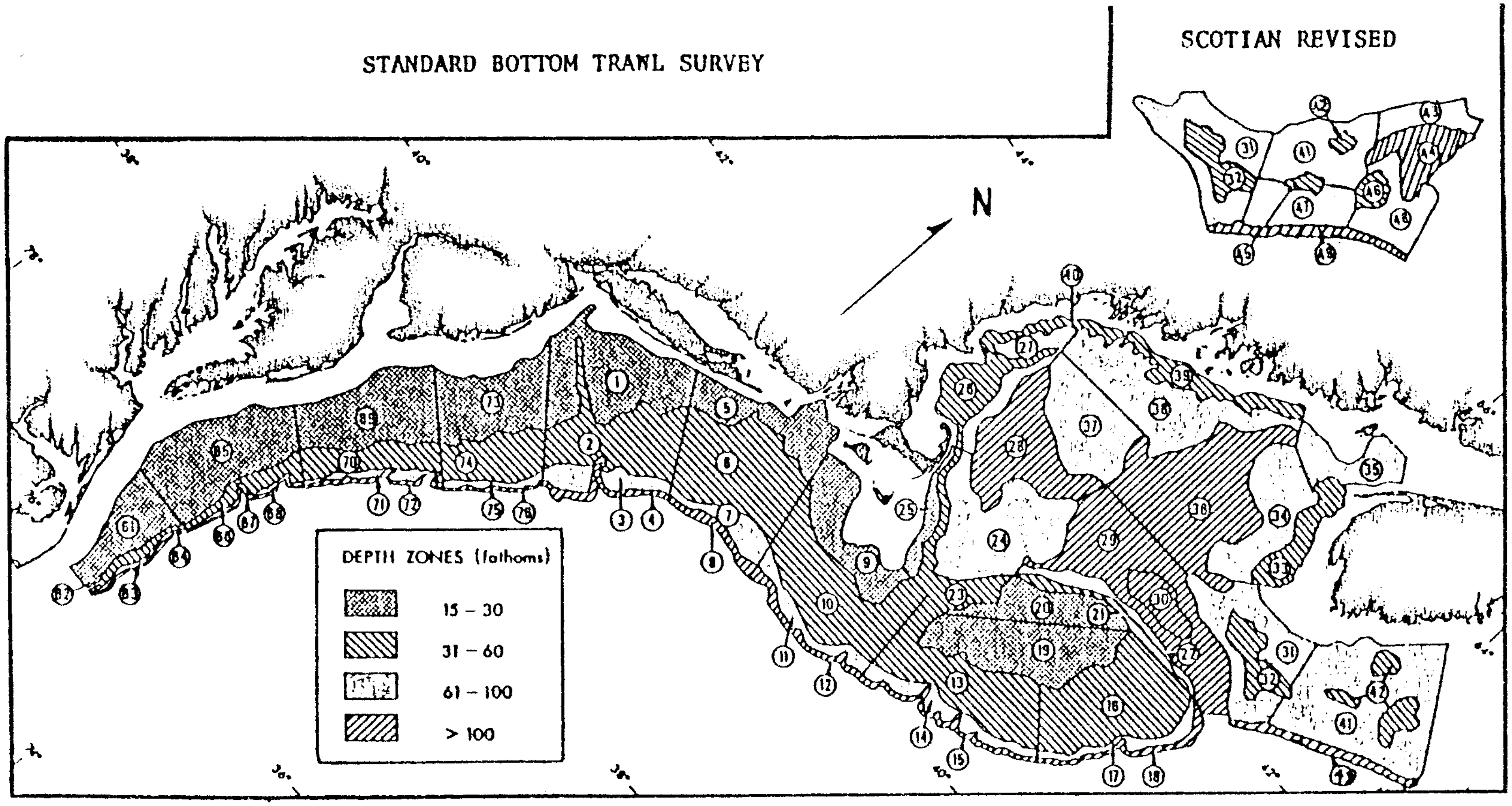
In 1977 a new time series of summer inshore surveys began (less than 60 fathoms or 110 m) in an effort to increase the comprehensive data base as well as to obtain more information on species of recreational interest. Coverage was carried out from Cape Hatteras to Maine that year, and in 1978 the summer survey was continued south to Cape Fear.

Methods--An objective of these survey efforts is to obtain a statistically valid sample, which will provide valid estimates of sampling error (variance). A method to assure a fairly uniform distribution of stations throughout all the possible ecological zones of the survey area is also required. To satisfy these statistical and biological considerations, a stratified random sampling design is chosen for the surveys.

Depth is used as the primary boundary determinant because of its known relationship to finfish distribution. Figure 6 depicts offshore and inshore strata from Cape Hatteras to the Nova Scotian shelf. The entire survey area from Nova Scotia to Cape Canaveral has been stratified, with the major stratum boundaries being determined by depth (less than 5, 5-10, 10-15, 15-30, 30-60, 60-100, and 100-200 fathoms).

Stations are selected randomly within each sampling stratum. Each of the larger strata is divided into areas equivalent to 5 minutes latitude by 10 minutes longitude. Each of these rectangles is considered a homogenous sampling unit. (This means only one trawl haul is necessary to characterize that unit.) Each of these units is further subdivided into 10 sub-units, which are numbered consecutively. Numbers are drawn from a random table or generated by computer and the stations are so selected. Only one station in each of the 5 x 10-minute areas is selected, to assure that the stations are disperse and that every possible trawling site within a stratum has an equal chance of being selected. The smaller narrow inshore and deeper offshore strata cannot be divided into the 5 x 10-minute rectangles; in this case, the smaller 2-1/2 by 2-minute rectangles are used.

The number of stations occupied within a stratum is roughly proportional to its area. Certain strata in priority areas, such as Georges Bank, and some of the inshore areas with great potential pollution impact, are



STANDARD BOTTOM TRAWL SURVEY SCOTIAN REVISED

Stratum	Sq.Miles	Stratum	Sq.Miles	Stratum	Sq.Miles	Stratum	Sq.Miles	Stratum	Sq.Miles	Stratum	Sq.Miles
1	2516	13	2374	25	390	37	2108	66	555	31	1875
2	2078	14	656	26	1014	38	2560	67	86	32	655
3	566	15	230	27	720	39	730	68	52	41	1478
4	188	16	2980	28	2249	40	578	69	2433	42	161
5	1520	17	360	29	3245	41	3752	70	1024	43	920
6	2775	18	172	30	619	42	589	71	281	44	1004
7	514	19	2454	31	1875	49	233	72	105	45	156
8	230	20	1221	32	655	61	1318	73	2145	46	265
9	1522	21	424	33	861	62	243	74	1273	47	1232
10	2722	22	454	34	1766	63	86	75	139	48	1249
11	622	23	1016	35	1097	64	60	76	60	49	233
12	176	24	2569	36	4069	65	2832				
								All Strat	71875	All Strat	9228

Figure 6.--Strata used in the standard bottom trawl survey from Cape Hatteras to the Scotian shelf.

sampled more heavily. Some of the small inshore and offshore strata are also sampled more heavily because at least two stations are needed to permit variance computation.

Approximately 400-450 stations are occupied in a complete survey between Cape Hatteras and Nova Scotia. This represents one station for every 200 square nautical miles; sampling allocation south of Cape Hatteras is about the same.

The surveys are conducted so as to minimize steaming time and maximize vessel time. Southern areas are usually completed first, with the ship generally working northerly to preserve synopticity.

The order in which the stations are visited depends in large measure upon their relation to the shortest cruise track and the overall cruise plan. An example of a cruise track for a portion of the bottom trawl survey is presented in Figure 7.

There are two standard survey trawls: a #36 Yankee and a #41 Yankee trawl. The #36 was used on spring and fall offshore surveys through 1972 and on all fall and summer surveys since then. The #41 has been used on spring surveys since 1973. Initially, the #36 trawl was adequate to provide the abundance indices needed for most commercially important species. However, in the late 1960s and early 1970s, the abundance of fish dropped and a larger trawl was needed. The #41 trawl opens to 5 m, about 2 m higher than the #36. The sweep on both trawls is rigged with rollers. Ground cables are not used, to permit fishing over rough bottom. During the inshore surveys conducted by the Sandy Hook Laboratory from the fall of 1972 until and including the spring of 1975, a 3/4 size #36 trawl rigged with a chain sweep and ground cables was used. All trawls have a 1.25 cm stretched-mesh liner in the cod-end and upper belly.

All trawls and otter doors are tested and measured during special gear mensuration cruises before being used on a survey. During these cruises, each trawl is towed in several directions relative to the surface current, at several different speeds, and at different scope (ratio of wire out to depth). During these tows the opening of the trawl is monitored acoustically with trawl-mounted transducers. Each trawl and set of doors must operate within certain specifications before they are used on a survey.

When arriving on a pre-selected station, and before the trawl is set, a temperature profile is obtained with an expendable bathythermograph (XBT) system. A surface bucket temperature is also taken, and a surface water sample is collected for subsequent salinity measurement. In inshore areas, an optional bottom salinity measurement is taken along with oxygen determinations, especially during summer months. Observations on weather, sea state, and position are also recorded.

A standard trawl haul begins when the predetermined amount of wire is let out and the winch drums are locked. The haulback process begins 30 minutes later. The scope varies from 5:1 in the shallow nearshore areas to 2-1/2:1 offshore in depths greater than 185 meters (100 fathoms). The trawl is towed at 3.5 knots (over-the-bottom speed). The tow direction is generally

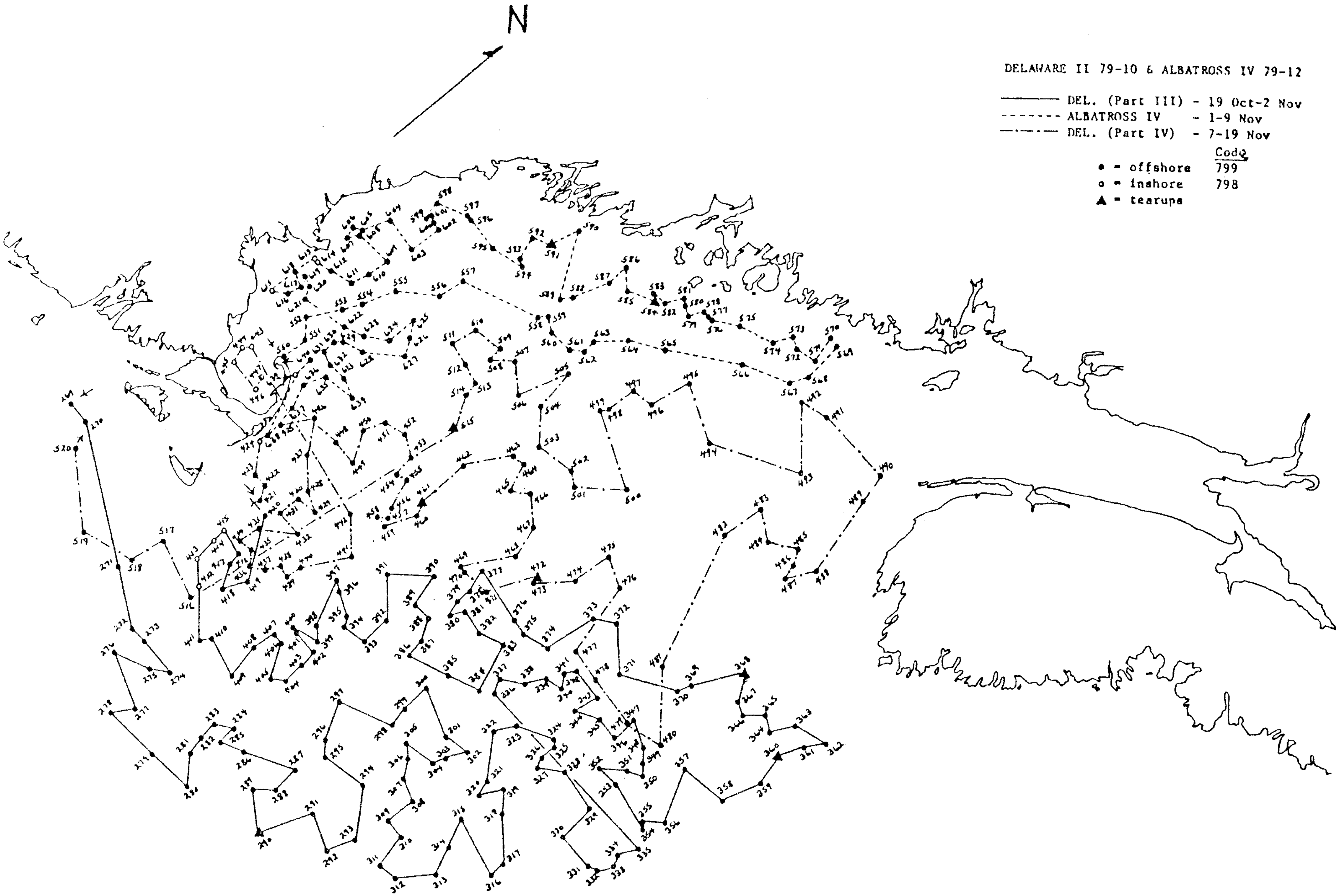


Figure 7.--Cruise tracks for the northern portion of the 1979 autumn bottom trawl survey from Long Island to the Scotian shelf.

toward the next station, although this is not always the case, especially in very rough weather or in areas where the bottom is steeply graded. Under the latter conditions, a depth contour is followed. A fathometer trace is also recorded during each tow.

The catch is dumped onto a table and sorted by species. The sorted fish and invertebrates are weighed to the nearest kilogram and measured to the nearest centimeter (to the end of the center caudal fin ray of the fish). When large catches are impractical or impossible to sort, they are subsampled by weight or volume before sorting. After weighing and measuring has been completed, sample collections are made.

Routine collections include scales, otoliths, or other hard parts, for age and growth studies, as well as stomachs for food habit studies. Tissue samples are taken for pathology or contaminant studies. Gonadal conditions are noted and ovaries are removed from selected species for fecundity studies.

Special sampling requests are numerous--occasionally too numerous to satisfy during a cruise--but a great deal of effort is devoted to obtaining special samples required by colleagues. Specimens have been collected for studies in taxonomy, evolution, and contaminants; for medical and physiological experiments; and for teaching collections. It is the policy to try, after the assessment and inhouse collections have been made, to honor all outside requests.

During many cruises, to better utilize vessel time, ichthyoplankton collections have also been made. Ichthyoplankton collections are generally made before a trawl haul, with bongo nets towed obliquely from surface to bottom and back to the surface. Frequently during the trawl hauls, a surface plankton net will be towed for neuston collections.

For each station, all pertinent data are recorded on a single, two-sided waterproof paper log. This log serves as an original written record of all data obtained at a station. It is also used by automatic data processing personnel. After a cruise, the field log is coded, and all required data are punched onto computer cards directly from the log. Most tallies, expansions, and coding were formerly done ashore because conditions at sea and their effects on the scientists created situations where errors could be introduced. With jurisdiction over an extended fishery conservation zone and the more immediate need for these data, the logs, if at all possible, are coded at sea and ready for keypunching within one or two days following a cruise.

Analytical techniques--The application of NEFC bottom trawl survey data to fish stock assessments has been reviewed by Clark (1979). For stocks in which biological sampling of the commercial and recreational catch has been limited or nonexistent, survey data have provided the only basis for determining basic population parameters such as size and age structure, geographic and seasonal distribution patterns, growth and mortality rates, maturity and fecundity, food habits, yield per recruit, and trends in abundance. These population characteristics are also evaluated for stocks for which a fishery data base exists, thereby providing a supplementary and independent source of information and evaluation.

Trends in stock abundance are evaluated from survey relative abundance indices calculated in terms of stratified mean catch per tow in numbers or weight; i.e.,

$$y_{st} = 1/N \sum_{h=1}^{k} (N_h \, y_h)$$

where y_{st} = stratified mean catch per tow,

N = total area of all strata within the set,

N_h = area of the h^{th} stratum,

y_h = mean catch per tow in the h^{th} stratum, and

k = number of strata in the set.

In cases where the variance of the distribution of catch-per-tow values is much greater than the mean (non-normal), individual tow catch values are logarithmically transformed, and stratified mean catch-per-tow is computed with the transformed values. This transformation generally results in stabilization of variance although the resulting distribution may not necessarily be normal.

The validity of survey mean catch per tow as an index of abundance has been demonstrated both on a stock basis and for the total fishable biomass as a whole (Clark and Brown 1977). For individual stocks for which adequate commercial data are available (i.e., Georges Bank haddock, Georges Bank silver hake, and Atlantic mackerel), trends in the time-series of survey abundance indices tend to parallel trends in stock size estimates derived from virtual population analysis (VPA) based on catch-at-age data (Clark 1979). Survey length-frequency data also tend to conform closely to those obtained from commercial catch samples when allowance is made for gear selectivity differences. Correspondence between survey and fishery data implies that survey data should be useful on a real-time basis for estimating stock parameters not attainable from fishery data.

Clark (1979) reviewed the use of survey data in estimating recruit year-class strength, stock abundance and total biomass levels, catch levels corresponding to specified levels of fishing mortality, and fishing mortality in the most recent year of the fishery. In most of these applications, empirical relationships between VPA results (year-class size, total stock size, fishing mortality), and survey values (catch-per-tow at age, total mean catch-per-tow values) are derived from a time series of observations and used with the most recent survey index for estimating current or future conditions of the parameter in question. For stocks in which fishery catch-at-age data are not available or sufficient for VPA, survey indices have been used in evaluating relative stock size and/or future catch through: 1) analyses of historical trends between fishery catch and concomitant survey values, e.g., Gulf of Maine cod; 2) analyses of commercial catch per effort and total and pre-recruit survey indices, e.g., Georges Bank yellowtail flounder, Gulf of Maine redfish; and 3) areal expansion of survey indices to obtain a minimum population biomass estimate, e.g., Loligo and Illex squid.

Example 6.--Eastern Bering Sea Crab-Groundfish Surveys

The Northwest and Alaska Fisheries Center survey of the southeastern Bering Sea has been planned to assess the crab stocks, with modifications to include assessment of groundfish. For the species of commercial crabs (red and blue king crab, Paralithodes camtschatica and P. platypus, respectively, and the snow (Tanner) crabs, Chionoecetes bairdi and C. opilio), the survey provides estimates of population size and distribution by size and sex. Additional information is gathered on shell, age, and egg conditions. Within-season density distribution information on legal crabs is transmitted to U.S. fishermen to aid them in locating productive areas. As an adjunct to the survey, tagging studies are conducted periodically to arrive at estimates of growth, mortality, exploitation rate, and movements. Survey and tagging results, plus information from the fisheries, provide the basic data for analysis of stock condition.

For the principal groundfish species, the survey provides estimates of apparent abundance, density distribution, size, sex, and age composition. Annual trends in survey abundance indices (total population by size and age groups) are compared with foreign fisheries information for evaluating stock conditions. The survey information is added to the data base, which forms an essential component of the Bering Sea ecosystem model (DYNUMES) developed by Laevastu et al. (1979).

Methods--The boundaries of the survey encompass the main distribution and fisheries for the principal crab species. Survey period is scheduled at a time of the year (May-August) that follows the spring molting and mating, and when population movements of crabs are slowed. For groundfish, the survey period also coincides with a favorable time for assessment, when bathymetric movements of several of the flatfish species onto the shelf and into the survey area have been completed. Although there is a depth shift to shallower waters by adult walleye pollock, Pacific cod, and the larger turbots, the survey only covers a modest portion of the geographical and bathymetric ranges for these species. It does cover the main distribution of crab and sole juveniles and a representative portion of the distribution of pollock, Greenland Turbot, and arrowtooth flounder juveniles. Thus, in terms of area and time of year, the survey appears to be optimal for surveying commercial crabs and soles.

Trawl stations are laid out on a systematic grid (Fig. 8), with each station located at the center of a 20 x 20-mile square. At each station, a standardized method of sampling takes place. A commercial-type bottom trawl with a weighted footrope for maintaining contact with the sea bottom is used. From scuba diver observations and acoustic mensuration, the trawl has been observed to sweep, on the average, a bottom width of 40 feet with a vertical opening of 4-6 feet. A small mesh cod-end liner is used for retention of small animals. Trawl accessories (number and size of floats, door type and

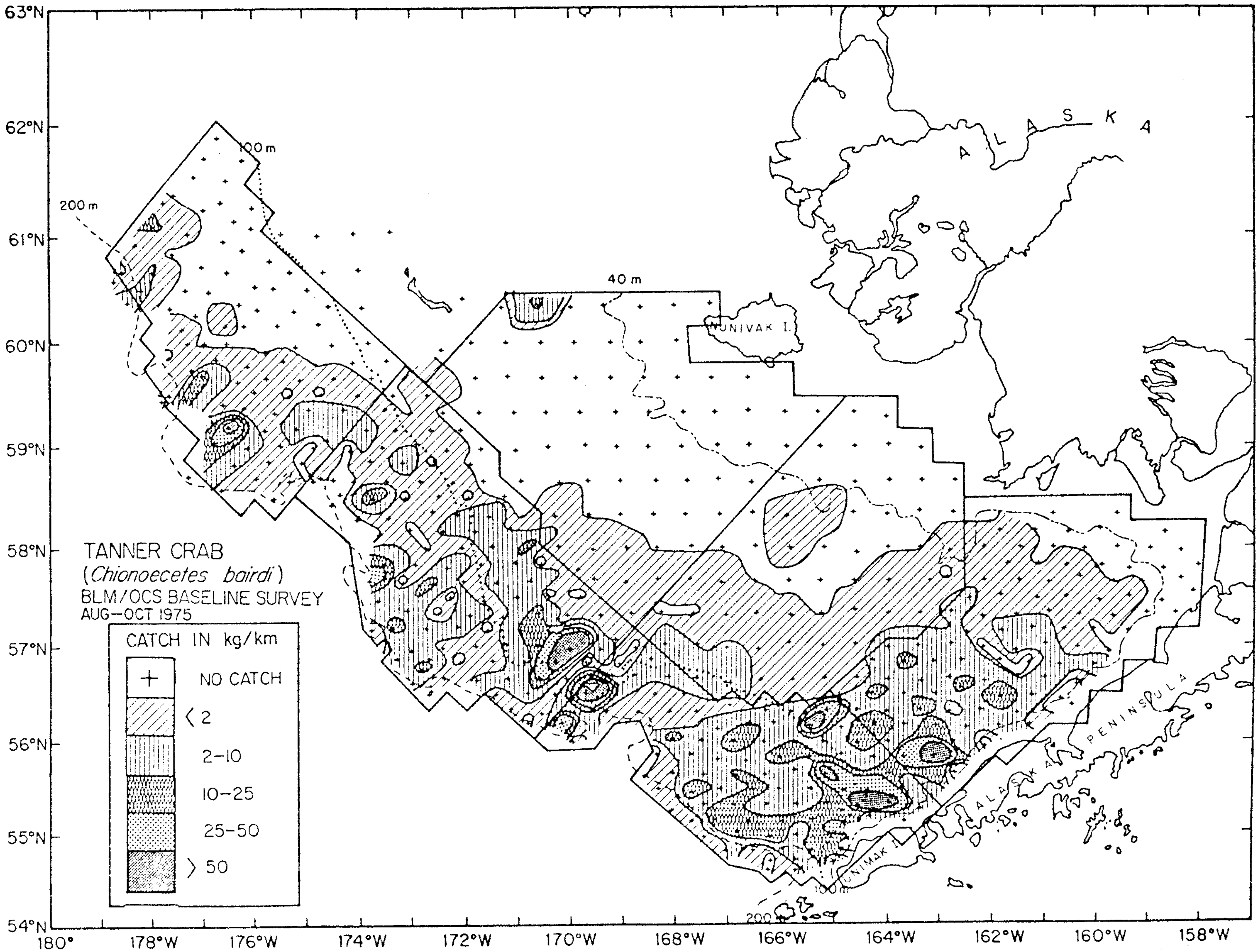


Figure 8.--Stratification scheme and snow crab distribution for the 1975 eastern Bering Sea survey.

size, dandy lines, etc.) are kept the same for each survey, and the same research vessel, the NOAA research vessel Oregon, is used. When another or other vessels assist the Oregon in the survey, trawling trials are conducted between the vessels to establish relative fishing power. Catches of assisting vessels are converted to standard (Oregon) units.

Station position is located by means of Loran-C, with radar used as a nearshore navigational aid. The trawl is set so that the intended station position is passed midway through the tow. Duration of trawling is 30 minutes, with the beginning of the tow timed when the trawl is estimated to have reached the sea bottom. The relation between bottom depth and settling time of the trawl has been estimated from trawl performance studies. After 30 minutes, the end of the tow is marked by the starting of the trawl winches. The Loran-C readings are recorded at the start and end of each tow, and the straight line distance between these points is computed for an estimate of the actual distance trawled along the sea bottom. The reference vessel Oregon trawls, on the average, a distance of one nautical mile in 30 minutes.

During each tow, the echo sounder obtains a continuous record of bottom depth and of fish signs that may be present in the water column. From depth soundings, an average bottom depth is computed for each station. The intensity, extent, and depth orientation of fish signs are related to fish catches. At each station, environmental data in the form of surface and bottom temperature, depth-temperature profile, and extent of cloud cover are collected. Water temperatures are measured by bucket thermometer and expendable bathythermograph cast.

In the handling of the catch at each station, the total catch is weighed by means of a dynamometer. If the total catch is less than 1,200 kg, the entire catch is sorted and subsampled for biological information. If the catch exceeds 1,200 kg, the crabs are removed and a representative portion of the fish catch is removed, by methods presented by Hughes (1976), before sorting and subsampling.

Most animals in the trawl samples are identified by species, although those that are difficult to identify reliably are grouped by genus or combined within a higher taxonomic level. Catch weights for all taxa are determined by weighing baskets of sorted animals to the nearest 0.5 kg on a 141-kg capacity platform scale. Numbers of individuals are determined by direct count or by expanding the number determined from a weighed subsample.

After weighing and counting, the catches of species of principal interest are further processed for length-frequency and individual specimen data, e.g., length-weight frequency, age structures, fecundity.

Aboard ship, pertinent station and catch data are placed on magnetic tape by means of a data logger which is programmed to format data, make range checks, and insure completeness; later at shoreside facilities, the taped information is transferred to computer media.

Analytical techniques--When the survey data have been placed on computer disk files, they are edited by a series of computer programs to detect errors and inconsistencies.

Age material collected during the survey is read by the Center's Age Reading Unit. For those species in which aging methods have been validated, age structures are read in a production mode with reliability checks of the readers.

When the survey data, including age determinations, have been checked for their accuracy, the data are ready for analysis and for the generation of the following standard outputs:

1) abundance indices for the principal groundfish and crab species and for species groups. These indices are expressed in weight and/or number caught per unit distance fished. They are computed by station and stratum for the total survey area and selected size and age groupings.

2) estimates of age and size composition of the available population by stratum and for the total survey area;

3) estimates of apparent biomass and population size by stratum and for the total survey area;

4) length-weight relationships;

5) growth rate parameters;

6) species composition of the catch by station;

7) relative ranking of the species in terms of weight and numbers caught and presented by strata, depth zones, and total survey area;

8) computer-generated plots showing (a) the locations of the stations, (b) the geographical distribution of catch rates of the principal species by size and age groupings, (c) distribution of surface and bottom temperatures in the survey area, (d) length-weight regressions, (e) length and age frequencies, and (f) growth rate curves.

Other estimates, such as mortality and survival rates, population composition in terms of stage of maturity, and species assemblages, can be generated from the survey data.

Variances and confidence intervals of abundance indices and population estimates for the principal species are computed based on stratified sampling theory (Cochran 1962). Stratification of the survey area for king crab data analysis differs from that for snow crab data analysis. For both species, stratification is based on historical and current information on density distribution. There is no stratification of the annual survey area for groundfish; periodically, however, when the annual survey area is expanded to include areas north of the survey area, and in deeper than usual water for sampling, a stratified scheme (Fig. 8) is followed, based upon density and commercial catch distribution patterns of the principal groundfish species (pollock, yellowfin sole).

All population estimates are provided in terms of sex and sexes combined. At times, information is provided on fecundity, species composition, predator-prey relations, and other aspects of the dynamics and ecology of the population surveyed. Surface and bottom temperature distribution for the survey area is also provided on a routine basis.

Since no reliable estimate of the catchability coefficient is available (ratio between the number of fish in the path of the trawl and the number actually caught), estimates of biomass and population size are in terms of the population available and therefore vulnerable to the sampling gear. Thus, for several of the species surveyed, particularly semi-demersal forms and species whose distribution extends beyond the survey area, estimates of biomass and population size are expressed as apparent, and abundance indices of these population are properly qualified.

For some important commercial stocks, such as king crab, yellowfin sole, and other sole species, a catchability coefficient of 1.0 is assumed for those sizes of animals fully recruited to the trawl. Both the adults and juveniles of these species appear to be confined to the survey area and live near or on the sea bottom. Thus, for king crab, an estimate of absolute abundance of the juveniles and adults is provided each year. These estimates are further broken down by size and sex groups[2]. An estimate of absolute abundance of yellowfin sole for animals ages six and older is also provided on a annual basis.

Although young ages of many of the populations are not fully recruited to the gear, abundance indices of these young ages or pre-recruits are given. For some populations, indices may be given for the young ages but not the older ages because of the latter's poor representation in the survey area.

Example 7.--<u>Northern Gulf of Mexico Groundfish Bottom Trawl Survey</u>

The Southeast Fisheries Center initiated a bottom trawl survey in 1972 in the Gulf of Mexico to monitor trends in groundfish biomass. The survey was in direct response to requests from groundfish fishermen and processors for better information concerning the status of these stocks. A fishery-independent assessment was the only practical way to provide this information as only a relatively small and apparently variable portion of the groundfish catch was ever recorded through fishery-dependent methods. The largest single harvester of groundfish is the shrimp fishery, with only about 20% of the harvest being taken by directed fisheries. The majority of the groundfish taken by the shrimp fleet is discarded and never appears on any of the fishing records.

Approximately 170 species of fish occur in the bottom trawl catch of the directed groundfish fishery or as discards from the shrimp fishery (Roithmayr 1965). Only six species, however, are of significance in the

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[2]Estimates are made of the number of legal size crabs (males greater than a specified size) and the number of males that will be recruiting to the fishery the following year.

fisheries, with Atlantic croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*), and seatrouts (*Cynoscion arenarius* and *C. nothus*) comprising the bulk of the catches.

Initially, trawl surveys were conducted seasonally to establish seasonal trends in biomass, species composition, distribution patterns, and to collect data for developing biological profiles of dominant species. After several years, however, the surveys were reduced in frequency in order to concentrate on periods of maximum and minimum abundance to obtain information for estimates of stock mortalities. Monitoring activity was maintained.

A major problem with groundfish surveys is that they do not encompass inshore waters where significant proportions of the groundfish stocks occur during all seasons. This lack of inshore coverage is due to depth limitations of the primary survey vessel, *Oregon II*. Several inshore surveys, however, were conducted from 1974 to 1976 with a shallow draft vessel, *George M. Bowers*.

Methods--Selection of the initial survey area was predicated on historical exploratory fishing data, data from the directed groundfish fleet, and information from selected commercial fishermen. It was later expanded to extend beyond the traditional fishing grounds to ensure that unforeseen shifts in population densities would not invalidate the surveys. Currently, the survey area is divided into one primary and two secondary areas (Fig. 9). The primary area includes most of the principal groundfish fishing areas and is characterized by relatively high and homogeneously distributed standing stocks of groundfish. Densities of groundfish decrease rapidly in the secondary areas, with concurrent increases in distributional variabilities.

The survey design essentially is completely random with some stratification imposed as a result of available vessel days. Coverage of the primary area is emphasized, with less attention given to the two secondary areas. The western secondary area, however, generally does receive more coverage than the eastern area due to higher standing stocks and more commercial fishing activity. The three areas are divided into 10-minute blocks of latitude and longitude which in turn are divided into sixteen 2 1/2-minute sampling areas. As a function of available vessel days, a selected number of 10-minute blocks is randomly picked, with replacement, from each of the three areas, and then one sample area is randomly selected, without replacement, from the 10-blocks. A computerized cruise optimization routine is used to both select the blocks and sample areas and to define the shortest possible cruise track to all of the sampling areas (Leming and Holley 1978).

Upon arrival at a sampling area, an XBT cast is made, along with a surface bucket sample for temperature and salinity measurements. When possible, secchi disk and water color measurements are also obtained. Three 10-minute tows generally are made in each sample area with a standard 12.2-m. (40-ft.) semi-balloon shrimp trawl rigged with a loop chain and rollers. Trawl mesh is 5.1-cm (2-in.) stretch throughout with 4.4-cm. (1.7-in.) stretch mesh in the cod-end. A tickler chain is used between the trawl doors. The sampling trawl is fished off the port outrigger with a 30-fm bridle attached

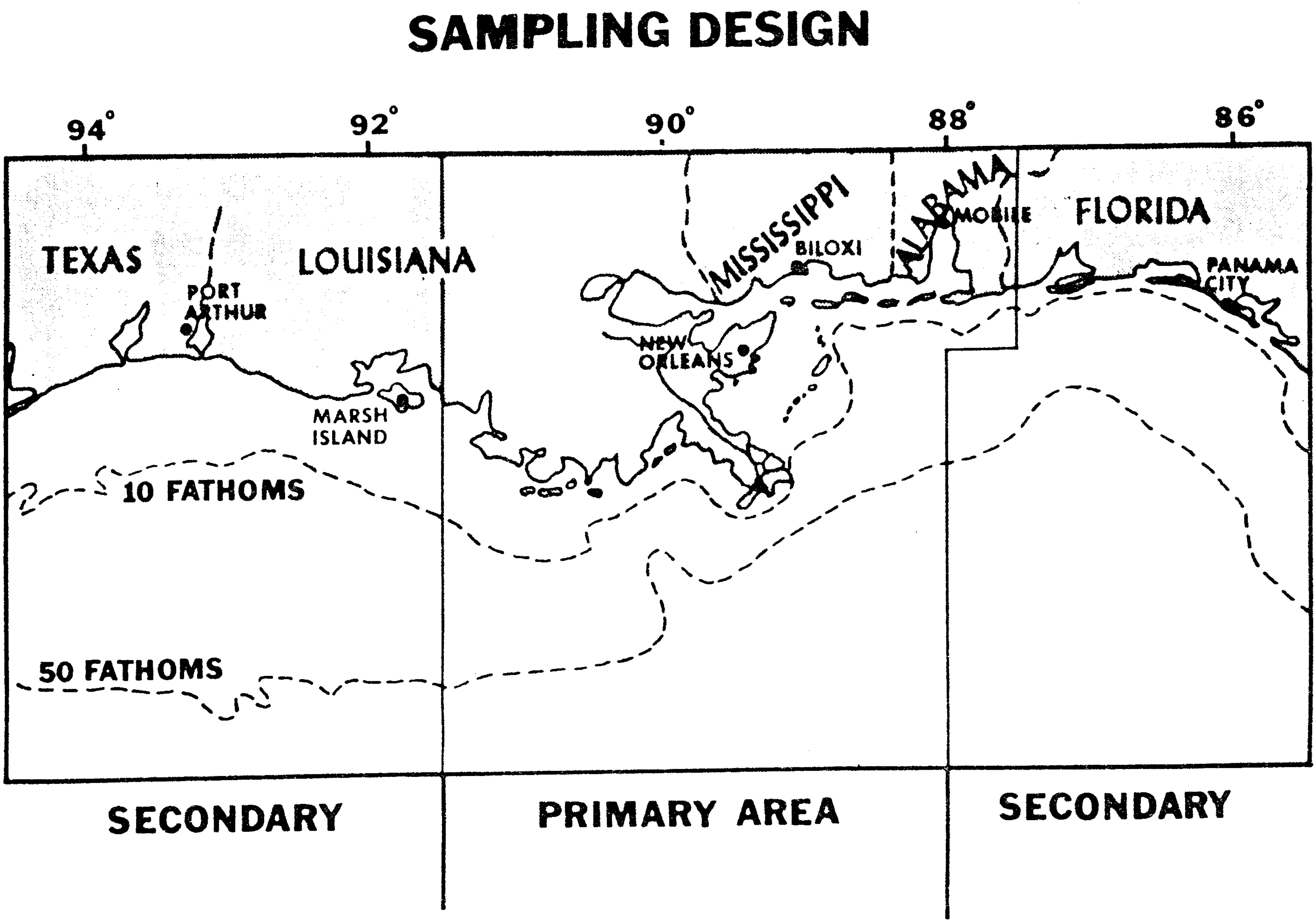


Figure 9.--Groundfish survey areas in the northern Gulf of Mexico.

to the towing wire. The sampling trawls are mensurated periodically, but not prior to each cruise. Normal towing speed is 3 knots.

