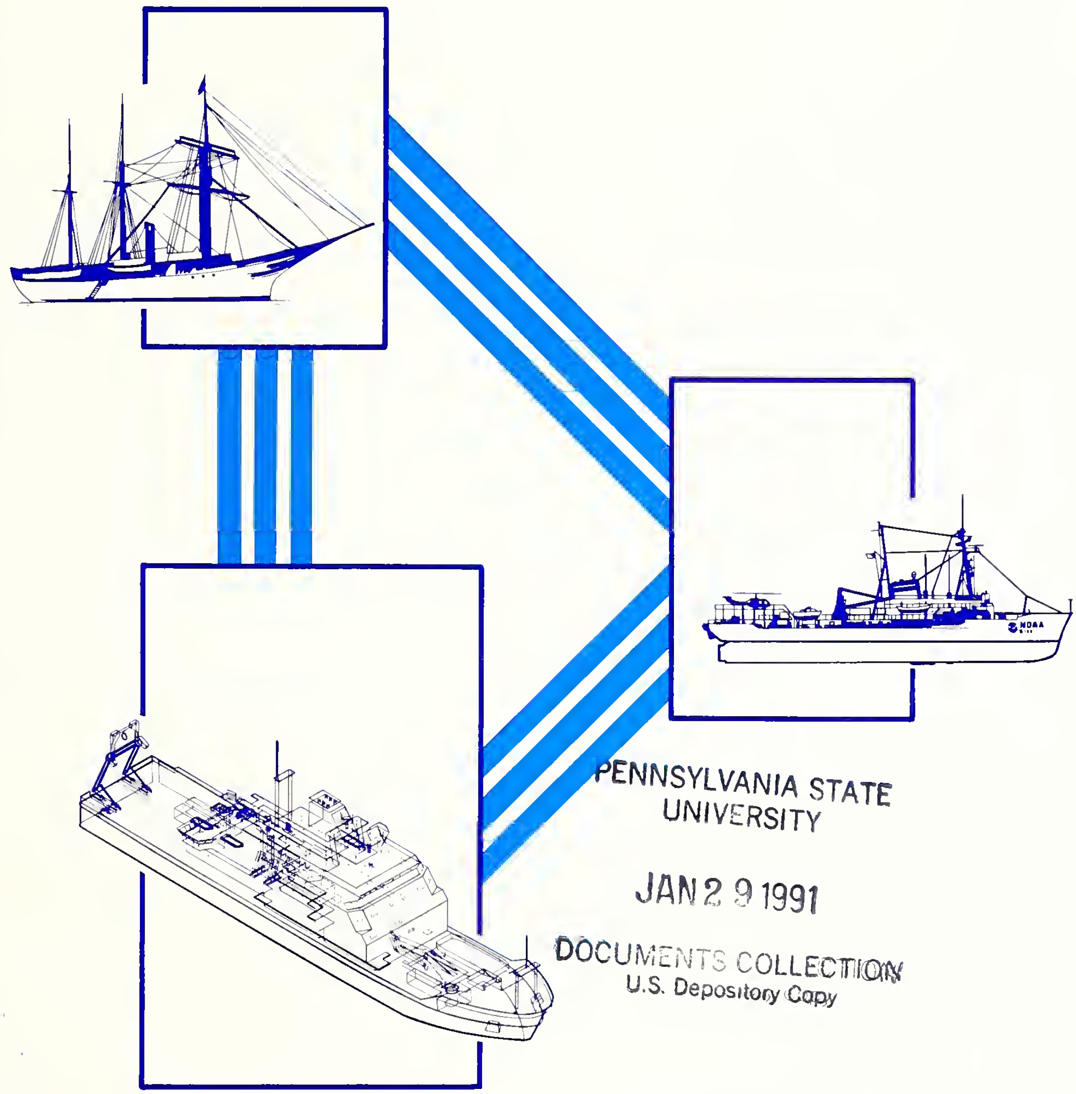
NOAA'S OCEAN FLEET MODERNIZATION STUDY

Phase 1: Mission Requirements



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of the Chief Scientist

NOAA OCEAN FLEET: YESTERDAY, TODAY, TOMORROW

NOAA was created in 1970 through a Presidential reorganization, but the survey activities of the fleet of one of its predecessor agencies, the U.S. Coast and Geodetic Survey, became well established in the nineteenth century. Sketched from a photo is perhaps the best-known survey vessel of its time, the PATTERSON, built by James D. Leary at Brooklyn, NY, in 1883. It was a wood auxiliary barkentine, 435 tons, 163 feet long, with a 27 foot beam, and a draft of 14 feet. Much of its survey work was done in Alaskan waters.

Commissioned in April 1960, the SURVEYOR, here depicted in a drawing, is a part of NOAA's current ocean fleet. The ship has a welded steel/ice-strengthened hull and is 2,653 gross tons, 292 feet long, with a 46-foot breadth and a draft of 19.5 feet. It was built by the National Steel and Shipbuilding Company of San Diego, CA. The SURVEYOR conducts worldwide oceanographic research but is nearing the end of its useful service life (see p.2).

A modernized NOAA fleet might employ ship designs such as the one shown for the JAMES CLARK ROSS which will soon join the fleet of the British Antarctica Survey. This ship is ice-strengthened. It is being built at the Swan Hunter Shipyard at Newcastle, England, and will be commissioned early in 1991.

(Photo of the PATTERSON and drawing of the SURVEYOR courtesy of NOAA/Office of NOAA Corps Operations. Sketch of the JAMES CLARK ROSS courtesy of British Antarctica Survey and Swan Hunter Shipyard.)

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Phase 1: Mission Requirements

SEPTEMBER 1990

U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

Office of the Chief Scientist
Ned A. Ostenso, Acting Chief Scientist

Acknowledgement

In the face of an aging and sometimes functionally obsolete fleet of ocean vessels, NOAA undertook, under the guidance of the Office of the Chief Scientist, an assessment of the Agency's mission in the areas of oceanographic and fishery research and charting/mapping. The results of this study are ships criteria which we believe are necessary to fulfill NOAA missions into the next century. As a result of this assessment process, NOAA is now well positioned to define the character of its next–generation oceanographic fleet.

This assessment effort was extremely ambitious in terms of both scope and time for completion. Thanks to a large number of very dedicated individuals a thorough estimate of NOAA's ocean mission needs was completed within a short time period. This required intensive efforts and dedication to the goal.

Deserving a large share of credit for this accomplishment were representatives from each of the NOAA Line Offices and from some Staff and Program Offices. To ensure a balanced approach to the study, persons from other federal agencies and from the university community were asked to participate. These scientists and technical experts deserve recognition for their contributions. Among them were representatives from the National Science Foundation; the U. S. Geological Survey of the Department of the Interior; the U.S. Environmental Protection Agency; the National Aeronautics and Space Administration; the Office of the Oceanographer and the Naval Research Laboratory, U.S. Navy, Department of Defense; Texas A&M University; and the University of Rhode Island. Individual participants, with their affiliations, and staff members involved in the preparation of this study are listed in Appendix B.

To all contributors, many of whom participated at the expense of other responsibilities and sometimes on their own time, we extend our appreciation. NOAA and the Nation's oceanographic and research community will profit from your effort and insight.

W. L. Stubblefield
Assessment Coordinator

September 1990

Preface

NOAA's ships are, on the average, nearly 25 years of age. This age is generally considered as the maximum productive age of a research vessel which has not undergone a major service–life extension. Few of the NOAA ships have undergone a major rehabilitation; none have undergone a comprehensive service–life extension. Also, some of the ships are functionally obsolete, that is, they are not able to fulfill the requirements levied by the scientific mission. This obsolescence, though existing to some degree in all the ships, is most acute to those vessels supporting multidisciplinary programs. The advanced age of the NOAA ships is widely recognized within and outside of the Agency. The functional obsolescence, though not widely known, is nevertheless clearly recognized. For example, a 1988 study by the Marine Board of the National Academy of Sciences drew attention to NOAA needing a fleet capable of supporting a diverse array of complex science needs.

To assess the next generation of NOAA ships, a three–phase process was initiated. Phase I identified the mission requirements from a user viewpoint; Phase II developed identifiable hull and instrumentation characteristics from these requirements; and Phase III examined these characteristics in light of vessels now in NOAA's fleet, and determined long–term strategies for implementing fleet modernization. This report addresses only Phase I.

Paramount in the Phase I Working Group determinations is the requirement for a *modern* fleet. Without modernization the functional obsolescence now existing in some of NOAA's ships will remain. Inherent to the concept of a fleet of modern oceanographic ships is the incorporation of new technology in both the hull and instrumentation. Equally important is the need for flexibility and versatility. To the maximum extent possible, the ships must possess the capability to keep pace with technological advances and changes in mission protocol. For the ship's laboratories and certain deck installations this can be achieved to a large degree through design prior to construction or refit.

The mission requirements, and hence the vessel criteria needed to satisfy these requirements, were grouped along traditional NOAA boundaries: Oceanographic Research, Fishery Research, and Charting and Applied Oceanographic Research. Written as an Executive Discussion, Chapter I describes the purpose of the study and the methodology used. The scope of the research and a brief review of the mission requirements for each of the three main divisions of Phase I are also included. Chapters II through IV describe the mission and objectives for each of these major areas, and a detailed discussion of vessel requirements needed for each. Included as Appendices are: A) position papers prepared by the participants; and B) list of participants.

Dr. John A. Knauss
Under Secretary for Oceans and Atmosphere
and Administrator

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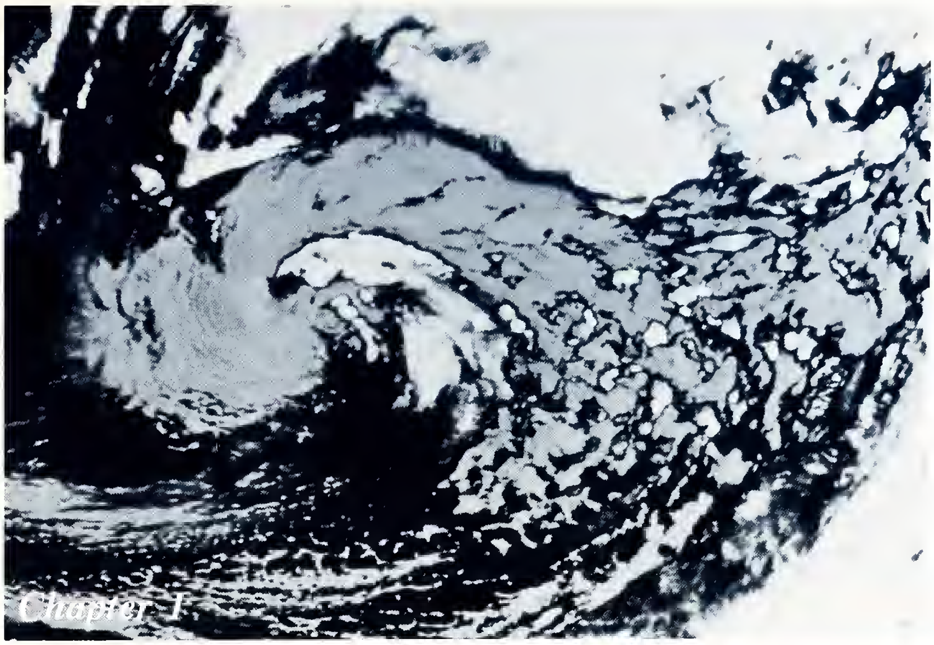


Executive Discussion

Background of Study

NOAA's ocean programs are heavily dependent on its oceanographic fleet. This fleet has served NOAA for many years. However, in the recent past two major problems have faced the NOAA user community, and, due to the nature of these problems, they are expected to become more severe in the near future. The problems are: 1) the age of the NOAA fleet and 2) the mission capability of various ships in the fleet.

