**Statement to the**
**US Commission on Ocean Policy**

# Scientific Challenges in Supporting Living Marine Resource Management

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## Introduction

Living marine resources are inextricably linked to the cultural and economic identity of New England. The proud traditions of whaling and fishing pervade both our art and literature. Today Northeast fisheries generate in excess of $1 billion in annual first-sale revenue. Recreational fisheries and non-consumptive uses of marine mammals are likewise important sectors that help support working coastal communities and promote tourism.

The history of New England living marine resources (LMRs) is also one of overfishing and sequential depletion – both in terms of the great whales and fishery resources. Even by the 1850s sensitive species were showing signs of decline (e.g., halibut, Atlantic salmon, sturgeon, and right whales) and fisheries were directed to more distant fishing grounds and to alternative species to maintain production – a trend that continues today. Under the provisions of the Sustainable Fisheries Act, Marine Mammal Protection Act, Endangered Species Act, other federal and state statutes, and international agreements, most of the overfished stocks are now regulated under prescribed rebuilding plans, with some species showing remarkable signs of recovery (e.g., striped bass, sea scallop, summer flounder, harbor and gray seals).

The scientific challenges we face in supporting the management of LMRs, in New England and elsewhere in the United States, are to provide answers to questions of applied ecology and social science. Specifically, the challenges are: (1) the determination of resource abundance and productivity, (2) the relation of that productivity to rates and methods of exploitation, (3) the evaluation of management options and distribution of benefits, consistent with sustainable utilization, and (4) the interrelationships between biological resources and variation in the physical environment (at various temporal and spatial scales). All of these factors come into play in the development of management plans for LMRs, and ambiguities in one or more of these factors drive most of the controversies that are common to fishery and protected species regulation.

Fishery research focuses primarily on observation rather than experimentation. This is because in most cases there is no possibility to have controls or to repeat observations of phenomena. Reasoning about the factors controlling fisheries is thus primarily inductive rather than deductive (that is, specific cases are used to form theories about how resources vary and respond to management measures, rather than having general "laws" that apply in all specific cases). Accordingly, the critical foundation of any program that seeks to manage the health of stocks in relation to human activities is an observing system providing periodic information about resource abundance and factors potentially influencing that abundance (either human-induced or naturally-occurring). These observations and measurements have to be sufficiently accurate and precise (e.g. have sufficient "signal to noise" ratio) and be obtained at appropriate time and space scales to be meaningful both in terms of biological processes (recruitment, migration, death) and contemplated management measures (e.g., catch or effort quotas, closed areas, fishing gear modifications, etc.).

We are fortunate in the Northeast to have a long tradition of systematic observation of fish, fisheries and oceanography. This tradition dates back to the founding of the U.S. Fish Commission in 1871 "*…to study the causes of the declining food fishery in the Northeast US"*. The Woods Hole oceanographic community, now multiple agencies and institutes, was thus founded in 1875. "Modern" fishery science in the region originated with the formation of the North Atlantic Fishery Investigations, under Dr. William Herrington. A series of studies was initiated in response to precipitous declines in the haddock fishery in the late 1920s (Figure 1). More than 70 years of collection of fishery-dependent data (catch, discard, effort and biological characteristics of the catch) for haddock make this stock the best studied in the region. However, it wasn't until the inception of scientifically based, multispecies trawling surveys, beginning in 1963, that a true ecosystem-based monitoring tool for fish stocks became available (Figure 2).

Observing systems for the biological components of marine ecosystems have expanded to cover a wide spectrum of trophic levels, including periodic shipboard and aerial surveys of marine mammals, dredge and net surveys of commercially important invertebrate species, and acoustic and net sampling of plankton and pelagic community dynamics. These studies continue to indicate a relatively healthy and productive (e.g., at lower trophic levels) ecosystem, capable of supporting rebuilt stocks of LMRs. Regional stock assessment capabilities for fishes, invertebrates, and protected resources are considered among the very best. The regional Stock Assessment Review Committee (SARC) process represents one of the most challenging and aggressive independent peer review forums for fishery science anywhere. Similarly, social science capabilities in the region (both federal and university) are among the best in the nation, and produce critical information with which to evaluate the economic and social consequences of policy choices.