The three short tows were selected instead of a single 30-minute tow in order to provide data for investigating small scale distributional patterns of the benthic organisms. Generally 500 to 700 tows representing 200 to 250 sampling areas are made per cruise. This sampling intensity equates to about one sample (three tows) for every 40 square nautical miles in the primary survey area, with less coverage in the secondary areas.

Once a trawl tow is completed, the entire catch is dumped on the deck and weighed. Depending on total weight, the catch is either examined in its entirety or a representative subsample is taken for processing. All species are identified, weighed, and measured for computations of species composition; scales and other hard parts are studied for age estimates; sex and maturation of individuals are determined, and stomach content are analyzed. Selected specimens and measurements are also collected to satisfy requests from other investigators.

All data are logged onto station data sheets. The format of these sheets allows recorded data to be key-punched directly onto computer cards for processing. Various edit routines are used to edit the data, although manual editing is still used extensively. All key-punching and computer processing occur after the vessel has returned to port.

Analytical Techniques--As soon as all data from a particular survey have been edited and are available in a computer-compatible format, computer-generated plots showing station locations and catch rates are developed for distribution to the groundfish industry (Fig. 10). These plots generally are only for total finfish, although species plots are also generated periodically to satisfy specific needs.

Attempts were made initially to increase the precision of the biomass estimates derived from the survey data, based on stratified sampling theory with the strata selected according to depth (Juhl et al. 1975). Depth, however, proved to be an inappropriate parameter for stratification. More recent attempts are concentrating on historical abundance indices, coupled with bottom type, to stratify the data to achieve a higher level of precision. Most available biomass estimates are based on analytical treatments with assumed random samples from a normally distributed population. Precision levels at 95% confidence thus often range as high as 100% of the estimate.

Improvements are needed in the analytical approaches used to estimate numbers and biomass of the groundfish stocks in the northern Gulf of Mexico. These improvements have been hindered in the past due to inadequate computer capabilities, a problem which is now beginning to disappear. A number of problems exist, however, which are not disappearing. These involve those assumptions common to most bottom trawl surveys which have their greatest impact on the accuracy of the survey samples. Examples include an assumed catchability coefficient of 1.0 for all species under all conditions and an assumption that all standard trawls fish the same under all conditions. These assumptions are known to be invalid.

FRS OREGON II CRUISE 71, 11/02/76 - 12/01/76

TOTAL FINFISH

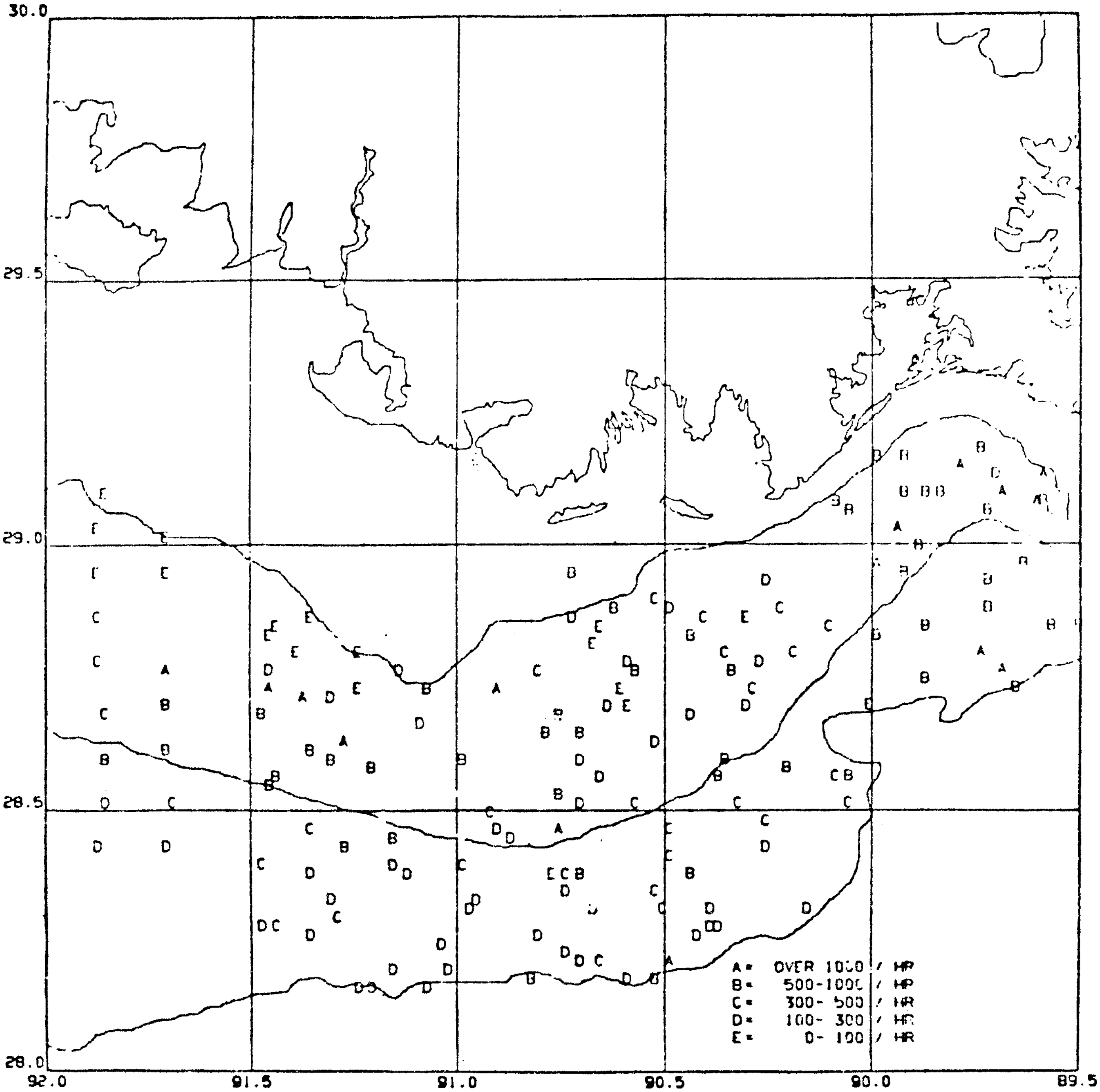


Figure 10.--Example computer plot of finfish biomass (pounds per hour with standard trawl) for area west of Mississippi River delta.

2.2.1.2. Longline and Trap Surveys

A number of important fish stocks are not available to traditional forms of fishery-independent surveys. These stocks occur in all waters under the purview of the United States but are especially prevalent in waters surveyed by the Southeast Fisheries Center. Various forms of survey techniques are used, although none is particularly quantitative and all have significant inherent biases. An example of one of these resources is the reef fishes which include not only the highly-publicized colorful species of the true coral reefs in south Florida and the Caribbean but also large and valuable stocks of snappers, groupers, grunts, and porgies. These species occupy rocky habitat on the outer South Atlantic shelf as far north as Cape Hatteras, and fishing banks and live bottom areas in the Gulf of Mexico. Reef fish communities are almost always associated with hard substrate and high relief; thus, trawl surveys are generally precluded. In those few areas level enough for trawling, trawls are still not a preferred survey technique as the heavy gear may damage habitat. Survey schemes based on existing acoustical systems also are not appropriate because of the often intimate association of reef fishes with their substrate, which makes it difficult if not impossible to distinguish the fish from substrate in acoustic records. Ichthyoplankton surveys also are not very effective because, even with fairly intensive sampling efforts, very few eggs and larvae from reef fish are ever taken. Apparently the typically tropical pattern of nonsynchronous and protracted spawning precludes the existence of sufficient densities of ichthyoplankton for stock assessment.

Trap and bottom longline surveys are used extensively for fishery-independent assessment of deep water snapper and grouper stocks in the southeast region. These gears will take a variety of species and are very useful for the more important market species.

In general, a completely random approach is used to select sampling stations within predefined areas. These areas are selected on the basis of known bottom conditions, historical sampling records, and commercial fishing reports. Station selection is randomized across depth strata and day-night periods. Because systematic sampling throughout all seasons has not been accomplished for most of the species taken with traps and bottom longlines, most of the sampling of a particular area is done during the same season year after year to develop an historical data base for trend analyses.

Bottom longline fishing gear generally consists of a 7.9-mm. (5/16 in.), three-strand braided nylon mainline with gangions used for hook attachment. The gangions normally are fabricated from 1-m. lengths of 136-kg. (300-lb.) test nylon monofilament. Snaps are used to attach the gangions to the mainline, and the hooks are normally of a #6 or #9 Japanese circle style. The gangions are spaced about 3.7 m. (12-ft.) apart on the mainline, with the latter set in 183-m. (600-ft.) shots. A set generally consists of two or three shots of mainline. Anchors are set at the start and finish of each set, along with sufficient longline to reach surface buoy poles. The poles normally are equipped with radar reflectors and blinking lights for ease of location under both day and night conditions. The sets are made from the stern of the vessel with pick-up along the side rail. Biological data collected generally include species, size, and weight; samples are taken of scales, otoliths, gonads, and stomachs.

Trap surveys are generally conducted with traps similar to those used in the commercial fisheries. These currently include rectangular, West Indies, Z-, Cuban, and modified lobster traps. Biological data identical to that collected from the bottom longine surveys are taken here as well.

Results from bottom longline and trap surveys generally are expressed in terms of a capture rate, rather than density. For example, longline results may be expressed as the number of a particular species caught per 100 hooks per 24 hours, and trap results may be expressed similarly as the number of organisms taken per trap per 24 hours of fishing.

Pelagic longline survey techniques are not used extensively for surveys of pelagic stocks. Their use historically has primarily been exploratory, to provide information on seasonal distribution, availability, and species composition. As they represent the only fishery-independent method available for sampling many of the pelagic fish stocks, such as large tunas and billfishes, they are used periodically for collecting specimens for tagging and for acquisition of biological samples.

2.2.2. Visual Surveys

2.2.2.1. Aerial Surveys

Surveys with commercial fishing gears, as noted earlier, have performed an important role in the stock assessment activities of the Northwest and Alaska Fisheries Center, the Northeast Fisheries Center, and the Southeast Fisheries Center. The method, however, is not nearly as applicable to pelagic and semi-pelagic species, and a variety of other techniques have evolved to assess these populations. Aerial surveys have frequently been used to assess populations of near-surface schooling pelagic fish species. Marine mammal populations in Alaska, eastern tropical Pacific, Gulf of Mexico, and South Atlantic, have also been extensively surveyed by scientists at NWAFC, SWFC, and SEFC, with aerial survey methods, especially for the ice-associated seals, endangered whales such as the bowhead and gray whale, oceanic tropical dolphins, and coastal bottlenose dolphins. Examples of aerial surveys are given below:

Example 8.--Aerial Surveys of Dolphins by Line Transect

The objective of this survey method is to count individual animals or groups of animals (schools, basking aggregations, etc.) from an aircraft along predetermined tracklines or flight paths. The numbers of animals or groups of animals seen per unit searching effort, and the amount of area "effectively" searched per unit of searching effort, provide information on spatial distribution and population densities of stocks of animals in question. Depending on the animal being studied and the amount of information which can be obtained on each sighting, estimates of absolute abundance of individuals may be possible at best, while relative abundance of aggregations can be calculated at the minimum.

Methods--The survey is conducted from an aircraft with unobstructed downward and lateral visibility on both sides. The aircraft must also have suitable range, dependent upon the location of airport facilities. To facilitate making detailed observations of animals sighted, the aircraft must have a relatively slow minimum cruising speed and good maneuverability for circling. These problems were encountered in aerial dolphin surveys made by the SWFC off the Pacific coasts of Mexico, and Central and South America, where a slower, shorter-range aircraft was finally selected.

The basic in-flight procedures involve several observers rotating through sighting positions, with one rest position. The observers need to be in communication via intercom. When sightings are made, it is usually necessary to deviate from the flight path at the time of sighting in order to make more detailed observations on the school; circling at lower altitude is frequently needed.

For surveys of pelagic animals, smoke bombs or dye markers thrown from the airplane at the time of initial flyover are useful in relocating the animals. Large format photography has proved useful in determining the numbers of animals in dolphin aggregations.

A major requirement for utilizing aerial survey techniques for stock assessment is that the animals be visible from the air. In addition, the fraction of the population which is being sighted must be estimable. In pelagic dolphin surveys, for instance, it is assumed that all of the animals which were on the trackline (line transect surveys) when the aircraft passed over were seen. Surveys of the number of pinnipeds hauled out of the water on beaches, and of the number of coastal bottlenose dolphins, Tursiops, in a strip (strip transect surveys), suffer because the proportion of the population which is actually visible at any one time is not known. The direct count methods will be discussed in the next section.

In the dolphin surveys, it has been noted that species differ in their visibility from the air. Barham (1979) suggests that Grampus griseus is an inordinately visible animal, especially near the trackline. Correspondingly, larger aggregations of dolphins are believed to be more visible at greater distances from the trackline than are smaller schools.

Environmental conditions affect the visibility of animals from the air: the presence of rain or low clouds, and especially sea state and sun position. Frequently, in extensive surveys, environmental conditions will change markedly over the course of single flights. Recent developments in line transect theory suggest that, if one conducts the survey so as to insure that all of the animals on the trackline are seen, such variations in visibility, within limits, will not seriously affect the stock assessment.

During an aerial survey, two separate data streams are obtained: the sequence of sightings, with ancillary detailed observations, and the record of survey tracks actually searched. Although these two must be analyzed together, they are best recorded separately. The actual trackline searched is complex in aerial surveys because observers cease searching while detailed observations of the sighted animals are made. The details of the track searched may be variously described; in the dolphin surveys, the starting and ending positions and times are recorded for several segments of each track flown. During each segment of each trackline, the sea state, ground speed, sun position, and altitude are recorded, along with times and positions at intermediate points for reference following.

When a sighting is made, observers complete a systematic list of specific observations. In the SWFC dolphin surveys off Mexico, observations are made for species identification, percent composition of each species present, number of animals present, and the position of the sighting relative to the trackline.

The measurement of the location of sighted animals relative to the trackline is extremely important, both for line transect and for strip survey analysis. For the latter, the frequency distribution of distances from the trackline to the animals can be used to validate the assumption that a strip was, in fact, searched completely. For the former analysis, the rate of decline of the frequency distribution of distances from the trackline provides the information for determining the area effectively searched per unit of searching effort.

The location of the sighted schools can be measured by the perpendicular distance from the trackline to the object, or by combining the bearing to the object and the straightline distance. Maximal precision in either case is essential. Inertial navigation systems have been successfully used to measure such distances (Jackson 1979).

The survey pattern is very important to the eventual inferences which can be made from an aerial survey. A priority trackline placement must be determined, ideally with the lines selected at random over the whole area inhabited by the population during the survey period. This can be a problem when the range of the stock is not clearly known or occurs substantially offshore. Additional problems are presented when the animals are visible only at certain points in their range, and when unknown fractions of the populations are at such sites. Aerial surveys of most pinnipeds have suffered from the inability to define meaningful "random samples" of the range of the populations to survey. It is important that accurate position information be recorded during the surveys, especially at the time of sighting, to determine exactly how much area was surveyed.

The two streams of data must be analyzed together in developing stock assessments from aerial survey data. For any but extremely small scale surveys, the data are best analyzed on a computer. Computer programs to integrate these two streams of data need to be written which are sufficiently flexible to allow for the extensive selection and reanalysis of the data necessary in a detailed analysis for stock assessment. In the analyses of the dolphin survey data, selections which were made included only those observations made while searching, only those of certain species, only those of certain minimum school sizes, and only those made within certain distances from the trackline (Holt and Powers 1979).

Analytical techniques--Under ideal conditions where an estimate of absolute numbers of individuals can be obtained, the basic equation to be used is

$$N = D \times S \times A$$

where N denotes the number of animals in the population; D, the density of schools; S, the average school size; and A, the area inhabited at the time of the survey. The techniques used to estimate S and A vary greatly, depending on the particulars of the situation. For example, if the school size is large and highly variable, sufficient observations may not be available to estimate this adequately from the survey data alone (Smith 1975).

The line transect approach to estimating density has been the subject of much recent research, culminating in a recent monograph by Burnham et al. (1980). They note several different estimation formulae which have been used in the literature and explore the statistical properties of many of these. While the proper choice of density estimation formulae is too complex a subject to discuss here, it can be noted that those authors favor a flexible curve-fitting approach, termed the Fourier series estimator, in most situations. This was used in the analysis of the dolphin survey data (Holt and Powers 1979).

The essential characteristic of all of the line transect estimators is, however,

$$D = \frac{n\,f(0)}{2L}$$

where n denotes the number of sightings made; L, the length of trackline searched; and f(0) a parameter estimated from the frequency distribution of perpendicular sighting distances. In one simple case where the numbers of sightings decline exponentially with distance from the trackline, the estimate of f(0) is the inverse of the mean sighting distance. In other situations the estimation of f(0) is considerably more complex. Laake et al. (1979) describe a general computer program TRANSECT which is available for obtaining some of the alternate estimators of this parameter. These estimators and corresponding sampling variation formulae are discussed in Burnham et al. (1980).

If estimates of the variances of the mean school size S and of the area inhabited A are available, it is possible to obtain an estimate of the variance of the estimate of total population size with the delta method (Seber 1973); for an example, see Holt and Powers (1979). Note that the details of this method will depend on the complexity of the final formulae used.

If the conditions of the survey do not allow for an estimate of absolute population size, it may be possible to obtain absolute density of individuals (by omitting A in the first set of formulae), or absolute density of schools (by omitting A and S). Finally, if some of the assumptions are violated, such as all of the animals on the trackline being seen, it may be possible to obtain relative population sizes to compare between surveys. It would then be necessary to repeat a survey with the same characteristics, however, in order to obtain useful information from the study.

Example 9.--Aerial Surveys by Strip Transects of Coastal Dolphins

Coastal populations of bottlenosed dolphin (*Tursiops*) in the southeastern and Gulf regions of the United States often live portions of their lives confined to bays and inlets where they are easily observed from aircraft. Aerial surveys, using a special case of line transect methods, i.e., strip transects, can be an effective way of estimating numbers.

Methods--A typical survey of this type was reported by Leatherwood (1979). With these methods, the aircraft surveys a strip of the population range, and it is assumed that all animals in that strip are seen. The numbers of herds encountered are recorded, and, since the aggregations of *Tursiops* in coastal waters are small, estimates may be made of the herd size and of the size of individual animals. Detailed observations on environmental conditions such as sea state and sun angle are also noted.

The strips are usually chosen so that the bay or inlet is systematically represented in the sample. In addition, flights are planned to be carried out only when weather, time of day, and other environmental factors are within a control range. If weather does not fall within this range, the flight is postponed. Leatherwood (1979) gives the specific criteria. Replicates of the strips are flown to enable estimate variations.

Analytical techniques--The basic formula for estimating abundance from strip surveys is as in the previous section

$$N = D \times S \times A$$

where N is the abundance of individuals, D is the density of herds (number per unit area), S is the herd size, and A is the area. Density of herds is:

$$D = \frac{n}{W2L}$$

where n is the number sighted per strip, W is 1/2 of the strip width and L is the strip length. As noted before, this is a special case of the general line transect model. Sampling variances are obtained from the replicate strips as in Seber (1973).

The effect of visibility and of environmental conditions has a significant impact on strip surveys. Sighting distances should be recorded even for those sightings within the strip, because the distribution provides some implications as to the validity of the assumption that all animals within the strip can be seen. Variable sighting conditions during the survey period also affect the visibility assumption, and may reduce the usefulness of the estimate as a minimum abundance index.

Example 10.--Aerial Survey by Commercial Fish Spotters

Method--The method provides indices of apparent abundance of near-surface schooling fish from observation logs of aerial fish spotters who locate fish concentrations from airplanes and guide commercial fishing vessels in the catching operation. This multiple species method has been used primarily off southern California for monitoring coastal pelagic stocks. The fishery for these stocks has utilized aerial fish spotters since the latter years of the sardine fishery. Many of these pilots have been under contract to NMFS since 1962 to provide flight logs of their observations. The spotters fly single-engine aircraft throughout the range of the fisheries in search of fish concentrations. Flights are made throughout the year during daylight and nighttime hours. Pilots do not follow any pre-specified flight track but scout those areas where concentrations of target species are likely to be found. In this sense, the survey pattern is opportunistic. Pilots record their observations of fish schools on log maps supplied by NMFS (Squire 1972). They also trace their flight track on the map (Fig. 11).

In past years, the flight logs were returned to NMFS for processing. Annual summaries of apparent abundance by species were compiled. More recently, a computerized data management system has been developed. Currently, as the flight logs are received, the data are coded on formatted forms and key-punched. These data are then verified and edited by a series of computer programs. After all the obvious errors are corrected, a data tape is made and stored in a data base system for retrieval and analysis at a later date.

This method of assessment works best for schooled fish species or marine mammals that are often observed in the surface waters. Daytime observations require good lighting and visibility so that color changes in the surface waters or surface disturbances, which indicate presence of a fish school, can be readily detected. Nighttime observations rely on the detection of the faint glow of bioluminescence emitted by plankton, resulting from the disturbance by a moving school of fish. Detection in the dark hours is inhibited by moonlight and the glow from city lights. Species are identified by characteristic school shape, speed, or behavior in the pattern of reflected glitter from sunlight in daytime hours. In dark hours, species identification is enhanced by characteristic school response to a directed flash of light.

Analytical techniques--The analysis of the fish spotter log information is similar to that for catch and effort data. In this case, however, a fish sighting, which is equivalent to a vessel catch, is not a removal from the population and the magnitude of the sighting is not constrained by vessel capacity. The pilot records the following for each flight: date, pilot name, time of day, plane identification, total flight hours, and flight path trace; and for each sighting: species, location, number of schools, and estimated tonnage of each school, or estimated tonnage of the school group. Effort should ideally measure the surface area of the ocean surveyed. Because of the nature of the system, pilots cannot record the detail that would be required for accurate estimates of effort. In the southern California area, for example, the coastal region has been divided into a grid of 10' square blocks (8 by 10 n.mi.), and effort is measured in units of block flights and total flying time. A block flight is defined as the crossing of a grid block by the flight path trace. The pilot may actually spend from a few minutes to a few hours with one grid block, depending on occurrence of fish schools or vessel activity.

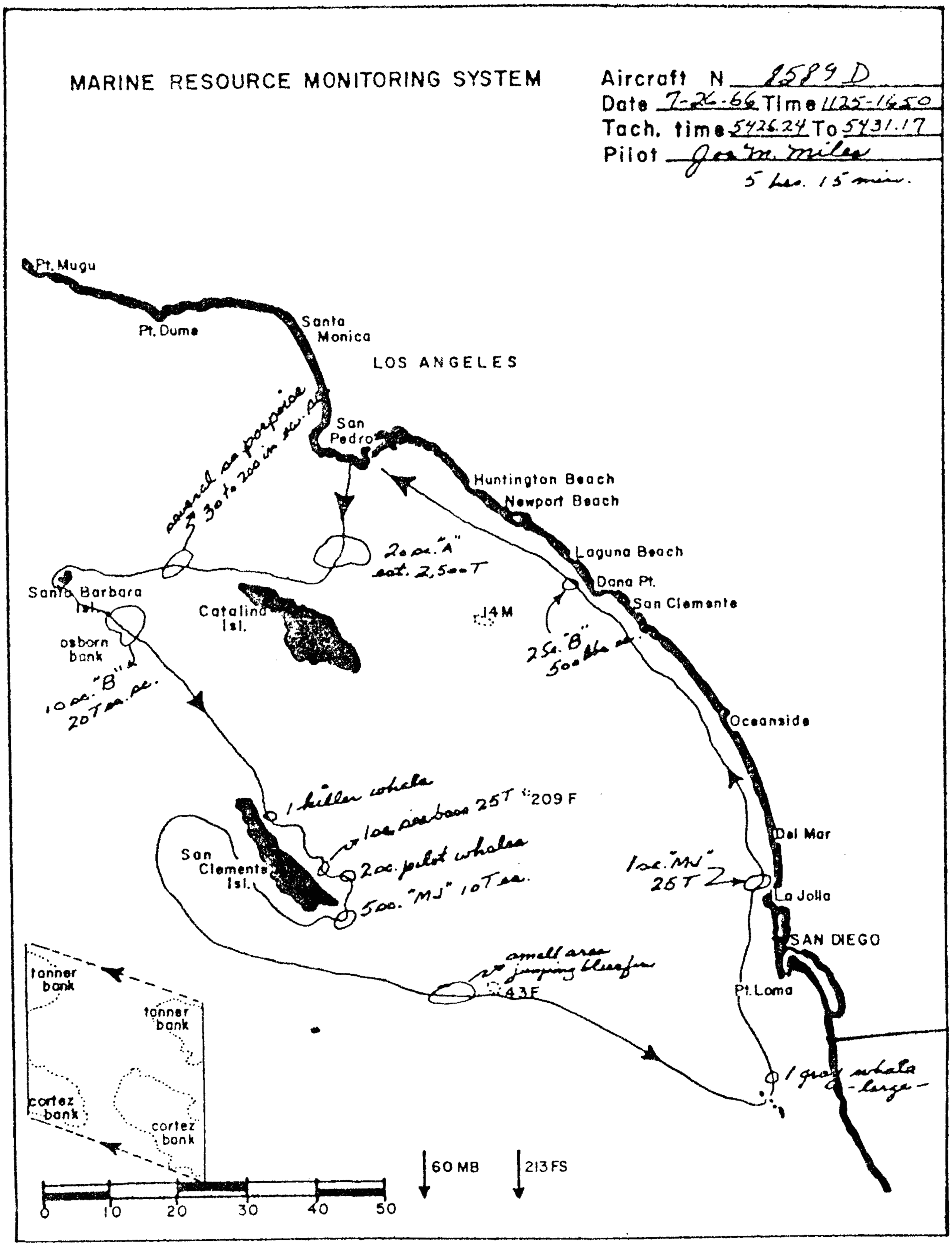


Figure 11.--Flight chart for southern California area showing typical flight track and fish and mammal observations. Block area grid is overlayed on chart for coding observations. (Squire 1972)

Quality control of the recorded observations is promoted through frequent contact with the pilots. Species identification and tonnage estimates can often be confirmed by associated vessel catches. In a few instances, sighted schools are diffuse and scattered, making estimates of school numbers and tonnages impractical. Flight path location is subject to potential inaccuracies because of the small scale of the flight log map relative to the size of the actual airspace surveyed. Accuracy can be improved with the addition of landmarks and popular fishing banks on the maps.

Survey design for this opportunistic method, as in the catch and effort case, cannot be rigorously controlled. Survey coverage over time and area can be promoted by contracting with as many pilots as possible. Off southern California, for example, the fishery targets on a variety of species. The seasonal distribution of these species is sufficiently variable to encourage the pilots to survey frequently over wide areas. Unfortunately, the areas surveyed are somewhat less than the full range of the species. Questions of sample size are not generally raised because of the relatively inexpensive nature of the data collection.

Analysis of these data for other than simple routine summaries requires use of computers and a well-structured data base. For the southern California example, a computerized data management system was developed by Caruso (1979). This system sets up a filing scheme for returned flight logs, data coding instructions, data verification, and data storage and retrieval. This system reduces the time needed to complete sophisticated analysis and insures that data accuracy does not deteriorate with processing.

The primary parameter estimate for stock assessment purposes is either a day or night index of apparent abundance. This estimate is a relative measure of the resource magnitude available to the fishery, and should reflect population densities in the area of the fishery in much the same way as CPUE. There is no obvious method for expanding this relative index directly into a population estimate. In the southern California example, the index measure has been in units of tons of fish per block flight for a calendar year. This index, calculated separately for day and night flights, is the ratio of the annual tally of observed school tonnages to the total number of block flights. Variance estimates have not been considered. The time series for northern anchovy, jack mackerel, Pacific mackerel, and Pacific bonito have shown trends that are consistent with results of other stock assessment methods. This estimation procedure assumes that pilots are essentially equivalent, i.e., their skills are similar and the effective width of their search paths are the same.

An alternative analytical procedure is currently under investigation which applies the fishing power analysis of the catch and effort method as described by Robson (1967) and Francis (1974). In this case, a multiplicative model of tons of fish T can be expressed as a function of various factors: pilots p, season s, region r, day/night t, fish abundance a, and effort as a covariate E, i.e.,

$$T = u \cdot p \cdot s \cdot r \cdot t \cdot a \cdot bE \cdot e \qquad (1)$$

where u is the mean and e is a lognormal error term. The factor a is interpreted to be the yearly fish abundance effect and can be estimated by analysis of variance models of the linearized log transformation of (1), i.e.,

$$T = u' + p' + s' + r' + t' + a' + b'\ln E + e \qquad (2)$$

where the factors are now the logarithm of factors in (1). Although this model appears to be the best method for estimating the index of abundance a, the applicability of the assumption to the southern California aerial spotter data has not been completely examined. Important assumptions are:

1) e is lognormally distributed,

2) interaction terms are negligible, and

3) effort is a significant covariate.

The advantage of this model is that the estimated index of abundance and its variance for the entire time series can be estimated in one analysis which takes into account major factors that influence sighting. In this case the abundance index will be dimensionless and the sum of the index over the years must equal zero (i.e., $a' = 0$). This means that with each new year, the updated analysis of variance will estimate a new time series of the annual abundance factor, a', slightly different from the previous values.

2.2.2.2. Land-Based Counts

Marine mammals, turtles, and salmon have evolved migratory patterns which temporarily visually expose the animals in specific areas. Censusing techniques developed to estimate population size from visual counts are distinctly different from the usual fishery methods. For example, whales typically undertake lengthy migrations between summer feeding grounds in high latitudes and winter breeding grounds in low latitudes. During these movements, some populations pass headlands or are confined to narrow pathways where individuals can be counted as they surface to breathe. Seals, on the other hand, typically swim ashore (haul out) on specific beach areas (rookeries) to give birth and to mate. Turtles crawl ashore on beaches to lay their eggs. Salmon, because of their anadromous behavior, are concentrated in the rivers of the Pacific northwest and Atlantic northeast during both the juvenile and mature adult stages. Research agencies will frequently set up stations along the rivers to monitor the seaward migration of the juvenile salmon smolts or to count the returning adults during their upstream migration to the spawning grounds.

A primary advantage of these counting techniques is that major funding levels are not required to obtain an observation platform. Rather than using valuable charter time to survey, the observer goes directly to the place where the animals are found. The primary disadvantage is that, despite intensive effort, some segment of the population may not be available for censusing. For example, some whales may be submerged when swimming by a station and not be seen, female seals may be feeding away from the rookeries when counts are taken, and only a portion of female turtles breed. In these cases, accessory experiments must be undertaken to derive correction factors which improve the accuracy of population estimates. Prior knowledge about the behavior of animals in the census area usually eases the task of designing and implementing such experiments.

The problem of estimating population size from direct counts of a proportion of the population is especially exemplified by beach surveys for sea turtles in the southeastern and Gulf regions of the United States. Surveys of the beach for evidence of turtle nesting activity have been made from aircraft and on the ground. However, only the adult females lay eggs and only some fraction of them may be breeding. In addition, the data unit being counted is the animals's track left as it crawls to the water. Some judgment can be made as to the freshness of the track, but this aspect compounds the problem by introducing a possibility of overcounting the nesting activity. Therefore, it must be reiterated that counting methods rely considerably on knowledge of behavior before the counts can be expanded to population estimates.

Since the estimation of the number of smolting or spawning salmon for a particular river system is generally the responsibility of state fishery agencies, the methodology will not be discussed in this report.

The following examples typify the counting methods used for whales and seals and may be contrasted with the usual fisheries stock assessment methods discussed previously. A full review of marine mammals census methods, of which these are a subset, is given by Eberhardt et al. (1979); many of these are derivatives of usual fisheries techniques.

Example 11.--California Gray Whales

Methods--The California stock of gray whales leaves its feeding grounds in the Bering and Chukchi Seas in October and migrates down the North American coast to winter along the west coast of Mexico. During this migration, the gray whales tend to hug the coast, and at various places the migratory corridor is quite narrow. Between Point Lobos and Point Sur on the Monterey Peninsula near Monterey, California, aerial surveys indicate that 93% of the population passes within 3.2 km of shore.

Since winter of 1967/68, the predecessor of the National Marine Mammal Laboratory has exploited the migratory behavior of gray whales along the Monterey Peninsula by making a shore count at either Yankee Point or nearby Granite Canyon, California. At a height of 21-23 m above sea level at these two places, an observer is likely to see most of the whales which pass by in daylight.

Each year a watch has been maintained from 0700 to 1700 by two observers alternating 5-hour shifts, seven days a week. An observer watches to the north for southward migrating whales. For each sighting, the number of groups seen, the number of animals in each group, and the time of sighting are recorded. When the whales pass by directly offshore, the observer also estimates the distance from shore and records wind direction, Beaufort Sea state, and comments on visibility (fog, glare, etc.).

Analytical techniques--The total counts obtained each year during December 18 - February 4 (excluding December 25 and January 1 holidays) are shown in Table 1. Reilly et al. (1980) examined these data in detail to obtain a statistically valid estimator for total population abundance. Their analysis indicated that observers consistently underestimated the number of whales in a group, that whales migrated at the same rate at night as during the day, and that observers' abilities to sight whales declined significantly beyond 2.4 km.