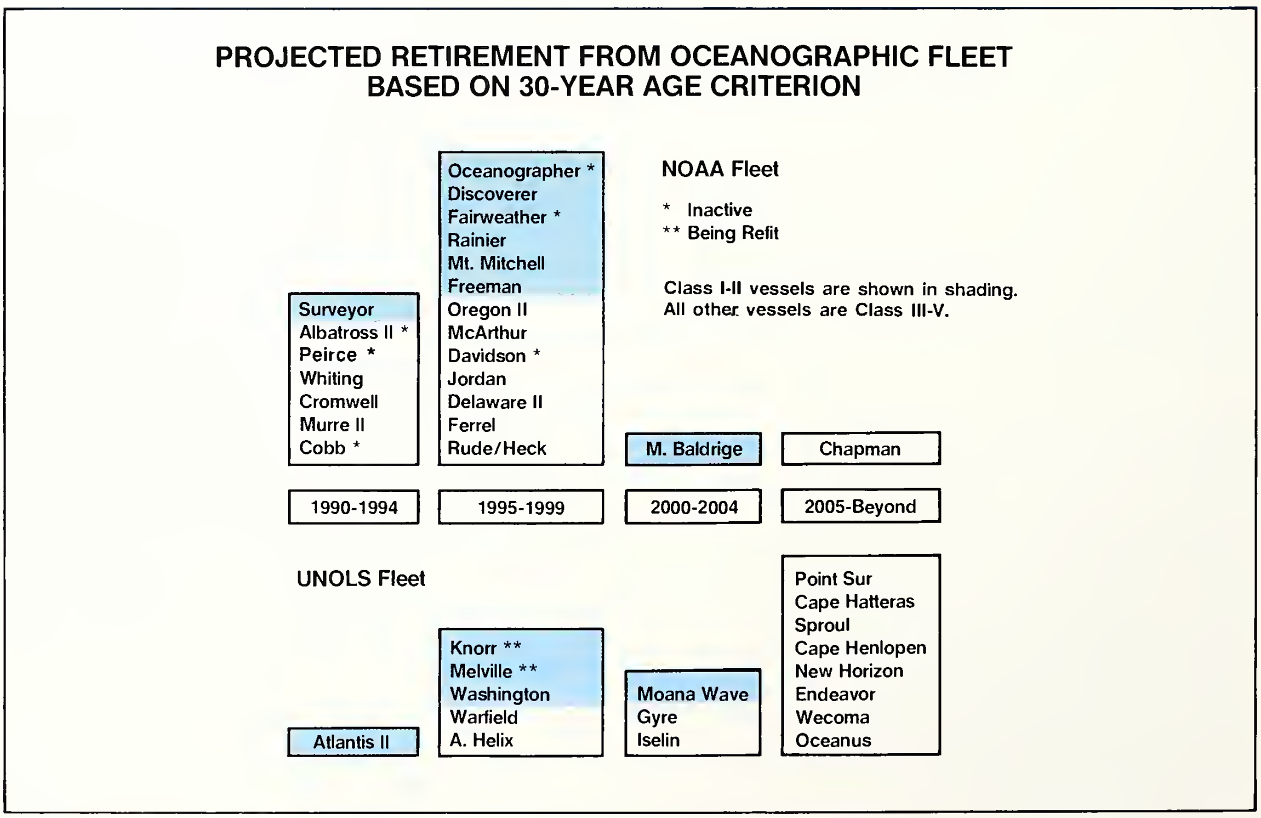
Age and Condition of Current NOAA Fleet. The average age of the NOAA ships is very close to 25 years. This age is comparable to what is generally considered as the maximum productive age of an oceanographic vessel which has not undergone a major rehabilitation. The age of the vessels affects the research mission of NOAA in a number of ways. The most obvious of these are the unscheduled breakdowns or delays inherent to old machinery regardless of how well it is maintained. As the ship ages, replacement parts are more difficult to obtain thus making repairs more costly and repair periods longer. Of comparable concern is the expense involved in operating these vessels due to increased maintenance and the added manpower costs relative to modern vessels with labor–saving technology, e.g., automated engine rooms.

Of the twenty–three NOAA ships, only six have had a partial midlife rehabilitation. For the other ships, the midlife rehabilitation has been deferred due to budget constraints or proposed replacement. Even with those ships which have undergone some rehabilitation, the work has not been comparable to the service–life extension practiced by the university fleet and certain foreign countries, where the ship is totally gutted and refitted with new machinery and facilities.

The age of the NOAA ships is more striking when compared to the age of the vessels in the University National Oceanographic Laboratory System (UNOLS) fleet (Figure 1–1). The UNOLS fleet, which in 1990 consists of 19 active vessels, is composed mainly of the larger university vessels whose operation is supported primarily by federal funds, and for which there is national cooperation (or at least communication) concerning scheduling, operations, and facilities. For the NOAA fleet, by the turn of the century only two ships will be less than 30 years old and of these, the M. BALDRIGE lacks only a few months turning 30 years. In contrast, only six of the UNOLS fleet will be as old. Also, some of the UNOLS ships are undergoing a full service–life extension which includes new engines and associated machinery, and lengthening of the hull to provide upgraded science spaces and living accommodations. By the end of 1990, the UNOLS fleet will be further augmented by two new vessels (M. EWING and T. THOMPSON). These service–life extensions and new constructions have resulted from the combined efforts of the university community and the funding agencies to avoid having a research fleet which is unable to meet its science needs. As a consequence, over the past few years an orderly process to upgrade the UNOLS fleet has been in effect. A comparable program has been missing in NOAA.

<u>*Mission Capability of Current NOAA Fleet*</u>. The mission capability of the NOAA vessels in many regards is of more serious concern

Figure 1–1. *By the turn of the century most of NOAA's ships will be 30 years or older. This is frequently considered as the maximum useful age of oceanographic vessels. The UNOLS fleet will soon be augmented by two new large oceanographic vessels, the EWING and the THOMPSON.*



than the age of the ships. The ships were built with the technology of the 1960's and to satisfy very specific oceanographic objectives. The principal NOAA missions at the time were geological and physical oceanographic research, launch hydrography, and trawling to determine stock assessment. During the past two to three decades, major advances have been made in areas of technology and mission protocol. The technological advances are quite apparent; the changes in science protocol are perhaps more subtle.

In terms of oceanographic research the snapshot of work as conducted three decades ago no longer applies. One major difference is scale. Thirty years ago descriptive investigations were still being conducted to obtain a localized understanding of the environment. Today the research is directed toward understanding those processes driving regional or global phenomena, such as climate change and long–term changes in fish stocks. Understanding these processes involves deciphering local events, frequently achieved though experimental studies and long–term monitoring activities, and relating these to the large–scale phenomena. Furthermore, this research involves multidisciplinary investigations using sophisticated analytical techniques unknown 20 to 30 years ago. NOAA's charting and mapping efforts have likewise seen a shift toward more efficient tools and methods. Only the traditional methods of stock assessment, e.g., trawling, have remained relatively constant over the years. However, with advances in various optical and acoustic remote–sensing technologies, changes in these methodologies are expected in future years.

The need for sophisticated research platforms is now being widely recognized. In a recent study, the Marine Board of the National Academy of Sciences (1988) recommended that: "NOAA should commission ... a study to define the characteristics of an idealized fleet to meet present and projected ship services needs. The results of this study should serve as the basis for the modernization of the NOAA Fleet..." In partial response to this stated requirement and a similar perception on the part of NOAA, such a study was initiated. This report reflects our efforts to determine NOAA's mission needs into the next century in the areas of oceanographic, charting/mapping, and fishery research and how these translate to the next–generation of NOAA ships.

Study Plan

To determine the character of NOAA's next generation of oceanographic vessels two considerations are most important. First, the users, rather than managers, must determine the mission requirements for the ships; and second, the assessment must focus on NOAA's future. To assure that such a study was not biased by existing resources, the approach was to delay any comparison to the present NOAA fleet until quite late in the process. To do so a method was chosen to identify, first, the mission requirements; second, define what type of platforms are needed to satisfy these requirements; and lastly, to compare these needs to the existing fleet. Figure 1–2 is a graphic presentation of this process. Each part, or phase, was designed to be independent of the others but using data obtained in previous phases. An accelerated time frame was developed in order to meet both a NOAA budget submission deadline and to ensure that the findings of the first part of the process were still valid at the conclusion of the study. (A capsule summary of the plan is on p. 5.)

Implementation of Phase I

Crucial to this approach was to develop as thoroughly as possible the direction of NOAA's research missions for the next several

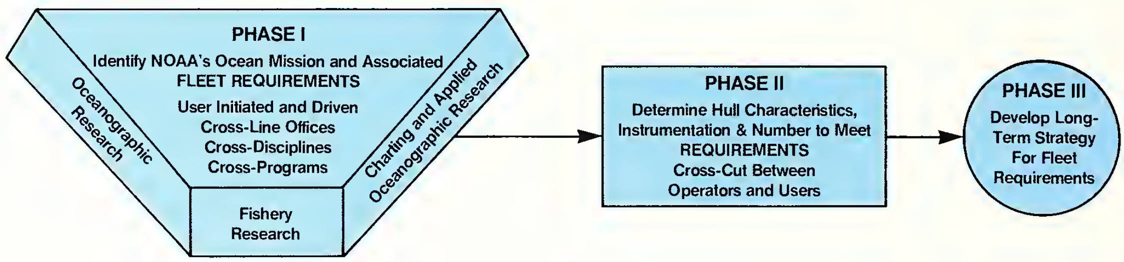


Figure 1–2. *A threefold process was used for the assessment. A serial rather than a parallel sequence was adopted.*

years. The make-up of the Working Groups in Phase I included some of the leading scientists and technical experts in their subject fields from within NOAA and outside of NOAA. Included were persons expert in such subject areas as satellite, physical, chemical, biological, geological, and acoustical oceanography; hydrography; and living marine resources. These persons were asked to consult with other colleagues, who were not part of the Working Group, in considering:

- Future directions of their research, especially as it supports national or international research programs
- Anticipated rate of growth in areas of activity, funding, and technology
- Geographical or seasonal time constraints and anticipated trends
- Trends in data collection, analyses, and communications

These ideas were presented as position papers prepared prior to the convening of the Working Groups (Appendix A). When the ideas presented in the position papers were viewed together, a reasonable prediction of NOAA's future research program emerged. From this future view, specific mission requirements for the ships to support this research were developed.

For the purpose of this study two points must be emphasized. Phase I did not consider mission requirements for vessels less than 65 feet. This is consistent with NOAA's policy as discussed in "Ships of the NOAA Fleet" (1989). Also, the criteria determined by UNOLS for various sizes of oceanographic research vessels were used as a guide. The

Plan of NOAA Fleet Assessment

Phase I

Objective:	Determine the mission requirements for NOAA into the next century and how they can be best met.
Method:	Convened three Working Groups of twelve to fifteen members each, consisting of leading scientists, both inside and outside of NOAA, in the areas of oceanographic, charting/mapping, and fishery research, to determine the expected mission directions and fleet requirements to satisfy these missions. Cross-representation between groups was sought.
Time:	Three months.

Phase II

Objective:	Translate the results of Phase I into identifiable hull characteristics and instrumentation requirements.
Method:	Convened a second working group, with representation from the previous Working Groups and the marine engineering community, to incorporate the results of Phase I into specific platforms. A break with tradition in determining new ways of accomplishing mission objectives was encouraged. State-of-the-art ship designs and instrumentation were examined. In addition to NOAA and non-NOAA technical representatives, persons involved with the budget and legislative processes participated.
Time:	Two months.

Phase III

Objective:	Develop a long-term strategy for fleet modernization.
Method:	Senior NOAA managers convened to compare the results of Phase II with the existing NOAA fleet and determine the best methods of ensuring a modern fleet capable of meeting NOAA's missions (as defined in Phase I).
Time:	Two months.

completeness of the UNOLS effort served as excellent points for departure.

Defining Scope of NOAA's Research Under Phase I

NOAA's ocean missions require a diverse array of research activities which can be viewed as a continuum with charting and living marine resource stock assessments as two end members, each with unique requirements. Bridging these two, without clear boundaries, is the umbrella of oceanographic research. Under this umbrella are virtually all aspects of marine science as they relate to understanding the oceans as part of the earth system. For the two end members, the organizational structure is clear:

charting is under the purview of National Ocean Service (NOS) and stock assessment is under National Marine Fisheries Service (NMFS). Oceanographic research, however, has no similar organizational boundaries. Portions of this research reside in each of the five NOAA line offices. The greatest involvement in ocean research, however, is found in the three line offices which are the principal users of NOAA ships. These are the Office of Oceanic and Atmospheric Research (OAR), NOS, and NMFS.