An important focus of regional ocean science is to induce process from observation by assimilating data into models that combine biological and physical elements. Work under such programs as the Global Ocean Ecosystem Dynamics (GLOBEC) and the emerging Census of Marine Life initiatives have sought to combine multi-institutional resources within overall frameworks to understand how biological communities function – particularly in the face of human intervention. Understanding governing processes is, perhaps, the greatest challenge of our science, since many of the most difficult management questions are not ones of "how much" (i.e., how many of species X exist?), but of "what if" (how will the species and fisheries respond to particular management control measures?). One such question of immediate importance is establishing rebuilding goals for the region's chronically overfished stocks. Determining the capacity of the region's marine ecosystems to support rebuilt stocks of all major resources hinges on understanding of the food web and how individual components can be manipulated therein. Likewise, the reliance on the use of year-round and temporary fishery closed areas has posed new questions about the extent and location of marine reserves and how both marine animals and fishermen respond to them. Similarly, we know approximately how many right whales exist in the Northwest Atlantic. Developing management techniques that ensure their survival, however, remains a vexing problem.

Overall, the regional capabilities to support management of LMRs could serve as a model for the rest of the country, particularly as they relate to the development of observational capabilities through systematic surveys. Management controversies will be a continuing issue because of the regulatory requirements for rebuilding depleted resources and the necessity of bringing harvest capacity in line with the productivity of the resources. Nevertheless, there are a number of challenges to the current system and opportunities that, if pursued, could enable fisheries and protected species science to provide more precise and timely answers to a broader set of resource management questions. Doing so will improve the credibility of science and management with the regulated communities and the general public. Below I consider four broad themes for maintenance and improvement of science capabilities in support of living marine resource management.

**Enhancing Science Capabilities in Support of LMR Management**

*Every Fisherman a Scientist*

Information provided by fishermen currently provides one of the critical foundations of stock assessment for fishes, invertebrates, and protected species. So-called "fishery-dependent" data are a cornerstone of such assessments because they document the magnitude of fishery removals, where and when they occur, and the biological characteristics (age, size, sex, etc.) of the catch. Without these data, accurate understanding the influences that fisheries have on marine resources would be impossible, since we could only speculate on fisheries vs. natural sources of mortality on the stocks. Improvements in the quantity, quality, and timeliness of fishery-dependent data in the Northeast have been identified as the highest priority issue for improving the quality of regional stock assessments (NMFS 2001). This is because, unlike other regions of the country, the time series of fishery-independent surveys are fairly well developed. Currently, these data are collected from fishermen and fish processors through mandatory vessel trip reports ("logbooks"). While data from these reports serve important management and enforcement functions, their utility as a scientific tool is limited. The system is a continuing source of contention among fishermen, scientists, and managers regarding the accuracy of such information.

A series of "town meeting" forums last winter identified the replacement of the existing system for collection of scientific data with an electronic-based reporting system, as a priority issue. The "study fleet" initiatives are now being implemented in several fisheries on a pilot basis (e.g., groundfish, squid).

There are over 250,000 fishing trips taken regionally in the EEZ each year, and these trips are conducted 12 months per year, in all areas (except those closed by regulation). Improving the accuracy and expanding the types of observations obtained from these trips could increase the synoptic quality of data available for assessments (e.g., where animals were caught) and improve the analysis of management options (e.g., the effectiveness of particular proposals for closed areas, etc.). Treating such observations as scientific data rather than "anecdotes" requires that information be of high quality (e.g., precise location data), and not be subject to misreporting. By allowing fishermen to participate in the design of such systems, they will be more apt to use their information (and that collected by others suitably aggregated to protect confidentiality), to develop greater understanding of patterns occurring in the fisheries. In this regard, having fishermen interpret varying patterns occurring in these data seems a fruitful exercise as a basis for more collaborative evaluation of resource trends, and one that can build confidence and relationships among fishermen, scientists, and managers.

One such effort already underway places temperature recorders on lobster traps to provide more complete coverage of bottom temperature measurements than is available from research ships and buoys. The fishing industry is interested in pursuing more such science-fishermen partnerships. These programs offer the opportunity to expand the capability to do operational oceanography and to improve the quality of information available for assessment.

Other critical fishery-dependent data include observations of fishery discards by trained observers, and biological characteristics of the catch (landings and discards). Current programs in these areas need to be strengthened.