Table 1.--Counts of southward migrating gray whales from stations near Monterey, California.

Season	Count	Season	Count
1967/68	3,120	1973/74	3,492
1968/69	3,081	1974/75	3,348
1969/70	3,064	1975/76	3,797
1970/71	3,034	1976/77	4,058
1971/72	2,588	1977/78	3,127
1972/73	3,304	1978/79	3,568

Shore observations were compared with results from concurrent aerial surveys. If a constant rate of migration occurred throughout 24 hours, the number passing in day j (n_j) was defined to be

$$n_j = (\Sigma_i f(n_i)/t_j)\cdot 24$$

where n_i = the number counted in the ith sighting

$f(n_i)$ = the bias correction function for undercounting by observers, as compared to concurrent aerial surveys

t_j = total time watched during the jth day,

and Reilly et al. defined the bias correction function as n_i as

$$f(n_i) = \begin{cases} n_i + 0.350 & \text{if } n_i = 1 \\ n_i + 0.0 & \text{if } n_i = 2,3 \\ n_i + 0.333 & \text{if } n_i \geq 4. \end{cases}$$

Whales which passed by before or after the census period were accounted for by assuming a normal distribution curve for the sightings. For those which were missed as a function of their distance from shore, Reilly et al. developed a correction factor by comparing sightings from shore inside and outside of 2.4 km with concurrent aerial observations.

The cumulative proportions of the population expected each day were calculated from past daily count data and found to fit a normal cumulative distribution.

The estimates of abundance and 95% confidence intervals obtained from the gray whale count data are shown in Table 2. The estimates all have confidence intervals under ± 20%.

Table 2.--Estimates of abundance for California gray whales and their confidence intervals expressed as a percent of the estimate. Source: Reilly et al. (1980).

Season	Estimate	Confidence interval (%)
1967/68	10,767	18.5
1968/69	11,384	19.0
1969/70	11,748	18.5
1970/71	11,356	19.1
1971/72	9,637	18.5
1972/73	13,167	18.3
1973/74	13,010	18.5
1974/75	12,069	19.2
1975/76	14,930	17.5
1976/77	16,511	17.5
1977/78	13,644	17.9

The aerial surveys were made during good visibility. No corrections in the counts have been made for low visibility counting periods. Reilly et al. concluded that, as a result, the reported estimates were below actual values since no correction had been made for changes in visibility; poor weather, for example, would affect an observer's ability to count passing whales accurately. The highest estimate, 16,511 for 1976/77, is probably the best estimate available since there was an exceptionally clear and stormless winter during which better than average visibility would be expected. The lowest estimate, 9,637 in 1971/72, occurred during a year which was reported to be "stormier" than usual. Further research will develop appropriate correction factors for visibility.

Example 12.--Northern Sea Lions

Methods--Northern sea lions haul out on the eastern Aleutian Islands throughout the year but occur in greatest numbers on land between May and October during the breeding and molting seasons. Seven rookeries, where breeding occurs, and 23 haul-out sites, where no breeding takes place, have been identified in this area. The height of the breeding period occurs during

June-August, and the maximum number of animals is expected to be ashore then at both the rookeries and haul-out sites.

During 1975-77, the National Marine Mammal Laboratory exploited this behavioral pattern to census the number of sea lions in the eastern Aleutian Islands (Braham et al. 1977). Aircraft were flown over each area within 400 m of the coastline, at altitudes of 90-240 m and at speeds of 150-190 km/hr. For sites having more than 20 animals, observers took photographs with 35 mm cameras equipped with telephoto lenses, motor drive units, and high speed color film (ASA 160-200). Otherwise, visual counts were recorded.

Analytical techniques--The total counts obtained during four aerial surveys are shown in Table 3. Examining the data in detail, Braham et al. found no statistical differences when the same sites were compared to succeeding survey years using Wilcoxon's Signed Rank Test (Hollander and Wolfe 1973). Consequently, it was possible to pool the 1975-77 data. However, as noted in Table 3, inclement weather affected visibility during the June 1975 survey, resulting in a rather low total count; therefore, that total count was not considered to be a replicate. Omitting it gave a mean value of 21,881 sea lions with 95% confidence limits of ± 11% (19,390 - 24,372).

Table 3.--Total counts of northern sea lions from the eastern Aleutian Islands. Source: Braham et al. (1977).

Year	Month	Total Count	Sites[a]
1975	June[b]	11,406	29
	August	21,221	40
1976	June	22,142	35
	August	20,239	41
1977	June	23,922	40

[a]Number of sites visited where sea lions were seen.
[b]Inclement weather affected visibility.

2.2.2.3. Underwater Surveys

The best current survey techniques for reef fish stocks are those based on visual methods supplemented with photographic and video imaging systems. Reef fishes almost invariably occur in clear water. Consequently, various survey techniques based on sightings (as used for numerous land animals) are possible. These techniques can be used two ways: visual surveys may be used alone to measure stocks on a selected reef, or a set of subsets of reefs may be taken as a sample of all reefs. In the latter case, the mean stock abundance computed for the subsets is extrapolated to total abundance by relating the mean to the total amount of reef habitat available. Reef habitat can be estimated in various ways, but vessel surveys which use over-the-side video methods are preferred.

A variety of visual methods is used to measure abundance of reef fishes. Generally these methods fall into two categories: 1) those which depend upon direct human sightings (Brock 1954, Parker et al. 1979, Stone et al. 1979) and those that rely on photographic and video records (Alevizon and Brooks 1975, Ebeling et al. 1971, Smith and Tyler 1973). Direct human sightings are generally preferred since available camera systems provide limited fields of view which make accurate species identification and quantification virtually impossible. Photographic and video systems, however, offer the advantage of providing permanent records which can be studied after completion of surveys.

Directed visual surveys generally are accomplished either by scuba divers or by manned submersibles. Scuba surveys are less expensive, although they are depth-limited. Submersibles, on the other hand, offer most of the advantages of scuba surveys and are not depth-limited. The cost of submersibles, however, is high: good submersibles and support vessels cost $8,000 to $10,000 per day.

Direct visual surveys require highly skilled biological observers to be effective. Species identification under water is difficult, especially since fish cannot be handled directly and all identifications have to be accomplished spontaneously. Fish collections, however, often are made in conjunction with man-in-the-sea techniques to provide specimens for verification of species identifications. Total kill of the fish in a selected survey area is usually attempted through the use of ichthyocides or explosives. Although ichthyocides provide the best method for collecting some of the small cryptic species, they are destructive and time-consuming to use.

Photographic and video surveys offer some advantages. They incur minimal risk to human life and, in their simplest form, are relatively inexpensive. Their disadvantages relate primarily to limited fields of view, which hinder accurate species identification. Surveys of this type include over-the-side television and photographic systems, tethered remotely-operated cameras, and cameras mounted on remotely-operated vehicles. Camera systems mounted on towed sleds [e.g., Remote Underwater Fisheries Assessment System (RUFAS)] have not proved to be very useful because reef fish tend to avoid rapidly-moving vehicles. A video scheme, based on a multicamera color television system lowered from a vessel to the bottom, could ultimately prove useful because it can simultaneously image a 360^{o} sphere. An observer placed in a hemispherical viewing chamber thus would have an enhanced view of the scene as if it were viewed from a submersible.

Analytical methods used for both visual and photographic/video surveys are generally based on line transect or quadrate count theory. For the former, measurements of the location of sighted fish relative to a given trackline must be accurately estimated. For the latter, counts must be reasonably representative of the area surveyed. Water clarity, currents, and time of day all affect interpretation of data and must be considered in the analysis.

2.2.3. Fish Egg and Larva Surveys

The assessment of the abundance of spawning stocks of fish can be accomplished by conducting surveys of the abundance of eggs, larvae, and juveniles. Pelagic fish eggs and larvae are the most numerous and vulnerable stages in the life history of fish and some shellfish, permitting convenient sampling with simple equipment over broad areas. Results from egg and larvae surveys are more reliably used for hindcasting (e.g., estimating the size of a spawning stock that produced the quantity of eggs ascertained from a survey) than for forecasting (e.g., predicting year-class strength from an estimated quantity of eggs or larvae).

The basis for this method is to sample quantitatively a known volume of sea water from a known area. The number of animals caught are then arithmetically expanded to determine the total population size. This can then be arithmetically converted to the size of the spawning stock if fecundity and the sex ratio of the adults are known. Details of the procedures are adequately explained by Smith and Richardson (1977).

In the U.S., the most extensive surveys have been conducted by California Cooperative Oceanic Fishery Investigations (CalCOFI) which has surveyed the waters from the Oregon-California border to the tip of Baja California and Gulf of California since 1950. These studies have focused principally on the California sardine and northern anchovy and, to a lesser extent, on Pacific mackerel, jack mackerel, and rockfishes. Smith and Richardson (1977, 1979) cite many examples of this work. Extensive egg and larvae (ichthyoplankton) surveys, which have been both single- and especially multispecies oriented, have been conducted by NMFS in the northwest Atlantic and in the Gulf of Mexico. Results from these surveys have not, however, provided the bases for stock assessments.

Use of surveys is wide-spread in European waters and is used to estimate population sizes of North Sea herring, capelin, cods, and flatfish (Smith and Richardson 1979). The relation between stock size and larval abundance has been shown for many species, especially the North Sea herring, where long time series of data are available (Postuma and Zijlstra 1974).

Example 13.--Ichthyoplankton Survey on Abundance of Adult Spawning Fish

This method assesses the abundance of adult spawning fish stocks with a shipboard ichthyoplankton survey designed to measure the distribution, density, and production rate of the spawning products, fish eggs, and larvae.

Methods--The survey can be conducted from almost any seaworthy vessel equipped with a hydrographic winch that can be operated in coordination with the vessel speed in order to maintain strict standards of a quantitative net tow. The basic piece of sampling gear is a fine-mesh plankton net which is towed along an oblique trajectory, although vertical and horizontal tows are also possible. A variety of net designs has been developed over the years. The most common nets used by CalCOFI and by NMFS researchers are the slow-speed bridle ring net and the paired Bongo net fitted with either 0.333 mm- or

0.505 mm-mesh nylon nets. Additional meters are required to measure the various parameters to quantify the net tow, such as a cable meter to measure amount of wire out, an inclinometer to measure the wire angle, and a flowmeter to measure the volume of water filtered.

The survey pattern is generally designed to sample the temporal and spatial distribution of the spawning distribution of the species being studied. Surveys are usually composed of multiple cruises, frequently with more than one research ship, scheduled over the spawning seasons of the target species. Station patterns follow a specified grid that encompasses the species' spawning distribution.

The basic information for each sample is the number of fish eggs or larvae beneath a unit sea surface area (10 square meters in the CalCOFI example). The required data for each sample are station identification, parameter values of the net tow, and number of fish eggs and larvae. The CalCOFI program has recently developed a sophisticated data management system whereby these data are compiled, verified, and stored for future retrieval and analysis.

The ichthyoplankton survey can be used to assess most marine fishes that have pelagic eggs and feebly swimming larvae distributed throughout the upper mixed layers of the ocean. The method, however, requires that the taxonomy of the eggs and larvae be reliably known, and would be effective for species with demersal or highly buoyant eggs only if the larvae are epipelagic, although horizontal neuston tows could be used to sample buoyant eggs. Species with fast-swimming, rapid-growing larvae could probably not be sampled successfully.

Analytical techniques--Data from this survey can be divided into field and laboratory observations. Field data identify the sample with station number, position, date, time, etc. and document quantitative characteristics of the net tow. The station standard haul factor (SHF, the number of 10 m^2 sea surface units sampled) is calculated from the latter net tow data by the equation

$$SHF = 10\ (a^{-1}\ b^{-1}\ d)$$

where a is area of the mouth of the plankton net in square meters,

b is the length of the tow in meters,

d is the effective depth of the tow in meters.

b, the length of tow, is measured by the number of revolutions of the flowmeter; d is estimated from the maximum length of wire out and average tangent of the wire angle taken at 30-second intervals over the retrieval of the net.

In the laboratory, the volume of plankton is measured, and large samples are fractioned into smaller subsamples. Trained sorters separate the ichthyoplankton from the rest and identify and count the eggs and larvae of the high priority species. For some studies, sorters may identify egg development stages or may measure length of larvae to the nearest 1/2 millimeter. Later, identification and counts are made for other eggs and larvae for which the species name is known. The two data sets of SHFs and egg and larva counts are combined via the station ID to give the standard number of eggs or larvae per station.

Quality control is a major concern. In the CalCOFI case, plankton nets must continually be examined for holes and flowmeters are frequently recalibrated. Net tows are repeated if the flowmeter fails during the tow or if the wire angle exceeds 51° at any time during the tow. Plankton sorters' identifications and counts are later confirmed by ichthyoplankton experts. The data management system includes a set of data verification programs which screen data errors and inconsistencies.

The survey pattern should be designed to cover the temporal and areal range of the spawning distribution of those species of concern. If there is a multitude of species, as in the CalCOFI example, then cruises must be scheduled at approximate monthly intervals for almost a year's period. On the other hand, if the objectives are to assess only one or two dominant species, cruises can be scheduled for the primary spawning months. The number of cruises then depends on the length of the spawning season.

The recommended station pattern is a centric systematic area sample grid. A CalCOFI example is shown in Figure 12. This station pattern meets the conditions for random sampling (Milner 1959) and is conducive to efficient ship operations. The number of samples per survey needs to be large enough to apply the central limit theorem to estimates of densities of the fish eggs and larvae. The number of stations required per survey is a question of the desired level of precision. For an annual multispecies CalCOFI survey, the target sample size is 2,000 plankton tows. For an abbreviated anchovy survey, a sample of 600 tows is adequate.

The basic results produce an egg and larva survey area distribution map of the spawning stock(s), an estimate of the density of eggs or larvae or their total abundance (egg or larva census estimate), and/or an estimate of the egg or larva production rate. These latter estimates require further information on egg and larva mortality rates. Analyses of egg stage or larva size-frequency data, along with knowledge of developmental rates or growth rates in order to age staged eggs and sized larvae, are also needed.

The density estimates in terms of average number of eggs or larvae per 10 m^2 sea surface area are best compiled by regions if the pattern of stations is not uniformly distributed over the survey area. In general, the density estimated C is the average

$$C = \left(\sum_{i=1}^{n} SHF\ C_i \right) n_i$$

where C_i is the count of eggs or larvae per station, and n_i is the number of samples in survey region or area. The empirical estimate of the variance of density is sufficent if the sample size is large enough so that the central limit theorem applies. Usually the frequency distribution of counts per

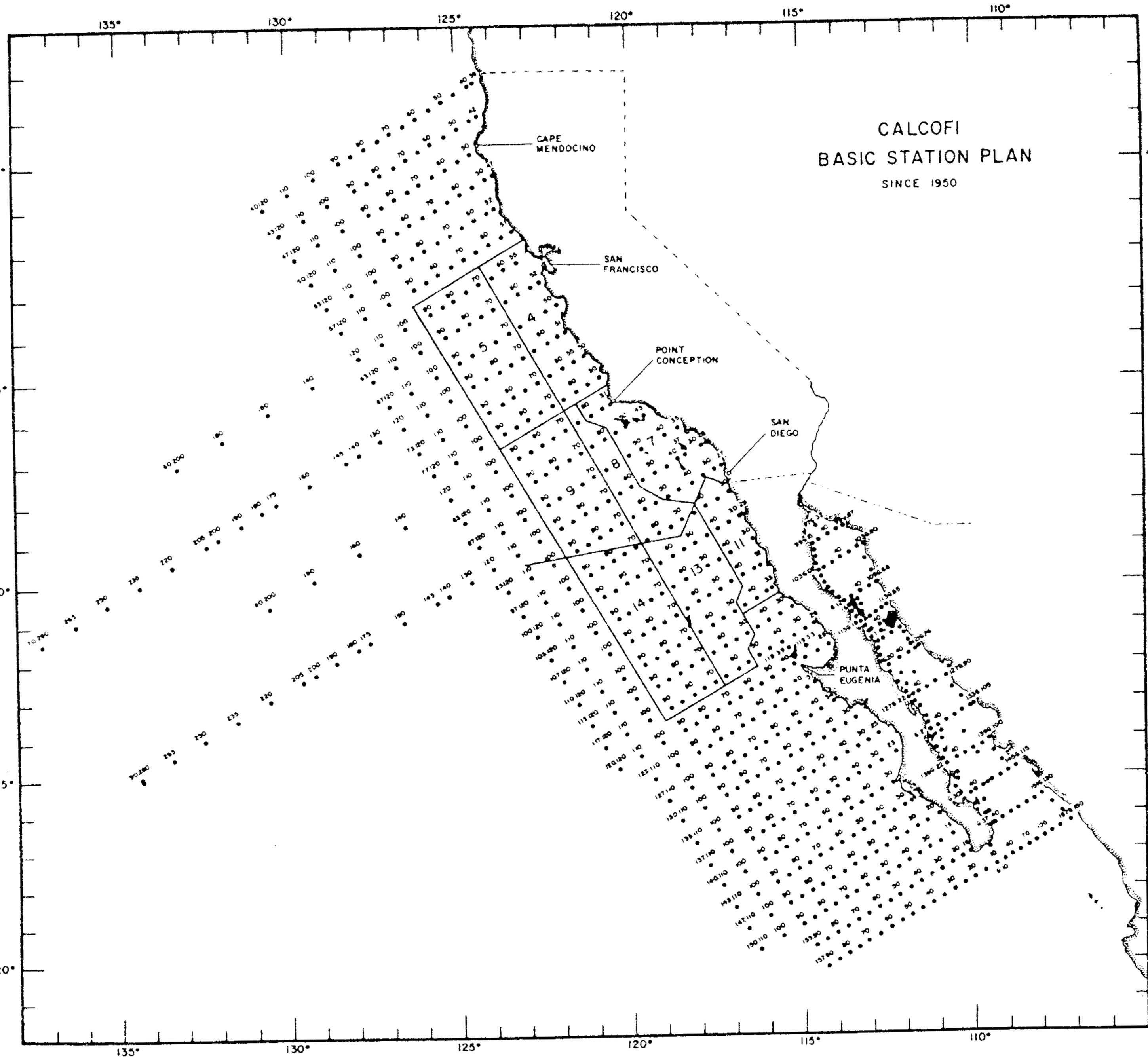


Figure 12.--California Cooperative Oceanic Fisheries Investigations basic station plan. The geographic range of the central subpopulation of northern anchovy is within the eight numbered regions.

sample is highly skewed because of the contagious (or patchy) distribution of eggs and larvae in the sea. Consequently, a large (ca. 100) number of samples is required before the probability distribution for the mean density estimate will be symmetrical.

The census estimate L is simply

$$L = C \cdot A$$

where A is the size of the survey area in 10 m^2 sea surface units. The estimation procedures for egg and larvae production rates are considerably more complicated.

For these indices to be consistent among years, a number of assumptions must hold. First, the station pattern must provide an unbiased sample of the spawning products. This problem can be minimized with a uniform station pattern or by stratifying stations into geographic regions. Second, the time period during which spawning products (eggs and larvae) are accessible to the gear must be the same year to year. This period is a function of their developmental and growth rates, which in turn are functions of ambient temperature and food supply. If large fluctuations in these parameters occur among years, then correction factors should be derived to adjust census index appropriately. If differential size-dependent net avoidance or retention occurs, and if the average egg stage or size of larva varies among years, then a second adjustment may be necessary. Finally, it is important that fecundity or female egg production be consistent among years. The results of a recent histological study of anchovy gonads by Hunter and Goldberg (1980) suggest that female anchovies spawn as frequently as once per week. Fecundity, therefore, is potentially a dynamic process.

Both the density and census estimates can be used as an index of abundance of the spawning stock(s). An up-to-date time series of such estimates provides useful information on the status of the resource. These indices, in turn, can be used indirectly and directly to estimate the magnitude of the spawning biomass that produced the eggs and larvae surveyed, although additional information is required. The indirect method requires a second historical time series of spawning biomass estimates derived from other independent methods, such as a cohort analysis of fishery catch statistics. If the correlation between the two time series is sufficient, biomass predictions can be estimated from the latest index value by the regression of spawning biomass on egg or larvae index.

An extension of this method was developed to estimate the spawning biomass of northern anchovies for the CalCOFI area. In this case, since a historical time series of anchovy abundance was not available, the existing relationship between the larva census estimate and spawning biomass for the closely related sardine was used to relate anchovy larvae to anchovy biomass. The development of this procedure is given in Smith (1972) and the Northern Anchovy Fishery Management Plan (Appendix I, PFMC 1978).

The direct method of estimating spawning biomass (B) is based on the relationship

$$B = E/e$$

where E is the estimated rate of egg production over the spawning area, and

e is the stock fecundity rate or the capacity for eggs by a unit weight of fish stock.

This is determined by the fecundity of mature females, expressed as eggs per unit time per unit weight, and the proportion by weight of the mature stock composed of spawning females within each unit time (Smith and Richardson 1977).

Preliminary application of this direct estimate has been attempted on northern anchovies in the CalCOFI area. In this case, two separate surveys are conducted: 1) to estimate daily egg production with plankton tows designed specifically to sample anchovy eggs, and 2) to estimate stock fecundity rate with midwater trawl samples to collect female gonads. The results to date are encouraging (Parker 1980), and further testing of the sampling procedures and parameter estimation algorithms is planned.

2.2.4. Remote Sensing

2.2.4.1. Acoustical Surveys

Two acoustical survey methods have been used by NMFS scientists to determine distribution and abundance characteristics of marine fishes. These include vertical (echo sounder) surveys, deploying fishing systems to verify targets, and sonar mapping surveys. Examples of each method are given below.

Example 14.--Vertical Acoustic Assessment With Trawling for Target Verification

At present, echo sounding is the most widely used hydroacoustical technique for estimating quantities of marine fish. It involves sending a sound wave downward and processing the received echo signals to estimate fish abundance. Equipment design is based on hydroacoustical theory and current scattering models. The echo signals received from a fish population may be either counted individually (echo counting) or integrated (or summed) over a selected interval of time (echo integration). To perform their counting function, echo counters must be able to resolve a single target with respect to its angle and range. Echo integrators, however, do not require single-target resolution because the resulting density estimate is a function of the received signal from the volume of water surveyed. As most target fish swim in aggregations (in such a manner that individual echo signals cannot be easily resolved), echo integration is the common technique currently used.

Methods--The present hydroacoustical system used at the Northwest and Alaska Fisheries Center is a portable real time digital echo sounder data processing system designed for echo integration and direct in-situ target strength measurement using a dual beam transducer (Ehrenberg 1974), which has been employed since 1976. Refinements since that time have been concerned mainly with improving the stability of the echo sounder receivers to meet the requirements of the dual beam measurement method. A large (higher resolution) dual beam transducer is also now used with the system described in Dark et al. (1980), Traynor and Ehrenberg (1979), and Traynor and Nelson (1979). During its development and application, a major effort has been expended on equipment calibration to ensure accurate knowledge of system parameters.

Using the present system and its predecessors, a survey program involving approximately 600 days of research vessel time has been conducted since 1974. This program was initiated based on experience obtained during more qualitative survey efforts conducted during 1966-73. The field work, in addition to helping meet the needs of several of NWAFC's stock assessment programs, has furnished a valuable background for evaluating the present system. Of equal importance is the acquisition of a large amount of information on the distribution, availability, vulnerability, and echo signatures of the important, acoustically-detectable fish stocks of the northeast Pacific and eastern Bering Sea. This information has primarily been derived from basic, and largely qualitative observations, i.e., the continuous real time examination of echogram displays as well as the process and results of midwater trawling operations. One of its primary values is that, when used in conjunction with a knowledge of stock management requirements and the capabilities and limitations of other methods, it has provided most of the basis for evaluating the feasibility of employing hydroacoustical surveys. Surveys have been conducted in conjunction with assessments of certain semi-pelagic stocks, such as offshore herring and shelf rockfish, and major semi-demersal stocks, such as Pacific whiting and eastern Bering Sea pollock.

All surveys have been conducted during daylight hours because the fish are aggregated and much more clearly segregated by species, making detection and identification more feasible. Surveys are usually carried out with systematic transect patterns which are designed to cross depth contours and maximize the likelihood of encountering the target species. There are large differences among species types with respect to their degree of patchiness. Therefore, differences exist both in the spacing of transects and in the amount of adaptive survey effort needed. This additional effort is beyond that required for the basic transect pattern necessary to delineate the distributions of the stocks.

Pacific whiting and, especially, eastern Bering Sea pollock are typically found in large, readily distinguished, mono-specific midwater "schools" (aggregations of schools) oriented parallel to depth contours. With these species, broadly spaced zig-zag transect patterns (Fig. 13 and Fig. 14) designed to provide relatively uniform coverage have been used successfully. No additional survey effort is expended to more precisely delineate school boundaries. Because of the size of schools, it is impractical to attempt to implement this kind of effort. However, because survey effort has usually been partially dictated by practical constraints, rather than by survey objectives alone, it would useful to be able to examine how changes in transect spacing affect the precision of abundance estimates.

The highly contagious spatial distributions of Pacific herring found off the Washington-British Columbia coast, and of most species of rockfish, require a substantially different survey strategy than that used with hake and

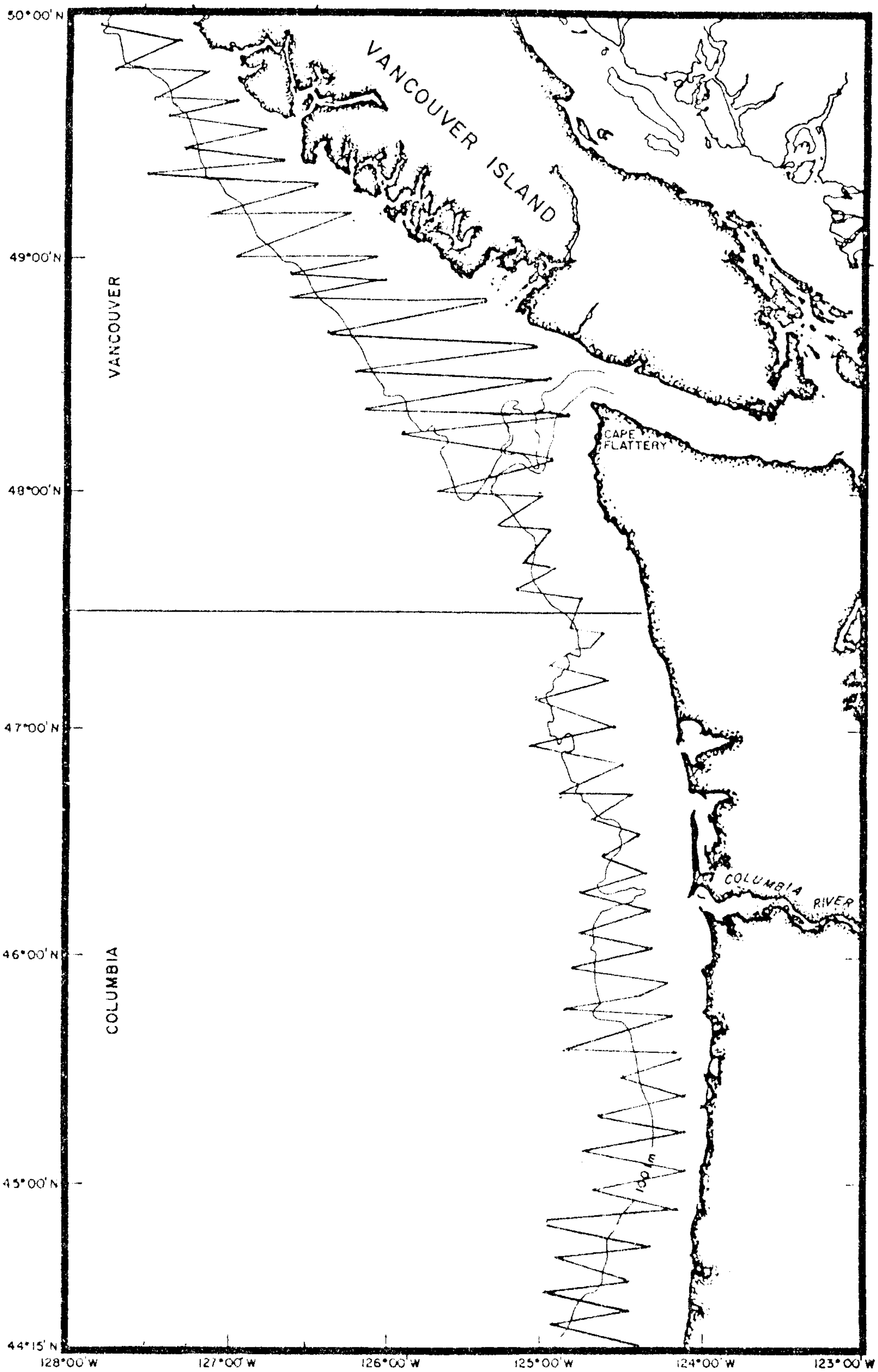


Figure 13.--A portion of the region covered during 1977 Pacific whiting survey, showing transects spaced at 10-n.mi. intervals.

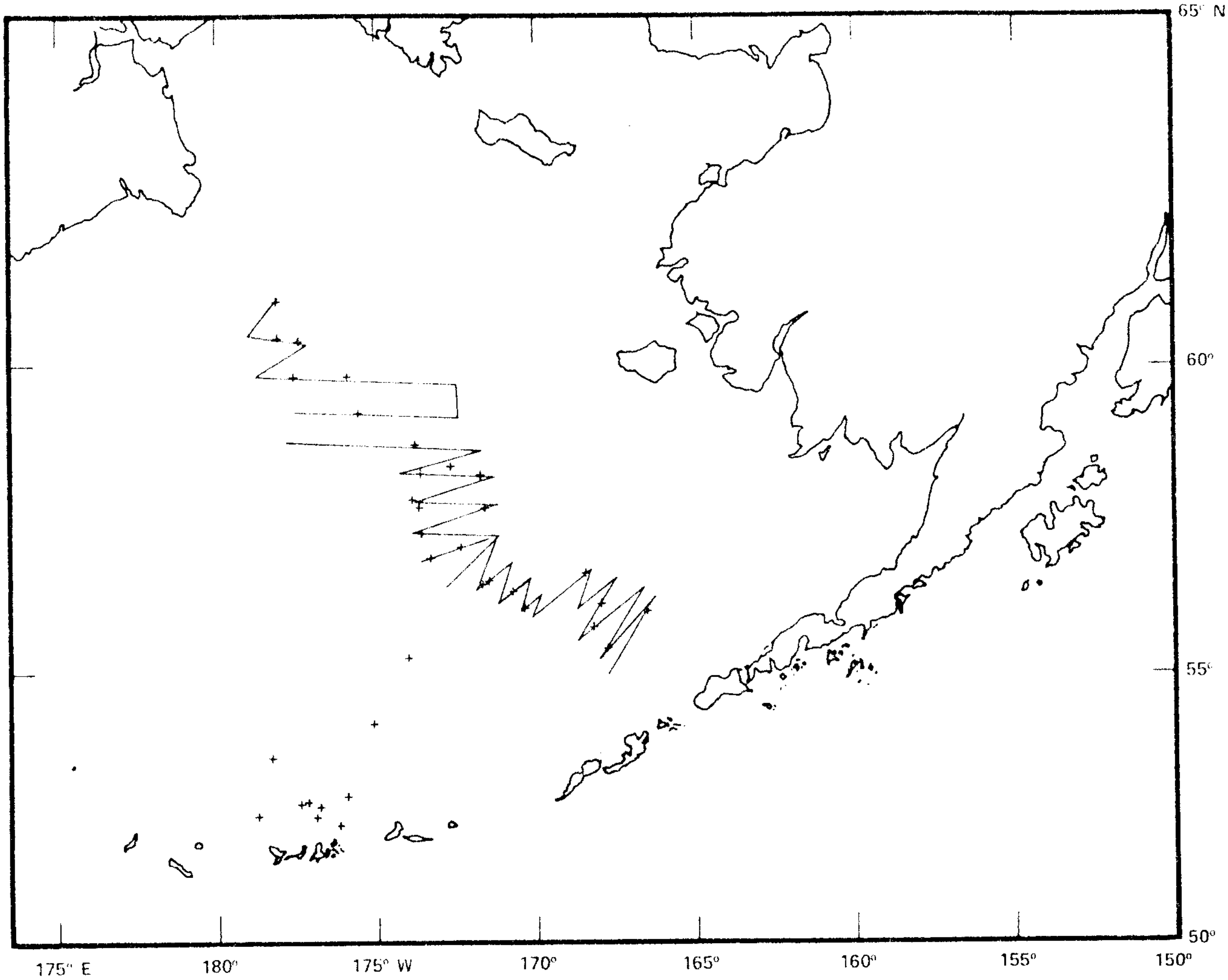


Figure 14.--Trackline covered during 1979 Bering Sea walleye pollock survey, showing transects spaced at 30-n.mi. intervals. Trackline was located between 50- and 250-fm isobaths. Locations are midwater trawl stations, including those made during special studies of Aleutian Basin pollock.

pollock. Although there are major differences in the characteristics of herring and rockfish stocks, they are alike in that they occur in extremely patchily-distributed near-bottom schools. If (as has been the case to date) the basic transect pattern is a systematic one, it is essential that transects be closely spaced, i.e., at about 2- to 4-mile intervals, and that a large part of the available survey time be spent delineating the distribution of individual aggregations as they are encountered. Because of these requirements, surveys of this type are essentially impossible to implement for broad geographic areas, e.g., those which must be covered during whiting and pollock surveys.

A good example of this type of survey is provided by a 1979 survey of herring stocks off the northern Washington-southwest Vancouver Island coast. During this survey, approximately 25% of the time was used for midwater trawl sampling, 20% for coverage of the systematic pattern, and 55% for intensive surveying of the few areas where herring were abundant. A stratified systematic survey design for herring might be more efficient, but it is difficult to specify criteria for stratification.

Survey experience with rockfish has clearly shown that hydroacoustical methods cannot yet be usefully applied as an assessment method (except in the case of the unique shortbelly rockfish, Sebastes jordani). In addition to the fact that they are very patchily distributed, the echo signatures of individual species are not easily recognized, and are very difficult to discern in mixed-species schools. These, and other complicating factors, have shown that intensive surveys designed to examine the microdistribution and schooling behavior of rockfish are needed to better define the potential of hydroacoustical and other survey methods. Recent information also suggests that certain species may be more successfully surveyed at night.

Analytical Techniques--The basic data collected during surveys are echo biomass density estimates (kg/m^3) obtained at one-minute intervals (0.15 n.mi. at 9 knots) along survey transects for each of up to 50 transducer-referenced and 10 bottom-referenced depth strata. Whenever possible, the estimates of target strength used to scale the basic echo integrator outputs [which are proportional to density] to estimates of density, are obtained in-situ using the dual beam measurement method (Ehrenberg 1974, Ehrenberg et al. 1976, Traynor and Ehrenberg 1979). The rationale for, and practical constraints on, the use of this method are described by Traynor and Nelson (1979). If dual beam measurements cannot be made, a value for the target strength parameter is obtained from the literature on fish target strength measurements.