A brief overview of NOAA's research missions as they relate to oceanographic research, fishery research, and charting and applied oceanographic research follows. A more detailed discussion of these missions and the specific ship requirements to satisfy these missions are presented later as part of the reports of the Working Groups. There is some overlap in mission requirements among these three groups for particular ships. At the Phase I level this overlap is natural and was encouraged; as part of the Phase II study these overlaps, where appropriate, will be integrated.

Oceanographic Research. Included under this umbrella are aspects of global climate and climate change, coastal ocean and Great Lakes studies, and seafloor processes as they relate to understanding the oceans as part of the earth system.

Climate and Global Change. For climate and global change the research goal is to be able to understand and predict the behavior of the climate system on different time scales. The climate system can be characterized as a global heat engine having two working fluids (oceans and atmosphere) transporting heat mainly from the equator to polar regions. Figure 1–3 depicts this system. Questions which must be answered regarding the global heat engine are:

- Where to where in the oceans is heat transport occurring and how much?
- What water masses are involved and how is the system forced?
- What is the temporal and spatial variability of the behavior of the climate system?
- How do changing ocean conditions influence the atmosphere and what ocean features are most important in this respect?

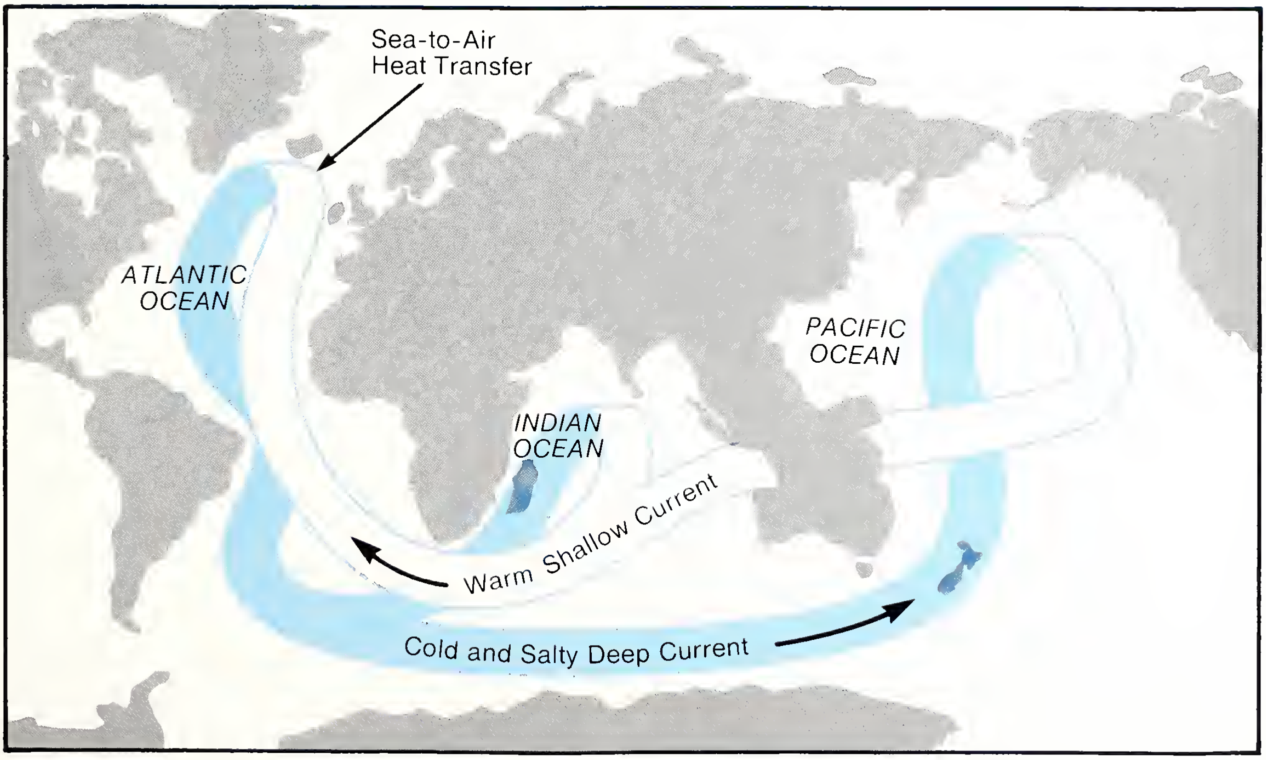
The scope of research required to address these questions involves vast areas of the world's oceans. As will be discussed in more detail in the chapter, "Oceanographic Research and Monitoring," satellites will influence the shipboard research, but not decrease its importance. The availability of complementary remote sensing and *in situ* automated observing systems will permit shipboard measurements to be made in the context of the large–scale variability. Complementary new technologies for underway shipboard measurements will actually increase the need for ships. These ship observations and envisioned large, ocean observatories will by necessity expand the traditional NOAA coverage. Future work will encompass the western Pacific, Indian, and Southern Oceans; the Norwegian and Greenland Seas; and portions of the western Arctic. In the polar regions, requirements to work farther into the ice for longer periods of time will expand over existing usage.

Coastal Ocean and Great Lakes Studies. NOAA's coastal ocean and Great Lakes studies will focus observational, research, assessment, and modeling efforts on key problems in the waters adjacent to our Nation's shores. The national economy and, especially, the local economies of many coastal communities often rely heavily on the environmental quality and physical stability of these coastal oceans. When beaches erode and are closed and people can't swim because of pollution, when fish and shellfish cannot be sold because of restrictions on their harvest, and when commercial and recreational fishing decline, the resulting costs have wide–ranging impacts.

NOAA plays a vital, national role in developing and implementing solutions to many of these coastal ocean problems. This role includes discharging its legislatively–mandated responsibilities as the Nation's steward for living marine resources and providing information, advice, and sound scientific bases for environmental decisions made by NOAA and other local, state, and federal agencies.

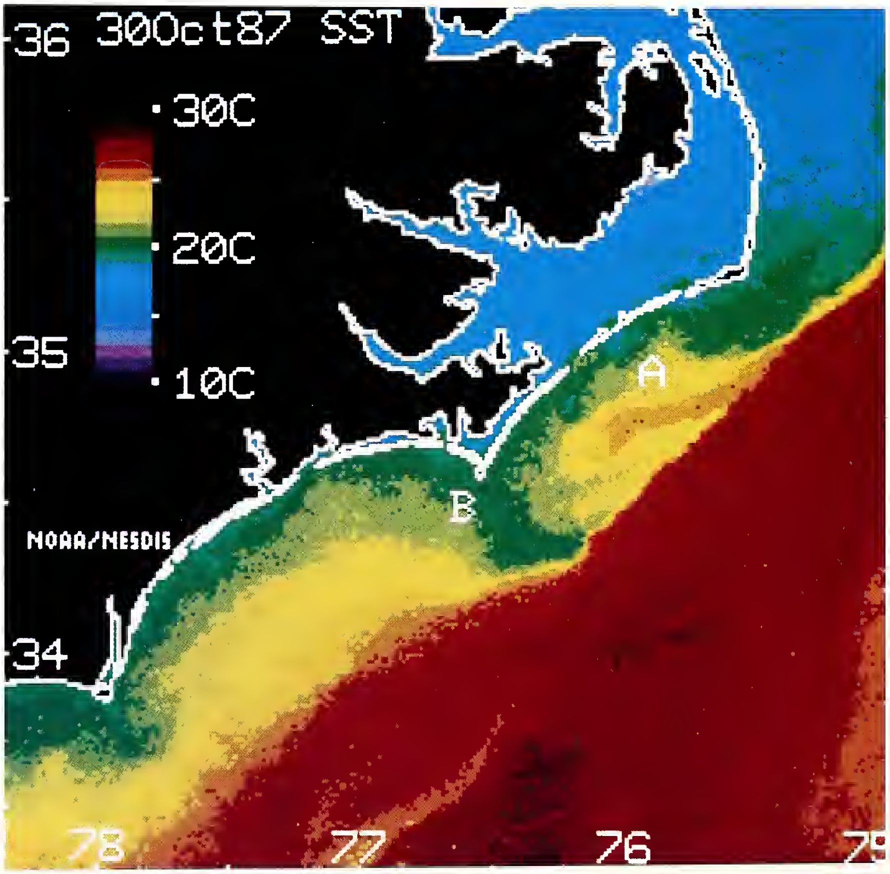
Much of the ongoing and proposed research to address the coastal ocean problems relies on similar sets of basic ocean observations. To meet these needs, NOAA is enhancing its coastal ocean observation network of ships, buoys, and other ocean platforms, and is developing the capability to acquire and rapidly disseminate remotely–sensed sea surface data. Ship support is required to deploy and service the myriad of buoys and ocean observation systems and to provide both verification and complementary data to the remote sensors. Specific research activities include nutrient–enhanced productivity, toxic chemical contamination, estuarine habitats, coastal fisheries ecosystems, physical impacts for coastal flooding, pollution transport, and global–scale sea–level change. These research efforts concentrate on the estuarine and coastal

Figure 1–3. *Ocean research must address questions about the global heat engine. Depicted here is the Great Ocean Conveyor Belt (Broeker 1987), a simplified view of the thermohaline circulation system of the global oceans. (Courtesy NOAA/OAR/Office of Climatic and Atmospheric Research)*



waters surrounding all the United States, including polar and sub-polar areas. An illustration of the interaction of these research processes is shown in Figure 1-4.

Figure 1-4. *Satellite imagery of the Gulf Stream off North Carolina on October 30, 1987. A finger of warm water which lingered off the coast is believed to have been the source of the organisms that caused a "red tide" episode. These data were complemented by surface ships' in situ measurements confirming the hypothesis. (Courtesy NOAA/NESDIS)*



Seafloor Processes. NOAA's research into seafloor processes is largely directed toward hydrothermal venting. The significance of this venting is its effect on the global chemical composition of the ocean and underlying sediments though long-term input of numerous chemical elements and dissolved gases. The global oceanic budgets of silica and phosphorous are especially important because they are micronutrients which play major roles in the biogeochemical cycles of the sea. The venting process, in the form of hydrothermal circulation, also has a global effect on the heat budget of the deep oceans. It is now estimated that hot springs and warm water vents play a significant role in cooling newly-formed oceanic crust, thus accounting for some of the earth's total heat loss. Additionally, the heat flux over a basin-long active ridge is sufficient to alter midwater circulation patterns (Stommel 1982).

Seafloor hydrothermal venting, which was discovered in the late 1970's, is now known to be a global phenomenon. However, the full range of seafloor spreading center processes and the magnitude of their effects throughout the world ocean are still in a stage of discovery. A growing number of investigations clearly show that these processes are not isolated, but are distributed throughout the world ocean. It is also clear that these processes have persisted as fundamental contributions to the chemical budgets for millions of years. Recent results suggest positive correlations between major plate motion changes, increases in seafloor hydrothermal activity, and long-term climate change. Supporting this suggestion is the discovery of large, episodic bursts of hydrothermal activity, which, in a single event, contain quantities of heat and mass equivalent to year-long continuous hydrothermal output of entire ridge segments. Figure 1-5 gives a composite sketch of the active systems at the Juan de Fuca Ridge. The spatial and temporal activity of the "megaplume" eruption is unknown, but if projected over the vast expanse of ocean ridges, then these ridge features are an even greater contributor to the ocean's chemical and heat budget than previously suggested.

Charting and Applied Oceanographic Research. The Exclusive Economic Zone of the United States totals approximately 3.4 million square nautical miles with a shoreline of 95,000 nautical miles (Figure 1-6). Within this area, NOAA is the only organization with the statutory responsibilities for and which conducts systematic marine surveys. For this area, NOAA maintains a suite of approximately 1,000 nautical charts and has compiled about 700 bathymetric maps, and these numbers are growing. NOAA also produces annual prediction tables for tides and currents in U.S. ports and harbors, tidal current charts for 13 estuaries, and has begun publishing model-generated current and water level atlases.