In addition to improving the quality of information documenting actual fishing activities, there are circumstances when resource surveys aboard commercial vessels can be an important augmentation of existing fishery-independent survey sampling programs. For example, recent industry-based survey projects documented abundance and spatial distribution of scallops and potential bycatch species prior to limited re-openings of closed areas. Similarly, industry-based surveys have aided resource management of monkfish and squid – and other such efforts are planned. The most significant issues in using industry vessels for such projects is the calibration of the catch rates among vessels participating in the work (i.e., efficiency of each vessel varies), and the development of adequate scientifically-based sampling designs. The latter issue is particularly important since fishermen's general observations about resource abundance are conditioned by where and when they fish, which is usually on the most abundant concentrations. Recent development of new technologies such as gear performance monitoring (bottom contact, gear dimension) make calibration a more realistic option. The development of sampling designs between scientists and fishermen has proved to be an encouraging opportunity for dialog about the best ways to provide information on stocks. Industry-based surveys have a place in providing precise information to managers, and these surveys are being aggressively pursued under cooperative research initiatives. It should be noted, however, that it is not logistically possible to conduct synoptic, region-wide multispecies surveys aboard commercial vessels (similar to those currently occurring on research vessels) due to the physical limitations of commercial vessels in the region and the calibration issues involved.

*Sharpen the Tools*

New tools used to measure resource species abundance and oceanographic factors that influence their variability are rapidly emerging. These technologies span the gamut from allowing monitoring of the activities of individual animals up to providing rapid and synoptic assessments of large-scale biological and physical phenomena. It is impossible to compile a comprehensive list or anticipate such emerging technologies- they range from electronics to molecular biological applications and observation and measurement systems. The important element in the technology cycle is support for a culture where need begets technology development and developed technologies become operationalized. Three classes of new tools that have been developed and are beginning to be put into use are briefly highlighted to illustrate the potentials of new marine technologies to assist in LMR management.

Fish tagging is an old idea that has been used to interpret distribution patterns, measure mortality, and infer stock structure. The classic technology relies on capturing the fish and tagging it, and recapturing it at some later date. Thus, an individual tag recapture spans but two time/space observations. New "smart" or data storage tags can be attached to individual fish, mammals, and turtles, with size and capacity of the tag determined by the size of the animal. These new tags include a small power source and microchips with built-in clocks and sensors. These devices offer potential new insights into the movement rates and routes of individual animals and allow the simultaneous collection of environmental data (depth, temperature, for example). The information from them may help in interpreting life histories of the more peripatetic animals, and in designing networks of closed areas that meet conservation goals with minimum impact on human activities, among other uses.

An increasingly important issue in marine resource management is the definition and protection of "essential" habitats. Potential threats to the integrity of marine habitats come from a variety of human activities, including the effects of towed fishing gears (trawls and dredges) in areas of high invertebrate density and diversity, and other activities related to coastal alterations of the seabed and water column. Studies of the relationship of animals to obligate "essential" habitats are in their infancy. This is because it is difficult to determine residence times of individual fish within habitats and if alternative habitat types could serve similar functions (e.g., nursery areas, spawning grounds). A key gap in our knowledge is a precise picture (map) of the habitat types extant in the coastal waters and the EEZ. Habitat characterization and classification is a primary requisite if we are to identify and protect those places considered “essential” to the life history of resource species. It has been said that we have a more comprehensive picture of the dark side of the moon than the bottom of the Gulf of Maine – one of the best-studied bodies of water on earth. New technologies (e.g., multibeam sonar) and techniques for ground-truthing of imagery, pioneered by the USGS and other institutions, make this a low-risk undertaking of potentially great importance. Canadian fishing industries, in concert with their government, have undertaken such studies off Nova Scotia and the Northeast part of Georges Bank.