The density estimates (kg/m^3) for each one minute interval are summed over depth intervals to provide estimates of areal biomass density (kg/m^2). The depth intervals appropriate for this summation and the transect sections to which the analysis is confined are determined both from echogram examination by experienced personnel, and from the results of midwater trawling. Midwater trawl samplng, for species identification and biological data collection only, is done in real time, i.e., during the echo integrator survey period, with aimed trawling techniques. The distributions of the individual areal biomass density estimates are examined to define the geographic boundaries appropriate for calculation and extrapolation of mean density estimates.

Because successive density estimates along the survey transects are serially correlated and therefore not independent, an estimate of the variance of the mean which uses the sample variance, S^2, will tend to be biased low. To correct for this bias, variance estimation methods based on cluster sampling theory are used. Each survey transect is usually treated as a cluster. The estimated variance of the mean density for a defined area is then calculated from information on the number of transects in the area, the average number of one-minute density (kg/m^2) estimates per transect, and the amount of within-transect correlation. Simulation studies (Williamson 1979) indicate this variance estimate is unbiased.

The total biomass estimate and its variance for the region surveyed are calculated by combining the estimates for those areas defined during analysis of the data. Although the effect on biomass estimates of any specified change in average target strength can be easily calculated, it is not yet practical to attempt to determine explicitly the variance of this parameter. Its probable range of values, however, can usually be estimated.

Example 15.--Sonar Mapping Acoustical Surveys

The sonar mapping method (Smith 1970) of stock assessment is a shipboard acoustical survey of the upper mixed layer of the ocean with a horizontal sonar beam directed perpendicular to the ship's path. This technique provides a count of the number of pelagic fish schools per unit area and a measure of their horizontal dimensions; together, these provide an index of fish biomass. The details of this method have been documented by Hewitt (1976), Hewitt et al. (1976), and Mais (1974).

Methods--The required survey platform is a seaworthy research vessel equipped with calibrated sonar electronics and midwater trawl gear. The sampling gear in this case is an acoustic beam directed horizontally on an axis perpendicular to the forward direction of the vessel. The sonar mapping systems developed by CalCOFI programs with NMFS and California Department of Fish and Game (CF&G) use 30 kHz sonars. The echo returns in most cases are considered to be fish schools. Midwater trawl gear is used to sample the species composition of the upper mixed layer.

Because of the highly patchy spatial distribution of pelagic fish schools, a survey grid scheme of 20' squares is recommended by CF&G. The vessel travels along transects that are spaced 6 to 20 miles apart and cross each grid. The vessel operates at 9 to 12 knots during daylight hours when fish predominantly form into schools and when the deep scattering layer is at maximum depth. Midwater trawl samples are taken in areas of the greatest fish school concentrations at night when fish are most vulnerable to capture.

The primary measurements of each observed fish school are its location in the horizontal plane and its diameter along the axis of the sonar beam. Any information from visual observations or from the vertical echo sounder on species, school thickness, fish size, behavior, and predators is also recorded. Collectively, the measurements yield the number and surface area of fish schools per unit area, the geographic distribution of fish schools within the survey area, and the frequency distribution of fish school sizes.

Acoustic echoes of fish schools can be recorded on sonar paper or magnetic tape. CF&G (Mais 1977) routinely uses paper records and manually counts and measures school dimension in the laboratory at the end of the survey. NMFS (Hewitt et al. 1976) developed a prototype computerized data processor that interprets acoustical echoes, and the size and intensity of the school is recorded on magnetic tape.

The side-scanning method of sonar mapping was developed to detect, with acoustical sensing, compact fish schools residing in the upper surface layer of the ocean. The usual vertical echo sounding method was found to be an inefficient acoustical sampler for such fish schools as northern anchovy in the CalCOFI area because the schools tend to avoid ships and the volume of the insonified water cone, through which the sound is emitted, in the surface layers is small.

Sonar mapping is most effective for a species that is the dominant schooling fish in the upper mixed layer. Schools, which will have a patchy non-random distribution, should preferably be small and scattered over a wide area. The adult schools must occur in pelagic waters where the bottom depth exceeds 50 fathoms; otherwise, the return echo from the bottom will mask any echo from an insonified school. Good weather conditions are necessary to maintain a steady horizontal acoustical beam unless the vessel is equipped with a stabilizing transducer. In addition, a mixed layer is desirable to minimize beam distortions that result from refraction of the beam by changes in water density at the thermocline. In the case of northern anchovies, whose schooling behavior can change quite rapidly, these conditions are best met during daylight hours in the winter spawning months when schools are the smallest and most widely scattered, and when the upper mixed layer has its maximum thickness.

Analytical techniques--The basic observations of the sonar mapping method are counts of fish schools and measure of the horizontal dimension in meters of the detected schools. Data on species identification, school thickness, and fish density within a detected school must be made by other means. In practice, species identification is determined subjectively by examination of the acoustical record by experienced personnel. They also supplement this decision with visual observation notes and midwater trawl catches in the general vicinity. For the moment, a practical survey method does not exist for determining fish density within a detected school. An underwater photographic procedure has been developed and purse seine captures of insonified schools have been done, but school compaction and estimates of school compaction are both extremely variable and these data give a wide range of values. Graves (1977) estimated densities of 50 to 366 fish/m^3 using free-fall cameras to take pictures of fish schools. Hewitt et al. (1976) estimated values that ranged from 0.52 to 533 fish/m^3 from catches of a purse seiner. School thickness can be measured from acoustical records of schools detected by an echo sounder. For most surveys, this sample will be small and is quite likely inaccurate because fish tend to avoid the ships.

Another basic observation is the measure of the effective range interval of the sonar beam in which 100% of all fish schools can be acoustically detected. In practice, the effective range interval for each transect is assigned upon inspection of the sonar records. Depending on the equipment, this range is normally from 200 to 1,000 meters (Mais 1977). This detection range frequently changes as a result of refraction of the sonar beam by internal waves and changes in the thermal stratification of the water column. Smith (1977) developed a sound velocity profile scheme which would provide quantitative criteria for setting the effective range, but this technique has not been implemented. The effective range interval varies for school size categories. Beyond some threshold distance from the ship, the probability of school detection declines as the distance from the ship increases and as the school size decreases. The strength of the acoustical signal and associated echo decays as it passes through water. This parallels the problem of estimating effective path width for line transect surveys. The estimation procedures for line transect theory should be applied to estimation for effective range intervals.

Quality control for sonar mapping surveys has two aspects. First, periodic calibration of the sonar electronics and transducer is important to maintain signal and echo quality that otherwise may deteriorate over time. Second, research cruises should be scheduled to coincide with the most favorable fish school behavior and hydrographic conditions to minimize the impact of environmental variability on the annual stock assessment.

Survey design criteria consider three main conditions: patchy non-random distribution of schools (Smith 1977), school formation in daylight hours, and season for best environmental conditions. Because of the highly contagious distribution of fish schools, the survey area should be divided using the grid system. At least two transects should transverse each grid, so that empirical variance estimates can be calculated for the mean number of schools per square mile. More transects should be run in grids with high frequency of schools. The data are then computed by transects, the transects averaged for each grid, and the grid summaries added together to obtain the total statistics for the survey region. In the CalCOFI example, sonar mapping can easily sample in a single survey as much as 2 or 3% of the sea surface area containing a major portion of the central subpopulation of northern anchovies.

The primary parameter estimated per transect is the number of fish schools per square mile and the average school diameter in meters. Empirical estimates of variance can be calculated. From these data, estimates of school surface area in each grid can be estimated, assuming circular school shapes. In practice, where school thickness measures are too few in number and actual fish packing density estimates are lacking altogether, expansion of the school surface area into biomass estimates is unreliable.

2.2.4.2. <u>Other Remote Sensing Methods</u>

A number of other remote sensing techniques have been experimented with and are occasionally used in exploratory fishing surveys. These techniques can be divided into two types. The first is of a direct form involving detection and enumeration of individuals or groups of animals (e.g., fish schools) and plants. The second type involves remote measurements of specific physical or biological parameters other than those directly associated with the animal or plant of interest, which may then be used to infer the desired information, such as the presence or absence of a certain species of fish. These two types can be further categorized according to the remote sensing platform used, e.g., satellite, aircraft, or vessel, and into passive and active forms depending on how the sensor is coupled to the phenomenon being sensed. Most of the remote sensing methods do not currently form the basis of important assessment activities but can offer technical opportunities to extend assessment methods.

Of the direct forms of remote sensing, aerial photography is probably the most commonly used technique for stock assessment. It has been used extensively for surveys of coastal pelagic species in the northern Gulf of Mexico and, more recently, to augment surveys of dolphins in the Pacific and seals and whales in the northwest (Kemmerer 1979, 1980). To be effective, however, aerial photography must be designed for a particular application, because high sun angles, optical properties of the water, and the color signature of the animal being sensed must be considered to ensure meaningful results. Multispectral photography has proved very useful for this application since it provides definitive information on best film and filter combinations for the specific conditions expected during assessment surveys.

A major advantage of aerial photography is that it provides a permanent record which can be analyzed in a laboratory. It can also provide useful information from significantly greater water depths under environmental conditions not possible with the naked eye. Photographic interpretation normally is done on viewing devices which enlarge the scene from three to forty times.

Another form of direct remote sensing is provided through the use of low-light-level image intensifiers which amplify the bioluminescence caused by fish agitating certain forms of plankton. This bioluminescence encases fish schools with a faint light which, when amplified sufficiently with an image intensifier, can be displayed on a video monitor and recorded on video tape. These systems have been used effectively in the southeast region for surveys of menhaden and other coastal pelagics, and are being used commercially for tactical direction of fishing operations and assessment of the harvest potential of selected pelagic species (Roithmayr 1971). Their principal limitations relate to species identification, limited water penetration (although substantially greater than that possible with the naked eye), poorly defined relationships between fish school surface area and biomass, and limited operation at night during dark-of-the-moon periods.

Another form of direct remote sensing is provided by the unmanned submersibles developed by NMFS which are periodically used for assessment of benthic animals. These submersibles are considered remote sensing systems because they rely on photography, television, or both, for data acquisition. They are of two types: those sledded or those flown across the bottom. Both types are towed by research vessels.

Examples of flown systems include Remote Underwater Fisheries Assessment Systems-I and -II (RUFAS-I and -II). The RUFAS-I consists of a towed submerged platform equipped with lights, television and photographic cameras, and acoustic transducers (Seidel 1970). It is flown about 1 m above the ocean floor by system operators using acoustical signals and television images to regulate flight. The system has been used extensively of the southeast coast off the United States for photographic surveys of calico scallop (Argopecten gibbus). RUFAS-II is not operational.

Indirect forms of remote sensing for stock assessment are generally used for sensors operating in spacecraft. Because of the lack of spatial resolution provided by spacecraft sensors, most marine animals cannot be detected. Consequently, investigators have concentrated on remote measurements of oceanographic parameters assumed to influence the distribution and abundance of marine animals. Satellite forms of remote sensing, however, are not used significantly for resource assessment although a number of experiments which show potential have been completed or are under way.

The remote measurement of sea surface temperature is sufficiently advanced so that it can be considered operational from satellites and aircraft. Temperature gradient measurements approaching 0.1°C in sensitivity and absolute accuracies of about 1.0°C, are possible with improved thermal scanners such as those aboard TIROS. The principal problems with satellite measurements relate to spatial resolution (only about 1 km) and cloud cover. With sensors operating in the microwave region of the electromagnetic spectrum, however, cloud cover problems disappear. Unfortunately, there are no operational microwave temperature sensors aboard any satellites; the ones which have been used experimentally indicate that spatial resolutions of 25 km are the best to be expected within the next decade. Aircraft thermal sensors are not spatially limited in resolution as resolution can be varied by changing the sensor or aircraft altitude.

Sea surface temperature measurements with remote sensors are not used significantly by NMFS for stock assessment purposes although they are used by west coast fisherman as a tactical aid for their fishing operations. An experimental program was initiated in 1975 by the National Environmental Satellite Service (NESS) and Sea Grant for delivering satellite-derived temperature information on coho salmon (Oncorhynchus kisutch), chinook (O. tshawytscha), and albacore (Thunnus alalunga) to fishermen. The primary sensor used was a very high resolution radiometer (VHRR) operated from NOAA-5. The experiment reportedly has been successful and is receiving strong support from fishermen (Jurick 1977). In a similar experiment, sea surface temperatures obtained from aircraft were successfully used to help fishermen locate coho salmon within a relatively small coastal area (Wright et al. 1976). On the east coast, temperature charts are mailed to longline fishermen by NESS for waters from Georges Bank south into the Gulf of Mexico. These charts reportedly are used by the fishermen to locate concentrations of swordfish (Xiphias gladius).

Ocean color remote sensing is currently available, principally from two NASA experimental satellite systems -- LandSat and Nimbus-7 -- and appears to be useful for inferred measurements of chlorophyll and turbidity, information on current systems and water mass boundaries, environmental and pollution studies, and for inferred distribution patterns of some pelagic schooling fish.

Several investigations have been recently completed or are under way which emphasize ocean color measurements from spacecraft and aircraft. The LandSat Menhaden and Thread Herring Investigation was conducted from 1975 to 1977 in the northern Gulf of Mexico to determine how remotely sensed data could be used in assessment and harvest applications. Menhaden was the primary target species. The investigation demonstrated that the distribution of these fish could be inferred from LandSat multispectral scanner data with accuracies approaching 90% (Kemmerer 1979, 1980).

Probably the most significant sensor for ocean color remote sensing is the Nimbus-7 Coastal Zone Color Scanner (CZCS). This sensor is designed specifically for inferred measurements of chlorophyll and turbidity. Good results already have been achieved although the satellite data have been very limited due to unrelated data processing problems.

In 1979, NMFS initiated a remote sensing program to evaluate the usefulness of remote color measurements for enhancing understandings of marine ecosystem dynamics related to fisheries. This program, referred to as Large Area Marine Pollution Experiment (LAMPEX), initially relied on aircraft sensors but, due to the demonstrated success of CZCS, has begun to emphasize the satellite sensor for measurements of chlorophyll and possibly turbidity. An expansion of LAMPEX into the southeast region currently is being considered so that marine ecosystems unique to each area can be compared and improved understandings related to fisheries can be developed.

Remote measurement of surface currents is a very difficult observation to make remotely. The most successful technique available is used only experimentally and is based on remote measurements from shore stations (Barrick et al. 1974). Radar signals are transmitted from the shore station and scattered by ocean waves. The waves act as tracers of superimposed currents due to slight velocity changes in the waves caused by the currents. The technique will provide current data on a 3-km by 3-km grid to a range of about 70 km from shore. Error estimates are about 3 degrees in azimuthal position and 10 cm/sec rms for current speed.

There appear to be several methods to determine surface circulation with satellite-supported sensors. None, however, with the possible exception of satellite-linked drifting buoys, is operational. These methods include the use of water color differences in near-shore areas to compute circulation, monitoring thermal fronts such as the Gulf Stream with infrared measurements, the use of radar altimetry as a measure of surface geostrophic set-up, and determining surface wind stress and its incorporation in calculations of Eckman transport. The accuracy of these various methods is not known, although it is likely that only the more energetic and discontinuous flows will be measurable from space with useful precision.

A special form of remote sensing is being used for studies of the movement and distribution patterns of marine mammals and sea turtles. This form requires attachment of a small transmitter to an animal for transmission to a receiver located in a surface vessel, aircraft, or spacecraft. In salt water, the transmitter antenna must be above the water surface for effective use. The limited range of most radio transmitters for animal tracking has prompted investigators to begin development of transmitters which can be located by satellites (Gandy et al. 1977). Developmental efforts have focused on the Random Access Measurement System (RAMS) on Nimbus-6 and, more recently, on the ARGOS system aboard TIROS. Both satellite systems are similar in that they enable suitable transmitters to be located several times a day with accuracies approaching a few kilometers.

Satellite tracking of marine animals has several limitations. The most obvious of these is that the animal must surface during a pass of the receiving satellite to be located. The transmitters also are relatively large and heavy, which limits their application to the larger marine animals. Finally, the transmitters are relatively expensive, costing in excess of $3,000 each. Significant advances in transmitter design and in the satellite-supported receivers may help to reduce the size and cost of these systems, although it is unlikely that any significant advances will be available for general application for at least 5 years.

2.2.5. Environmental Indices

The use of marine environmental information in assessment of the abundance and distribution of marine fish populations is, in itself, a developing science. Frequently, environmental information is offered as a possible explanation, in a qualitative sense, of observed trends in stock abundance or fishery success and, in particular, to changes in recruitment, stock distribution, growth, or mortality rate. Ocean "climate" influences a broad range of biotic activity including behavior, distribution patterns, accessibility, etc. The collection and evaluation of such information vary widely, as do analytic evaluations. As a result, the formulation of environmental indices into stock assessment models is in the theoretical stage and varies for each application. It does, however, have the promise of reducing costs and increasing precision in stock assessment.

Large scale variation in atmospheric circulation patterns results in changes, such as wind strength direction, air temperature, storms, cloud cover, etc., which can drastically affect fishery resources and their habitats. From the viewpoint of fisheries conservation and management, the most important effect of such environmental changes is on the recruitment of young fish into harvestable stocks. Pronounced effects may be experienced in early life stages due to such factors as changes in wind-driven ocean current patterns which alter the normal drift of larvae from spawning to nursery grounds; changes in primary production patterns and associated planktonic community structures that affect the availability of suitable food for normal larval development; and altered mixing processes and/or stability of the water column that change the availability of suitable food for normal larval development.

The use of environmental information can range in sophistication from scientists' expressed opinion on the likely relationship between observed biological and environmental conditions, to a complex multivariate regression analysis. This latter approach generally requires concurrent time series of biological and environmental conditions. Often biological events or parameters are measured on an annual scale while the actual causal mechanism may occur over a relatively short time period. At the same time, the ability to obtain continuous measures of the environment is limited to such factors as surface temperatures, winds, sea surface heights, or atmospheric pressure. These may be only secondarily related to the actual causal environmental variable which, in turn, is modifying the biological condition of the stock.

The use of environmental information in the predictive mode is the subject of numerous research projects in fisheries science. These studies involve finding empirical correlations between one of a number of environmental indices and annual yield, abundance, or recruitment, and/or investigating the causal environmental mechanisms that contribute to the recruitment success. In this way, environmental information contributes to the precision of stock assessment by improving the forecasts of stock abundance based on better estimates of recruitment, or by the inclusion of environmental variables in one of the traditional fishery analysis models (surplus production, stock recruitment, etc.) or ecosystem models. These studies are not only important to future NMFS stock assessment but also to related fishery habitat studies, fishery oceanography, and aquaculture programs. An understanding of the causal mechanisms associated with survival in the early life stages is the basis for environmental monitoring programs which, in turn, could improve forecasting ability. The goal is to use environmental data to understand better environmental influences and, ultimately, to increase the accuracy of stock assessments.

For the pelagic fisheries, the more readily obtainable surface and near surface oceanographic data have been used for recruitment assessments of such species as Atlantic menhaden, Pacific mackerel, and northern anchovy, and for locating commercial concentrations of such species as yellowfin tuna, skipjack tuna, albacore, and swordfish, based on their association with oceanic frontal structures. New satellite technologies, enabling large area surveillance of sea surface temperatures, chlorophyll, currents, etc., should permit even further applications of environmental information in assessments of pelagic biological populations.

For midwater and demersal populations, as Pacific hake and Dover sole, the situation is quite different due, in part, to the greater difficulty in monitoring subsurface environmental conditions. Progress is being made, however, in understanding pre-recruit survival for such species which have pelagic eggs and larvae that, for a period of time, occupy the ocean's upper layers.

Recent NMFS research to define trophodynamics and direct environmental effects is demonstrated in the following two examples:

Example 16.--<u>Stock Recruitment Studies of Northern Anchovies</u>

Considerable progress has been made in recent years in forecasting recruitment of the northern anchovy stock in the California Current region from environmental indices. It was hypothesized that the strength of an incoming year-class is determined by the mortality rate of early larvae. The abundance of food particles of the proper size and species in the ocean's upper mixed layer has been found to be critical to the survival of first-feeding anchovy larvae. By monitoring the density, distribution, and species of food particles during the spawning season, the failures of the

1974, 1975, and first half of the 1978 year classes were predicted (Lasker, in press). This work also demonstrated that adequate food patches occur when the upper mixed layer is relatively stable. Major storms or upwelling can disperse food particles to concentrations below the level of successful feeding and larval survival. Continued research and monitoring of these environmental variables will lead to improved recruitment forecasts and stock assessments. The methods developed in this research program for the northern anchovy should have broad application to other fishery regions around the world.

Example 17.--Correlation Models

A number of research studies have met with some success in finding correlative physical, chemical, and/or biological ocean variables which help explain some of the large annual fluctuations in recruitment, population biomass, and fishery yield as measured from fishery information. This approach generally incorporates significant environmental covariates into traditional equilibrium yield models. These fits often offer reasonable hypotheses of the causal mechanisms of early mortality and, therefore, the factors that regulate recruitment. Working with fishery statistics on Pacific mackerel (*Scomber japonicus*) off California, Parrish and MacCall (1978) found good correlations between upwelling and surface transport indices, and year-class strength. In this case, the environmental indices were added as covariates to a Ricker spawner-recruit model. Their recruitment models, incorporating both density-dependent terms and environmental terms, accounted for as much as 75% of the variation. With this model coupled to a cohort model, they were able to evaluate various management schemes for setting size limits and harvest quotas based on criteria of long term stock size and yield.

On the east coast of the United States, Nelson et al. (1977), using a similar model, showed that the deviations from a Ricker spawner-recruit model for Atlantic menhaden were highly correlated to zonal Ekman transport. Based on this, they hypothesized that onshore transport acted as a mechanism to move larval menhaden from offshore spawning areas to inshore nursery grounds. Therefore, strong year classes resulted from years with strong onshore transport.

Along the Gulf Coast, researchers have developed yield models of penaeid and other Gulf shrimps where annual yield is expressed as a function of fishing effort, Mississippi River discharge, and/or estuarine temperatures. Such models are much more appropriate than surplus yield models because of the overriding impact of the environment on yield, and the extremely short life span of shrimp. At average levels of river discharge and effort, the model predicts yield estimates which approximate MSY derived from the production model. In general, low freshwater discharge and high estuarine salinity and temperature result in lower yields. Using this model, it should be possible to forecast annual yields (or quotas) from projected river discharge values for a given level of fishing effort. Such models provide criteria for raising or lowering annual harvest, based on the quantity of shrimp available.

2.3. Fisheries Analysis for Stock Assessment

Fisheries analysis uses mathematical models to combine statistical, survey, and environmental data in assessing trends in stock sizes, and in determining yield estimates from harvested resources. Stock conditions may be interpreted from simple total catch trends, catch-per-unit-effort (CPUE) trends, or from more complex evaluations involving an integration of catch data with biological and environmental parameters for the stocks under study. There are many books on this subject (e.g., Beverton and Holt 1957, Gulland 1969, and Ricker 1975). All fisheries centers within NMFS normally utilize a series of standard fishery models to evaluate stock conditions and theoretical equilibrium yields available at various stock sizes. A description of these models follows.

2.3.1. Surplus Production Model

Adequate information frequently is not available to provide an understanding of the complexities of the population process--growth, natural mortality, and reproduction. Under these circumstances, surplus production models can be very useful in determining empirical relationships between surplus production (extracted as equilibrium yield) and stock biomass (as measured by an index, usually CPUE). These relationships can then be used to model the effect of fishing on the population.

Models relating surplus production to biomass usually assume that surplus production is greatest at some intermediate level of biomass, not at maximum population biomass (Fig. 15). There are several reasons for smaller surplus production at higher population biomasses:

1) Near maximum biomass, efficiency of reproduction is reduced and the number of recruits is often less than at lower biomass levels;

2) If food supply is a limiting factor, then growth is inhibited at large biomass levels.

Under stable environmental conditions, recruitment and growth are balanced by natural mortality for an unexploited population, and thus there is no surplus production. When fishing begins, biomass is reduced and any of a combination of things may happen--the available food may be used more efficiently by the remaining population, reproductive efficiency may be increased, or natural mortality may be reduced. Surplus production is then generated, which would induce the population to recover to the maximum biomass level if fishing were stopped.

The basic data requirements for conducting a production model analysis are: 1) total catch in weight (sometimes numbers) from the population by year, and 2) total fishing effort in standardized units by year. While these basic data requirements appear to be rather simple, this appearance is only superficial. Total catch (particularly the by-catch or incidental species and recreational catch) is frequently difficult to obtain. Fishing effort must be adequately separated when more than one species is being caught, and must be standardized to some common units when different gear types are used.

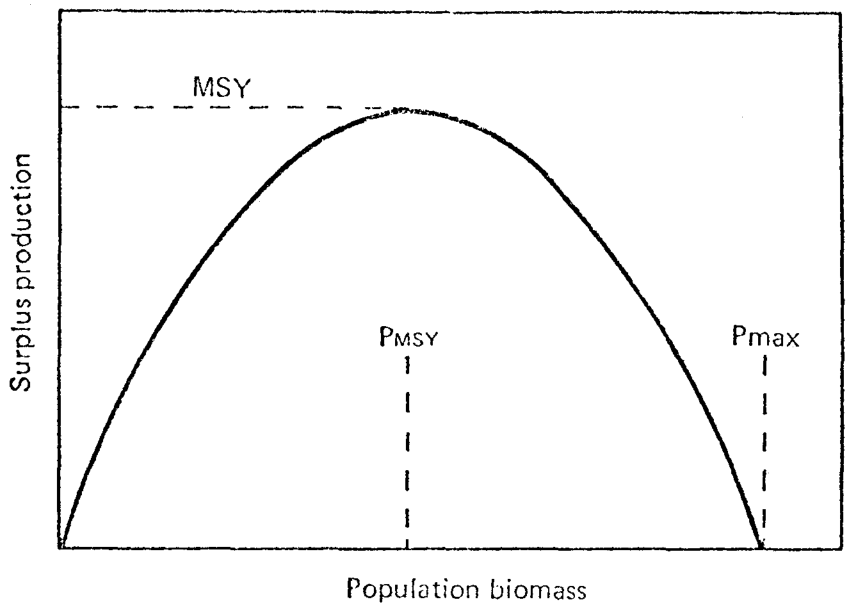


Figure 15.--Relationship between population biomass and surplus production (sustainable yield). Maximum sustainable yield (MSY) usually occurs at some intermediate population biomass (Pmsy).

This is especially difficult when there are different gear types exploiting relatively different age groups, and/or there are strong efficiency interactions among population densities, time-area strata, gear types, and amount of effort employed. The fishing effort data are usually generated through logbook or interview systems.

Surplus production model outputs which are most useful to the fishery manager include estimates of maximum sustainable yield, and the corresponding levels of fishing effort and population size. The exploited population is treated in this very simplistic manner primarily when there is a lack of adequate data for a detailed assessment of the effects of exploitation. The costs accrued in obtaining this benefit are the creation of numerous assumptions, many of which are known, a priori, not to be satisfied fully, and the inability to analyze the effects of altering the variables which can be controlled by fishery managers (e.g., fishing season, size at first capture, relative rates of fishing mortality among age groups, etc.).

2.3.2. Yield per Recruit Model

One of the most useful concepts in fishery science is that of equilibrium yield per recruit. When growth and mortality rates can be estimated, growth can be balanced against mortality to obtain optimum yield (Fig. 16). The concept has proved useful not only as a stimulating theory about the productivity of exploited fish stocks, but also as a basic working tool for fishery managers.

The concept of equilibrium is intimately tied to the yield per recruit approach. Equilibrium implies that, given a constant rate of fishing, a population will attain some long-term average biomass level and produce long-term average yield. Under equilibrium conditions, the yield or net production by a given year-class (a cohort of fish spawned during the same year) is the difference between the sum of the weight gained by individuals in the population and the sum of the weight of fish lost due to death (natural or fishing) in any given year. Since the size of an incoming year class is generally difficult to estimate, the yield per recruit, as opposed to total yield, is modeled by assuming a constant level of reproduction.

Fishery managers can use this concept to further their understanding of a fishery, and to make predictions as to how the yield per recruit will respond to changes in the amount of fishing effort and to which sizes or uses of fish it is applied. Generally, yield per recruit models are used in three ways: 1) Given that the fishery operates at a certain level of fishing effort, changes in the yield per recruit are examined by changing the age-at-first-capture by the fishery (Fig. 17a); 2) Given that the fishery operates on a certain age-at-first-capture pattern, changes in the yield per recruit are examined over a range of fishing effort (Fig. 17a); or 3) A simultaneous combination of 1) and 2) are examined for changes in yield per recruit due to concomitant changes in fishing effort and age-of-first-capture (Fig. 17b). This latter approach has also given rise to the concept of eumetric fishing, whereby a nearly constant total population size can be maintained, and possible density-dependent effects on growth, mortality, and

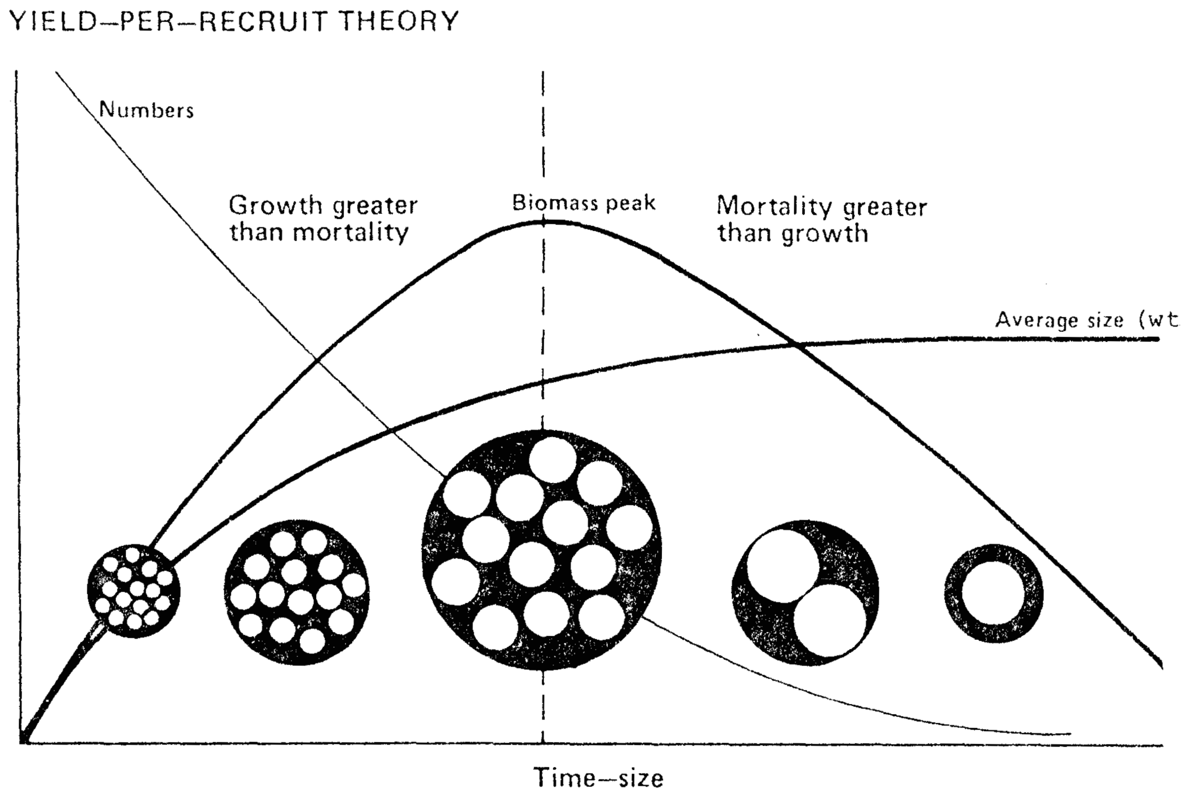


Figure 16.--Changes in biomass, number, and average weight of animals in an unfished cohort during its lifetime.

1. Animals increase in weight and decrease in numbers with time.
2. At some point in the life span, biomass peaks.
3. Yield-per-recruit strategy: set the size limit as close as possible to the size of peak biomass (critical size).

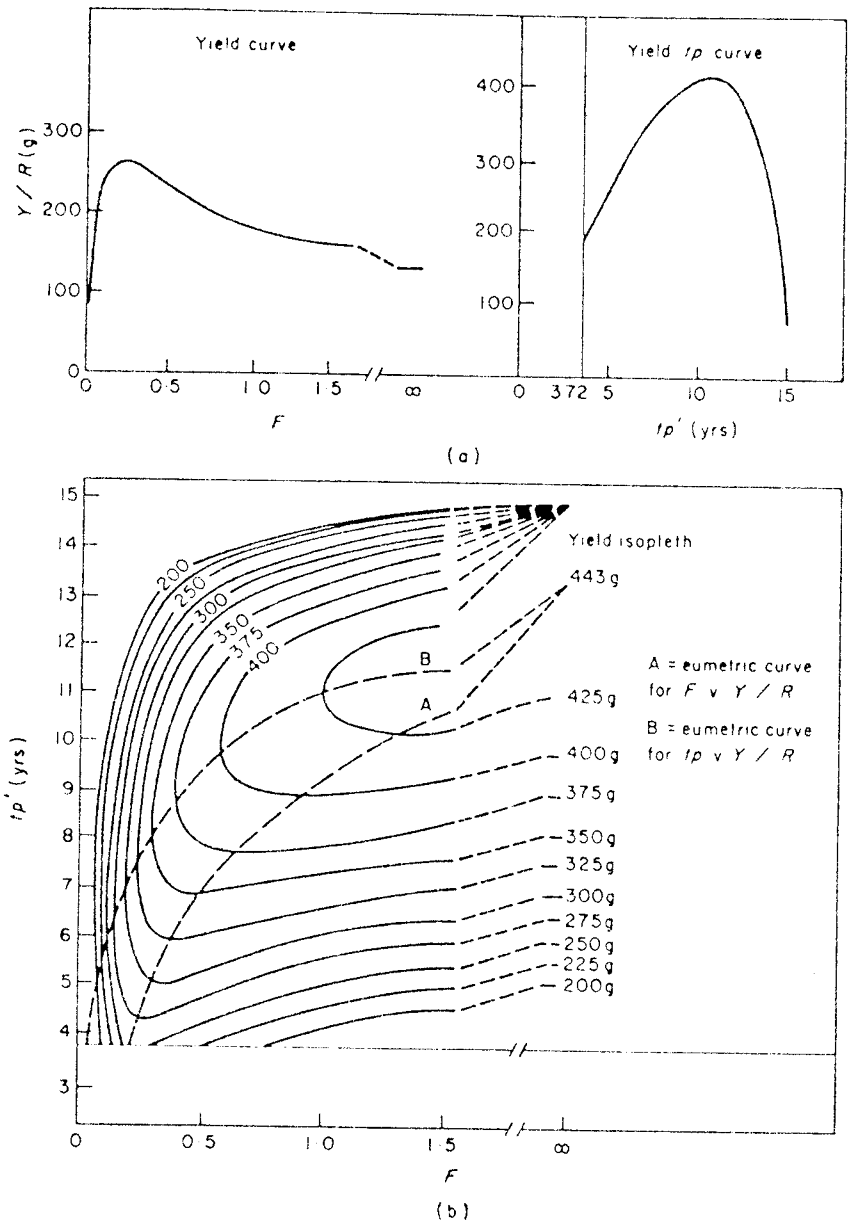


Figure 17.--Yield per recruit (Fig. 17a) shown as a function of fishing mortality F and of age-at-first-capture tp for a fixed F. Figure 17b is a two-dimensional isopleth relating yield per recruit to age (tp') and fishing mortality (from Bannister 1977)

reproduction minimized by selecting the age-at-first-capture level which maximizes yield per recruit for each level of fishing effort (Fig. 17b).