These data are multipurpose and important to a wide variety of users. Offshore efforts produce bathymetric maps for fishing and resource assessment, identification of geohazards, and proper management of the offshore marine environment. Important national decisions about matters ranging from energy supply to waste disposal depend on having a base of information about the physical characteristics of the EEZ. The energy industry requires such data to help in oil and gas exploration and engineering of drill sites and pipelines. The mineral industry seeks data to aid in the search for sand, gravel, placer, phosphorite, and other mineral deposits. Fishermen and fisheries managers need maps of deep water fishing grounds and need to locate areas of high biological productivity (hard or live-bottom areas). National defense requires data for submarine navigation and acoustic prediction. Basic scientific research users survey data to target more detailed studies of dynamic geological processes and fluxes through the seafloor. Nearshore bathymetric data are required for coastal zone monitoring, identification of sediment transport mechanisms, and prediction of shoreline erosion. Knowledge of bottom processes is often critical in management of hazardous material, dredging operations, and oil spills, as well as in monitoring of waste discharges and dumpsites. As in the deep ocean, surveys must gather information on sediment characteristics; sub-bottom structure and other characteristics; as well as depths, tides, and currents.

Much of these data, however, are used to support NOAA's responsibility for providing marine charts. These charts support the safety of life and property and the development of commerce. At present, 99.8%, by weight, of the U.S. international commerce is conveyed by marine transportation. In doing so, many transits are with ship drafts that exceed port approach channel depths. Due to economics of marine transportation, shipping will continue to push available depths to the limit. Accurate charts for navigation of these waters are a critical need.

The challenge is to provide products which are based on accurate data, of sufficient detail, to provide the mariner an uncompromising view for safe navigation. NOAA is held liable for the accuracy of these charts. With improvements in satellite navigation systems, manufacturers are producing products which automatically record the last half-hour of position data. This may act to increase federal liability. NOAA must respond to the needs for digital map and chart data and maintain a reasonable cycle of resurveys to maintain an accurate data base. This requires systematic data collection.

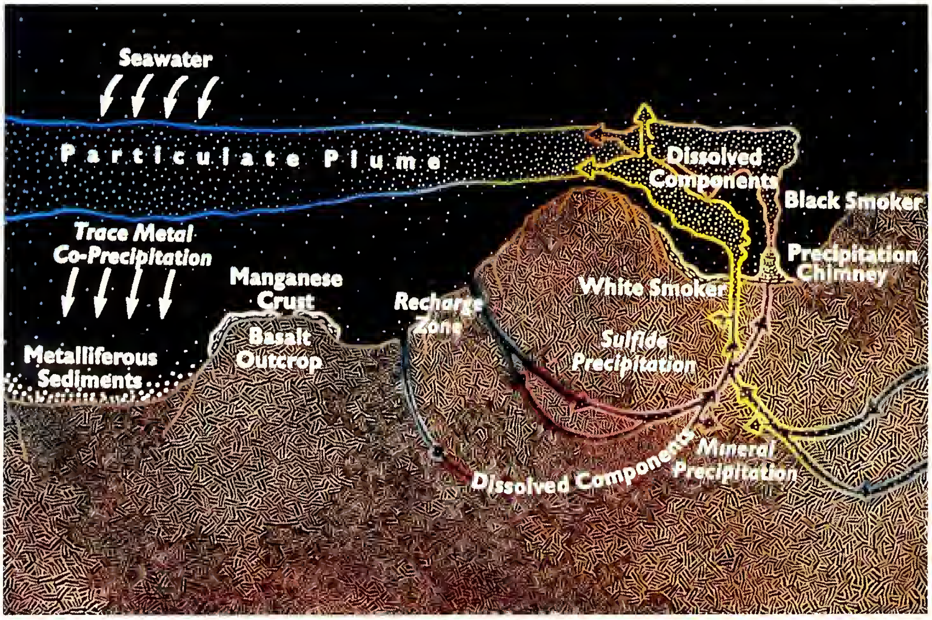


Figure 1–5. *Activity around hydrothermal vents has presented a new challenge to oceanographic research. Shown here is a composite sketch of the active systems on Juan de Fuca Ridge off the coast of Oregon. (Courtesy NOAA/OAR/Pacific Marine Environmental Laboratory)*

Figure 1–6. *A depiction of the U.S. Exclusive Economic Zone and Fishery Conservation Zone in which NOAA has sole statutory responsibilities. (Courtesy NOAA/NOS/Office of Charting and Geodetic Services)*

The Stratton Commission (1969) recommended that a cycle of resurveys be maintained at a 50–year interval, with more frequent surveys in certain important areas where seafloor change is suspected. This has never been attained. In fact, many of NOAA's nautical charts are in part based on data collected with lead–line surveys (Figure 1–7). The more significant problems associated with the old lead–line surveys is the sparsity of data which is not adequate to support computer contouring, the generally poor positioning offshore, and the lack of confidence associated with not knowing what lies between the point depths. Besides the difficulty of meeting the recommended cycle of resurveys, NOAA is constantly asked to conduct specific surveys. There are at present over 1,600 requests to support such wide–ranging interests as national defense, search and rescue, waterborne commerce, resource development, commercial fishing, and recreational boating.

The ultimate goal of NOAA's charting effort is to attain 100% bottom coverage with digital survey data throughout all coastal and estuarine areas of the U.S. and its Trust Territories. With existing technology, for the offshore area in water depths greater than 100 m, this is estimated to be approximately 185 ship years. For the inshore area, 500 ship years are estimated. Even then the survey effort to simply insonify an area is estimated to be only 25 to 30 percent of the total effort, which involves shoal delineation, wreck and

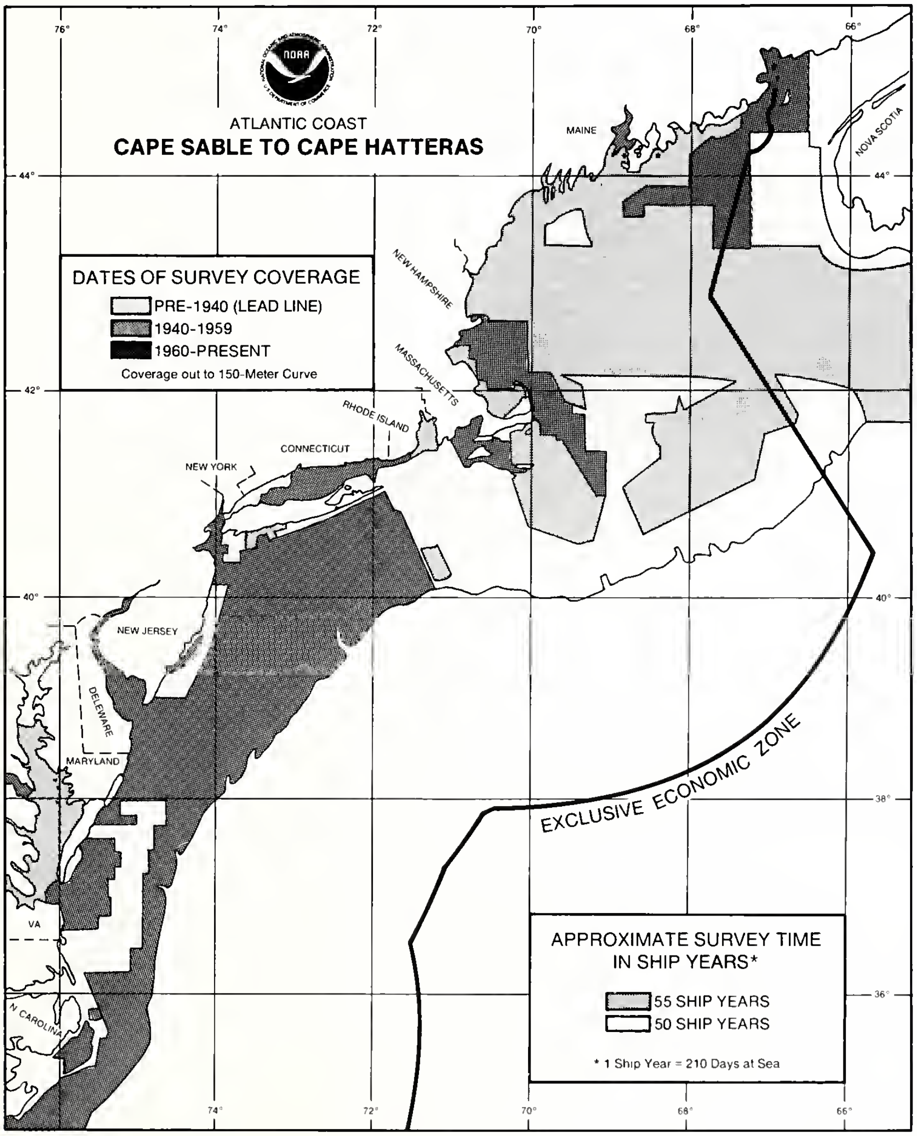


Figure 1–7. For much of the Atlantic Coast between Cape Sable and Cape Hatteras NOAA lead–line surveys continue to be the source of bathymetric data. This figure shows the dates of survey coverage and approximate ship years needed to complete the work. (Courtesy NOAA/NOS/Office of Charting and Geodetic Services)

obstruction investigation, and other aspects for a basic charting survey. In total, the effort is estimated to be 1,500 to 2,000 ship years. This is a shocking statistic; fortunately not all areas require near-term surveys, and, with new technologies becoming available, new survey approaches are expected to relieve some pressure from the survey vessels. Examples are the use of airborne laser hydrography in water depths less than 30 m and greater multibeam swath coverage than now possible. These technologies notwithstanding, the pressure on NOAA to conduct timely and accurate hydrographic surveys is immense.

Fishery Research. The scope and complexity of NOAA's research responsibilities on Living Marine Resources (LMR) is challenging. Principal goals are to improve stock assessments and knowledge of the effects of fishing and habitat degradation for better conservation and management of LMR's, and to gain better understanding of the natural processes in marine ecosystems which control LMR population changes.

A key responsibility under the Magnuson Fishery Conservation and Management Act is the regular assessment of more than 200 species of marine fish, shellfish, and mammals, most of which are included under national and international fisheries management plans either in place or under development. These exploited stocks and protected species occupy an enormous geographic area encompassing: 1) the coastal waters out to the edge of the EEZ for the U.S. and its flag islands of the Pacific, an area of more than 3.3 million square nautical miles (Figure 1–6); and 2) waters beyond the EEZ in the Gulf of Mexico and Caribbean, Gulf of Alaska and Bering Sea, and large portions of the Atlantic and Pacific Oceans. In addition, the U.S. has international treaty commitments for conservation and research on LMR's in the Antarctic, and an evolving interest in the migratory fish resources in the tropical Indian Ocean.

Each assessed stock requires collection and analysis of a wide array of information including catch statistics and data on abundance, population composition, and distribution. For exploited species, these data are analyzed to make short-term predictions of surplus stock available for near-term harvest, and to document the statistical relationship between sustainable, long-term, harvest levels and exploitation rates. At present, these activities make large demands on NOAA vessels in terms of days at sea, with an increase projected to achieve more accurate assessments and the assessment of additional species. Compounding ship requirements is a growing need for conservation engineering studies to develop new commercial fishing gear for reducing incidental catch of high value fish species, particularly pre-recruit sizes, and other marine animals such as porpoises and turtles; and for measuring gear selectivity biases of the standard stock-assessment sampling gear.

Although resource assessment is essential for meeting mandates related to conservation and management of LMR's, it is by itself not sufficient for predicting long-term effects of environmental and man-induced changes on LMR's. Other critical types of research are those directed toward the natural processes which control harvest potentials and population fluctuations in marine ecosystems. These include: 1) recruitment processes which involve the relative importance of physical and biological mortality mechanisms in early life stages and development of better yield forecasts; 2) predator-prey interactions involving both juvenile and adult fishes and other components of the food web as a basis for developing models of the long-term effects of different harvest strategies on aggregate fish production; 3) density–dependent, population–control mechanisms (affecting growth, age–at–maturity, fecundity) which exert fundamental control over the relation between sustainable production levels; and 4) dynamics of lower trophic levels production. Each of these process–oriented studies is critical to a better understanding of the dynamics of marine ecosystems, which in turn serves as a basis for modeling potential long–term effects of nature and man.