Tracking systems based on satellites are a standard technology ashore used in various commercial and regulatory applications. In the Northeast, tracking systems are now used to manage days at sea quotas for some fisheries (e.g., mandatory in the scallop fleet, optional for groundfish fleets). They have obvious advantages for enforcement of closed area boundaries and management of vessel allocations of time at sea, but data from them have proved to be scientific windfall. Precise vessel locations (usually made at hourly intervals) have provided exciting new opportunities to interpret the spatial pattern of fishing in relation to resource distribution and marine habitats. Even rudimentary ancillary information about vessel activity associated with the stream of vessel locations can provide important new information for developing models of how fishermen respond to patterns of resource abundance, regulations, and enforcement. These scientific applications do not require real time monitoring, just periodic logging of electronically-derived locations and recording of vessel activities (e.g., haul-by-haul catch data). These systems are now under development in the Northeast for a variety of large- and small-boat applications under the “study fleet” program funded under cooperative research initiatives.

These new technologies can provide important insights into how marine animals relate to fishing activities and their environment. However, they cannot replace the high quality long-term time series of fishery-independent abundance data. These time series, some of which date back about 40 years, are the yardsticks by which progress in management efforts is measured (Figure 2). Their value increases every year as we attempt to gauge management success and set goals for our efforts to restore overfished populations. These time series also supply information for new or developing fisheries (e.g., the relatively new fishery for hagfish). These data will continue to be the primary tools by which the status of stocks is measured.

A particular issue we face in the Northeast in maintaining the continuity of long time series of fishery stock observations is the aging fleet of purpose-built fishery survey vessels (FSVs). The NOAA R/Vs *Albatross IV* and *Delaware II* were built in the 1960s (1962, 1968, respectively) and have exceeded (*Albatross*) or are nearing (*Delaware*) planned and functional obsolescence. These vessels provide the platforms from which critical long-term monitoring surveys are conducted – functions that cannot necessarily duplicated with the available fleet of general purpose oceanographic ships or on commercial fishing vessels. The President’s 2003 budget calls for the completion of funding for a replacement for *Albatross IV* as part of the ongoing NOAA fleet modernization program. This is a high priority as the *Albatross IV* becomes less reliable over time, thus placing at risk the important time series of fishery-independent observations of resource status. The new FSVs are being designed to be very quiet and to carry the most modern hydroacoustic survey electronics. Those capabilities will significantly improve the quality of acoustic survey data available for assessments of pelagic species (Atlantic herring, Atlantic mackerel, etc.), and for other studies where ship noise is a potential issue.

*Manage Ahead of the Crest*

The pace and intensity of fishery and protected species management has increased greatly in recent years. Part of this is due to regulatory statutes requiring rebuilding of depleted stocks, and maintenance of healthy ones. Other pressures include the ever widening array of species being targeted by fisheries, and, frankly, the increasingly litigious aspects of resource management that drain scientific and management resources from their primary missions. An important trend occurring in the fisheries is the development of markets for species for which there was no significant historical exploitation. The development of these new fisheries has resulted both from the depletion of traditional fishery species and the increasingly stringent limits places on them, including access control. Thus, during the last decade, important and valuable fisheries have developed for spiny dogfish, monkfish, hagfish and others. Because of the widening array of issues to be addressed and limited scientific and management-related resources, fishery resources generally do not come under management until there are resource abundance or allocation issues arising from the unregulated fishery. This is because there are limited resources that must be prioritized and no legal requirement to implement an FMP for a stock that is not overfished. This results in management and science that is constantly playing catch up. Many of the most contentious issues arise when new fisheries are just beginning to be considered for regulation and science produces its first findings regarding the species involved. Science will become more systematic when management needs become more stable and predictable. If we are constantly managing resources just "behind the crest" of resource decline followed by increasing regulation, then management and the science supporting it will remain contentious and inefficient.

*Maintain the Vigor of Science*

An oft-quoted homily is that necessity is the mother of invention. If that is so, then a corollary is that invention is the agent of progress and change. This duality exists wherever the fruits of scientific research are used in applied fields. A cogent regional example is the renowned medical research and hospital complex in the Boston area. Many pioneering discoveries are made there by researchers who are also practicing clinicians advising patients on courses of treatment and therapies. Their exposure to difficult real-world problems inspires directions for research and new ways of looking at difficult problems. Their patients are assured that if new and promising treatments are available, their advisors are aware of them, being current in the field. So it is in fisheries and protected species research and the provision of management advice. The existing systems in the federal and state resource agencies generally foster this duality. Individual researchers/scientific advisors may, at times, be frustrated by the mix of these activities, but the record is clear. Some of the most scientifically creative and thoughtful work is being produced by people "on the front lines" of advising management bodies and regulators. This is not to say that a vigorous academic and private research community does not have an important place – one need only look at the accomplishments of the GLOBEC and Cooperative Marine Education and Research (CMER) programs to find such examples. Specific short-duration projects are well suited to these institutions. Academic institutions also train the badly needed quantitative biologists necessary to do such work. However, it would be a mistake to separate the functions of conducting research on stock dynamics from the provision of management advice as both enterprises would suffer – the research would soon lack relevance and the advice would lack scientific rigor, instead devolving into formulaic and pedantic responses to the needs of managers.