Three analytical methods have been developed for implementing the yield per recruit model. The first method, developed by Baranov (1918), assumes that: the average growth rate in length is constant for all fish which are of exploitable size, weight is proportional to the cube of length, and recruitment is spread uniformly throughout the recruiting year. Because of these assumptions, a very simple mathematical model can be used to examine changes in yield per recruit due to changes in fishing effort and length at recruitment. Although Baranov's method is sound, its usefulness is limited since most fish stocks violate one or more of its assumptions. The second method, developed by Beverton and Holt (1957), is similar to Baranov's method except that the von Bertalanffy (1938) growth function is used in place of the assumption of a constant growth rate in length. The third method, developed by Ricker (1975), is the most flexible in that it allows growth and mortality rates to change over the exploitable life span of the fish. Although Ricker's method is computationally more difficult to use than Beverton and Holt's method, it is commonly used when mortality rates are age-specific, or when growth is not representable by the smooth asymptotic growth functions.

Some of the difficulties encountered by fishery managers in applying the yield per recruit concept are:

1) Because of the large variability in recruitment, it is often convenient to recommend maximizing yield per recruit for each entering year class, ignoring the factors that control year class strength. Unfortunately, fishing effort levels which maximize yield per recruit can substantially reduce spawning stock size and may adversely affect future recruitment.

2) It is difficult to achieve maximum yield per recruit level in a fishery where several gear types exploit different size ranges.

3) It is difficult to obtain projected increases in yield per recruit in a fishery where discarding occurs.

4) If recruitment is not constant, optimal management strategies based on yield per recruit can differ substantially from strategies based on assessments of the maximum sustainable yield.

2.3.3. Virtual Population Analysis/Cohort Analysis

Virtual population analysis, or cohort analysis, is a technique used to calculate past fishing mortality rates and abundance of year classes (cohorts) at successive ages. When the analysis is applied to all year classes of a particular stock of fish, the result is an estimate of fishing mortality and stock size at all ages in each calendar year represented in the data base. The stock sizes by age in each year can then be summed to give the total stock size for that year. The fishing mortality estimates by age group in each year show the mortality pattern and also enable the calculation of an average mortality rate for the stock for each year.

This analysis is a sophisticated method of stock assessment, requiring a comprehensive statistical collection program to provide a lengthy time series of total catch/landing data and annual samples of length-age composition of the stock, as well as an estimated or assumed natural mortality rate for each age, and an estimated or assumed fishing mortality rate for at least one age for each year class. However, where virtual population analysis is applicable, i.e., where good aging is possible, the level and quality of scientific advice that can be provided is among the most accurate available.

Current population sizes can be estimated from the correlation of historical time series of abundance at recruitment size. Fishing mortality can be estimated by VPA with indices of abundance, recruitment, or fishing effort, using projected index values derived from fishery statistics or resource surveys.

2.3.4. Spawner-Recruit Model

The spawner-recruit (stock-recruitment) model describes the relationship between the number of spawners in a stock and the number of recruits produced (Fig. 18). The model has rather limited application on a year-to-year basis because the relationship of recruitment to parental stock is obscured by environmentally-induced fluctuations and the high fecundity of most marine species. Successful reproduction, and subsequent recruitment, may rest largely on favorable environmental conditions and, in the short term, may actually have little relationship to the size of the parental stock.

The model has been useful, however, in assessing the stocks of Pacific salmon which spawn once and die. The model is relatively effective in this case because: 1) recruitment depends to a substantial degree on the size of the parental stock, 2) recruitment to the fishery occurs mostly just prior to spawning, and 3) the factors which tend to limit the size of the stock operate principally in the freshwater spawning and nursery areas, and not in the ocean feeding grounds.

The data required by the model, escapement (number of spawners) and subsequent catch, are relatively easy to obtain compared to most fishery data. Direct counts of spawners are made in many streams, and catch statistics provide an estimate of recruitment when added to the escapement. The result is a curve relating the number of recruits which can be expected from a given number of spawners when a long time series of data is available.

2.3.5. Models for Use with Marking Experiments

A whole class of models has been derived to take advantage of information obtained from tagging experiments. Among the parameters which can be estimated from these data are survival rates, population sizes, recruitment estimates, and estimates of movement or migration.

Typically, a large number of fish are randomly selected from the population, marked or tagged in some manner, and reintroduced into the population. The fish are recovered subsequently by either research fishing

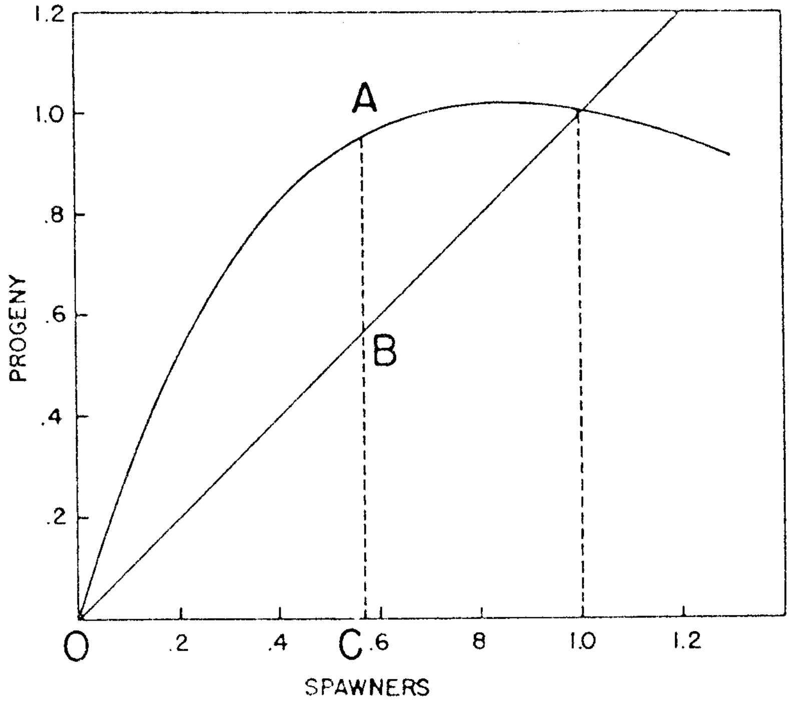


Figure 18.--Example of a generalized stock-recruitment curve of the type $R=\alpha Pe^{-\beta P}$, where R is the number of recruits, P is the size of parental stock or spawners, and α and β are constants.

efforts or by a commercial or recreational fishery. In a simple situation, individuals are tagged on only one occasion and recaptures made over an extended period of time. More generally, tags are placed on a number of occasions and recaptures made at subsequent sampling periods.

Problems which can affect estimates of population parameters made from tagging data include: mortality due to the tag, different animal behavior induced by the tag, and incomplete reporting of recovered tagged fish due either to their being nonrecognizable or by deliberate intent. Often if these situations are suspected, the tagging procedure itself can be modified to take them into consideration.

Extensive use has been made of tagging studies in the crab populations of the Bering Sea and in sablefish populations throughout the northern Pacific.

2.3.6. Change in Ratio Models

Fishery managers have made use of changes in observed sex ratios or marked-to-unmarked ratios to estimate population abundance and survival. The models are particularly effective where a differential harvest occurs, such as the male-only seal harvest on the Pribilof Islands.

2.3.7. Ad Hoc Models

Analytical situations often arise which cannot be fitted into a "standard" model. These generally occur where the life history of the fish is unique or where the sampling procedures clearly violate the assumptions made by traditional models. In these cases, traditional models are either modified to the specific application or ad hoc models are created to estimate the population parameters. For example, a model was created specifically for the estimation of growth and natural mortality of king crab in the eastern Bering Sea, and that model will probably have little application elsewhere.

2.3.8. Ecosystem Models

Newer computer-based models provide multispecific and ecosystem approaches to stock assessment. Ecosystem models employed in the marine fisheries context focus on the mechanisms of species interactions, both among themselves and with the marine environment, and their effects on the production of commercially harvestable fish biomass. Unlike the rigid single species models mentioned above, these models attempt to focus, in a functional manner, on the interspecific and intraspecific relationships which have the most significant impacts on biomass dynamics.

The most fundamental difference between single species and ecosystem models is that predation, and trophodynamics in general, is included in the latter, thus quantitatively connecting the dynamics of all species represented in a given ecosystem. Therefore, trophodynamics forms the basis for fish stock assessment methods when the ecosystem approach is employed. One of the great shortfalls of the single species approach has been the determination of the all-encompassing parameter "natural mortality," referring to deaths from all causes other than fishing. In its traditional form, this parameter has rarely been adequately estimated. However, in the ecosystem approach, "natural mortality" is broken down into functional components (losses due to predation, internal or external stress, etc.) which can be estimated more directly. Ecosystem models also provide a potential method for understanding and representing the relationships between marine mammals and fish resources. These links can only be represented as they occur in the food chain itself.

The basic processes which are represented in most ecosystem models are:

1) Trophodynamics - representation of predation as the most important quantitative linkage between species in the ecosystem;

2) Growth - parameters which vary with trophic and environmental effects;

3) Mortality - component effects such as spawning stress, predation, starvation, and environmental stress;

4) Reproduction and recruitment;

5) Migration - representation of biomass distribution over time, area, and depth, primarily as a function of environmental effects;

6) Age or size structure - key to the representation of trophodynamics; and

7) Effects of fishing.

Ecosystem models require more and different data than do conventional single species models. If these models are to play an important role in fisheries assessment and management in the future, there will have to be a major reorientation of fisheries data collection, e.g., more emphasis on the estimation of trophodynamic and environmental parameters.

Two examples of ecosystem models presently being used in fisheries assessment and management are a numbers-based Andersen-Ursin model for the North Sea, and the Laevastu-Favorite Dynamic Numerical Marine Ecosystem Model (DYNUMES), a biomass-based model developed at the Northwest and Alaska Fisheries Center.

While direct use of ecosystem models for management purposes lies in the future, output from existing models has already provided significant information on stocks. Examples include first-order estimates of abundances of presently unexploited species which may come under exploitation in the future (e.g., squid in the Bering Sea), results which suggest that marine mammal and bird predation on certain species (e.g., herring in the Bering Sea) may exceed commercial harvests, determinations of "carrying capacities" of given regions, representations of the effects of large scale "natural fluctuations" on fish resource dynamics, and evidence that certain species may be exploited at different trophic levels with significant differences in yield.

3.0. ADEQUACY OF TECHNOLOGY

Two major issues are involved in discussing the adequacy of assessments. From the perspective of the manager, adequacy is judged by whether or not the assessments meet the needs expressed by management objectives. For example, information on growth, mortality, and size selectivity may be sufficient to assess the effects of using different mesh sizes in trawls on yield per recruit, but estimates of recruitment and population magnitude may not be sufficient to estimate the effect of setting a quota on catch. Sufficiency is judged by the risk that managers are willing to take with respect to achieving the goals of the management plan.

From this perspective, the scientist can advise on the adequacy of assessments only in the context of expressed needs of management. The scientist can, in general, relate the scale of assessment information to the scale of stock manipulation required to meet management objectives; thus, his report may deal with the adequacy of assessments for meeting a particular goal but not the adequacy of that goal.

This section deals with the adequacy of current assessments in the context of technological sufficiency. This can, in turn, be viewed from two different aspects. First, how well can the present populations be described quantitatively and qualitatively? Secondly, how well can the future state of stocks be predicted with and without changes in the fisheries?

All of the methods employed have certain advantages and disadvantages in terms of conducting stock assessment activities. The factors influencing choice are largely dependent on the applicability of the method to the species or stocks examined, and the resources and manpower available to undertake stock assessment; in some instances, however, certain factors are applied in the absence of other reliable approaches. In this section, strengths and weaknesses of each approach previously described will be discussed, and adequacy of the technology for resource assessment will be commented on briefly.

3.1. Fishery and Marine Mammal Statistics

Fisheries statistics (including marine mammal statistics), as noted earlier, have been traditionally utilized in stock assessment; statistical data can be collected relatively cheaply and made available to the scientists for assessment. The data, if collected in a reasonably reliable fashion, can be applied to a number of standard fisheries models which provide a theoretical framework for understanding the functioning of a fish and marine mammal stock under exploitation.

A tally of the season's total catch is the primary statistic required for fishery analysis. The adequacy of this statistic depends on the nature and extent of the fishery. Many circumstances can reduce its accuracy, e.g., incomplete reporting, at sea-discard, etc. For many fisheries which operate from a number of ports and use various types of gear, catch records should preferably be recorded by vessel landings so that catch statistics can be subtotalled and analyzed for any fishery component.

For fisheries regulated by a quota, the collection of catch statistics to monitor the accumulative catch imposes the constraint of real time data compilation. In most fishery cases, compilation of catch statistics is too slow for real time stock assessment analyses. This tends to create a bottleneck in updating stock assessments in a timely manner for resource managers or advisory groups.

Stock assessment using fishery statistics also suffers because, in many instances, the data are collected for purposes other than analyzing the conditions of fish stocks, e.g., tax purposes. In addition, for many stocks, the data collected are incomplete, vary among states, and provide little information on the origin of catch and the amount of effort deployed for its retrieval.

The quality-of-effort data depends on the specification of the unit of measurement. For stock assessment purposes, effort must be proportional to fishing mortality. For a newly developing fishery, it is the biologists' responsibility to specify the requirement. In this case, idealism must be sacrificed for simplicity so that fishermen are willing to provide needed data. In the case of developed fisheries for which effort statistics have not been rigorously collected, scientist have often had to assemble an effort-time series from the available data. Often the specified unit is less than desired.

The fishery assessment models, other than the surplus production model, use estimates of growth and mortality rates and the age composition of the catch. This requires a catch sampling program with sound statistical design and sufficient sample size. For a dynamic population and/or changing fishery, the catch sampling program must be ongoing. The adequacy of parameter estimates is dependent on the ability to correctly age the fish sampled. In all instances, aging techniques are tedious and not 100% accurate.

Tagging studies in marine fisheries often rely on the commercial/recreational fisheries to catch fish for tagging and to recapture tagged fish. These studies on fish or marine mammals require considerable planning and experimental design. The primary assumption is that behavior of tagged animals is unchanged by the tag and tagging operation. The adequacy of tagging studies depends on cooperation of the fishery in returning tags and associated information, experimental design of the study and representativeness of the tagged individuals in the population. Tagging studies without too many problems can give insight to stock structure and migrations. On the other hand, estimates or rates of exploitation and abundance are less reliable because of the differential behavior and mortality of the tagged segment of the stock. In general, tagging studies are not designed to provide timely estimates because the analysis of the data cannot be completed until tagged individuals are recaptured.

3.2. Fishery-Independent Resource Surveys

3.2.1. Fishing Surveys

3.2.1.1. Trawl Surveys

The strength of trawl surveys stems from the long-term standardization of data collected, as well as the kinds of data collected. Survey data may be used to obtain current estimates of parameters of stock condition (abundance, fishing mortality, and age composition) that could not readily be obtained from commercial fisheries sources for many species. Estimates of stock condition can be available a few months after the completion of a survey, allowing timely decisions and early action by management.

The annual abundance indices from survey series can be of utmost importance in examining past trends in order to estimate current stock abundance. There are many examples in which survey abundance indices reliably reflect abundance changes. The validity of these indices has been demonstrated for species which have adequate commercial data available for comparison. For a few species, such as eastern Bering Sea king crab and yellowfin sole, surveys have provided a close approximation of exploitable population or biomass size. For many of the important species in demersal animal communities, survey abundance indices provide a current reference of stock condition for the management specialist. Current estimates of age composition for important demersal stocks can also be obtained from surveys. For some species, this estimate may be the only one available because data collected from the fisheries may not be reliable.

An important strength of surveys is that biological information (growth rate, age, size, sex, maturity, fecundity, tissue samples for genetic studies, food habits, population density distribution) can be obtained from a great number of species within their main geographical distribution. Thus, the surveys can give insight into the dynamics of populations, stock structure, reproductive potential, trophic interactions, etc., that could not be obtained otherwise.

Currently, three types of forecasts are feasible, based on survey and fisheries information: recruitment strength; population abundance from estimates of recruitment; and catch levels, given estimates of fishing mortality. There is accumulating evidence that surveys are providing a reliable index to recruitment or year-class strength for many species. Where there is an adequate time series on abundance by age from both the survey and the fisheries, a relationship between survey pre-recruit abundance indices and the strength of the corresponding year-classes in the fisheries has often been observed. Such examples have been found with eastern Bering Sea pollock and king crab, and for certain finfish species off the Atlantic seaboard.

Surveys also provide reliable and relevant data for use in traditional fishery dynamic models and the formulation of new conceptual and analytical frameworks of fishery production. This is made possible because of the design and synoptic nature of the surveys in identifying and measuring major scales of temporal and spatial variability in populations and their environment, and in revealing trophic interactions which occur within the intervening populations.

Surveys provide a long-term documentation of physical conditions (water mass characteristics, temperatures, and salinity) associated with resource distribution, density, recruitment, and growth, as well as other descriptors of populations and population interactions. Such documentation has not been available from the fisheries.

On the negative side, surveys are very costly and provide somewhat imprecise estimates of relative abundance. Indices of relative abundance from single surveys of northwest Atlantic fish stocks have exhibited a 95% confidence interval of plus or minus 50%. Similarly, low levels of precision have been found for estimates of abundance of fish stocks from resource surveys conducted in the northeast Pacific and eastern Bering Sea.

A limitation of multispecies trawl surveys is that they have been developed for many species and therefore are not as optimal for many individual species as a single-species survey would be. This can be readily appreciated by examining the differences between species in terms of optimal allocation schemes to increase precision (Table 4).

A serious drawback to the analysis of survey data is the difficulty in determining the underlying probability distribution function for trawl survey catch data. We have only a general knowledge about the distributional features of populations and are almost totally uninformed on how these features change relative to environment. We also know very little about an animal's response to sampling gear, because response depends upon size/age, physiological state, temperature, light, etc.

The performance of the sampling trawl itself may vary in relation to depth, topography of the sea bottom, surface and subsurface currents, and the interaction of these with the speed of the vessel. Even if all gear factors were kept constant, change in the behavior of the animals would still present various probabilities.

3.2.1.2. Longline and Trap Surveys

Longline and trap surveys use passive gears, requiring the cooperation of the fish for capture. The cooperation, or catchability, varies by species, size within species, area, season, time of day, type of gear, and other factors. All of these factors introduce biases of varying and unknown degrees into the surveys. Overall, the best results obtainable with these gears include statements of the presence, but not the absence, of certain species, and crude estimates of relative abundance. When combined with other survey techniques, however, such as mark and recapture, they will provide useful assessment information. In general, traps appear to collect a wider variety of the animal life of a particular area, while bottom longlines, by virtue of hook and bait size, tend to collect the larger fish.

The primary advantage of bottom longline and trap surveys is that they provide a means to sample areas which could not otherwise be surveyed. Their primary disadvantage is the unknown selectivity and the resulting inability to use results directly for stock assessment. Pelagic longline surveys suffer the same disadvantage, as well as requiring significantly more gear in a set, thereby increasing costs.

Table 4.--Optimal allocation of sampling effort for minimizing the sampling error in estimating the relative abundance of selected species. Results are based on the analysis of catch data from the 1975 eastern Bering Sea trawl survey and include expected reduction in actual sampling error if the optimal effort allocation by species had been used.

Stratum	Actual Effort	Optimal effort allocation by species (Number of trawling stations)					
		Pollock	Pacific cod	Yellowfin sole	Arrowtooth flounder	King crab	Snow crab
1	107	20	43	262	24	294	111
2	92	224	206	85	294	231	191
3S	119	74	127	124	190	2	123
314	89	153	123	8	26	0	67
4S	65	66	31	0	0	10	20
4N	66	1	8	59	0	0	26
Expected reduction in sampling error		58.2%	67.3%	53.1%	41.9%	38.6%	76.3%

Longline and trap surveys have many inherent problems but represent the only available fishery-independent survey technique for acquiring information on certain fish stocks. Significant increases in survey coverage with these techniques would greatly enhance the value of the results and, in turn, would probably provide needed information with which to evaluate their effectiveness. A major advantage of these forms of surveys, much like trawl surveys, is that biological information (e.g., growth rate, age, size, sex, maturity, fecundity, tissue samples for genetic studies, food habits, and population distribution) can be obtained from a great number of species within their area of primary geographical distribution. Thus, the surveys can give insight into dynamics of populations, stock structure, reproductive potential, trophic interactions, etc., which could not be obtained otherwise independent of the fisheries.

3.2.2. Visual Counts

3.2.2.1. Aerial Surveys

The general approach of aerial surveys for stock assessment appears to be useful and, in some cases, is perhaps the only possible approach. In the case of the porpoise populations off Mexico and Central America, for example, ship-based surveys and mark-recapture studies have not been adequate. The method has the advantage of being relatively fast to execute in the field and can be applied to large areas easily. As opposed to ship surveys of marine mammals, there is little or no response by the animals to the airplane prior to first fly-over; if movement occurs, it is moderate and occasional. The success of aerial surveys for population assessment depends heavily on the experimental design and on the assumptions that all of the animals are seen on the trackline or in a given path. In addition, the line transect methods rely on precision in measurements of the distances to the sighted objects.

The strength of aerial surveys by commercial fish-spotters lies in the relative inexpense of collecting abundance information on local pelagic fish stocks because aerial fish-spotters are commonly utilized by the fleet. A pilot logbook system may generate a superior data base for stock assessment compared to the usual vessel catch and effort data. Based on results from the southern California example, this index of apparent abundance, calculated from simple annual summaries, appears to be responsive to population fluctuations when compared to other measures of abundance. Implementation of this assessment method is only feasible for epipelagic resources which spend a considerable portion of their time near the surface and are commercially fished with the aid of spotter aircraft.

One weakness of the method is that quality of the data is the responsibility of the contracted pilots. Differences in the pilots' searching abilities and school size estimates must be considered in the final analysis. The unit of measurement for effort is not precise and, therefore, adds variance to the estimate. For more sophisticated analysis of variance procedure, annual values of the time series will change each time a new data year is added. In this case, since the index is dimensionless, an absolute measure of abundance cannot be directly calculated from the index.

As with all fishery-dependent surveys, aerial surveys by commercial fish spotters suffer from the fact that the sample obtained is not random. Search is directed toward those areas where communication and/or intuition have indicated that fish will be. Therefore, the assumptions made to effect standardization of the search effort are important but lack generality between surveys. Fishery-independent aerial surveys can solve some of these problems only through increased cost. However, the cost per survey area is less than comparable ship surveys, and the assumptions of analysis are more closely met with aircraft. Therefore, fishery-independent aerial surveys should take their proper place along with other survey methods for stock assessment analysis.

The problems with aerial surveys (both fishery-dependent and -independent) are obvious: they are limited to oceanic areas relatively close to land or landing areas, and they survey only the surface layer of the ocean. In addition, the probability of mechanical or human failures increases with extended flight times and flight frequency, and safety becomes a consideration.

Another problem with aerial surveys is the inability to identify adequately the species or stock encountered and to obtain high precision, low-bias estimates of aggregation size. These abilities can be improved by comparing aerial sightings with shipboard sampling efforts, but the cost of doing so is great. Other more technical methods have included photography which, under the right conditions, has proved to be useful.

3.2.2.2. Land-based Counts

The apparent advantage of counting methods for marine mammals and turtles is the high degree of precision which is achieved. The precision is misleading, however, because the number of animals (sea lions, whales, porpoise or turtles) which may be seen at any given time depends not only on season but also on the time of day, weather, and other factors which remain unknown. The bias of the counts may be reduced by proper stratification of the sampling effort, but at an increased cost. For example, there may be a period during the day in which the number of animals at a sea lion rookery is at a maximum. If an aircraft has to fly one hour each way to view the rookery for a short optimal period, then the cost per sample is large. Further study is needed to estimate the missing proportion of the population: the sea lions not at the rookery, the cetaceans or turtles beneath the visible surface layer, and the turtles not crawling up onto nesting beaches. Until that time, the counts can be considered only minimum estimates and, thus, indices of abundance. The use of counts in conjunction with other techniques, however, can be very productive.

Future problem areas in which counting methodology might be usefully applied include assessing the impact of outer continental shelf oil development projects and evaluating the interactions of marine mammal populations with fisheries. In either case, population estimates and trends in abundance are necessary to assess the status of marine mammal stocks relative to contemplated or ongoing management decisions.

3.2.2.3. Underwater Counts

Underwater visual forms of assessment can provide reasonably precise and accurate estimates of relative abundance. They are expensive to conduct, however, and have spatial and temporal limitations. Man-in-the-sea approaches have the added need for skilled and experienced observers, and the disadvantage of risk to human life.

3.2.3. Fish Egg and Larva Surveys

Egg and larva surveys for stock assessment have a number of advantages. The sampling gear, excluding the platform, is relatively inexpensive, and standard frames, nets, and various flow meters are readily available. The survey can be conducted from any seaworthy vessel without major installations of equipment. With relatively little training, standard quantitative tows can be taken within the accepted tow guidelines. The technique can be applied to a wide variety of marine fish species because most marine species have pelagic eggs and/or larvae. Simultaneous oceanographic measures of physical and chemical environment of the epipelagic zone can easily be added to the survey. Plankton samples contain not only fish eggs and larvae of a variety of species, but also information on phytoplankton and other zooplankton. In addition to the indices of abundance, considerable information can be gained on spawning seasons, distribution of the adult population, and possible stock boundaries.

The method also has weaknesses. Species identification of eggs and larvae is limited, although great strides have been made in recent years for species of the California Current and in waters off the mid-Atlantic states. The survey technique requires a major commitment of vessel sea time, particularly if a time series of the index of abundance is established. It requires a large staff of marine technicians, plankton sorters, fish identifiers, data managers, and research personnel to collect, process, and analyze the samples. The analysis of the data can follow acceptable statistical procedures, but a number of statistical problems still exist in compiling and interpreting the complex distributions of sample egg and larva data. The potential dynamics of stock fecundity rate could add variation in the index values that would otherwise be interpreted as fluctuation in stock abundance. This topic needs further study.

3.2.4. Remote Sensing

3.2.4.1. Acoustical Surveys

The principal advantages of quantitative echo sounder surveys include: 1) the possibility of obtaining information on abundance of many pelagic, semi-pelagic, and semi-demersal fish stocks for which there are no practical alternative assessment methods, as well as providing information needed for evaluation of other methods, e.g., bottom trawl surveys for semi-pelagic and semi-demersal stocks; 2) distinctly greater sampling volume (most of the water column) and sampling rate than other methods; 3) the ability to provide a large quantity of information on distribution, behavior, and potential vulnerabiity of many fish stocks, that is not attainable by other means; 4) lower data collection costs than other methods in some cases, due to rapid geographic coverage, quantity of data collected per unit time, and potential for basic data processing to be done in real- time; 5) a theory of basic quantification technique, i.e., echo integration, which is well developed (Swingler and Hampton 1979); 6) the estimation of scale factors required to estimate absolute density (via target strength measurement and related studies), usually a more tractable problem than that encountered when estimating similar factors (catchability and other conversion coefficients) required for alternative survey methods; and 7) the ability to monitor calibration of sampling equipment continuously.

Another advantage is the ability of the physical scientist to analyze theoretically the performance of hydroacoustical signal processing techniques. This advantage has to be qualified, however, because it has too often focused an undue amount of attention on the "worst case" limitations of the method. A realistic evaluation of the method's usefulness can only be done after a fish stock has been specified, and the desired types of information (distribution, relative abundance, absolute abundance, etc.) and their quality defined. The advantages and disadvantages of the total survey process, therefore, must be considered.

The main limitations of quantitative echo sounder surveys are: 1) the inability to detect targets on the seabed and at the surface, and sampling volume limitations in near surface waters (or near transducer); 2) the inability to identify targets directly, because identification is dependent on experienced personnel and/or direct capture techniques, the latter being essential when collection of biological data is required; 3) the requirement for more highly trained equipment operators and technical support personnel than most other survey methods; 4) the echo integration technique which is not applicable to species which frequently occur in densities high enough to cause multiple scattering, shading, etc., e.g., northern anchovy; however, echo sounder surveys of such species provide useful information on distribution, behavior, and relative abundance; 5) the determination of scale factors required to convert echo integrator outputs to estimates of absolute density, a difficult and complex task; 6) higher initial equipment cost than that for most other survey methods; however, as shown by its widespread use by other nations, this is infrequently significant compared to the cost of research vessel time and the lack ofalternative methods; and 7) poorly understood capabililties and limitations of the method, and a theory that is questioned.

In any type of survey, knowledge of the stock's distribution-availability pattern is critical to the reliability of abundance estimates derived by averaging and extrapolating the basic survey data. Its importance, however, tends to be overlooked when hydroacoustical methods are evaluated. Improvements in the precision and accuracy of the abundance estimates can do nothing to correct for uncertainties in the distribution-availability pattern. This has significant implications with respect to deciding which types of investigations should be pursued to improve the survey process. Although improvements in the precision and accuracy of estimates of echo integrator output scale factors are important to increasing the reliability of absolute abundance estimates, it often is equally important to better define the spatial and temporal distribution of the stocks which are the subject of hydroacoustic surveys. This can be done with existing survey equipment and gear, but either an increase in the intensity of survey efforts, a change in survey designs, or the development of experimental surveys designed specifically to provide answers to the distribution question are required.

For stock assessment, sonar mapping provides two indices: estimated number of fish schools and estimated surface area of schools. The quality of these estimates is determined by the subjectivity of species identification and the measurement of effective range interval. Biomass estimates are based on the total surface area of schools, depending on school volume estimates and fish-packing densities. Volume estimates depend on the assumption that schools have a consistent geometric shape, such as a cylinder. Squire (1978) showed that the assumption of a circular school overestimates the surface area by 72%. Because of the large variation in the few estimates of fish-packing densities, there is no reliable value that can be assumed for any particular survey. Although it is interesting to assume various values of fish-packing densities, there is no criterion for judging the best biomass estimate from the wide range of possible values. On the other hand, if great care has been taken each year to schedule the survey each year to coincide with prime conditions and the time when the target species is by far the dominant schooling fish, the estimate of the total surface area of schooled fish should then provide a good index of abundance of the target species in the upper mixed layer.

Sonar mapping is a relatively quick and comparatively inexpensive survey method. Survey results are relatively simple to compile and can be presented soon after the end of the survey. Sonar mapping, however, is likely to be an effective survey method for only a short seasonal period.

3.2.4.2. Other Remote Sensing Methods

Other remote sensing methods involving photography and TV images (both aerial and underwater) for primary means of detection are not used extensively in NMFS stock assessment programs. The inclusion of remote measures of oceanographic parameters in stock assessment analysis is becoming the topic of a number of research efforts within NMFS, but they are not in general use yet in routine stock assessment efforts. For purposes of this report, brief comments on adequacy of these methods are included in the respective description section 2.2.4.2. Much of the adequacy discussion of line and strip transects given in section 2.2.2.1 also applies to photographic and TV image surveys.

3.2.5. Environmental Indices

The use of environmental indices in stock assessment has proceeded in two directions. First, the incorporation of environmental covariates into classical fishery management models has, in a number of instances, been successful in reducing the variance about fit of the models. Second, research has been directed toward understanding causal mechanisms by which environmental conditions affect the survival of fish in marine populations. Particular emphasis has been placed on early life stages where recruitment levels are determined. These studies have only been possible for those stocks having available an accumulated information base on stock structure, recruitment, and/or detailed catch statistics. In general, necessary environmental data time series are only available for a few of the more common parameters. In most cases, these data must be synthesized by the appropriate time/area scale, which can be expensive and time-consuming. Furthermore, the key environmental variables will probably not be those that are routinely monitored, such as surface ocean temperatures, wind, etc. Because the interaction between population dynamics and the environment is complex, it is quite likely that one or a set of environmental indices will be found only for the critical or more understood species for which stock assessment can be improved. Few, if any, of these research studies to date have been implemented into routine stock assessment analyses to generate timely information for fishery managers. If such models prove valid with continued monitoring of the stocks and environment, it is only a matter of time before fishery managers will use environmental information to forecast recruitment, stock levels, and exploitation rates.

3.3. Fisheries Analysis for Stock Assessment

Models used for stock assessment attempt to represent, with a series of equations, the biology of the fisheries on a particular stock. To do this, it is necessary to make a number of simplifying assumptions. As knowledge of the stock increases, and as the time series of fisheries data becomes longer, the degree of complexity of the model can be increased and the number of assumptions reduced. This evolution through a series of increasingly complex models is common. For example, the major assumptions associated with the production model are as follows:

1) The fishery can reach an equilibrium; i.e., stock structure will adjust to, and stabilize at a given constant level of fishing effort.

2) Environmental factors are constant or average out over the long term.

3) The fishery is operating on a "unit stock," i.e., a stock capable of independent exploitation or management and containing as much of an inter-breeding unit, or as few reproductively isolated units, as possible.

4) One unit of fishing effort produces the same relative effect on the stock; that is, it catches the same percentage of the stock, regardless of the time or place it is applied, or of the size of the stock.

5) The rate of natural increase of stock responds immediately to changes in population density; i.e., the time lag between spawning and recruitment of progeny to the catchable stock is ignored.

6) The rate of natural increase at a given weight of population is independent of the age composition of the population.

As more data become available and biological knowledge accumulates, a yield-per-recruit model may be formulated to account specifically for, or relax a number of, the above assumptions, including at least numbers 4, 5 and 6. Thus, even when sufficient data are available, the results must be interpreted with caution. When inadequate data are used, the results are usually little more than pro forma and should be clearly recognized as such. The major benefit of standard fisheries models is to provide a theoretical framework for understanding the functioning of a fish stock under exploitation and for estimating stock parameters. In addition, the application of the model itself will often point out data deficiencies and, consequently, will direct future data acquisition.