Simultaneously, it is necessary to monitor the state of the natural marine ecosystems supporting LMR's (e.g., changes in species composition of lower trophic levels) as a framework for helping interpret results of process studies. Complementary research involves marine paleoecology to establish an empirical "historical" basis for helping predict effects of long–term, climatic changes on LMR's. Although important advances are being made in these areas, progress must be accelerated significantly to develop adequate predictive capability.

Of comparable research interest is the impact of habitat degradation on productivity, especially that of major coastal fisheries. The problem of integrating multiple mortality factors, which includes those of natural and anthropogenic origins, into an overall fish production model is quite complex, and will require a concentrated series of experiments and monitoring of contaminant loading.

Achieving these goals will require a greatly expanded array of monitoring and research activities by modern NOAA vessels equipped with new technology. To meet increasing demands on NOAA's studies related to fishery management, greater versatility is required of the vessels and a significant increase in ship days is projected.

Summary of Mission Requirements Identified in Phase I

As identified by the Phase I working groups, there are several trends in NOAA's mission which impact vessel characteristics. The impact is not constant between programs or between types of vessels. What is required on certain large vessels primarily supporting multidisciplinary research is not necessarily required on smaller ships engaged in nearshore charting or estuarine research activities. The following chapters address these mission requirements in detail and also identify specific vessel criteria. However, for the purpose of the Executive Discussion only, brief descriptions of these requirements are presented. These cover a broad spectrum but, in general, can be grouped as: 1) increased operation in progressively more remote areas; 2) a greater emphasis toward multidisciplinary research; 3) enhanced sample collection and storage; 4) productivity; 5) continuous collection of a larger spectra of environmental and physical data; and 6) enhanced communication.

1. Remote Operation. Global climate research will expand into the western Pacific basin, the Southern and Indian Oceans, and the Norwegian and Greenland Seas. Charting and mapping will expand to include the U. S. Trust Territories in the central and western Pacific Ocean. Assessment of certain over–exploited, migratory fish may require voyages into all parts of the Atlantic, Pacific, and Indian Oceans. Global climate research, fishery oceanography, and living–marine–resource assessments will require more frequent and longer cruises to be made to the polar and sub–polar regions, the Arctic (global climate studies), and Antarctica (stock assessments). In high latitudes, there will be increased pressure to work for a greater portion of the year and on some occasions to work further into the ice.

For the larger vessels, these remote operations will require ships capable of long endurance (up to 60 days), range of 15,000 nm, and carrying large science payloads [i.e., 15 ocean moorings, one or more remotely-operated vehicles (ROV's), 30 meter spar buoys]. All size vessels, however, will require greater endurance and longer range than generally available on NOAA ships. To ensure maximum utilization of station time these vessels must be able to operate in higher sea states than now possible with less risk of injury to personnel and loss or damage to equipment. At least one vessel needs to be able to operate within the ice (ice-capable, but not an icebreaker).

2. *Multidisciplinary Research.* In the areas of global climate, fishery oceanography, and coastal ocean programs, the research efforts are becoming progressively process-oriented. The processes which drive phenomena as diverse as climate, nearshore circulation, and fisheries recruitment are quite complex, encompassing components of several science disciplines. The roles of biology, chemistry, physics, and geology in influencing global and regional oceanic circulation patterns, which in turn influences climate, have yet to be fully understood. Likewise, the understanding of climatic variability and circulation patterns on fishery recruitment processes is in its infancy. This complexity requires multidisciplinary research efforts. Within various disciplines, such as biological and chemical oceanography, several specialties are often involved. In order to support the wide-ranging research requirements the vessels must be able to berth large numbers of scientists. Dedicated analytical laboratories to support multi-disciplinary research must be much more sophisticated and varied for specific analytical functions than now exist on NOAA ships. Also the laboratories and deck equipment must be sufficiently flexible and versatile to accommodate a variety of science requirements.

Flexibility for the laboratories should be achieved through interchangeable modules rather than vans or containers. These modular laboratories should mate with the ship structure in a way that provides for inside passage and complete communication including access to the ship's navigation, systems status, and data input via local area networks. The modules should be standardized to be easily transportable by air freight. Versatility can be achieved through the use of structural inserts which will provide means of easy rearrangement of the laboratory. Deck equipment should be interchangeable through standardization with a deck grid of hold-down bolts.

3. *Enhanced Data and Sample Collection/ Storage.* With the advances in remote-sensing technology, these tools are being used in more varied and more demanding sampling protocols. Future research envisions even greater use of this technology, especially ROV's, *in situ* bottom instrumentation, and sophisticated buoy systems (Figure 1-8). The ROV's can provide access to otherwise inaccessible areas, such as beneath the polar ice and spreading center venting features. *In situ* instrumentation will provide much-needed time-series data. Ship capabilities need to be upgraded to more efficiently deploy and recover these instruments and to better monitor the position and control the operation of ROV's.

Another aspect of enhanced sampling is precision station-keeping and speed control. Especially in the study of seafloor processes and around ocean fronts, the importance of precisely maintaining the ship's position is assuming even greater importance. With the development of the Global Positioning System (GPS), real-time navigation is now

Figure 1–8. *NOAA's ocean fleet of the future will need the capability to deploy and monitor remotely operated vehicles (ROV's). Here an ROV used in NOAA's Undersea Research Program is shown alongside a sensor. (Courtesy NOAA/OAR/Undersea Research Program)*

sufficiently exact to permit the required positioning. What is needed now is computer control of thrusters and main propulsion systems to fully utilize the GPS data input. Precise speed control at slow speeds for prolonged periods of time is required for tracking ROV's or tagged marine animals, and for fine tuning the shape of bottom and mid–water trawls.

The sophistication of analytical tools now permits elucidation of chemical and biological parameters which a few a years ago were thought impossible. Unfortunately, with rare exceptions, this sophistication has not been incorporated into a real–time sampling while at sea. Furthermore, for certain chemical and biological species, without real–time processing, valuable data are lost. Depending on size, the vessels should be equipped with some or all of the following analytical facilities to perform these analyses: environmentally–isolated laboratories; input from a wide spectra of environmental data; ability to process large volume of samples, precise temperature control in the range of −25 to −2°C, − 2 to +5°C, +5 to +25°C; ultra clean facilities; "clean" power; and onboard production of liquid nitrogen and oxygen.

With the developments in hydroacoustics, acoustically–quiet vessels are required for fish finding, bottom profiling, side scanning, or bathymetric surveys. Present systems can be grouped into several frequency ranges:

- Sub–bottom profiling -- nominally 3.5 kHz but more advanced systems range from 2 to 10 kHz
- Echosounding--12 kHz for deep ocean systems but often higher frequencies (up to 200 kHz) in shallow water
- Acoustic positioning and communication with sub–sea instruments and remote vehicles--range from 15 to 50 kHz with lower frequencies used in deeper water for longer range but requiring larger arrays
- Water–column characterization--typically in the 100 to 300 kHz range for current measurements, biological scattering layer, biomass estimation, and suspended sediments

Vessels must be designed to accommodate these systems. Machinery should be installed so as to minimize interference due to radiated or structure–borne noise. Hull shapes and propulsion must be designed to avoid disruption to acoustic sensors due to noise, bubble sweepdown, or other phenomena. Access to transducers or transducer spaces without the ship going into drydock is needed.

4. *Productivity.* All programs seek to maximize productivity. For those ships engaged in charting and mapping activities this can be accomplished through broader swath sonars, and eventually, through the use of remote vehicles. Vessels capable of faster speeds, both during transit and surveying, are needed. Furthermore, the ships must be designed so that personnel and equipment can continue to operate over a broad range of weather conditions. Automation and remote monitoring systems need to be incorporated in ship designs to reduce crew manpower requirements. In terms of design, the ships should be able to operate for greater portions of the year, both in terms of increased number of sea days and an extended field season.

5. *Continuous Collection of Data.* The working groups recognized the importance of continuous collection of environmental and physical data on a routine basis. The environmental data, collected, and transmitted in near-real-time, serve two major functions: input into global and regional oceanic and atmospheric circulation models and verification of earth-observing satellites. Physical data, whereas not required in near-real-time, are used for a multitude of solid-earth studies and provide important collaborative input to satellite data.

Ship observations provide the only surface data over large portions of the earth. For these data to be effectively incorporated, the environmental and physical parameters must be collected digitally on a continuous basis. Required data streams include:

Positioning: X, Y, and Z

Meteorological: Relative Humidity, Short- and Long-Wave Insolation, Visibility, Water Vapor

Water Column: Directional Wave Spectra, Ocean Skin Temperature, Surface Temperature/Salinity, Chlorophyll, Oxygen, Subsurface Current Shear, Mixed Layer Depth, Particulates, Biological Scattering Layers

Ocean Bottom: Swath Bathymetry, Shallow Sub-Bottom, Magnetic Field, Gravity Field

At present, none of the NOAA ships provide these required sensory data on a continuous basis.

6. *Enhanced Communications.* Communications falls into three categories. These are:

Internal communication into and between science spaces including van, key working areas, and selected science staterooms; in addition to high quality voice, the communication should include real-time transmission, monitoring and recording systems of all data, closed-circuit television monitoring and recording of working areas, and monitoring of ship control, environmental parameters, and over-the-side equipment performance.

External communication to include high-speed data transmission to shore laboratories and other ships on a continuous basis, high-speed graphics and hard-copy text, and reliable voice channels.

Satellite monitoring to receive readouts of environmental remote sensing.

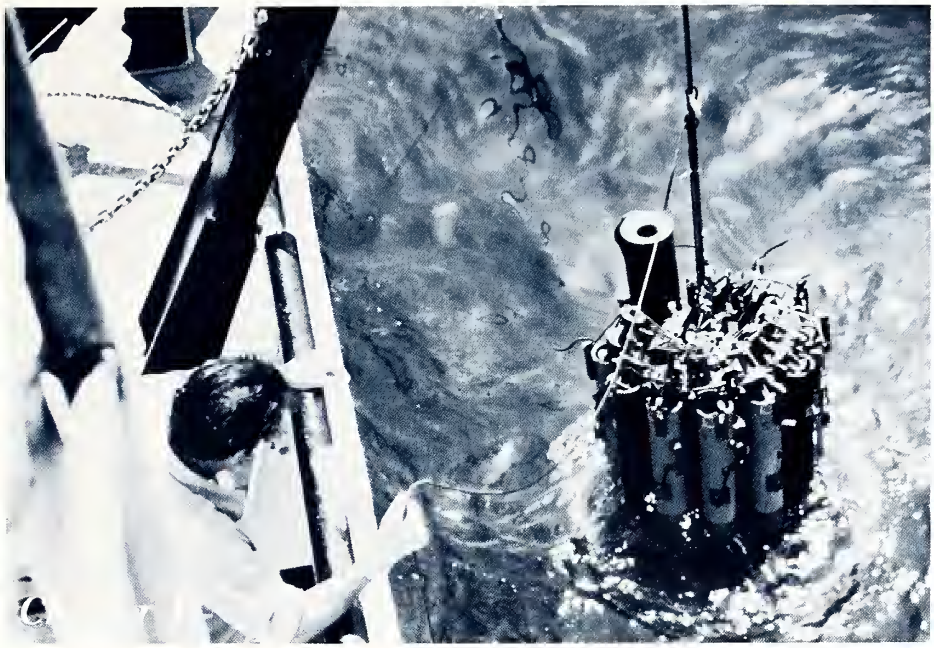
References

National Research Council. Committee on Alternative Strategies for Obtaining Ship Services. **Strategies for Obtaining Ship Services: Alternatives for NOAA.** Marine Board Commission on Engineering and

Technical Systems, National Research Council, 100 pp., National Academy Press, Washington, DC, 1988.

Office of NOAA Corps Operations June 1989. **Ships of the NOAA Fleet.** U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 100 pp.

Stommel, H. 1982. "Is the South Pacific Helium-3 Plume Dynamically Active?" **Earth and Planet Sci. Lett.** 1G1/G3-G7.