Scientific research upon which management decisions are made must be subject to independent review. Challenging and thorough debate on issues of science assures that alternative interpretations of data and sources of uncertainty are fully considered. This is good scientific practice, and is a primary element in maintaining the credibility and independence of research. The general standard for such review is that the list of reviewers of such work should not include those that produce it. Peer review can occur in many different forums – most of which are used at one time or another in the region. As with many fields (including medicine) difficult decisions must be made in the face of imperfect information and alternative theories explaining data- this is the role of expert advice. Peer review should be an aid in ensuring that various interpretations are carefully weighed and technical errors are corrected. It should not, however, be an excuse for "paralysis by analysis". Given the increasing involvement by scientists in litigation and other activities outside the realm of traditional stock assessment, we cannot afford multiple layers of peer review considering the same issue- which often occurs given the controversality of many management decisions. It is notable in this regard, that there has never been a successful legal challenge in federal courts based on the quality of regional science in support of management decisions. The adequacy of regional science has been supported by several recent studies by the National Research Council.

Despite the general popularity of marine sciences as a college major, we face shortages of quantitative biologists and other key professions. The shortages are particularly critical in the areas of fishery stock assessment, resource modeling, and social sciences (economics, sociology, and anthropology). To illustrate this point, all five of the NMFS Science Centers are currently seeking quantitative biologists, and are engaging in nation-wide searches. The reality is that the nation's graduate schools of fishery science produce few scientists with advanced quantitative skills, and many of the ones that are produced are not US citizens. Resultantly, in many cases the cadre of existing qualified staff are often recruited from one Center to another, or into academia. With the aging of the NMFS workforce (many of whom were trained in the 1970s), the need for an infusion of new talent is increasing. Efforts by NOAA to increase the pool of trained personnel through partnerships with universities under the CMER, Sea Grant fellowship, and Dr.

Nancy Foster scholarship programs provide an important first step. Additional efforts to stimulate the academic community are still required. Increasing the quality, quantity, and timeliness of studies in support of LMR management depends first and foremost on scientists- this needs to be a greater priority in academia and government.

A difficult issue faced in all of marine sciences is the continued under representation of some groups in the professions. The gap is not closing. Renewed efforts to encourage and support participation of all groups are a priority of NMFS and NOAA. In this regard, targeted training and recruitment activities at historically black and minority serving institutions have increased. Talented minority students must be identified, encouraged and supported in their efforts to enter marine science professions.

## Summary

Science in support of the management of living marine resources was born in this country under a directive from then President U.S. Grant to "*to study the causes of the declining food fishery in the Northeast US"*. At that time neither the facilities, technologies, nor the people existed to make such a daunting enterprise a reality. In the ensuing decades marine sciences have flourished – and along a parallel track with them new problems of overfishing and laws regulating how humans interact with the ocean environment. The collective marine science enterprise currently being supported by agencies and other institutions in the Northeast USA provides meaningful data products and synthetic advice with which to support difficult resource management decisions. Continued strategic investments in technologies, institutional interrelationships, and people can improve the precision, relevance, and timeliness of science in support of LMR management. Such investments can and will improve confidence of the regulated groups and the general public in the government's stewardship of the nation's living marine resources.

## Reference

NMFS. 2001. Marine fisheries stock assessment improvement plan. Report to the National Marine Fisheries Service Task Force for Improving Fish Stock Assessments. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-56, 69 p.

Figure 1.  Otter trawl fishing vessels offloading at the Boston Fish Pier, c.a. 1931.  The primary species taken in the fishery was haddock (seen in the hand carts on the dock). The vessel at the end of the pier (with the “B” on the stack) is the *Spray*.  Build in 1906, she was the first steam-powered trawler in the US fleet.  The Boston haddock fleet was intensively studied, beginning in 1931.