The question of adequacy, then, is not just one of adequacy of the models but also adequacy of the data base and of the criteria for choosing the proper model. It must be decided whether a single-species representation will suffice for management or if a multispecies ecosystem model is required, before meaningful management advice for a specific fishery can be offered. If the latter, a data base is needed upon which estimates of the parameters of multispecies holistic ecosystem-type approaches can be based. It is in this area that fisheries analysis is lacking.

3.4. Geographic Coverage

Information on the stocks of fishes and marine mammals for which NMFS Research Centers are currently undertaking stock assessment studies is given in Table 5. For each assessment activity, information is provided on the importance of the technique, frequency of assessment, character of the survey, and cooperative nature of assessment, if relevant.

One hundred and fifty different stocks are currently being assessed by the NMFS Research Centers. In general, these are the stocks that have been identified in fisheries management plans. In many cases the assessment, while based on the best scientific information available, is adequate only in the context of the pro forma requirements of the act. This is the case for many minor fisheries and for many stocks that occur as by-catches in targeted fisheries. Consequently, the fact that a method is listed as "primary" in Table 5 does not necessarily imply that it is "adequate."

For most stocks, the primary technique of stock assessment is analysis of fisheries statistics. In many cases, these are limited to catch and production statistics. However, in all assessments, fisheries statistics provide basic information and data essential to more sophisticated analysis. The latter are possible when statistical data on effort, size, age, and growth characteristics are available.

Stock assessments are frequently augmented by survey data collected by research vessels independent of the biases inherent in data from the fisheries themselves. Table 5 indicates that trawl surveys of adults are the most frequently employed survey technique. Trawl surveys have a long history of use and provide samples from mixed fish populations that can be used to extract species, size, and age data needed for further analysis. Such surveys also provide data on enviromental parameters, associations, and feeding that are needed for ecological studies.

Table 5.--Application of certain resource assessment techniques by NMFS Research Centers to stocks identified in Council management plans or to meet Marine Mammal Act or treaty requirements.

Center Council Species with Separate OY	Source of Data Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic--Remote sensing	Environmental Indices	Marine Mammal Counts
NWAFC							
Pacific Council							
Groundfish - WA/OR/CA[1]							
Pacific whiting	1-A-i-Fo	-	2-T-b	2-A-i-Fo	2-S-i-Fo,2-T-b	2-A-i-Fo	-
Shortbelly rockfish	2-A-i-St	-	1-T-b-St	-	1-T-b	-	-
POP	1-A-i-St	-	2-A-b 2-T-b-St	-	3-T-b 0-S-i-Fo	-	-
Sablefish	2-A-i-St	-	2-A-i	-	-	-	-
Lingcod	1-A-i-St	-	2-T-b	-	-	-	-
Pacific cod	0-A-i	-	1-A-i	-	-	-	-
Canary/yellowtail	1-A-i-St	-	1-T-b	-	3-T-b,0-A-i-Fo	-	-
Chilipepper/boccaccio	1-A-i-St	-	1-T-b	-	3-T-b,0-A-i-Fo	-	-
Other rockfish	2-A-i-St	-	1-T-b-St,Fo	-	3-T-b,0-A-i-Fo	-	-
Dover sole	1-A-i-St	-	2-T-i-St	-	-	-	-
English/petrale sole	1-A-i-St	-	2-T-i-St	-	-	-	-
Other flatfish	1-A-i-St	-	2-T-i-St	-	-	-	-
Other fish	1-A-i-St	-	2-T-i	-	-	-	-
Troll salmon	1-A-i-St	-	-	-	-	-	-
Shrimp	2-A-i-St	-	1-A-i-St	-	-	-	-
Herring	0-A-i-St	-	-	-	2-A-b	-	-
Dungeness crab	1-A-i-St	-	-	-	-	-	-
North Pacific Council							
Groundfish--E. Bering Sea	1-A-i-Fo	-	2-A-b 2-A-i 2-A-i-Fo	3-D-t-Fo	2-A-b-Fo	2-A-q-Fo	-
Walleye pollock	1-A-i-Fo	-	2-A-i 2-T-b	3-D-t-Fo 3-D-t-Fo	2-T-b 2-A-q-Fo	- -	- -
Pacific cod	0-A-i-Fo	-	1-A-b	-	-	-	-
Atka mackerel	1-A-i-Fo	-	2-A-i	-	-	-	-
All rockfish	1-A-i-Fo	-	2-T-b	-	-	-	-
Turbot	1-A-i-Fo	-	2-A-i	-	-	-	-
Yellowfin flounder	1-A-i-Fo	-	1-A-i 2-T-b	-	-	-	-
Other flatfish	2-A-i-Fo	-	1-A-i	-	-	-	-

Table 5.--cont.

Center Council Species with Separate OY	Source of Data Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic--Remote sensing	Environmental Indices	Marine Mammal Counts
Sablefish	1-A-i-Fo	-	2-A-i-Fo	-	-	-	-
			2-T-i				
Squid	0-A-i-Fo	-	0-T-q	-	-	-	-
Other	1-A-i-Fo	-	2-A-i	-	-	-	-
			2-T-b				
Tanner crab							
C. bairdi	2-A-i-Fo,St	-	1-A-b	-	-	-	-
C. opilio	2-A-i-Fo,St	-	1-A-i	-	-	-	-
Herring--E. Bering Sea	0-A-i-Fo	St-A-i	0-T-q	-	-	-	-
Shrimp	-	-	-	-	-	-	-
Snails--E. Bering Sea	2-A-i-Fo	-	2-A-i	-	-	-	-
			1-T-i				
Clams--E. Bering Sea	0-A-i	-	-	-	-	-	-
King crab							
P. camtschatica	2-A-i-St	-	1-A-b	-	-	-	-
P. platypus	2-A-i-St	-	1-A-b	-	-	-	-
Groundfish-Gulf of Alaska	-	2-T-b	2-A-q-Fo	-	2-F-A-i	-	-
		2-A-i					
Walleye pollock	1-A-i-Fo,St	-	1-A-i	-	2-A-i-Fo	-	-
			1-T-b				
Pacific cod	1-A-i-Fo,St	-	1-A-i	-	-	-	-
			1-T-b				
Pacific ocean perch	1-A-i-Fo	-	1-T-b	-	-	-	-
Other rockfish	1-A-i-Fo	-	1-T-b	-	-	-	-
Flounders	0-A-i-Fo	-	1-A-i	-	-	-	-
			1-T-b				
Sablefish	1-A-i-Fo,St	-	2-A-i-Fo	-	2-A-i-Fo	-	-
			2-A-i				
Atka mackerel	1-A-i-Fo	-	1-T-b	-	-	-	-
Squid	0-A-i-Fo	-	-	-	-	-	-
Rattail	0-A-i-Fo	-	1-A-i-Fo	-	-	-	-
Other	1-A-i-Fo	-	1-A-i	-	-	-	-
			1-T-b				

Table 5.--cont.

Center / Council / Species with Separate OY	Source of Data: Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic-- Remote sensing	Environmental Indices	Marine Mammal Counts
Marine Mammal Laboratory							
Whales							
Gray[1,2]	-	2-A-i	2-A-i-Fo	-	3-D	-	1-A-
Bowhead[2]	-	2-A-q	2-A-q-Fo	-	3-D	-	1-A-i
Humpback[2]	-	2-D-q	1-A-t,i	-	3-D	-	-
Fin[2]	1-A-i-Fo	-	-	-	-	-	-
Sei[2]	1-A-i-Fo	-	-	-	-	-	-
Bryde's[2]	1-A-i-Fo	-	-	-	-	-	-
Minke[2]	1-A-i-Fo	-	-	-	-	-	-
Sperm[2]	1-A-i-Fo	-	-	-	-	-	-
Dall's porpoise[3]	-	-	1-A-i-Fo	-	3-D	-	-
Killer[5]	-	-	1-A-t,i	-	3-D	-	-
Belukha[2]	-	1-A-q	-	-	-	-	-
Harbor porpoise[5]	-	3-D-q	-	-	-	-	-
Blue[2]	-	-	2-D-q-Fo	-	-	-	-
Seals							
Northern Fur[4]	1-A-i-Fo	-	-	-	-	-	2-A-t
Guadalupe Fur[1],	-	-	-	-	-	-	1-A-t
California Sea Lion	-	-	-	-	-	-	1-A-t
Northern Sea Lion[5]	-	2-D-q	-	-	-	-	1-A-t
Harbor	-	-	2-M-t	-	-	-	1-M-t
Northern Elephant[5]	-	-	-	-	-	-	1-A-t
Bearded[5]	-	1-D-q	-	-	-	-	-
Largha[5]	-	1-D-q	-	-	-	-	-
Ribbon[5]	-	1-D-q	-	-	-	-	-
Ringed[5]	-	1-D-q	-	-	-	-	-
NEFC							
New England Council							
Atlantic Groundfish							
Cod	1-A-i	-	1-Tr-i,b[6]-Fo	3-Bi-i-Fo	-	-	-
Haddock	1-A-i	-	1-Tr-i,b[6]-Fo	3-Bi-i-Fo	-	-	-
Yellowtail	1-A-i	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Atlantic Herring	1-A-i-Fo	-	2-Tr-i-Fo	0-Bi-i-Fo	3	-	-

Table 5.--cont.

Center / Council / Species with Separate OY	Source of Data: Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic--Remote sensing	Environmental Indices	Marine Mammal Counts
Silver hake	1-A-i-Fo	-	1-Tr-i,b^6-Fo	3-Bi-i-Fo	-	-	-
Other hake							
Red hake	1-A-i-Fo	-	1-Tr-i,b^6-Fo	3-Bi-i-Fo	-	-	-
White hake	0-A-i-Fo	-	0-Tr-b-Fo	3-Bi-i-Fo	-	-	-
Redfish	1-A-i	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Pollock	1-A-i	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Scallop	1-A-i-Fo	-	1-A-i	3-Bi-i-Fo	-	-	-
Red crab	0-D-i	-	0-D	3-Bi-i-Fo	-	-	-
Northern shrimp	1-A-i-St	-	1-Tr-i	3-Bi-i-Fo	-	-	-
Mid Atlantic Council							
Surf clam	2-A-i	-	1-A-i	3-Bi-i	-	-	-
Ocean quahog	2-A-i	-	1-A-b	3-Bi-i	-	-	-
Atlantic mackerel	1-A-i	-	1-Tr-i,b^6-Fo	3-Bi-i-Fo	3	-	-
Butterfish	1-A-i	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Squid							
Illex	2-A-i-Fo	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Loligo	2-A-i-Fo	-	1-Tr-i-Fo	3-Bi-i-Fo	-	-	-
Shark	0-A-i	-	0-D	3-Bi-i	-	-	-
American lobster	1-A-i	-	1-Tr-i	3-Bi-i	-	-	-
Summer flounder	0-A-i	-	1-Tr-i	3-Bi-i	-	-	-
Bluefish	1-A-i	-	1-Tr-i	3-Bi-i	-	-	-
Scup	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
American shad	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
Hickory shad	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
River herring	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
Sea Bass	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
Tilefish	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
Dogfish	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-
Other flounder	0-A-i	-	0-Tr-i	3-Bi-i	-	-	-

Table 5.--cont.

Center Council Species with Separate OY	Source of Data Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic--Remote sensing	Environmental Indices	Marine Mammal Counts
SWFC							
California Coastal Species							
Anchovy[7]	2-A-i-St	2-A-i	-	1-A-b-Un,Fo	-	2-A-b	-
Jack mackerel[7]	2-D-i-St	2-A-q	-	2-T-i-Un	-	-	-
Pacific mackerel	2-D-i-St	2-A-i	-	-	-	2-A-q-St	-
Pacific bonito	2-D-i-St	2-A-i	-	-	-	-	-
Pacific tunas (north Pacific)							
Bluefin tuna	-	0-A-q	-	-	-	-	-
Albacore	1-A-i-St,Fo	-	-	-	2-A-q-Un	-	-
Pacific tunas (central & western Pacific)[9]							
Yellowfin tuna	1-D-i-Fo	-	-	-	-	-	-
Skipjack tuna	0-D-i-Fo	-	-	-	-	-	-
Pacific tunas (south Pacific)[9]							
Albacore	1-D-i-Fo	-	-	-	-	-	-
Pacific billfish[7,10]							
Striped marlin	1-D-i-Fo	-	-	-	-	-	-
Swordfish	1-D-i,q-St,Fo	-	-	-	-	-	-
Atlantic tuna[11]							
Yellowfin tuna	1-A-i-Fo	-	-	-	-	-	-
Skipjack tuna	1-A-i-Fo	-	-	-	-	-	-
Bigeye tuna	1-A-i-Fo	-	-	-	-	-	-
Albacore	1-A-i-Fo	-	-	-	-	-	-

Table 5.--cont.

Center Council Species with Separate OY	Source of Data Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic--Remote sensing	Environmental Indices	Marine Mammal Counts
Pacific Island species							
Lobster[10]	1-A-i-St	-	2-A-i-St	-	-	-	-
Groupers	-	-	0-D-i-St	-	-	-	-
Snappers	-	-	0-D-i-St	-	-	-	-
Seamount resources[10]	-	-	0-D-i-Fo	-	-	-	-
Marine mammals[5] (eastern tropical Pacific)							
Dolphins	-	1-D-b	2-A-i	-	-	-	-
Large whales[8]	-	0-D-i	0-D-i	-	-	-	-
Marine mammals (coastal)							
Dolphins	-	-	0-D-q	-	-	-	-
Large whales[8]	-	-	0-D-q	-	-	1-A-i	-
Pinnipeds[8]	-	-	0-D-q	-	-	1-A-i	-
SEFC							
Gulf of Mexico Council							
Stone crab	1-A-i	-	-	-	-	-	-
Spiny lobster[12]	1-A-i	-	-	-	-	-	-
Coastal Migratory Pelagics[12]							
King mackerel	1-A-i	-	-	-	-	-	-
Spanish mackerel	1-A-i	-	-	-	-	-	-
Dolphin	0-A-i	-	-	-	-	-	-
Bluefish	0-A-i	-	-	-	-	-	-
Cobia	0-A-i	-	-	-	-	-	-
Shrimp							
Brown	1-A-i-St	-	-	-	-	-	-
White	1-A-i-St	-	-	-	-	-	-
Pink	1-A-i-St	-	-	-	-	-	-
Royal Red	1-A-i	-	-	-	-	-	-
Sharks and Rays	0-A-i	-	-	-	-	-	-
Corals[12]	0-A-i	-	-	-	-	-	-

Table 5.--cont.

Center / Council / Species with Separate OY	Fisheries Statistics	Aerial Surveys	Ship Surveys (adult)	Ship Surveys (egg & larvae)	Acoustic-- Remote sensing	Environmental Indices	Marine Mammal Counts
	Source of Data						
Groundfish	1-A-i	-	2-S-i	-	-	-	-
Reef fish	1-A-i	-	2-D-q	-	-	-	-
Coastal herrings	-	-	-	1-D-b-Un	-	-	-
South Atlantic Council							
Billfish[13]							
Blue marlin	1-A-i	-	-	-	-	-	-
White marlin	1-A-i	-	-	-	-	-	-
Sailfish	1-A-i	-	-	-	-	-	-
Swordfish[13]	0-A-i	-	-	-	-	-	-
Snapper/Grouper	0-A-i	-	0-D-q	-	-	-	-
Calico scallops[14]	-	-	-	-	1-A-b	-	-
Caribbean Council							
Spiny lobster	0-A-i	-	-	-	-	-	-
Shallowwater reef fish	0-A-i	-	-	-	-	-	-
Other							
Menhaden	1-A-i	-	-	-	2-D-q	2-D-q	-
Tunas	1-A-i	-	-	2-A-b	-	-	-
Bottlenose dolphins	-	1-q-i	-	-	-	-	-
Sea Turtles	-	-	-	-	-	-	1-A-i

Footnotes

1. In cooperation with SWFC
2. International Whaling Commission
3. International North Pacific Fisheries Commission
4. North Pacific Fur Seal Commission
5. Marine Mammal Protection Act
6. Biomass indices for components of the population e.g. recruitment in addition to relative abundance indices for total population biomass.
7. Pacific Council
8. In cooperation with NWAFC
9. IPFC/IOFC Tuna Management Committees
10. Western Pacific Council
11. ICCAT
12. In cooperation with South Atlantic Council
13. In cooperation with New England, Mid-Atlantic, Gulf of Mexico, and Caribbean Councils.
14. In cooperation with Gulf of Mexico Council

Table 5.--cont.

SOURCE OF DATA

CODES

Data Usage

0	Used but not adequate method
1	Primary method
2	Secondary method
3	Developmental stages only

Frequency

D	Ad hoc - special purpose
M	Monthly
Bi	Bi-monthly
N	Monthly in season
Q	Quarterly
S	Semi-annual
Tr	Tri-annual
A	Annual
B	Biennial
T	Triennial

Survey Type

b	biomass index
i	relative abundance
q	qualitative index
t	total counts

Cooperative Source

Fo	Foreign cooperative research

Acoustical remote sensing techniques have been the subject of considerable research in recent years, and their application has become the preferred method for surveying schooling pelagic fish (anchovy, capelin, herring, etc.) and semi-demersal fish (Pacific whiting, pollock, etc.). Egg and larval surveys provide comprehensive assessment data but have most frequently been applied to pelagic fish.

Finally, it should be noted that Table 5 does not list certain important stocks. In general, these include the complex array of near-shore or shoal water species exploited principally by marine recreational fishermen, and a number of species which occur primarily as by-catch in commercial fisheries.

3.5. Financial, Personnel, and Vessel Resources

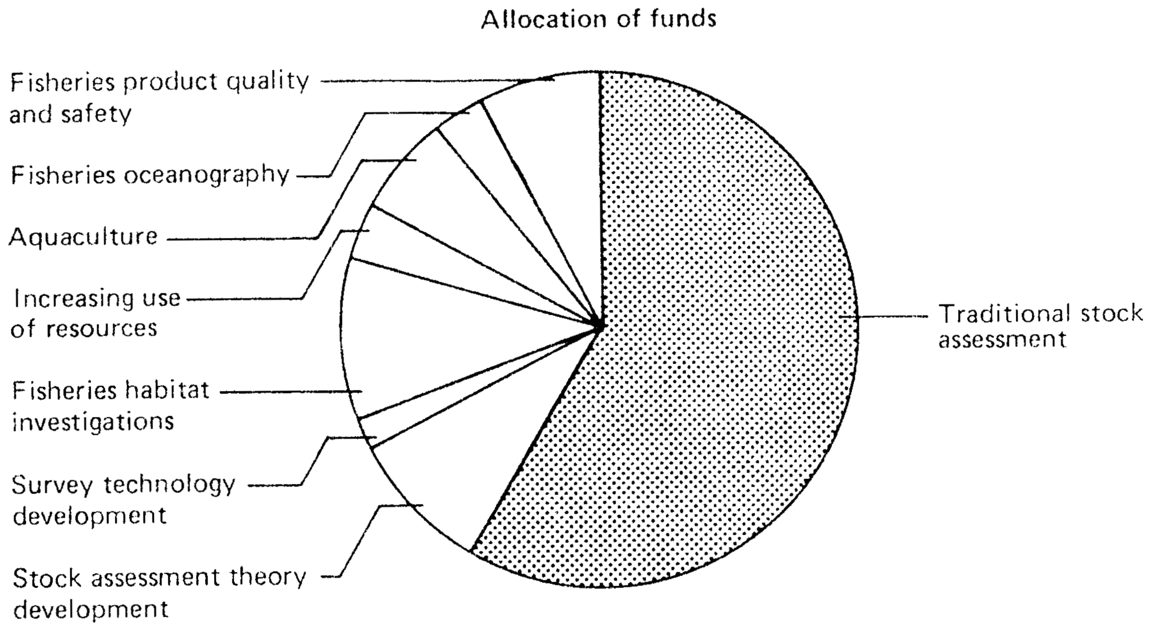
A breakdown of the funds and positions expended for research at NMFS Centers and Regions during Fiscal Year 1979 is given in Table 6. Of the national total made available for research (approximately $41.5 million), 59% was made available for stock assessment activities, and another 9% was allocated to the development of stock assessment theory and/or survey technology. Management costs were not included as research. In many cases, the line item title serves as an accurate descriptor of the research activity category. Besides "Stock Assessment" and "Stock Assessment Theory Development," the line items "Fisheries Oceanography," "Survey Technology Development," "Fisheries Habitat Investigations," "Increasing Use of Resources," "Aquaculture," and "Fisheries Products Quality and Safety" are used as research activities categories in this analysis. "Stock Assessment" includes most of the activities in the "Resource Surveys" and "Data Analysis" line items of MARMAP, collection of Commercial and Recreational Fisheries Statistics, collection of biological information through the Foreign Vessel Observer Program, and studies of Recreational Fish, Marine Mammals, Endangered Species, and Anadromous Fish. The category of "Stock Assessment Theory Development" is derived from activities, included in "Data Analysis" line items, which devote significant effort to improving our understanding of fish/fish-multispecies; ecosystem modeling would be included in the category.

There is some artificiality in the assignment of field studies to budgetary line items from which this information is derived (i.e., from current year task plans). Therefore, the numbers given in Table 6 and Figure 19 represent general comparisons. For example, some of the habitat investigation work (especially in the northwest) could well be assigned to "Stock Assessment" or "Stock Assessment Theory Development" categories. A large majority of funds available for research has, in recent years, been spent on stock assessment activities, although a growing proportion of research in some regions is channeled to undertake a variety of fisheries habitat investigations. Of the 788 fulltime permanent ceilings available for research, 54% were allocated to traditional stock assessment activities and another 10% to undertake the development of stock assessment theory and/or survey technology. Although the remaining research categories are itemized separately, they are not in all instances mutually exclusive from stock assessment activities. Areas of research, such as fishery oceanography and fishery habitat investigations, contribute significantly to the evolution of stock assessment theory and/or the development of life history information

Table 6.--Breakdown of approximate funds and positions devoted to research at NMFS Centers and Regions.[1/] Percentages are of total spent on research.)

Types of research	$K (%)	# Pos. (%)
Stock assessment	24,308.1 (59%)	425 (54%)
Stock assessment theory development	2,980.1 (7%)	54 (7%)
Survey technology development	921.5 (2%)	23 (3%)
Fisheries habitat investigations	4,721.9 (11%)	125 (16%)
Increasing use of resources	1,542.9 (4%)	45 (6%)
Aquaculture	3,678.6 (9%)	61 (8%)
Fisheries oceanography	1,136.1 (3%)	22 (3%)
Fisheries products quality and safety	2,067.3 (5%)	33 (4%)
Total research	41,356.5	788

1/ Approximate figures for funding and personnel were derived by categorization of FY 1979 CYTPs.



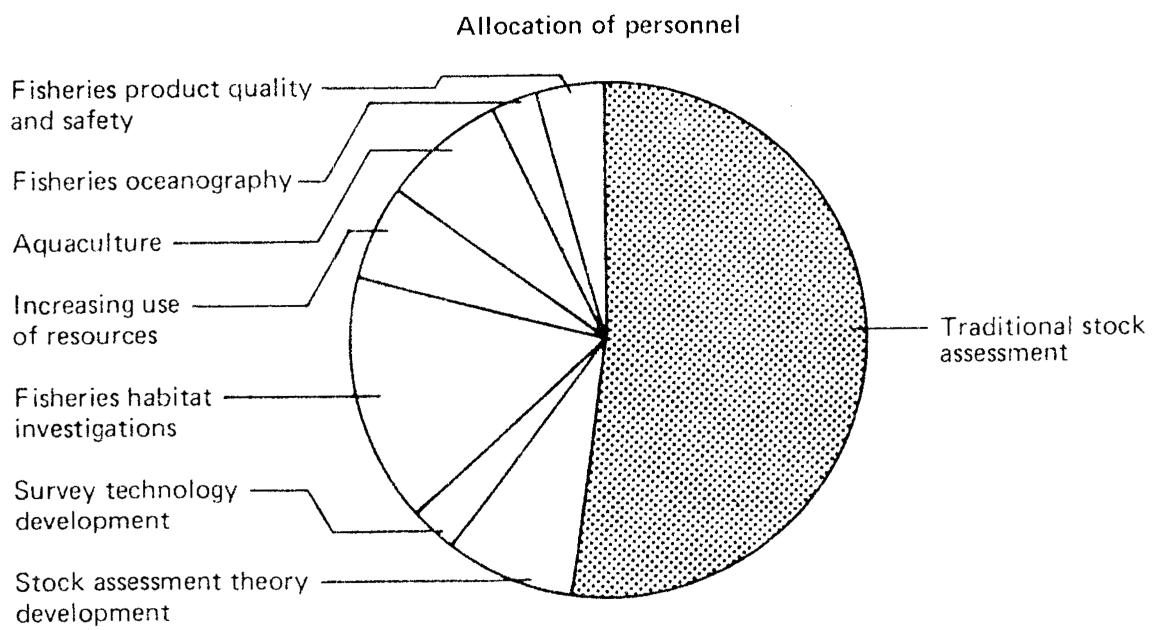


Figure 19.--NMFS allocation of research resources, FY 1979
(Centers and regions combined)

which is critical in the execution of stock assessment work. In this sense, no single research category can stand alone, due to the large degree of interdependence in the progress of marine science. In all NMFS Centers, the allocation of personnel and funds depends, to a degree, on the urgency of information requirements and the adequacy of supporting scientific studies in the other disciplines.

Another major input to stock assessment is the use of surveys of various kinds (trawl, eggs and larvae, hydroacoustical, and environmental) conducted from NOAA, NMFS, and charter vessels. Approximately 95% of the 3,215 sea days used by NMFS in Fiscal Year 1979 was identified as contributing to stock assessment research. Table 7 lists the number of sea days used for stock assessment surveys by vessel type.

Table 7.--FY 1979 sea days used for assessment surveys by vessel category.

Vessel category	Number of sea days
NOAA fleet	1,710
NMFS program vessel	400
Charter	460
Foreign vessels	400
Other	100
Total	3,070

Fishery Centers vary greatly in the utilization of surveys as a method of assessment (Table 8). This is due to the inherent differences in available resources, research interests, and needs in each Region, all of which help determine where the current research emphasis will be.

Table 8.--Sea days used for assessment surveys by NMFS Fisheries Centers during fiscal year 1979.

Center	Number of sea days
NWAFC	1,254
NEFC	770
SWFC	722
SEFC	274
Total	3,070

3.6. Technology

The technological adequacy of the different resource assessment methods employed by NMFS has not been directly evaluated in this report. This adequacy relates primarily to the accuracy of survey samples, which, for the most part, is largely unknown. For example, almost no information is available with which to computeaccurately sampling efficiencies for one of our primary assessment tools -- the survey trawl. Advances in appropriate technology, while not revolutionizing resource assessment, could aid significantly in establishing accuracy levels, which, in turn, would increase confidence in survey results.

Throughout this report, the need for fisheries-independent surveys has been stressed; yet, for a number of our most important fisheries, the technology for independent surveys is lacking. Examples include menhaden and other shallow water coastal pelagic species in the southeast, oceanic pelagics such as billfish and tunas, most reef fish species, and many crabs. Table 5 lists many more species where fisheries-independent surveys are not, or are seldom, used because cost-effective survey technologies are lacking.

There are many other areas in stock assessment where technological advancements, while not revolutionizing assessment strategies, should nevertheless significantly improve our understanding of fishery ecosystems. The remote sensing technologies, including ocean acoustics and aerospace remote sensing, offer many potentials, ranging from improvements in applications of traditional sampling techniques, to synoptic monitoring of estuarine and oceanic parameters affecting the distribution, movement, recruitment, and general well-being of fish stocks. In addition, synoptic information on ocean productivity, circulation, source and fate of pollutants, water mass patterns, and other parameters should significantly aid in monitoring the dynamics of marine ecosystems and, in turn, improve our ability to abstract and model fishery ecosystems.

Technological advancements also are needed specifically to reduce the amount of labor needed to age fish (e.g., automatic scale readers) and to sort, count, and identify fish eggs and larvae. Advancements in the technology related to materials, hydrodynamic stability, and attachment procedures for fish tags are also needed to improve retention characteristics for long-term tagging studies. Technological improvements in tracking technologies for fish, marine mammals, and sea turtles, such as those offered by satellites, would also provide a capability to monitor the movements and migration patterns of these animals over their entire distributional range and throughout a significant portion of their life cycle.

Technology also could improve current methods of gathering fishery statistics and, at the same time, reduce labor costs. Examples range from simple devices placed on commercial trawls to monitor actual time fished, to more complicated data logger systems aboard research vessels to record automatically vessel location and activity. Satellite monitoring of fishing effort and distribution could also be an important contribution, using technology such as transponders on the vessels to provide location information and fishery independent methods such as synthetic aperture radar surveillance approaches.

Advances in computer and communication technologies should also have significant benefits for stock assessment. These latter technologies should provide new capabilities in applications of complex multidiscipline and multispecies analytical and simulation approaches to resource assessment and management questions.

Evaluation of such technologies is beyond the scope of this report but is to be the subject of additional studies proposed by NOAA and the Office of Technology Assessment.

4.0. COMMUNICATION OF RESULTS

The communication process is a vital link between the scientists preparing stock assessments and the user groups (industry, councils, states, NMFS management components, other management agencies, etc.). This process is not merely the dissemination of assessment results to the users but also includes participation by the users in planning scientific studies (e.g., trawl surveys) which will provide data to be used in the assessments, and in review of the results and implications of the assessments.

Communication begins in the planning phase of the assessment process. Currently, council, state, industry, and academic representatives meet with NMFS scientists from the Southwest and the Northwest and Alaska Fisheries Centers, to assist in the planning of resource surveys. Such user group participation also occurs to some extent in the Northeast and Southeast Fisheries Centers. This involvement is vital in establishing understanding and cooperation, and insuring that the assessment results will have credibility with the users. During the process of data analysis and interpretation, NMFS scientists can, should, and do confer with industry and other user components to obtain supporting quantitative and qualitative information. Participation by NMFS scientists on scientific and statistical committees of fishery management councils, council oversight committees, various planning committees, etc., provides formal means for exchange of ideas, proposals, and results, which serve to enhance the communicative process. In the Northeast Fisheries Center, a series of regional federal-state-council assessment workshops has been held for the purpose of reviewing NMFS assessments, including data bases and their limitations and inadequacies, areas of needed research, etc.; reviewing state research activities which relate to assessment data needs; and establishing and furthering channels of communication among scientists.

In the Southeast Fisheries Center, which provides scientific support for three Councils, the Office of Fishery Management was established as the primary interface between the Councils and the Center. Focusing the exchange of needs and information through a primary channel, rather than having the three Councils deal independently with each of the Center's seven laboratories, has contributed to enhancing the communication process in the southeast.

Adequate communication is essential for the dissemination of assessment results. This should essentially be a continuous process that can go forward in a variety of ways and in varying degrees of formality and complexity. Initial phases include the distribution of trawl survey results in the form of industry or fishermen's reports. Informal cruise reports are also issued, which describe the general objectives, scope of activity, and results of each survey. These reports include the location, magnitude, and approximate size composition of species catches on a per tow basis.

Assessment results (i.e., recent harvest levels, catch-per-unit effort, survey abundance indices, estimates of stock size, recruitment, and fishing mortality and prognosis of future catch levels) for species-stocks of concern are presented informally to Councils, industry, etc., at which time there is opportunity for user group criticism and verification. Presentations may be enhanced by the use of visual aids and non-technical vocabulary to ensure maximal understanding by the audience.

Following completion of all assessment analyses, a final report, generally in the format of a laboratory reference report, technical report, or other internal document, is prepared and issued to the councils, states, industry, NMFS management components, and others. Where management may involve an international commission, the report may be issued as a research document to International North Pacific Fisheries Commission, International Convention for Conservation of Atlantic Tuna, International Commission for North Atlantic Fisheries, etc. Final written reports at this stage generally comprise the scientific input to fishery management plans or amendments thereto. In some of the Centers, particularly the Northeast Fisheries Center, an annual status-of-the-stocks report is issued as an internal document to summarize the most recent assessment for each species-stock done at that Center. This document has proved to be of particular interest and value to managers and others.

The assessment process may result in publication in a professional or otherwise refereed scientific journal; however, this usually occurs only if the assessment presents new techniques or approaches, or a previously unreported assessment analysis of a particular species or fishery.

Communication of assessment results to those who utilize them in implementing management decisions, and equally to those (industry, public) who are affected by management, is a necessity. Constant attempts must be made to improve the quality of the communication process. Scientists must be receptive to the users to gain their respect and understanding. If industry recognizes and understands how assessments are conducted, how and why their data are incorporated into and employed in the process, and the sensitivity of the results to errors in the data and the implications thereof; and if industry feels that it is contributing significantly to the assessment process, it may achieve a greater sense of responsibility and concern. If industry and others better understand the assessment process, they will be less apt to negatively criticize the results. Communication at a level where mutual comprehension is attained also will tend to improve credibility.

5.0. SCIENTIFIC MIX

Within NMFS, stock assessment research is directed by mandates of federal legislation (MFCMA, MMPA, and ESA) and of international treaties such as ICCAT for Atlantic tunas. For resources where stock assessment is not mandated by legislation, research is guided by the NMFS scientific mission to understand the population dynamics and to monitor important fish stocks. The question of proper mix of NMFS research can be addressed at three levels: stock assessment work versus other fisheries-related research; allocation of stock assessment research among fishery resources under the centers' purview; and level of stock assessment analysis for a particular resource with respect to frequency, precision, and combination of methodologies. With respect to the first level, the overall NMFS allocation of budget and personnel for traditional stock assessment, as given in an earlier section, is 59% of research dollars and 54% of research personnel. Developmental stock assessment activities make up an additional 15% of the budget and 10% of the personnel. The remaining 30% of the budget and 36% of personnel are distributed among fisheries habitat investigations, aquaculture, fishery resource development, fishery product quality and safety, and fishery oceanography.

The mix of science in each Center varies considerably. These differences result from 1) the amount of funding, equipment, and type of personnel available, and 2) the varying assortment of species within its area of concern that come under legislative or congressional mandates. Differences also result from the size of these resources, their ecological and economic value, and the extent of external social-political pressures. Although the primary purpose of NMFS stock assessment research is to provide advice to the decision-making process of fishery management, the analyses that make up the stock assessments are an integral part of other NMFS research, such as habitat investigations and fishery resource development.

Allocation of the Center's resources depends on the evaluation of such criteria as: legislative mandates, level of resource management, intensity of fishery relative to some maximum, generation time of the stock, political urgency of the problem, intensity of user review and expectations, quality of available stock assessment technology, available budget and manpower, and perceived national need. Resource questions requiring scientific investigation are in a constant state of flux. The status of individual fishery resources is continually undergoing change to some unknown extent. For anything other than retrospect, any particular stock assessment is good for only an instant in time, soon to become outdated. As a result, today's proper mix of science and resources to solve today's problems will not necessarily be proper tomorrow with tomorrow's problems.