Oceanographic Research and Monitoring

In the 20 years since NOAA's organization in 1970, the need for ocean research related to our understanding and predicting the environment has become critical. The threat of global warming, the degradation of the coastal ocean, and the significance of seafloor spreading centers have underlined the need for improved knowledge of oceanic processes. The future quality of life on earth is, indeed, clearly linked to our ability to understand the oceanic processes that impact environment and to our ability to predict, modify, and control them. As our need to understand has increased, so too has the atmosphere in which research is conducted been enhanced. Today's ocean science is increasingly dominated by global dimensions, multidisciplinary approaches, and high technology.

Background

Oceanographic research within NOAA will progressively emphasize long–term monitoring so as to better understand processes affecting the environment. Phenomena on almost all space scales, from the smallest to global, will be increasingly emphasized in these efforts. This will place extreme demands on sampling abilities, the need for rapid transfer of data, and the ability to synthesize the various data sets in close–to–real–time. It is clear that various classes of oceanographic and meteorological models will play a central role in synthesizing this information. It is also evident that remote sensing is essential to providing high–resolution data on global scales. Despite the rising importance of the use of numerical models and remote sensing, shipboard sampling will continue to play a vital role. Rather, the need for complementary shipborne measurements will increase as the total research effort increases in both volume and diversity. At the same time, nontraditional methodologies not directly based on board ship may place significant new demands on the ship and its equipment, e.g., in instrument deployment and *in situ* calibration procedures. To determine how best to modernize the NOAA fleet in order to meet these science requirements was the task of the Oceanographic Research and Monitoring Working Group.

Activities of the Working Group

The Oceanographic Research Working Group represented a cross–section of government and academic oceanographers from several research specialties. It included scientists conducting research in areas of physical, chemical, biological, geological and satellite oceanography, and those active in climate modeling. Within this diverse group, geographic research interests spanned from equatorial to high latitudes, from deep ocean to coastal and estuarine provinces. Common to all participants was ocean–going experience, an awareness of the current direction of their research interest, and a feel for the future direction of their research within the scope of national priorities. From this rich experience and interest, the participants were able to envision the direction of oceanography, especially within NOAA's mission for environmental prediction, for the next decade. Barring an unforeseen scientific revolution or an unpredicated quantum leap in technology advancement, their insight is valid into the next century.

The Working Group was unanimous in the view that the next few decades will witness an increasing role for ocean remote–sensing from satellite platforms and a concomitant impact of satellite data analyses on new knowledge of the ocean. This will couple directly with the long–term and large–scale research being conducted to understand global change and climate processes. Ocean remote–sensing, however, will not make the surface platform obsolete. On the contrary, a balance of orbiting and surface platform observations are needed for a rigorous ocean sampling strategy to support climate monitoring, process–oriented analysis, and modeling.

While satellites can provide globally synoptic surface measurements, ***in situ*** observations are needed to measure the deep circulation, vertical structure, geochemistry, biological and other variables not observable from space. It may even be safe to predict that an increasing need for complementary ***in situ*** data will accompany the growing wealth of satellite data over the next few decades.

The Working Group examined the oceanographic science needs from the aspect of three program areas: Climate and Global Change, Coastal Ocean, and Seafloor Processes. Of these, Seafloor Processes, as defined in NOAA's programmatic mission, can be argued as falling into either of the other two categories. The Working Group felt, however, that seafloor processes, as addressed by NOAA's VENTS program, is sufficiently unique from the other two categories to warrant being viewed separately.

In preparation for a workshop the members wrote position papers. As a focus for this exercise, each working group member was asked to address a series of questions which when assimilated would provide an overview of the expected research in the areas of Global Climate, Coastal Oceans, and Seafloor Processes. Their views are reflected in the sections which follow.

Current Mission Requirements

Climate and Global Change. Developing an understanding of and the ability to predict global environmental changes, and particularly, global climate change, has been one of the major forces driving interest in ocean programs over the last several years. The role of the ocean in climate change is recognized as one of the central uncertainties in our ability to project future climate change and is thus one of the highest priorities in the both the NOAA Climate and Global Change Program and the U.S. Global Change Research Plan. Understanding and forecasting climatic change requires an understanding of the processes of heat, moisture, CO_2, and momentum exchange between the ocean and atmosphere as well as the large–scale transports of heat within the atmosphere and ocean.

NOAA's ocean climate research program conducts studies of both local and basinwide ocean dynamics and the coupled ocean–atmosphere circulation, with the goal of determining the physical mechanisms that generate anomalies in sea surface temperature (SST) distributions in the tropical and polar ocean. A crucial step is to develop and validate ocean circulation models that are capable of simulating the evolution of globally important events such as El Niño or to predict global climate.

To achieve NOAA's Climate and Global Change goals there is no substitute for actual ship observations. Accurate time–series records have several functions in the global change research program. These warn of natural and man–induced changes, signal the existence of previously unexpected phenomena, and provide observational tests of the ability of models to explain the global system. Without such an approach prediction will not be possible.

Coastal Ocean and Great Lakes. The coastal ocean from a depth of 100 m on the continental shelves and all shallower depths to the heads of estuaries contain the vast majority of the valued commercial, recreational, and aesthetic resources of the sea. The quality of our coastal environment and marine resources is declining. We must restrict where we swim and the fish and shellfish we eat. We are losing important coastal habitats and coastal property at alarming rates. The management of complex fisheries with conflicting interests is increasingly difficult.

These problems and others are formidable, but they are not insurmountable. NOAA, through several focused programs, is providing leadership and support to the overall national effort to provide cleaner and safer environments, sustainable and wholesome fisheries, and coastal communities whose citizens are forewarned about storms, flooding, and erosion. NOAA's program will be undertaken in concert with other ongoing federal, state, and local programs.

NOAA's coastal ocean programs are designed to make effective environmental decisionmaking possible by supplementing current retrospective analyses with timely forecasts and prediction. The ability to predict environmental change will allow us to prevent problems and exploit opportunities through proactive regional approaches, rather than only monitor and react to runaway problems. Providing decisionmakers with useful predictions of environmental change -- change caused naturally, as well as by society -- is the goal of these programs.

NOAA is integrating its base programs to focus its talents and capabilities on reaching the following goals: prediction of coastal ocean degradation and pollution, conservation and management of living marine resources, protection of life and property in coastal areas.

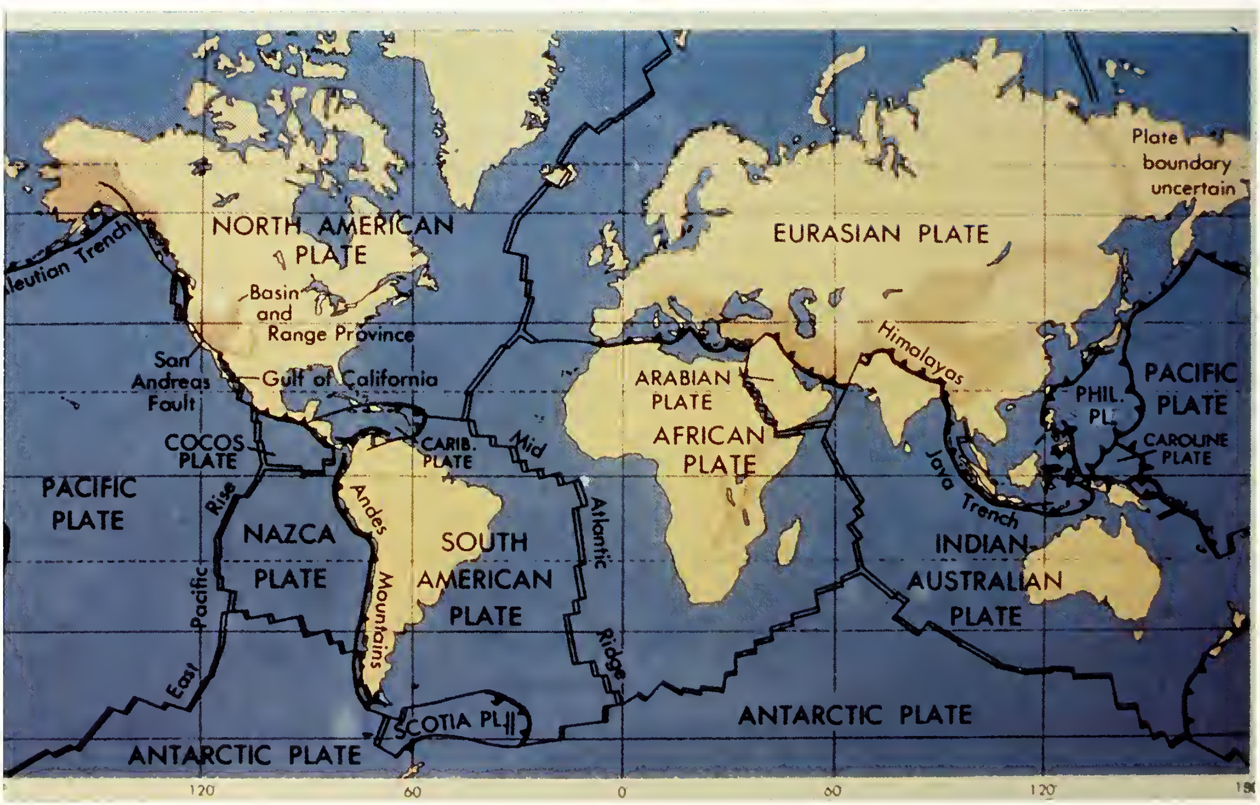
Seafloor Processes. NOAA's principal effort in this area is in the VENTS program. Hydrothermal venting, now known to occur along the entire global seafloor spreading–center system, is a significant contributor to the heat and mass budgets of the ocean (Figure 2–1). In order to quantify, and eventually predict, the thermal and chemical oceanographic consequences of venting, the VENTS Program is engaged in a multidisciplinary effort to 1) determine the effects and fate of hydrothermal mass and heat on seawater through geochemical studies; 2) determine the physical oceanographic processes whereby hydrothermal heat, chemicals, and gases are distributed throughout the ocean; and 3) determine conditions that control the location, style, and duration of active venting through geological and geophysical studies. From these studies a better understanding will evolve of the role hydrothermal venting plays in global climate change.

Future Research Directions

Climate and Global Change. The ocean's role in global climate change must first be understood before progress can be made in the prediction of climate. The vast heat capacity of the ocean and its ability to take up large amounts of atmospheric carbon dioxide will certainly influence the timing and extent of global warming. For this reason, studies of ocean circulation and heat flux and of biosphere/atmosphere/ocean fluxes of trace species are among the highest priorities in global climate change research. The various components of this research are described below.