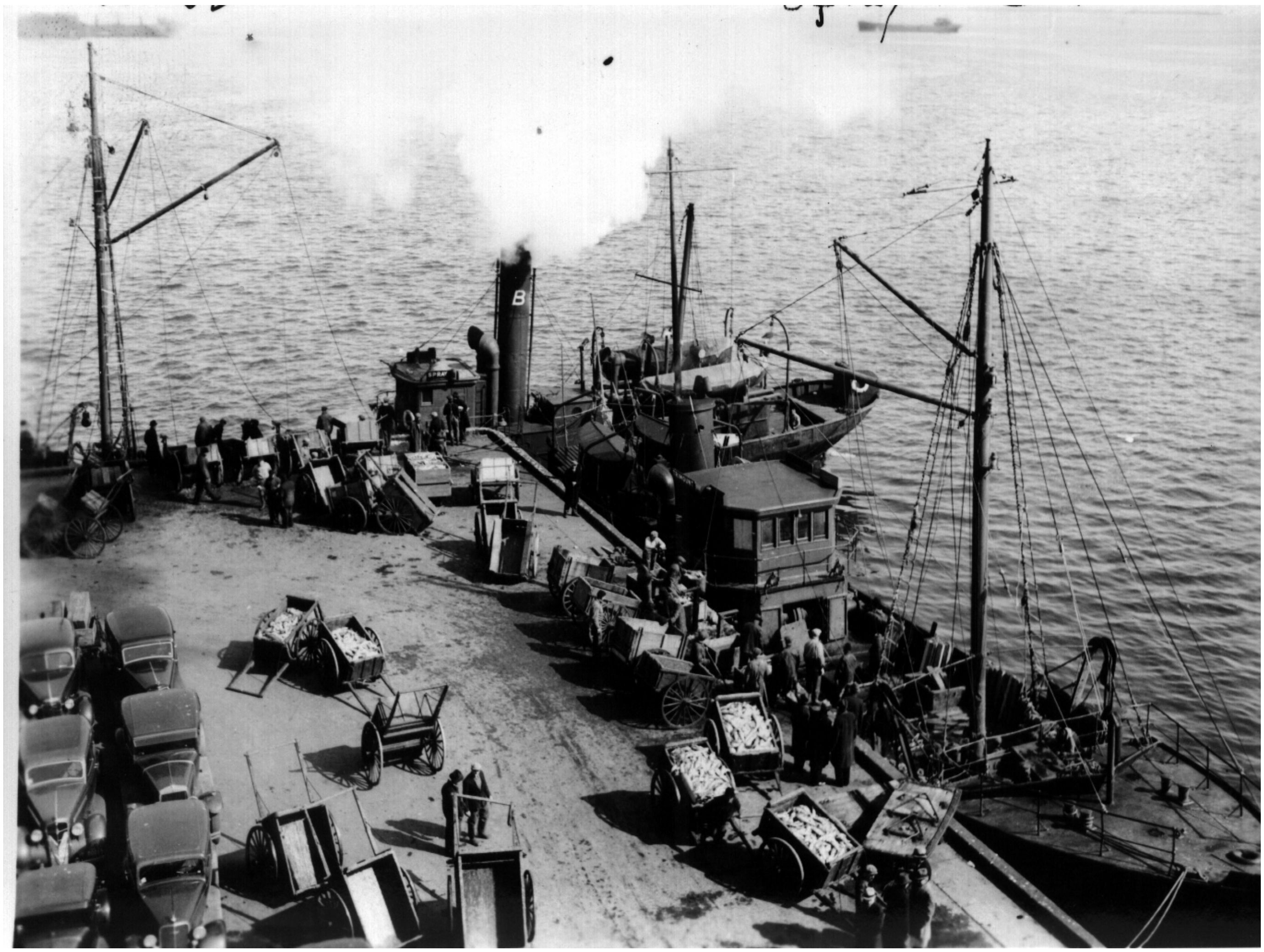

Figure 2. Trends in relative abundance (kg per standardized bottom trawl tow) of four groups of finfish species off the Northeast USA, 1963-2001. Data are derived from stratified-random trawl surveys using NOAA research vessels and conducted in the spring and autumn of each year.