Evaluation of criteria must be a continuing process to maintain a current proper mix of research activities; an ideal systematic process for attaining a proper mix is not a reality. Even so, the mix of research activities would not necessarily appear advantageous to a user group or to the research staff, for example. These groups will have a narrower focus of the criteria and different priorities. Any user group will assign the highest priority to research on its associated resource (or the lowest priority if it fears restrictive regulations). To the research staff, the approved research assignments become first priority, independent of earlier priority. The question of "proper mix" then is a matter of one's perspective. When questioned with respect to proper mix, the Center Directors should be prepared to discuss the Centers' responsibilities, allocation criteria, and the criteria evaluation in relation to manpower and budgetary limitations.

With all this said, the remaining underlying question for any particular stock assessment research is "When is enough, enough?" This question cannot be answered technically without a quantitative analysis of alternative stock assessment methods for each resource problem, including such things as the most cost-effective method or mixture of methods, required levels of precision, frequency of results, and a forecast of the risks associated with being wrong. Prior to these types of analyses and evaluations, no one can say whether the mixture of science is proper although the mix may be "satisfactory" to solve the problems or answer the questions being addressed.

The arrays of research studies currently under way throughout NMFS ultimately affect the status of the fishery resources and the resulting stock assessments. Understanding population trends and interactions of the population with other biota in the ecosystem is contingent on fundamental knowledge of the impact on survival and growth of natural events in the environment, habitat alterations, disease, predator/prey relationships, competition, and the whole area of man's impact on the environment and its resources. Hence, stock assessment must be seen in a much more holistic manner than it has in the past, and the aggregate of current activities are all designed ultimately to understand the processes and events of the inanimate and biological environment.

6.0. DISCUSSION AND RECOMMENDATIONS

The current level of stock assessment activity in NMFS was mandated by new legislation aimed at protecting U.S. fisheries, endangered species, and marine mammals. Prior to these legislative acts, stock assessments were done largely for high-value fisheries or fisheries requiring international agreement for management purposes. This was considered reasonable because neither the manpower nor the money was available to do assessments for all stocks. The advent of conservation and environmental legislation over the past decade has resulted in a sense of urgency concerning improvements in the quality and timeliness of stock assessment information. There has been, in addition, a significant extension of stock assessment studies to provide information on resources harvested by domestic fisheries, thus increasing the demand for data on a wide variety of fish, shellfish, and marine mammals. Additional monies were provided to support the activity; however, manpower restrictions remain. In addition, the required new stock assessments are, in many cases, for stocks on which few of the necessary basic data exist; research is therefore required to provide estimates of the basic parameters before stock assessment can begin.

Put in this political and scientific context, and considering the state-of-the-art in stock assessment theory and technology, the assessment coverage accorded to fish and marine mammal stocks as indicated in Table 5 may or may not be considered adequate, depending on one's perspective. For example, the fishery management council in its plan development cycle might consider a given level of assessment effort as inadequate, while the scientists feel it is the best they can provide under the circumstances and that it may be adequate for first-round management decisions. Certainly, the scientist would like to provide a better assessment, just as the Council member would like to have one; however, reality should produce a compromise as to what really is adequate in terms of quantity and quality of assessments in the management/legislative context.

The perfect stock assessment methodology does not exist. Existing methods are not completely interchangeable; each measures a slightly different aspect of stock abundance, and its use depends on the questions or problems at hand. Each method has a particular set of biological and physical conditions under which it works best. Each method has a specific set of assumptions and associated costs. In all cases, there is a degree of risk that conclusions will be inaccurate. We must further recognize that assessment methods are frequently imprecise and that improving on precision and accuracy may be costly. This can be important if crucial management decisions are being weighed.

In considering methodology, it is apparent that no single approach or technique is suitable for all species or areas. In addition, assessments are not one-time endeavors but require continuous updating due to the dynamic nature of the stocks involved. Regardless of these shortcomings, stock assessment activities do provide estimates of stock size and they do generate information on trends in stock sizes. In this sense, we accept that the technology applied is generally the best available at the present time. Stock assessment scientists are continuously seeking new technologies to improve the quality of the stock assessment information techniques. However, the greater immediate need lies in timely collection and processing of improved fisheries data to meet the near-term needs of resource managers.

The Stock Assessment Task Force cannot overemphasize the importance of improving the quality and timeliness of fishery statistics collected from the commercial and recreational fishermen. Although substantial progress has been made in this area under the MFCMA, effort data are still lacking for a large number of species, and total catch for some species is still a best guess. To gain more effective access to the information available on commercial fishing activities, it is necessary to develop cooperative arrangements with the fishing fleet itself to make greater use of logbook information, observations at sea, etc.

The Task Force does recognize the need to improve substantially the quality of communications on stock assessment activities to the various user groups. Some of the problems which have arisen may reflect a tendency of the scientific community to have oversold its ability to provide accurate information on stock trends and abundance. Hence, stock assessment scientists themselves may be partially responsible for constituent and peer expectations which are too high with regard to precision and timely availability of stock assessment data.

The view of the Task Force is that stock assessment activities do not constitute a separate scientific discipline pursued only for management purposes. On the contrary, a great portion of the data collected for biological studies, ecological studies, and environmental research contributes to the data base for stock assessment. As noted earlier, stock assessment studies reflect an interpretation of natural and man-imposed events on living marine resources; hence, the aggregate of mortality coefficients generated by changes in the natural environment--pollution, fishing, etc.--must be integrated to interpret factors influencing changes and consequences of management strategy. There is a growing recognition of the need to expand the concept of a multidisciplinary approach to stock assessment investigations, and managers should avoid fractionalization of research programs along disciplinary lines.

The foregoing discussion leads us to conclude that the improvement in knowledge about the recruitment function and inter-specific relations represents two of the most important needs. Both the biotic and abiotic aspects of these two processes need investigation. Managers will not be able to adjust resource productivity, nor evaluate the effects of many commonly used regulatory methods, without such knowledge.

Technological limitations which confront stock assessment activities have not been addressed in this report in any depth. The Task Force recognizes, however, the importance of technology for providing improvements in these areas. The Task Force, in recognizing that research demands and management needs vary among regions and fisheries, recommends that NMFS act to:

1) enhance the timely collection and processing of improved or new fisheries data, both commercial and recreational, to meet the needs of resource managers and researchers;

2) expand the concept of a multidisciplinary (ecosystem) approach to stock assessment which integrates information from environmental, ocean variability, and fisheries impact studies;

3) improve knowledge of both biotic and abiotic aspects of the recruitment function and inter-specific relations, so that resource managers may evaluate the potential of regulatory measures affecting resource productivity;

4) advance the theoretical and technical bases for stock assessment;

5) communicate more effectively with user groups to improve their understanding of the strengths and weaknesses of assessment techniques and their implications to management decisions; and

6) recognize that new information demands for management have eroded the peer review process and that NMFS should explore methods to improve such review.

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APPENDIX

EVALUATION MATRICES

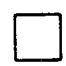
The development of the assessment report pointed out the complexity and large volume of the work conducted by NMFS to carry out its management responsibilities. To put this into a condensed form, a series of matrices was developed.

MATRIX I: Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

The first matrix identifies the current status of NMFS assessment efforts and the additional efforts that are needed to meet management unit requirements. Each management unit, within a fishery management plan or preliminary management plan, is identified by ecological group (Matrix III) and importance. Methods currently in use to provide stock assessments for each management unit were identified with a general indication of the methods' accuracy. The level of assessment (Matrix IV) derived from the method(s) used was then identified. The levels ranged from a simple catch trend to a complex ecosystem yield estimate. To put the existing efforts into a proper perspective the assessment level and accuracy level currently required by a management unit was identified. Additional efforts needed to meet the current requirements of the management unit were then identified. The matrix concludes with the identification of FY 1980 base budget figures and the additional resources needed, if any, to meet the currently required level of effort.

The various elements included within Matrix I are identified below:

Element no.	Name and Description/Examples
1.	Management Category: Specific FMP, international agreement, or mandate, e.g. Gulf of Alaska Groundfish Management Plan, Marine Mammal Protection Act.
2.	Management Unit (within Management Category): A species or species group, e.g., northern anchovy, reef fishes, Pacific whiting, flounder complex.
3.	Ecological groups: See List 1 below (page A30).
4.	Commercial importance (of a Management Unit): Indicated by Value and weight (Volume) of annual landings, using the following categories and associated code symbols.

Value	Volume (m.t.)	Symbol
> $150 million	> 100 thousand	
$76-150 million	51-100 thousand	
$10- 75 million	10- 50 thousand	
< $10 million	< 10 thousand	
None	None	

The current "Fishery Statistics of the United States for 1979," is the source document. The value of foreign catch is calculated from the ex-vessel prices used to compute poundage fees charged (see page 87 of the reference). Discard estimates, if available, are footnoted or entered in Remarks.

5.	Recreational importance (of a Management Unit): Indicated by Participation (No. of fishermen), Costs ($), and Volume of catch, using the following categories and associated code symbols.

Participation (No. of fishermen)	Costs	Volume (m.t.)	Symbol
> 5 million	> $150 million	> 50 thousand	
2-5 million	$76-150 million	26-50 thousand	
0.5-2 million	$10- 75 million	5-25 thousand	
< 0.5 million	< $10 million	< 5 thousand	
None	None	None	

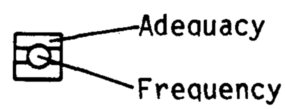
6. Protected and/or Endangered species. Checked if species or species group (Management Unit) is protected and/or endangered; otherwise left blank.

7. Adequacy of NMFS Current Assessment Methods (for methods listed below).

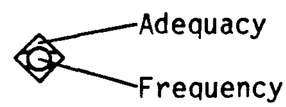
(a) Fisheries information
(b) Aerial survey (counts)
(c) Ship surveys (adults and/or juveniles)
(d) Ship surveys (eggs and larvae)
(e) Ship surveys (acoustical)
(f) Other remote sensing surveys
(g) Environmental surveys

The adequacy and frequency of use of each method are indicated by the following symbols:

(1) For methods other than primary methods:



(2) For primary method:



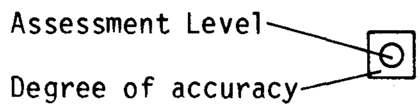
Adequacy levels and code symbols:

Adequacy level	Symbol	Symbol (if primary method)
Adequate		
Marginal		
Inadequate		
Unknown		

Frequency of use (indicated in circle in center of symbol) is coded as follows:

Frequency	Circle code
Occurs more than once a year	●
Occurs once a year	①
Biennial	②
Triennial	③
Irregular	⊕

8. Assessment Level and its degree of accuracy. This pertains to each Management Unit. Assessment Levels are defined below (see List 2, page A30). Information on Assessment Level and its accuracy is entered for: (a) Current Level by NMFS for the Management Unit, and (b) Current Level required for the Management Unit. The following code symbol is used for both (a) and (b):



Assessment Level	Circle code	Degree of accuracy	Symbol
None	①	Within 30% of true value	
Catch trend	②		
Relative abundance trend	③		
Equilibrium yield	④		
Annual yield forecast	⑤		
Multispecies total biomass yield	⑥	Conservatively biased (31-60%) less than true value)	
Ecosystem yield	⑦		
		Grossly accurate (+31-60% of true value)	
		Inaccurate (> ±60%)	
		Unknown	

9. 10. 11. Additional technological, analytical, and sampling effort needed to meet current and projected management requirements. These items relate to effort required with respect to what are considered to be the two (note 2 columns under each item) most critical Information Elements for a Management Unit. Information Elements are shown in List 3 (page A31). In this case, as indicated below, effort is not defined in terms of funds and personnel.

For the Technological and Analytical efforts the categories and symbols are:

Technical and Analytical effort category	Symbol (No. of Information Elements is entered in center circle)
Developmental program needed. (No technique or present technique requires replacement.)	
Increase effort in current developmental program. (No technique or present technique requires replacement.)	
Improve present technique.	
No effort, i.e., no Information Element identified for additional effort.	

For the Sampling efforts, the categories and symbols are:

Sampling effort category	Symbol (No. of Information Elements is entered in center circle)
Introduce new sampling program.	
Increase present sampling effort (either size of individual samples, no. of samples, geographic coverage, frequency of sampling).	

No effort, i.e., no Information Element identified for additional effort. ○

Under each of items 9, 10, and 11, the most important Information Element (of the two selected) is indicated in the left half of the column.

12. Funds and Personnel by Management category. Estimates of funds and man-years are entered as indicated. Note that estimates are for Management Categories, not Management Units.

MATRIX I.

Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

NORTHEAST FISHERIES CENTER

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76-150	51-100	
10-75	10-50	
<10	<10	
None	None	

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2-5	76-150	26-50	
0.5-2	10-75	5-25	
<0.5	<10	<5	
None	None	None	

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol
- Within 30% of true value. - Conservatively biased (31-60% < true value).	
- Grossly accurate (±31-60% of true value).	
- Inaccurate (> ±60%).	
- Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

- Dev. program needed.
- Increase effort in current dev. program.
- Improve present technique
- No effort

Sampling Effort Category

- Introduce new program
- Incr. present sampling eff.
- No effort

Circle Code: Refer to LIST 3 for key to code. pg A-31

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods - Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
ATLANTIC GROUNDFISH FMP	Atlantic cod	7,8,9,10																	17	23	20			540	11	185	1	
"	Haddock	7, 8																		23	20							
"	Yellowtail Flounder	7, 8																		23	20							
ATLANTIC HERRING FMP	Atlantic Herring	4																		23	20			540	11	185	1	
SEA SCALLOP FMP	Sea Scallop	16																		23	20			540	11	185	1	Commercial volume equals in-the-shell weight.
REDFISH FMP	Redfish	9, 10																		23	20			360	7	123	0.6	
RED CRAB FMP	Red crab	16																		23	20			180	3	62	0.3	
POLLOCK FMP	Pollock	9, 10																		23	20			360	7	123	0.6	
NORTHERN SHRIMP FMP	Northern Shrimp	9, 10																		23	20			180	4	62	0.3	
AMERICAN LOBSTER FMP	American Lobster	16																		23	20			180	4	62	0.3	
HAKE FISH'RS OF THE NW ATLANTIC PMP	Silver Hake	9, 10																		23	20			360	7	123	0.6	
"	Red Hake	7, 8																		23	20							

* - SEE LIST 1 page A30 Ecological Groups Key

** - SEE LIST 2 page A30 Assessment Level

NEFC - I (1)

MATRIX I.

Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

NORTHEAST FISHERIES CENTER

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)
>150	>100
76–150	51–100
10–75	10–50
<10	<10
None	None

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)
>5	>150	>50
2–5	76–150	26–50
0.5–2	10–75	5–25
<0.5	<10	<5
None	None	None

CODE KEY - ITEM (7)

Adequacy Level: Adequate; Marginal; Inadequate; Unknown

Circle Code Frequency: >once a year; once a year ①; Biennial ②; Triennial ③; Irregular ⊕

CODE KEY - ITEM (8)

Degree of Accuracy:
- Within 30% of true value.
- Conservatively biased (31–60% < true value).
- Grossly accurate (±31–60% of true value).
- Inaccurate (>±60%).
- Unknown.

Circle Code Assessment Level **:
1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category:
- Dev. program needed.
- Increase effort in current dev. program.
- Improve present technique
- No effort

Sampling Effort Category:
- Introduce new program
- Incr. present sampling eff.
- No effort

Circle Code: Refer to LIST 3 for key to code. pg A31

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
FOREIGN TRAWL FISHERIES OF THE NW ATLANTIC PMP	Miscellaneous other finfish	4, 7, 8, 9, 10														3	6		17	23	20			180	3	62	0.3	
SURF CLAM / OCEAN QUAHOG FMP	Surf clams	15														3	6	17		23	20			540	11	185	1	Commercial volume equals in-the-shell weight.
"	Ocean Quahogs	15														3	6		17	23	20							" "
ATLANTIC MACKEREL FMP	Atlantic Mackerel	4														6	6		17	23	20			360	7	123	0.6	
ATLANTIC BUTTERFISH FMP	Butterfish	9, 10														4	6		17	23	20			180	4	62	0.3	
ATLANTIC SQUID FMP	Long-finned Squid	4, 9, 10														4	6		17	23	20	17		360	7	123	0.6	
"	Short-finned Squid	5, 9, 10														3	6		17	23	20	17						
ATLANTIC SHARKS FMP	Large Sharks except Dogfish	4, 5, 6														2	4			23	20			180	3	62	0.3	
SUMMER FLOUNDER FMP	Summer Flounder	7, 8, 9, 10														3	6		17	23	20			180	4	62	0.3	
BLUEFISH (Atlantic Coast) FMP	Bluefish	4, 9, 10														3	6		17	23	20			180	4	62	0.3	
SCUP FMP	Scup	9, 10														3	6		17	23	20			180	4	62	0.3	
DOGFISH FMP	Dogfish	9, 10														3	6		17	23	20			180	3	62	0.3	

* - SEE LIST 1 page A30 Ecological Groups Key
** - SEE LIST 2 page A30 Assessment Level

NEFC - 1 (2)

CODE KEY - ITEM (4)

Value ($·10⁶)	Volume (m.t.·10³)	Symbol
>150	>100	
76–150	51–100	
10–75	10–50	
<10	<10	
None	None	

CODE KEY - ITEM (5)

Participation (fishermen·10⁶)	Costs ($·10⁶)	Volume (m.t.·10³)	Symbol
>5	>150	>50	
2–5	76–150	26–50	
0.5–2	10–75	5–25	
<0.5	<10	<5	
None	None	None	

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)	Circle Code Frequency	
Adequate			>once a year	●
Marginal			once a year	①
Inadequate			Biennial	②
Unknown			Triennial	③
			Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol
–Within 30% of true value.	
–Conservatively biased (31–60% < true value).	
–Grossly accurate (±31–60% of true value).	
–Inaccurate (>±60%).	
–Unknown.	

Circle Code Assessment Level **

① None
② Catch trend.
③ Relative abundance trend.
④ Equilibrium yield.
⑤ Annual yield forecast.
⑥ Multispecies total biomass yield.
⑦ Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

– Dev. program needed.
– Increase effort in current dev. program.
– Improve present technique
– No effort

Sampling Effort Category

– Introduce new program
– Incr. present sampling eff.
– No effort

Circle Code: Refer to LIST 3 for key to code. pg A31

MATRIX I.

Evaluation of Current NMFS Assessment Effort Related to Management Needs.

NORTHEAST FISHERIES CENTER

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
SEA BASS FMP	Black sea bass	8, 10														2	6	3	17	23	20	4	6	180	3	62	0.3	
TILEFISH FMP	Tilefish	7														2	6	3	17	23	20	4	6	180	3	62	0.3	
OTHER FLOUNDERS	Flounders except yellowtail and summer flounder	7, 8														3	6	3	17	23	20	5	6	180	4	62	0.3	

* – SEE LIST 1 page A30 Ecological Groups Key
** – SEE LIST 2 page A30 Assessment Level

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	■
76–150	51–100	▬
10–75	10–50	▬
<10	<10	▤
None	None	□

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	■
2–5	76–150	26–50	▬
0.5–2	10–75	5–25	▬
<0.5	<10	<5	▤
None	None	None	□

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)	Circle Code Frequency	
Adequate			>once a year	●
Marginal			once a year	①
Inadequate			Biennial	②
Unknown			Triennial	③
			Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol	Circle Code Assessment Level **
–Within 30% of true value.		① None
–Conservatively biased (31–60% < true value).		② Catch trend.
–Grossly accurate (±31–60% of true value).		③ Relative abundance trend.
–Inaccurate (>±60%).		④ Equilibrium yield.
–Unknown.		⑤ Annual yield forecast.
		⑥ Multispecies total biomass yield.
		⑦ Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
–Dev. program needed.		Refer to LIST 3 for key to code. pg A34
–Increase effort in current dev. program.		
–Improve present technique		
–No effort		

Sampling Effort Category

- –Introduce new program
- –Incr. present sampling eff.
- –No effort

MATRIX I.

Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

SOUTHEAST FISHERIES CENTER

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: (a) Fisheries Information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
OCEANIC PELAGICS PROGRAM																								920	26	620	3	Dollars and man-years cannot be broken down below the program level
Billfish G, SA, C ***	Marlins Sailfish Spearfish	5	▤	▤	▤	▬	▤		◇1							4	4	10	○	6	3	4	6					
Swordfish G, SA, C	Swordfish Pelagic	5	▤	▤	▤	▤	▤		◇1							2	4	○	○	4	6	4	6					
Sharks and Rays	Sharks Rays	5	▤	▤	▤	▤	▤		◇1							1	3	○	○	4	6	10	12					
Tunas	Bluefin Small Tunas	5	▤	▤	▤	▤	▤		◇1		1					5	5	○	○	4	6	9	11					
COASTAL PELAGICS PROGRAM																								340	10	1570	8	
Coastal Migratory Pelagics G, SA	King mackerel Spanish mack. Cobia Dolphin Bluefish	4	▤	▤	▬	▬	■		◇1							4	4	10	3	11	9	4	6					
Migratory Coastal Pelagics C	King mackerel Wahoo Dolphin	4	▤	▤	▤	▤	▤		◇1							2	4	10	3	11	9	4	6					
MENHADEN/ HERRING PROGRAM																								880	24	1070	8	
Coastal Herrings G	Herrings	4	▤	▤	□	□	□				◇⊕					1	3	10	3	○	○	10	3					
Menhaden	Menhaden	4	▤	■	□	□	□		◇1					⊕	⊕	4	4	18	19	18	20	18	22					

* – SEE LIST 1 page A33 Ecological Groups Key
** – SEE LIST 2 page A33 Assessment Level

*** – G= Gulf of Mexico
SA= South Atlantic
C= Caribbean

SEFC-I (1)

MATRIX 1.

Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

SOUTHEAST FISHERIES CENTER

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76-150	51-100	
10-75	10-50	
<10	<10	
None	None	

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2-5	76-150	26-50	
0.5-2	10-75	5-25	
<0.5	<10	<5	
None	None	None	

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol
-Within 30% of true value.	
-Conservatively biased (31-60% < true value).	
-Grossly accurate (±31-60% of true value).	
-Inaccurate (>±60%).	
-Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY - ITEMS (9), (10), (11)

Technical & Analytical Effort Category	Symbol	Circle Code
-Dev. program needed.		Refer to LIST 3 for key to code. pg A34
-Increase effort in current dev. program.		
-Improve present technique		
-No effort		

Sampling Effort Category	Symbol
-Introduce new program	
-Incr. present sampling eff.	
-No effort	

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods - Adequacy & Frequency: (a) Fisheries information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
MM & ES PROGRAM																								2,250	32	700	1	
	Turtles	14						✓	①							①	③	12				16	③					
	Mammals	12						✓		①						①	③					16	③					
SHRIMP & GROUNDFISH PROGRAM																								2,210	66	1,120	6	
SHRIMP G ***	Pink, Sea Bob, White, Brown, Royal red	16							①							④	④	⑤		22	20	11	⑨					
ROCK & ROYAL RED SHRIMP SA	Rock, Royal red	16							①							④	④			④	⑥	④	⑥					
GROUNDFISH G	Croaker Spot	7							①		①					④	④	⑤		22	20	10	17					
REEF FISH PROGRAM																								732	24	1,520	7	
REEF FISH G	Snappers, Groupers, Black Sea Bass	2,3							①							④	④	22	20	22	20	④	⑥					
SNAPPER / GROUPER SA	Snappers, Groupers, Black Sea Bass	2,3							①							②	④			22	20	④	⑥					
SHALLOW WATER REEF FISH C	All Reef Species Combined	2							①							②	④			22	20	④	⑥					
DEEP WATER REEF FISH C	Snapper, Grouper	3							⊕							①	④			22	20	④	⑥					

* - SEE LIST 1 page A33 Ecological Groups Key
** - SEE LIST 2 page A33 Assessment Level

*** - G=Gulf of Mexico C=Caribbean
SA = South Atlantic

SEFC - I (2)

MATRIX I.

Evaluation of Current NMFS Assessment Effort Related to Management Needs.

SOUTHEAST FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76-150	51-100	
10-75	10-50	
<10	<10	
None	None	

CODE KEY – ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2-5	76-150	26-50	
0.5-2	10-75	5-25	
<0.5	<10	<5	
None	None	None	

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol
– Within 30% of true value.	
– Conservatively biased (31-60% < true value).	
– Grossly accurate (±31-60% of true value).	
– Inaccurate (>±60%).	
– Unknown.	

Circle Code Assessment Level **

① None
② Catch trend.
③ Relative abundance trend.
④ Equilibrium yield.
⑤ Annual yield forecast.
⑥ Multispecies total biomass yield.
⑦ Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
– Dev. program needed.		Refer to LIST 3 for key to code pg A34
– Increase effort in current dev. program.		
– Improve present technique		
– No effort		

Sampling Effort Category	Symbol
– Introduce new program	
– Incr. present sampling eff.	
– No effort	

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries Information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
TROPICAL REEF FISH G, SA ***	All Reef Species Combined	2, 3																		12	22		10					
INVERTEBRATES PROGRAM (Excluding Shrimp)																								400	14	800	3	
STONE CRAB G																												
SPINEY LOBSTER G, SA																												
SPINEY LOBSTER C																												
CORAL G, SA																						16						
PRECIOUS CORAL C																						16						
CALICO SCALLOP-SA, G																				10	17	10						
CONCH & WHELK C																						10						
																							TOTALS	7,732	182	7,150	36	

* – SEE LIST 1 page A33 Ecological Groups Key
** – SEE LIST 2 page A33 Assessment Level

*** – G = Gulf of Mexico C = Caribbean
SA = Southern Atlantic

SEFC – I (3)

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76–150	51–100	
10–75	10–50	
<10	<10	
None	None	

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2–5	76–150	26–50	
0.5–2	10–75	5–25	
<0.5	<10	<5	
None	None	None	

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)	Circle Code Frequency	
Adequate			>once a year	●
Marginal			once a year	1
Inadequate			Biennial	2
Unknown			Triennial	3
			Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol
–Within 30% of true value.	
–Conservatively biased (31–60% < true value).	
–Grossly accurate (±31–60% of true value).	
–Inaccurate (>±60%).	
–Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

- –Dev. program needed.
- –Increase effort in current dev. program.
- –Improve present technique
- –No effort

Sampling Effort Category

- –Introduce new program
- –Incr. present sampling eff.
- –No effort

Circle Code: Refer to LIST 3 for key to code. pg A31

MATRIX I.

Evaluation of Current NMFS Assessment Effo[rt] Related to Managemen[t] Needs.

SOUTHWEST FISHERIES CENTER

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
PACIFIC COUNCIL	Northern Anchovy	4			BAIT					1		1	1			5	5	16	17	16	17	16	17	250 2	4 2	300 2	2.5 3	1 CF+G conducts annual acoustic surveys. 2 Excludes ship operations. 3 Development of recruitment measure has application to many other fisheries.
PACIFIC COUNCIL GROUNDFISH	Rockfish	8,10							1				1 4							22	20	4	16	120	4.5	300 5	2.0	4 Assessment in conjunction with NWAFC. 5 Part sampling through contracts.
PACIFIC COUNCIL BILLFISH AND OCEANIC SHARKS	Striped Marlin Swordfish and Oceanic Sharks	4,5							2										11			10	19	48	1	100	2	
INTERAMERICAN TROPICAL TUNA CONVENTION	Yellowfin and Skipjack Tuna	5							⊕										11			10	11	0	0	100	1	Sampled adequately by an international commission. But NMFS does not have access to data.
ATLANTIC TUNAS CONVENTION	Yellowfin, Skipjack, Bigeye, and Albacore	5							1										11			10	11	360	8	40	1	Yellowfin is the dominant species in the fishery.
WESTERN PACIFIC COUNCIL BILLFISH	BILLFISH	4,5							⊕									12	14					10	0.2	50	1.0	Production models are available for entir[e] stock, but these have no bearing on management analysis within the FCZ.
WESTERN PACIFIC COUNCIL PRECIOUS CORAL	Precious Corals	16							⊕									16				16		0	0	50	1.0	Current assessments cover only one coral bed out of many.
WESTERN PACIFIC COUNCIL SEAMOUNT	Armorheads and Alfonsin	1							⊕		⊕							10	22			10	22	10	0.2	50	1.0	Assessment based on sketchy foreign data.
ENDANGERED SPECIES ACT	Hawaiian Monk Seal	13						✓			1							16	22	16	22	16		50	1	100	2	No fishery, assessment by direct counts and tagging.
ENDANGERED SPECIES ACT	Green Turtles	14						✓			1							22	16	16	11	10	22	10	0.2	100	2	" "

* – SEE LIST 1 page A30 Ecological Groups Key
** – SEE LIST 2 page A30 Assessment Level

MATRIX I.

Evaluation of Current NMFS Assessment Effort Related to Management Needs.

SOUTHWEST FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·$10^6$)	Volume (m.t.·10^3)	Symbol
>150	>100	■
76–150	51–100	▬
10–75	10–50	▬
<10	<10	▤
None	None	□

CODE KEY – ITEM (5)

Participation (fishermen·10^6)	Costs ($·$10^6$)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	■
2–5	76–150	26–50	▬
0.5–2	10–75	5–25	▬
<0.5	<10	<5	▤
None	None	None	□

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)	Circle Code Frequency	
Adequate	■	◆	>once a year	●
Marginal	▣	◆	once a year	①
Inadequate	▤	◇	Biennial	②
Unknown	□	◇	Triennial	③
			Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol	Circle Code Assessment Level **
– Within 30% of true value.	■	① None
– Conservatively biased (31–60% < true value).	▣	② Catch trend.
– Grossly accurate (±31–60% of true value).	▤	③ Relative abundance trend.
– Inaccurate (> ± 60%).	▤	④ Equilibrium yield.
– Unknown.	□	⑤ Annual yield forecast
		⑥ Multispecies total biomass yield.
		⑦ Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
– Dev. program needed.	●	Refer to LIST 3 for key to code pg A34
– Increase effort in current dev. program.	◉	
– Improve present technique	◎	
– No effort	○	
Sampling Effort Category		
– Introduce new program	●	
– Incr. present sampling eff.	◉	
– No effort	○	

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
WESTERN PACIF. COUNCIL SPINY LOBSTER	Spiny lobster	2	▤	▤	▤	▤	▤		◇⊕		▤⊕	▤⊕				■3	■5	16	9	3	1	10	11	100	8.0	100	8.0	
WESTERN PACIF. BOTTOMFISH	Bottomfishes	3	▤	▤	▤	▤	▤		◇⊕		▤⊕	▤⊕	□○			■3	■6	15	9	3	7	10	15	100	8.0	100	8.0	
																								1,993	36.6	1,500	6	
MARINE MAMMAL PROTECTION ACT																												
	ETP Pelagic Dolphin / Tuna	12	▬ 1	1	2	2		✓	■○	◆3	▣1					▣4	■7	16	17	3	24	25	10 3					1 Commercial value is for tuna caught in association with porpoise. 2 Intangible values and non-consumptive values not reflected. 3 Biological samples needed from research platforms to determine representativeness of samples from fleet. 4 Costs due to interference with coastal fisheries alledged; estimates vary widely
	California Coastal Dolphin	4	4	4	2	2		✓			◆1					□1	■7	16	17	24	3	19	25					In absence of any understandable information I have interpreted "technology" as pertaining to List 3; "analytical" as pertaining to List 4, A; and "sampling" as pertaining to List 4, B.
	California Pinnipeds	13	4	4	2	2		✓								□1	■7	16	17	1	3	19	19					To fit marine mammal work I have constructed two new categories: (24) new analytic category: sighting survey (see 25) analysis methods, and (25) new sampling category: sighting survey (like 76).

* – SEE LIST 1 page A33 Ecological Groups Key

** – SEE LIST 2 page A33 Assessment Level

SWFC – I (2)

MATRIX I.

Evaluation of Current NMFS Assessment Effor[t] Related to Management Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	solid
76–150	51–100	solid, one white band
10–75	10–50	black centre band
<10	<10	lined
None	None	open

CODE KEY – ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	solid
2–5	76–150	26–50	solid, one white band
0.5–2	10–75	5–25	black centre band
<0.5	<10	<5	lined
None	None	None	open

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
> once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol
– Within 30% of true value.	
– Conservatively biased (31–60% < true value).	
– Grossly accurate (±31–60% of true value).	
– Inaccurate (> ±60%).	
– Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
– Dev. program needed.		Refer to LIST 3 for key to code. pg A34
– Increase effort in current dev. program.		
– Improve present technique		
– No effort		

Sampling Effort Category	Symbol
– Introduce new program	
– Incr. present sampling eff.	
– No effort	

Matrix — Part 1: Importance

Management category (1)	Management unit (2)	Ecological group (3)*	Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)
GULF OF ALASKA GROUNDFISH								
	Pollock		76–150	>100	None	None	None	
	Pacific cod		<10	51–100	None	None	None	
	Flounders		<10	51–100	None	None	None	
	Pacific Ocean Perch		<10	<10	None	None	None	
	Other Rockfish		<10	<10	None	None	None	
	Sablefish		<10	<10	None	None	None	
	Atka mackerel		<10	<10	None	None	None	
	Squid		<10	<10	None	None	None	
	Halibut		76–150	<10	<0.5	<10	<5	✓

Matrix — Part 2: (7) NMFS Current Assessment Methods – Adequacy & Frequency; (8) Assessment Level & Accuracy

Management unit (2)	(a) Fisheries information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit
Pollock	Adequate ①		Adequate ③	Inadequate	Inadequate ③			④	⑤
Pacific cod	Adequate ①		Adequate ③	Inadequate	Inadequate ③			④	⑤
Flounders	Adequate ①		Adequate ③	Inadequate				③	④
Pacific Ocean Perch	Adequate ①		Adequate ③	Inadequate	Inadequate ③			④	⑤
Other Rockfish	Inadequate ①		Marginal ③	Inadequate	Inadequate ③			③	④
Sablefish	Adequate ①		Adequate ①	Inadequate	Inadequate ③			④	⑥
Atka mackerel	Adequate ①		Adequate ③	Inadequate				②	④
Squid	Inadequate ①		Inadequate ③					①	③
Halibut	Adequate ①		Adequate ①	Inadequate				⑤	⑥

Matrix — Part 3: Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements); (12) Funds & Personnel by Mgmt. Category

Management unit (2)	Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	Current (FY 1980 Base) $1,000s	Current (FY 1980 Base) Man-years	Additional (needed annually for rqmts.) $1,000s	Additional (needed annually for rqmts.) Man-years	Remarks
GULF OF ALASKA GROUNDFISH							1,860	25.4	200	1.5	
Pollock	③	20	⑦	open	⑰	20					
Pacific cod	⑨	⑪	⑦	open	21	open					
Flounders	⑪	⑮	⑦	open	⑫	open					
Pacific Ocean Perch	⑩	⑰	⑦	⑤	21	open					
Other Rockfish	[illegible]	⑰	⑦	open	21	open					
Sablefish	[illegible]	⑨	⑦	①	⑭	⑪					
Atka mackerel	⑪	⑮	⑦	open	⑰	open					
Squid	②	③	⑦	open	⑩	open					
Halibut	⑰	⑲	⑦	⑤	open	open					

* - SEE LIST 1 page A33 Ecological Groups Key
** - SEE LIST 2 page A33 Assessment Level

NWAFC - I (1)

MATRIX I.