Tropical Ocean/Global Atmosphere (TOGA). NOAA research into the role of the oceans in climate change began with the study of the El Niño/Southern Oscillation (ENSO) phenomenon in the Pacific Ocean. Recognition of the importance of ENSO to year–to–year changes in the global climate

Figure 2–1. *A major area for NOAA research in the future will be concerned with quantifying the phenomena associated with hydrothermal venting along seafloor spreading centers. Shown here are the junctures between the lithospheric plates of the earth. Such junctures are the sites of active venting and volcanism. (Courtesy Department of Interior/USGS)*

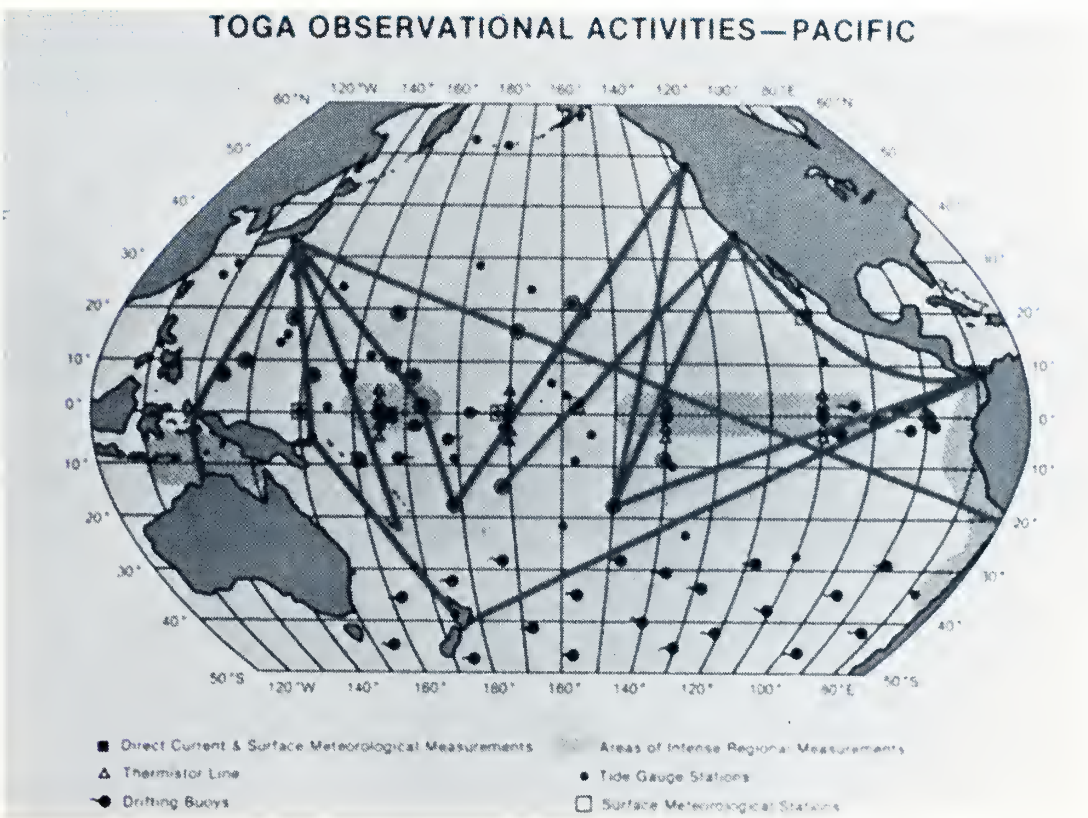


has led to continued focus on this problem. In many ways ENSO research can be considered to be an example of a mature climate study. Numerical General Circulation Models (GCM's) are now able to simulate, reasonably well, the tropical ocean response given the atmospheric forcing and the atmospheric response given the ocean sea surface temperature (SST). Progress on improving the models requires improved measurements for data assimilation and model validation.

A major thrust of the Tropical Ocean/Global Atmosphere (TOGA) research in the next 10–15 years is the development of a real–time, long–term, ocean–observing system. Providing requisite data for ENSO forecasting is the primary motivation for development of this system. NOAA has undertaken a long–term commitment to maintain a gridded network of moored buoys in the equatorial Pacific [the TOGA Tropical Atmosphere–Ocean (TAO) array (Figure 2–2)] to measure wind speed, humidity, and atmospheric and upper–ocean temperature. It is considered likely that such buoy technology may be expanded to other areas of the global ocean.

Specific, shorter–term process studies will continue, but these will be embedded in the long–term observing array. One such program is the Coupled Ocean–Atmosphere Response Experiment (COARE), which will examine the mechanisms controlling the growth and decay of the warm pool of the western equatorial Pacific. As the research emphasis expands to include interdecadal climate variability and climate change, the role of the deep equatorial circulation becomes more critical. In addition, the interaction of the air–sea exchange and

Figure 2–2. *Schematic of NOAA's Tropical Atmosphere–Ocean (TAO) array, a system of moored buoys in the Pacific Ocean that predict ENSO–type activity. This array, which is deployed and serviced by surface ships, measures wind speed, humidity, and atmospheric and upper–ocean temperature. (Courtesy NOAA/OAR/Office of Climatic and Atmospheric Research)*



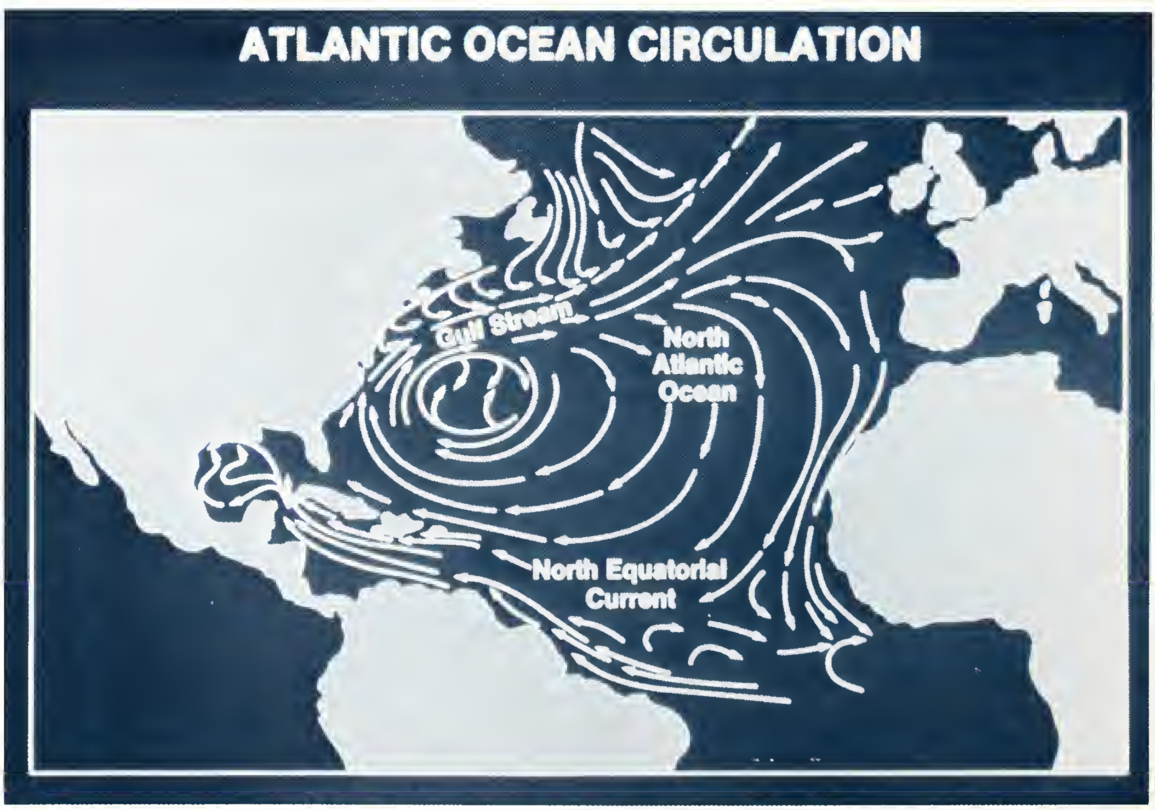
oceanic circulation of CO_2 and trace gases will require development of joint physical and chemical oceanographic and atmospheric studies. Examples of this research are the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS), which are already underway, and the plans for NOAA's Climate and Global Change Program.

Atlantic Climate Change. The interaction between the large-scale, meridional circulation of the Atlantic (Figure 2-3), sea surface temperature, and global climate has been a particular focus of scientific interest over the last several years. A Science Plan to address these issues has been drafted, and it is apparent that the Atlantic, particularly the North Atlantic, will be an area of considerable field effort over the next one to two decades.

Polar Studies. Increasingly, a component of global climate and climate change is being focused toward polar regions. Since the polar regions play a unique role in the workings of the planet, this trend is likely to continue. For example, the ventilation of the deep and intermediate world ocean is driven from high latitudes, and the mechanisms appear to be both complete and highly variable. Also, the stability of the circulation in polar regions is questionable.

Shipborne, high-latitude research efforts by the United States have in the past been almost entirely limited to the polar margins, and they have also been primarily conducted during the summer and fall, when conditions for navigation are most favorable. This is not a desirable state, since many of the most important scientific issues require

Figure 2-3. *NOAA research vessels are playing a large part in the worldwide investigation of Global Climate Change. Depicted here is large-scale meridional circulation in the Atlantic Ocean. This circulation is the mechanism for low-to-high-latitude heat transfer. (Courtesy NOAA/OAR/Office of Climatic and Atmospheric Research)*



measurements within the ice pack and during the cold seasons. Our present situation is, in fact, a prime example of science being driven by logistics, in this case, in a highly limiting way. As a result, our Nation's marine scientists have increasingly been forced to work from more–capable foreign vessels, particularly those of western European nations, but also Canadian and Soviet ships. In this situation, our overall scientific capabilities will be increasingly vulnerable, and our choices of scientific problems and geographic areas in which to work will be limited. Significant improvements in the ability of the research fleet to operate within the ice and during cold and stormy weather are required.

Tracer Studies. Monitoring of the distribution of oceanographic tracers such as chlorofluorocarbons (freons), carbon–14, and tritium is the only practical way to describe the ocean's response to (and interaction with) climate change on long time scales. These tracer fields are essential for comparison to the output of coupled ocean–atmosphere models. Interpretation of these fields is difficult without a broad array of sophisticated oceanographic observations of temperature, salinity, and nutrients.

Ocean Flux Studies. The flux of radiatively–active species to and from the ocean, particularly carbon dioxide, is a major issue in global change research since the ocean is a central component of the global carbon cycle (Figure 2–4). As such, a major goal of chemical oceanographic research will be to determine biogeochemical cycles and budgets over extended spatial and temporal scales. Programs to address these issues, including the JGOFS and NOAA Ocean Carbon research programs, are envisioned as lasting through the next decade and will require that large data sets be incorporated into general circulation models. In the next 10–30 years, chemical oceanographers will strive to increase the data flow to approach a more nearly global coverage by employing improved instrumental capabilities and increased numbers of shipboard analyses (as opposed to storing samples for analysis at shore–based laboratory facilities). In addition, the increasing specialization of the chemical oceanographic disciplines implies progressively more sophisticated ship analysis.

Marine Atmospheric Chemistry. Atmospheric dynamics as well as chemical and photochemical processes determine the global distribution of climatically–active trace species. Marine atmospheric chemical research will be aimed at developing a thorough understanding of the fundamental processes controlling global tropospheric biogeochemical cycles. These processes include marine sources and sinks of atmospheric species, their long–range transport and distribution, their transformations, and their removal mechanisms. This research will require observational programs in remote oceanic regions for extended periods of time, and will involve the deployment of global observational networks as well as intensive, multidisciplinary experiments in critical air–sea exchange regions.

Air–Sea/Upper Ocean Parameters. The launch of large numbers of multiparameter sensors in the 1990's on such satellites as ERS–1, TOPEX, SeaWIFS, ADEOS and the EOS platforms holds the potential for production of global, near–synoptic ocean fields of sea level, wind stress, and ocean color. Existing operational satellites also provide measurements of sea surface temperature and sea ice extent and concentration. However, a carefully–implemented ocean–observing network will require a balance of remote and *in situ* sensing. There will be a corresponding role for quality shipboard, moored buoy, and drifter observations to serve two obvious

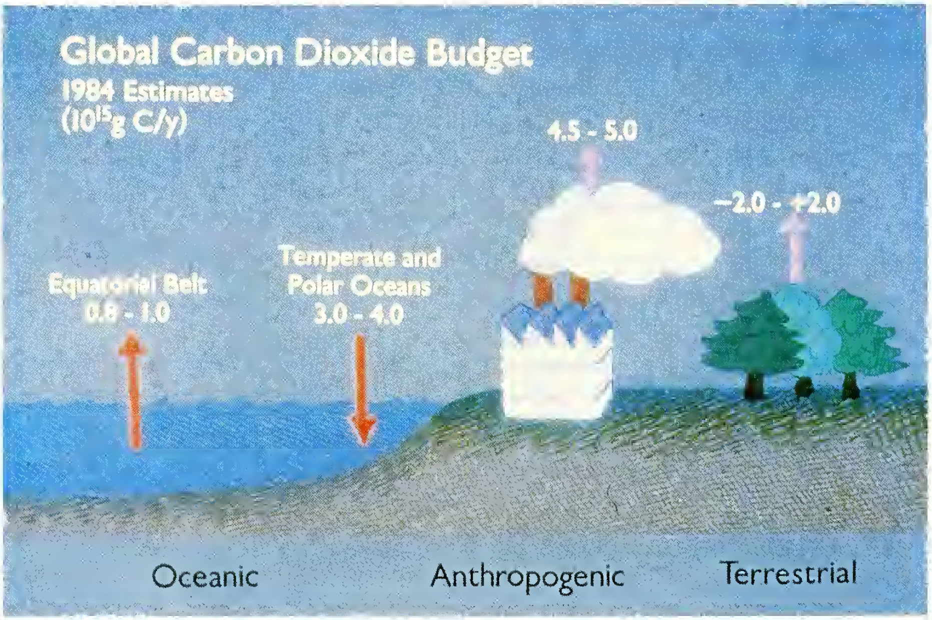


Figure 2–4. *The oceans are increasingly being investigated for their role in absorbing global carbon dioxide. NOAA vessels will continue to collect data for use in chemical oceanographic research and circulation models to support our understanding of the global carbon dioxide budget. (Courtesy NOAA/OAR/Office of Climatic and Atmospheric Research)*

needs: 1) to provide high–quality data for validation and calibration of the satellite measurements, and 2) to furnish complementary data which remote sensors cannot provide.