Evaluation of Current NMFS Assessment Effo[rt] Related to Management Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·10⁶)	Volume (m.t.·10³)	Symbol
>150	>100	■
76–150	51–100	▤
10–75	10–50	▤
<10	<10	▤
None	None	□

CODE KEY – ITEM (5)

Participation (fishermen·10⁶)	Costs ($·10⁶)	Volume (m.t.·10³)	Symbol
>5	>150	>50	■
2–5	76–150	26–50	▤
0.5–2	10–75	5–25	▤
<0.5	<10	<5	▤
None	None	None	□

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate	▣	◆
Marginal	▣	◆
Inadequate	▣	◇
Unknown	□	◇

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol
– Within 30% of true value.	▣
– Conservatively biased (31–60% < true value).	▣
– Grossly accurate (±31–60% of true value).	▣
– Inaccurate (>±60%).	▣
– Unknown.	□

Circle Code Assessment Level **

① None
② Catch trend.
③ Relative abundance trend.
④ Equilibrium yield.
⑤ Annual yield forecast.
⑥ Multispecies total biomass yield.
⑦ Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

– Dev. program needed.
– Increase effort in current dev. program.
– Improve present technique
– No effort

Sampling Effort Category

– Introduce new program
– Incr. present sampling eff.
– No effort

Symbol / Circle Code: Refer to LIST 3 for key to code. pg A34

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: (a) Fisheries information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
PACIFIC COAST GROUNDFISH																								1,094	13.6	200	2.5	
	Pacific whiting	9, 10	▤	■					◆		3	1	3			4	5	○	○	17	18	17	18					
	Sablefish	7	▤	▤					1		1					3	4	16	6	○	○	16	2					
	Pacific Ocean Perch	7, 8	▤	▤					1		5					6	5	○	○	○	○	6	○					
	Shortbelly Rockfish	9, 10	□	▤							3		3			4	4	16	○	○	○	16	22					
	Lingcod	8	▤	▤	▤		□		1		3					3	4	16	8	○	○	12	16					
	Pacific Cod	7	▤	▤	▤				1		3					2	3	○	○	○	○	17	19					
	Canary/yellow tail Rockfish	7, 8	▤	▤	▤		▤		1		3					3	4	16	10	○	○	10	16					
	Chilipepper/bocaccio Rockfish	7, 8	▤	▤	▤		▤		1		3					3	4	16	10	○	○	10	16					
	Other Rockfish	7, 8	▤	▤	▤		▤		1		3					2	3	10	22	○	○	10	22					
	Dover Sole	7	▤	▤	▤				1							4	4	○	○	○	○	16	12					
	English/Petrale Sole	7	▤	▤	▤				1							4	4	○	○	○	○	5	19					

* – SEE LIST 1 page A33 Ecological Groups Key
** – SEE LIST 2 page A33 Assessment Level

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76-150	51-100	
10-75	10-50	
<10	<10	
None	None	

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2-5	76-150	26-50	
0.5-2	10-75	5-25	
<0.5	<10	<5	
None	None	None	

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol
- Within 30% of true value.	
- Conservatively biased (31-60% < true value).	
- Grossly accurate (±31-60% of true value).	
- Inaccurate (>±60%).	
- Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
- Dev. program needed.		Refer to LIST 3 for key to code. pg A34
- Increase effort in current dev. program.		
- Improve present technique		
- No effort.		

Sampling Effort Category	Symbol
- Introduce new program	
- Incr. present sampling eff.	
- No effort	

MATRIX I.

Evaluation of Current NMFS Assessment Efforts Related to Management Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods - Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)		Analytical (10)		Sampling (11)		(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
	Other Flounders	7																				22	16					
	Other Fish	7, 8, 9, 10																				22	16					
BERING SEA & ALEUTIAN GROUNDFISH																								2,411	23.3	200	3.0	
	Pollock																			17	20							
	Cod																			16	20							
	Pacific Ocean Perch																			16	20							
	Other Rockfishes																			16	20							
	Flounders																			17	20							
	Sablefish																			16	20							
	Atka Mackerel																			10	20							
	Squid																			10	20							
	Halibut							✓												5	20							

* - SEE LIST 1 page A33 Ecological Groups Key
** - SEE LIST 2 page A33 Assessment Level

MATRIX I.

Evaluation of Current NMFS Assessment Effort Related to Management Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	
76–150	51–100	
10–75	10–50	
<10	<10	
None	None	

CODE KEY – ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^6)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	
2–5	76–150	26–50	
0.5–2	10–75	5–25	
<0.5	<10	<5	
None	None	None	

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
>once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol
–Within 30% of true value.	
–Conservatively biased (31–60% < true value).	
–Grossly accurate (±31–60% of true value).	
–Inaccurate (>±60%).	
–Unknown.	

Circle Code Assessment Level **

1. None
2. Catch trend.
3. Relative abundance trend.
4. Equilibrium yield.
5. Annual yield forecast.
6. Multispecies total biomass yield.
7. Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

- –Dev. program needed.
- –Increase effort in current dev. program.
- –Improve present technique
- –No effort

Sampling Effort Category

- –Introduce new program
- –Incr. present sampling eff.
- –No effort

Circle Code: Refer to LIST 3 for key to code. pg A34

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: Fisheries information (a)	Aerial surveys (counts) (b)	Ship (adults, juveniles) (c)	Ship (eggs, larvae) (d)	Ship acoustical (e)	Other remote sensing surveys (f)	Environ. surveys (g)	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)	Technological (9)	Analytical (10)	Analytical (10)	Sampling (11)	Sampling (11)	(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
WESTERN ALASKA KING CRABS	Red King Crab Blue King Crab	16 16	Red Blue	Red Blue				✓			Red Blue					Red Blue						Red Blue	Red Blue	279	6.1	100	0.5	
ALASKA TANNER CRABS	C. Bairdi (B) C. Opilio (O)	16 16	Both					✓			B O					B O						B O	B O	331	6.7	100	0.5	
WESTERN ALASKA SHRIMP	Pink Shrimp	16						✓																78	2.6	30	0.4	
MARINE MAMMALS																								250	4	300	1	
	Killer whale	12																										
	Guadalupe Fur Seal	13						✓																				
	California Sea Lion	13																										
	Northern Sea Lion	13																										Basis of native subsistence hunt.
	Harbor seal	13																										Basis of native subsistence hunt.
	Northern Elephant Seal	13																										
	Bearded Seal	12																										Hauls out on ice for pupping & breeding. Basis of native subsistence hunt.
	Largha Seal	12																										Hauls out on ice for pupping & breeding. Basis of native subsistence hunt.

NWAFC - 1 (4)

* - SEE LIST 1 page A33 Ecological Groups Key

** - SEE LIST 2 page A33 Assessment Level

MATRIX I.

Evaluation of Current NMFS Assessment Effor[t] Related to Management Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

CODE KEY – ITEM (4)

Value ($·10⁶)	Volume (m.t.·10³)	Symbol
>150	>100	■
76–150	51–100	▣
10–75	10–50	▬
<10	<10	▤
None	None	□

CODE KEY – ITEM (5)

Participation (fishermen·10⁶)	Costs ($·10⁶)	Volume (m.t.·10³)	Symbol
>5	>150	>50	■
2–5	76–150	26–50	▣
0.5–2	10–75	5–25	▬
<0.5	<10	<5	▤
None	None	None	□

CODE KEY – ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)
Adequate		
Marginal		
Inadequate		
Unknown		

Circle Code Frequency	
> once a year	●
once a year	①
Biennial	②
Triennial	③
Irregular	⊕

CODE KEY – ITEM (8)

Degree of Accuracy	Symbol
– Within 30% of true value.	
– Conservatively biased (31–60% < true value).	
– Grossly accurate (± 31–60% of true value).	
– Inaccurate (> ± 60%).	
– Unknown.	

Circle Code Assessment Level **

① None
② Catch trend.
③ Relative abundance trend.
④ Equilibrium yield.
⑤ Annual yield forecast
⑥ Multispecies total biomass yield.
⑦ Ecosystem yield.

CODE KEY – ITEMS (9), (10), & (11)

Technical & Analytical Effort Category

– Dev. program needed.
– Increase effort in current dev. program.
– Improve present technique
– No effort

Sampling Effort Category

– Introduce new program
– Incr. present sampling eff.
– No effort

Circle Code: Refer to LIST 3 for key to code pg A34

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: (a) Fisheries information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)		Analytical (10)		Sampling (11)		(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s	Current Man-years	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
	Ribbon Seal	12	▤	▤											◇①	①	⑤	④	⑥	●[17]	●[11]	⑧	⑨					Hauls out on ice for pupping and breeding. Basis of native subsistence hunt.
	Ringed Seal	12	▤	▤											◇①	①	⑦	④	⑥	●[17]	●[11]	⑧	⑨					" "
	Hawaiian Monk Seal	12	□		□			✓							◆①	③	③	●[14]	○	●[17]	●[11]	⑧	⑨					
INTERNATIONAL WHALING COMMISSION																								599	12	750	4	
	Gray Whale	12			▤	▤		✓							◆①	⑤	⑦	⑥	●[15]	●[17]	●[11]	⑧	⑨					Basis of Eskimo subsistence hunt. U.S. and USSR value is 179 whales/year.
	Bowhead Whale	12						✓							◆①	⑤	⑦	⑥	⑥	●[17]	●[11]	⑧	⑨					Basis of Eskimo subsistence hunt. U.S. take is 26 struck or 18 landed in 1980.
	Humpback Whale	12			▤	▤		✓			◆①					③	⑥	○	○	●[17]	●[11]	⑧	⑨					
	Blue Whale	12	□		□			✓			◇①					③	⑦	○	○	●[20]	●[17]	○	○					
	Fin Whale	12	▤	▤	▤	▤		✓	◆①							⑤	⑦	⑩	●[15]	●[20]	●[17]	⑧	⑨					
	Sei Whale	12	▤	▤					◆①							⑤	⑤	⑩	●[15]	●[20]	●[17]	⑧	⑨					
	Bryde's Whale	12	▤	▤					◆①							⑥	⑦	⑩	●[15]	⑩	●[17]	⑧	⑨					
	Minke Whale	12	▬	▬				✓	◆①							⑤	⑦	⑩	●[15]	●[20]	●[17]	⑧	⑨					

* – SEE LIST 1 page A33 Ecological Groups Key
** – SEE LIST 2 page A33 Assessment Level

MATRIX I.

Evaluation of Current NMFS Assessment Effo[rt] Related to Managemen[t] Needs.

NORTHWEST AND ALASKA FISHERIES CENTER

CODE KEY - ITEM (4)

Value ($·10^6)	Volume (m.t.·10^3)	Symbol
>150	>100	■
76-150	51-100	▣
10-75	10-50	▣
<10	<10	▤
None	None	□

CODE KEY - ITEM (5)

Participation (fishermen·10^6)	Costs ($·10^5)	Volume (m.t.·10^3)	Symbol
>5	>150	>50	■
2-5	76-150	26-50	▣
0.5-2	10-75	5-25	▣
<0.5	<10	<5	▤
None	None	None	□

CODE KEY - ITEM (7)

Adequacy Level	Symbol	Symbol (if primary)	Circle Code Frequency	
Adequate	■	◆	>once a year	●
Marginal	▣	◇	once a year	(1)
Inadequate	▣	◇	Biennial	(2)
Unknown	□	◇	Triennial	(3)
			Irregular	⊕

CODE KEY - ITEM (8)

Degree of Accuracy	Symbol	Circle Code Assessment Level **
-Within 30% of true value.	■	(1) None
-Conservatively biased (31-60% < true value).	▣	(2) Catch trend.
-Grossly accurate (±31-60% of true value).	▣	(3) Relative abundance trend.
-Inaccurate (>±60%).	▣	(4) Equilibrium yield.
-Unknown.	□	(5) Annual yield forecast.
		(6) Multispecies total biomass yield.
		(7) Ecosystem yield.

CODE KEY - ITEMS (9), (10), & (11)

Technical & Analytical Effort Category	Symbol	Circle Code
-Dev. program needed.	●	Refer to LIST 3 for key to code. pg A34
-Increase effort in current dev. program.	◉	
-Improve present technique	◉	
-No effort	○	
Sampling Effort Category		
-Introduce new program	●	
-Incr. present sampling eff.	◉	
-No effort	○	

Management category (1)	Management unit (2)	Ecological group (3)*	Importance: Commercial (4) Value	Commercial (4) Vol.	Recreational (5) Part.	Recreational (5) Exp.	Recreational (5) Vol.	Protected and/or Endangered Species (6)	(7) NMFS Current Assessment Methods – Adequacy & Frequency: (a) Fisheries information	(b) Aerial surveys (counts)	(c) Ship (adults, juveniles)	(d) Ship (eggs, larvae)	(e) Ship acoustical	(f) Other remote sensing surveys	(g) Environ. surveys	(8) Assessment Level & Accuracy: Current NMFS level and accuracy for Mgmt. Unit	Current level and accuracy required by Mgmt. Unit	Additional Effort Needed to Meet Management Unit Requirements (for 2 most critical Info. Elements): Technological (9)		Analytical (10)		Sampling (11)		(12) Funds & Personnel by Mgmt. Category: Current (FY 1980 Base) $1,000s[1]	Current Man-years[2]	Additional (needed annually for rqmts.) $1,000s	Additional Man-years	Remarks
	Sperm whale	12	▤	▤				✓								[5]	[7]	(6)	(15)	(17)	(11)	(8)	(9)					
	Beluga whale	12	□		□					◇(1)						[2]	[5]	(4)	(6)	(17)	(11)	(8)	(9)					Basis of Eskimo subsistence hunt.
INTERNATIONAL NORTH PACIFIC FISHERIES COM.	Dall's porpoise	12	▤	▤							◇(1)					[2]	[6]	(4)	(6)	(17)	(11)	(8)	(9)	0	2	300	1	Taken incidentally in Japanese salmon gillnet fishery.
NORTH PACIFIC FUR SEAL COM.	Northern Fur seal	13	▤	▣	▤	▤			◇(1)							[5]	[7]	○	○	20 ◉	(17)	(18)	(15)	702	14	0	0	
PACIFIC HERRING WEST COAST	Pacific Herring	4	▣	▤	▤	▤	▤		[1]			◇(1)				[3]	[5]	(2)	(16)	○	○	(2)	(16)	135	3.0	50	0.5	Some states also employ spawning ground surveys.
TROLL SALMON (ALASKA)		11	▤	▤	▤	▤	▤		[1]		◇(1)				[1]	[3]	[5]					(17)	(19)	253	6.6	30	0.4	Research is directed on survival and growth of young salmon as related to environmental conditions & enhancemen[t] programs.
HIGH SEAS SALMON (ALASKA)		11	▣***	■***	□	□	□		◇(1)							[3]	[3]					(3)	(2)	424	3.5	1,047	1.0	Basic problem is continent of origin of sockeye & coho salmon in Japanese land-based fishery. Program will be expanded to examine early life history of salmon, trans-boundary problems with Canada, and domestic fishery nee[ds].
PACIFIC HERRING BERING SEA	Pacific Herring	4	▣	▣	□	□	□		[1]	◇(1)						[3]	[5]	(18)				(3)	(17)	135	2.5	300	2.0	This is a general pelagics (clupeids, smelts, squid.) program with initial emphasis on Bering Sea herring. The program is ecosystem oriented to inclu[de] food chain studies involving marine mammals.

* - SEE LIST 1 page A33 Ecological Groups Key
** - SEE LIST 2 page A33 Assessment Level

*** Value & Volume of U.S. Alaska catch plus Japanese high seas catch in FCZ.

1 Base funds only; exclude supplemental, reimbursible, or S-K funds.
2 FTP's only; exclude all others

NWAFC I (6)

MATRIX II: Applicability of Assessment Methods to the Information Elements Required.

The second matrix identifies the many information elements used in fisheries management. Most of the elements are data series. The matrix indicates the sampling methods used to obtain informational elements and identifies which informational elements are needed for specific analytical methods. Assessment methods are shown in List 4 (page A31).

● = Method applicable for acquiring data for Information element.
Blank = Method not applicable for acquiring data for Information Element.

SOUTHWEST FISHERIES CENTER

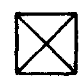
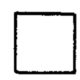
Matrix II. Applicability of Assessment Methods to the Information Elements required

Information Elements	Analytical Methods (Nos. 1 - 9)									Sampling Methods (Nos. 10 - 23)													
	(1) Mark and recovery	(2) Change in ratio	(3) C/E analysis Surplus production	(4) Yield per recruit	(5) VPA/cohort	(6) Spawner-recruit	(7) Multispecies models	(8) Ecosystem models	(9) Predictive regressions	(10) Sampling the fisheries	(11) Tagging	(12) Bottom trawl survey	(13) Dredge survey	(14) Trap or pot survey	(15) Setline survey	(16) Acoustical survey	(17) Acoustical-bottom trawl survey	(18) Landbased counts	(19) Aerial survey	(20) Fish eggs and larvae	(21) Environmental	(22) Underwater survey	(23) Other remote surveys
1. Species description										●		●	●	●	●		●	●		●		●	
2. Species distribution	●							●		●	●	●	●	●	●	●	●	●	●	●	●	●	●
3. Stock identification	●									●	●	●	●	●	●		●			●			
4. Catch series										●													
5. Discard series										●		●	●	●	●								
6. Effort series										●													●
7. Length series										●		●	●	●	●		●	●					
8. Age series	●									●	●	●	●	●	●		●	●					
9. Growth rates / length-weight	●								●	●	●	●	●	●	●		●						
10. Relative abundance	●		●		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●
11. Mortality rate	●	●	●		●			●	●	●	●	●	●	●	●		●			●			
12. Exploitation rate	●	●	●	●	●			●		●	●												
13. Reproductive rate					●	●		●		●		●	●	●	●		●						
14. Behavior	●							●			●	●	●	●	●	●	●	●	●	●	●	●	●
15. Catchability	●	●	●		●				●	●	●	●	●				●		●		●	●	
16. Absolute population size	●	●	●		●	●	●		●	●	●	●	●			●	●	●	●	●		●	
17. Annual recruitment					●	●	●		●	●		●	●	●	●	●	●	●	●		●	●	
18. Environmental indices												●	●	●	●	●	●			●	●		●
19. Causal environmental mechanisms			●	●	●	●	●	●	●												●		●
20. Species interactions							●	●		●		●	●				●		●	●		●	
21. Physiological							●	●													●		
22. Multiple factors							●	●		●													

MATRIX III: Applicability and Adequacy of Sampling Type Assessment Methods Relative to Different Ecological Groups.

In Matrix III an attempt was made to condense the various management units into 16 ecological groups. The applicability or adequacy of various sampling methods for assessing the ecological group was then identified using estimates of precision and accuracy associated with each method/group pairing.

Accuracy and precision levels and their corresponding symbols are:

Accuracy	Precision	Symbol
Within ± 30%	Within ± 30%	
Conservatively biased (31-60% less than true value)		
Grossly accurate (± 31-60%)	Grossly precise (± 31-60%)	
Inaccurate > ± 60%	Imprecise > ± 60%	
Unknown	Unknown	Blank

Note that estimates of accuracy and precision levels are indicated for the Ecological Group as a whole, not the example of the group.

NORTHEAST FISHERIES CENTER

Matrix III. Applicability and adequacy of Sampling Type Assessment Methods relative to different Ecological Groups, i.e., applicability/adequacy of methods for deriving relative and/or absolute estimates of population size (biomass or numbers) for species in different Ecological Groups.*

CODE KEY - MATRIX III

Accuracy*	Precision*	Symbol
Within ± 30 %	Within ± 30 %	■
Conservatively biased (± 31-60% less than true value)		◙

Accuracy*	Precision*	Symbol
Grossly accurate	Grossly precise	⊠
Inaccurate > ± 60%	Imprecise > ± 60%	□
Unknown	Unknown	Blank

Assessment Method

Ecological Group	Regional Example (species or species group)	(10) Sampling the fisheries *A	(10) *P	(11) Tagging A	(11) P	(12) Bottom trawl survey A	(12) P	(13) Dredge survey A	(13) P	(14) Trap or pot survey A	(14) P	(15) Setline survey A	(15) P	(16) Acoustical survey A	(16) P
1. Seamount fish															
2. Reef-shallow water															
3. Reef-deep water															
4. Coastal pelagic	Sea herring	■	■	■	⊠	■	⊠	□	□						
5. Oceanic pelagic	Sharks	■	■	■	⊠	■	⊠	□	□						
6. Mesopelagic															
7. Demersal-smooth bottom	Yellowtail flounder	■	■	⊠	■	■	⊠	■	⊠						
8. Demersal-rocky bottom	Haddock	■	■	⊠	■	■	⊠	□	□						
9. Semidemersal-smooth bottom	Pollock	■	■	⊠	■	■	⊠	□	□						
10. Semidemersal-rocky bottom	Redfish	■	■	⊠	■	■	⊠	□	□						
11. Anadromous															
12. Pelagic marine mammals															
13. Landbased marine mammals															
14. Turtles															
15. Infauna	Surf clams	■	■	■	■	□	□	■	⊠						
16. Epibenthic invertebrates	Lobster	■	■	■	■	■	⊠	■	⊠						

Ecological Group	(17) Acoustical-bottom trawl survey A	(17) P	(18) Landbased counts A	(18) P	(19) Aerial survey A	(19) P	(20) Fish eggs and larvae A	(20) P	(21) Environmental indices A	(21) P	(22) Underwater survey A	(22) P	(23) Other remote surveys A	(23) P
1. Seamount fish														
2. Reef-shallow water														
3. Reef-deep water														
4. Coastal pelagic								□				□		
5. Oceanic pelagic								□				□		
6. Mesopelagic														
7. Demersal-smooth bottom								□				⊠		
8. Demersal-rocky bottom								□				⊠		
9. Semidemersal-smooth bottom								□				□		
10. Semidemersal-rocky bottom								□				□		
11. Anadromous														
12. Pelagic marine mammals														
13. Landbased marine mammals														
14. Turtles														
15. Infauna														
16. Epibenthic invertebrates								□						

SOUTHEAST FISHERIES CENTER

Matrix III. Applicability and adequacy of Sampling Type Assessment Methods relative to different Ecological Groups, i.e., applicability/adequacy of methods for deriving relative and/or absolute estimates of population size (biomass or numbers) for species in different Ecological Groups.

CODE KEY - MATRIX III

Accuracy*	Precision*	Symbol
Within ± 30%	Within ± 30%	■
Conservatively biased (± 31-60% less than true value)		⧗
Grossly accurate	Grossly precise	☒
Inaccurate $> \pm 60\%$	Imprecise $> \pm 60\%$	□
Unknown	Unknown	Blank

Assessment Method

Ecological Group	Regional Example (species or species group)	(10) Sampling the fisheries *A	*P	(11) Mark-Recapture Tagging A	P	(12) Bottom trawl survey A	P	(13) Dredge survey A	P	(14) Trap or pot survey A	P	(15) Setline survey A	P	(16) Acoustical survey A	P
1. Seamount fish															
2. Reef-shallow water	Gray snapper, Yellowtail snapper	■	■	■	■	●	●	●	●	☒	☒	☒	☒		
3. Reef-deep water	Red snapper	■	■	■	■	●	●	●	●	⧗	☒	☒	□	●	●
4. Coastal pelagic	Spanish mackerel	■	■	■	■	□	□	●	●	●	●	☒	☒	☒	☒
5. Oceanic pelagic	Bluefin tuna	■	■	□	□	□	□	●	●	⧗	☒	⧗	☒	□	□
6. Mesopelagic															
7. Demersal-smooth bottom	Shrimp, Scallops	☒	☒	☒	☒	□	□					●	●	●	●
8. Demersal-rocky bottom	Lobster, Stone crab	☒	☒	☒	☒	□	□			☒	☒	●	●	●	●
9. Semidemersal-smooth bottom	Silver trout, Croaker, Cutlass fish	■	■	■	■	☒	☒	●	●	□	□	□	□		
10. Semidemersal-rocky bottom	Sheephead	■	■	■	■	□	□	●	●	□	□	□	□		
11. Anadromous	Striped bass	■	□	☒	☒	●	●	●	●	●	●				
12. Pelagic marine mammals	Whales	■	■	■	■	●	●	●	●	●	●	●	●		
13. Landbased marine mammals															
14. Turtles	Loggerhead turtles			□	□	□	□			●	●	●	●	●	●
15. Infauna															
16. Epibenthic invertebrates (in above categories)															

Ecological Group	(17) Acoustical-bottom trawl survey A	P	(18) Landbased counts A	P	(19) Aerial survey A	P	(20) Fish eggs and larvae A	P	(21) Environmental indices A	P	(22) Underwater survey A	P	(23) Other remote surveys A	P
1. Seamount fish														
2. Reef-shallow water							☒	☒	☒	☒	■	■		
3. Reef-deep water	●	●	●	●	●	□	☒	☒			■	■		
4. Coastal pelagic	□	□	□	□	□	□	☒	☒	☒	☒	□	□	□	□
5. Oceanic pelagic	●	●	●	●	⧗	⧗	☒	☒	☒	☒				
6. Mesopelagic														
7. Demersal-smooth bottom	●	●	●	●	●	●	□	□	☒	☒	□	□		
8. Demersal-rocky bottom	●	●	●	●	●	●	☒	☒			□	□		
9. Semidemersal-smooth bottom			●	●	●	●	□	□	☒	☒	□	□		
10. Semidemersal-rocky bottom			●	●	●	●	□	□	☒	☒	□	□		
11. Anadromous			●	●	●	●	☒	☒	☒	☒				
12. Pelagic marine mammals	●	●	●	●	⧗	■	●	●	●	●	●	●		
13. Landbased marine mammals														
14. Turtles	●	●	⧗	☒	□	☒	●	●	●	●	●	●		
15. Infauna														
16. Epibenthic invertebrates (in above categories)														

● = not applicable

SOUTHWEST FISHERIES CENTER

Matrix III. Applicability and adequacy of Sampling Type Assessment Methods relative to different Ecological Groups, i.e., applicability/adequacy of methods for deriving relative and /or absolute estimates of population size (biomass or numbers) for species in different Ecological Groups.

CODE KEY - MATRIX III

Accuracy*	Precision*	Symbol
Within ± 30 %	Within ± 30 %	■
Conservatively biased (± 31-60% less than true value)		⧗

Accuracy*	Precision*	Symbol
Grossly accurate	Grossly precise	☒
Inaccurate >± 60%	Imprecise >± 60%	□
Unknown	Unknown	Blank

Ecological Group	Regional Example (species or species group)	Assessment Method: (10) Sampling the fisheries A*	(10) P*	(11) Tagging A	(11) P	(12) Bottom trawl survey A	(12) P	(13) Dredge survey A	(13) P	(14) Trap or pot survey A	(14) P	(15) Setline survey A	(15) P	(16) Acoustical survey A	(16) P	(17) Acoustical-bottom trawl survey A	(17) P	(18) Landbased counts A	(18) P	(19) Aerial survey A	(19) P	(20) Fish eggs and larvae A	(20) P	(21) Environmental indices A	(21) P	(22) Underwater survey A	(22) P	(23) Other remote surveys A	(23) P
1. Seamount fish	Armorhead Alfonsin	□	□			□	□																						
2. Reef-shallow water	Spiny lobster	■	■	☒	☒					☒	☒																		
3. Reef-deep water	Bottomfish	☒	☒	☒	☒	□	□			☒	☒	☒	☒																
4. Coastal pelagic	Northern anchovy Jack mackerel	■	■											☒	■					☒	☒	■	■	□	□				
5. Oceanic pelagic	Yellowfin tuna	■	■																										
6. Mesopelagic																													
7. Demersal-smooth bottom	Dover sole	☒	☒	□	□	☒	☒							□		☒	☒					☒	☒						
8. Demersal-rocky bottom	Lingcod Rockfish	☒	☒	☒	☒	□	□							□		□													
9. Semidemersal-smooth bottom	Hake	☒	☒	☒	☒	□	☒							⧗	■	■	■					☒	☒						
10. Semidemersal-rocky bottom	Rockfish	☒	☒			□	□							□		☒	☒					□	□						
11. Anadromous																													
12. Pelagic marine mammals	Pelagic dolphin	☒	■	☒	☒													■	■	■	■								
13. Landbased marine mammals	Hawaiian monk seal			☒	☒													☒	☒	□	□								
14. Turtles	Marine turtles			☒	☒													☒	☒	□	□								
15. Infauna																													
16. Epibenthic invertebrates	Precious corals							□	□																	■	■		

NORTHWEST AND ALASKA FISHERIES CENTER

Matrix III. Applicability and adequacy of Sampling Type Assessment Methods relative to different Ecological Groups, i.e., applicability/adequacy of methods for deriving relative and/or absolute estimates of population size (biomass or numbers) for species in different Ecological Groups.

CODE KEY - MATRIX III

Accuracy*	Precision*	Symbol
Within ± 30%	Within ± 30%	■
Conservatively biased (± 31-60% less than true value)		⧗

Accuracy	Precision	Symbol
Grossly accurate	Grossly precise	⊠
Inaccurate >± 60%	Imprecise >± 60%	□
Unknown	Unknown	Blank

Assessment Method

Ecological Group	Regional Example (species or species group)	(10) Sampling the fisheries A*	P*	(11) Tagging A	P	(12) Bottom trawl survey A	P	(13) Dredge survey A	P	(14) Trap or pot survey A	P	(15) Setline survey A	P	(16) Acoustical survey A	P	(17) Acoustical-bottom trawl survey A	P	(18) Landbased counts A	P	(19) Aerial survey A	P	(20) Fish eggs and larvae A	P	(21) Environmental indices A	P	(22) Underwater survey A	P	(23) Other remote surveys A	P
1. Seamount fish	Rattails					□	□					□	□																
2. Reef-shallow water	Lingcod	□	□	□	□	⊠	⊠																						
3. Reef-deep water	Widow rockfish	□	□			□	□							□	□	□	□												
4. Coastal pelagic	Bering sea smelts	□	□							□	□									⊠	⊠								
5. Oceanic pelagic	Pomfret									□	□																		
6. Mesopelagic																													
7. Demersal-smooth bottom	Yellowfin sole	⧗	■	□	□	□	□																						
8. Demersal-rocky bottom	Pacific ocean perch	⊠	⊠			⧗	⊠							□	□	⧗	⊠												
9. Semidemersal-smooth bottom	Walleye pollock	⧗	⊠			⧗	□							⧗	■	⧗	■					□	□						
10. Semidemersal-rocky bottom	Yellowtail rockfish	⊠	⊠			⧗	⊠							□	□	⧗	⊠												
11. Anadromous	Sockeye salmon	⊠[1]	⊠[1]																										
12. Pelagic marine mammals	Gray whales																	■	■										
13. Landbased marine mammals	Northern fur seals																	■	■										
14. Turtles																													
15. Infauna	Surf clam							□	⊠																				
16. Epibenthic invertebrates	Red king crab	⊠	⊠	⧗	■	■	■																						

[1] When combined with escapement estimates based mainly on direct counting techniques.

MATRIX IV: Information Elements Required for Different Assessment Levels.

Matrix IV identifies the informational elements required for each level of assessment.

The relative need for Information Element in order to achieve Assessment Level is categorized as follows:

Requirement	Symbol
Information Element essential	■
Information Element desirable	⊠
Information Element not required	Blank

CODE KEY – MATRIX IV.

Requirement	Symbol
Information Element essential	■
Information Element desirable	☒
Information Element not required	blank

MATRIX IV.

Information Elements required for different Assessment Levels.

INFORMATION ELEMENTS	ASSESSMENT LEVELS: None (1)	Catch trend (2)	Relative abundance trend (3)	Equilibrium yield (4)	Annual yield forecast (5)	Multispecies total biomass yield (6)	Ecosystem yield (7)
1. Species description	☒	■	■	■	■	■	■
2. Species distribution		☒	☒	■	■	■	■
3. Stock identification		☒	☒	☒	☒	■	■
4. Catch series		■	■	■	■	■	■
5. Discard series		☒	☒	☒	☒	■	■
6. Effort series			☒	■	■	■	■
7. Length series			☒	☒	■	■	■
8. Age series				☒	■	■	■
9. Growth rates/length-weight			☒	■	■	■	■
10. Relative abundance			■	■	■	■	■
11. Mortality rate				■	■	■	■
12. Exploitation rate				☒	■	■	■
13. Reproductive rate				☒	■	■	■
14. Behavior				☒	☒	☒	■
15. Catchability				☒	☒	☒	■
16. Absolute population size				☒	■	■	■
17. Annual recruitment				☒	■	■	■
18. Environmental indices					☒	☒	■
19. Causal environmental mechanisms					☒	☒	■
20. Species interactions					☒	■	■
21. Physiological						☒	■
22. Multiple factors						☒	■
23. Multispecies models						☒	■

7. Ecosystem yield. - Highest order assessment, requiring extensive knowledge of characteristics, dynamics, and interrelationships of biotic and abiotic components.

Note: It is implied in these definitions that each succeeding Assessment Level has the benefit of all information available to preceding levels.

List 3 - Information Elements

1. Species description
2. Species distribution
3. Stock identification
4. Catch series
5. Discard series
6. Effort series
7. Length series
8. Age series
9. Growth rates (assumes sufficient length-weight data)
10. Relative abundance
11. Mortality rate
12. Exploitation rate
13. Reproductive rate
14. Behavior
15. Catchability
16. Absolute population size (biomass or number)
17. Annual recruitment
18. Environmental indices
19. Causal environmental mechanisms
20. Species interactions--competition, predator-prey
21. Physiological
22. Multiple factors (behavior, environmental, population parameters, etc.)

List 4 - Assessment Methods

A. Analytical

1. Mark and recovery
2. Change in ratio
3. Surplus production
4. Yield-per-recruit
5. Virtual population/cohort
6. Spawner-recruit
7. Multispecies models
8. Ecosystem models
9. Predictive regressions

B. Sampling

10. Sampling the fisheries
11. Tagging
12. Bottom trawl survey
13. Dredge survey
14. Trap or pot survey
15. Setline survey
16. Acoustical survey
17. Acoustical-bottom trawl survey
18. Landbased count
19. Aerial survey
20. Fish eggs and larvae
21. Environmental indices
22. Underwater survey
23. Other remote surveys

MATRIX II: Applicability of Assessment Methods to the Information Elements Required.

The second matrix identifies the many information elements used in fisheries management. Most of the elements are data series. The matrix indicates the sampling methods used to obtain informational elements and identifies which informational elements are needed for specific analytical methods. Assessment methods are shown in List 4 (page A31).

● = Method applicable for acquiring data for Information element.
Blank = Method not applicable for acquiring data for Information Element.