These data are envisioned to be collected by spar buoys with meteorological towers at least 10 meters high, so as to obtain wind shear profiles. The subsurface elements will be thermistor/conductivity chains extending to the bottom where an anchor/instrument package will keep the unit on station and measure bottom pressure. Optical sensors over a range of one optical depth are required; optical depths in deep water are typically 100 m. Other sensors will undoubtedly be placed on the spar buoys; these buoys will possibly achieve lengths of 30 m or more and delicate instruments will be on both the buoy and mooring cable. Due to their remote location the buoys must be deployed, recovered, and serviced by research ships.

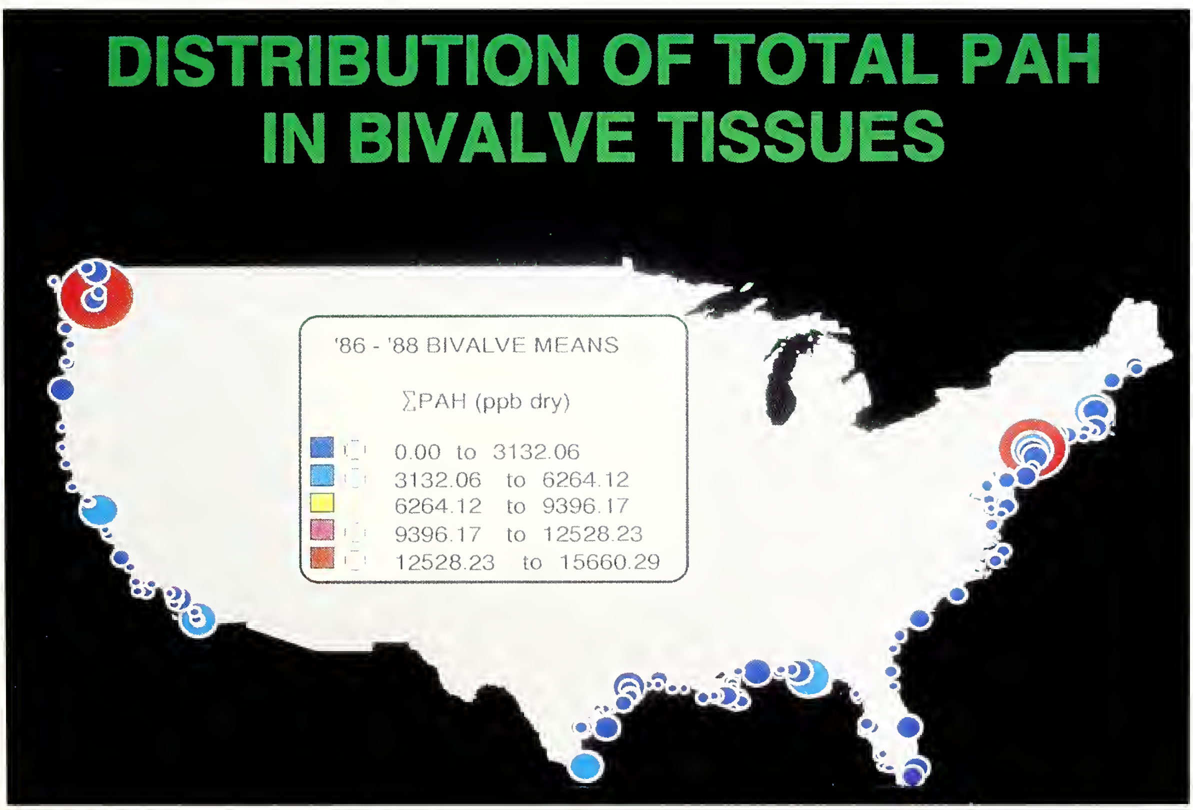
Coastal Ocean and Great Lakes. There is growing evidence that coastal ocean environments, on a global basis, are deteriorating. Visible examples leading to this perception include the closing of U.S. east coast beaches because of garbage and discarded medical supplies washing onto the beaches, banning of several popular sport fisheries in the 1980's, large mortality of bottlenose dolphins along the east coast, ocean outfalls and sewage dumping, closing of numerous shellfish beds (Figure 2–5), and several major oil spills.

As a consequence of this perception, there is a growing need for better technical information on the state of, and changes to, our coastal environment. Rather than focus on separate aspects of the problem, the emphasis of future research will be on the "whole ecosystem function" studies which, when appropriate, will be incorporated into global problems. This is the function of NOAA's Coastal Ocean Program (COP). Examples of NOAA efforts which, to varying degrees, fall under the umbrella of the Coastal Ocean Programs are research addressing ocean margin enrichment and environmental degradation [Nutrient Enriched Coastal Ocean Productivity (NECOP)] and in fishery recruitment (GLOBEC, FOCI). Other examples are the time–series monitoring achieved through NOAA's Status and Trends Program and Mussel Watch. Such monitoring is quite valuable in judging whether protective or restorative steps are warranted or are effective.

Central to these studies is the environmental condition of the coastal oceans, especially as it affects the living marine resources (LMR's). Particularly important to the living resources is recruitment of both fish and shellfish. Three main factors affecting recruitment are suitable spawning habitat, trophic conditions which permit survival in the face of starvation and predation, and transport of surviving eggs and larvae from the spawning grounds to areas where they can develop. Research on eggs and larval transport and the relationship of variability in the coastal oceans, both natural and man–induced, offers the most promise in understanding the recruitment process.

The ultimate goal of research is that the coastal ocean may be viewed as twofold: protect the environment and maximize the long–term yield obtainable from living resources. Essential to both is prediction, possible only through multidisciplinary research and monitoring activities. Even where prediction capabilities are still at early stages of development, coastal ocean research is critical to ocean resource managers by partitioning variation in resource production into understandable components, e.g., variability caused by physical dynamics, biotic interactions or large–scale climatic fluctuations, etc. This objective implies an effort to better understand the fundamental

Figure 2–5. *NOAA's research fleet collects data for the agency's Mussel Watch Program which measures the amount of contaminants in bivalve tissue at various survey sites along the U.S. coasts. Depicted here is the distribution of polynuclear aromatic hydrocarbons (PAH) found in a recent survey. (Courtesy NOAA/NOS/Office of Oceanography and Marine Assessment)*



linkages between population variability and the physical environment; which in turn implies utilization of the theoretical and technical advances being made within the wider oceanographic community.

Of growing interest in coastal ocean research is that of polar and subpolar regions. On a regional basis, issues common to most areas of the U.S., e.g., relating to resource harvest and extraction, environmental protection, and transportation, loom large for the foreseeable future. In fact, with the Arctic Research and Policy Act there will be increased emphasis on arctic research involving several federal agencies.

Seafloor Processes. NOAA's research concerning seafloor processes over the next 10–30 years will be primarily focused on determining the oceanic chemical and thermal effects of hydrothermal venting along the global system of seafloor spreading centers. At present, only a very small percentage of the global seafloor spreading–center system has been studied in any detail in terms of hydrothermal venting. However, from this limited investigation, hydrothermal–venting processes are now known to function as both important chemical sources as well as chemical sinks, particularly for elements that are important in oceanic biogeochemical cycles. The oceanic impact of hydrothermal heat is not yet well understood but may be a significant driving force for intermediate–depth ocean circulation. Assessing these oceanic impacts constitutes NOAA's role in hydrothermal research. In addition to NOAA's research, several other federal agencies have complementary active research programs addressing hydrothermal processes. These include the National Science Foundation RIDGE program with a major emphasis on deep–earth volcanic and magmatic processes; the U.S. Geological Survey support of hydrothermal research focusing on hard mineral resources associated with hydrothermal precipitates; and the Navy's several programs involving spreading centers and hydrothermal research, notably efforts in seafloor monitoring instrumentation and acoustic–image processing and enhancement. Each of these research programs is expected to continue into the next century, and NOAA will be a key player in this interagency effort to understand seafloor processes.

A NOAA mission over the next 10–30 years in the area of seafloor processes will be to conduct bathymetric, geophysical properties (gravity, magnetics, and reflection seismology, heat, and transmissivity), and chemical oceanographic surveys at key spreading center locations. For the next several years, there will be a critical requirement for ship–based reconnaissance as well as detailed surveys to continue ongoing–time series physical and chemical studies of active hydrothermal regions on the northeast Pacific, the Mid–Atlantic Ridge and possibly one or two other locations on the northern East Pacific Rise.

Geographic/Seasonal Considerations

Climate and Global Change. In projecting demands for global–scale oceanographic studies, it is difficult to rule out any part of the global ocean. For example, the WOCE Hydrographic Program will make extensive hydrographic tracer measurements in the Pacific Ocean over the next several years, followed by a measurement program in the Indian Ocean. The Indian Ocean is relatively poorly explored, especially in terms of long time–series, *in situ* observations. The TOGA Program and its subsequent observational network will ensure a high degree of activity in the tropical Pacific for as far into the future as we can project. The Atlantic Climate Change program will have an emphasis on the high northern latitude regions of deep water formation. This emphasis, which may quite conceivably extend to high southern latitudes in other programmatic areas, argues for the development of a fleet capability in polar oceanography, i.e., a fleet capable of operating near and within the ice during cold and stormy weather.

Coastal Ocean and Great Lakes. Initial ship needs for the NECOP program are in the Gulf of Mexico and in the South Atlantic Bight through FY 91. Expansion into the Gulf of Alaska is planned for FY 92. The Toxic Algal Bloom Program planned for initiation in FY 92 will most likely be in the Gulf of Maine/Georges Bank area. In future years, likely areas of interest will be the Mid–Atlantic Bight, the Southern California Bight, and the Washington/Oregon coastal area.

Coastal Ecosystems Program plans to initiate or expand programs in the South Atlantic Bight, the Bering Sea, and the Great Lakes in FY 91. Plans for future program expansion in outyears will probably include programs in the northeast, southern California, and the Gulf of Mexico. The Habitat and Physical Impacts Programs geographic areas are less well defined, but some west coast, Hawaii, and Alaska region ship time may be required for tsunami research.

Overall, NOAA's Coastal Ocean Program envisions significant activities requiring NOAA ships in all U.S. coastal waters and in the U.S. EEZ over the next one to two decades.

Seafloor Processes. Given the global scale of research addressing seafloor processes, areas of operation will range from tropical to polar latitudes. Megaplumes, which originate along spreading centers at high latitudes, for example, may be capable of reaching the ocean surface. Should that be observed, an extensive sampling program will be initiated. During the next decade, these high–latitude megaplumes notwithstanding, it is anticipated that most seafloor processes research will be conducted at mid to tropical latitudes. Present emphasis of the VENTS Program on northeast Pacific spreading centers will constrain ship operations to summer months; work at hydrothermal sites along the Mid–Atlantic Ridge will be constrained to exclude months of high risk of hurricanes.

Remote Sensing and Shipboard Observation

Climate and Global Change. None of the anticipated advances in remote sensing or automated technology are likely to diminish the need for high–quality shipborne research over the foreseeable future. Rather, the need for complementary shipborne measurements will probably increase as the total research effort increases in both volume and diversity. For example, a continually growing suite of oceanographic tracer measurements within the water column, many of which hold great promise for dealing with ocean circulation issues, is beginning to be applied aggressively to both tropical and polar research. The sampling and analysis of these tracers will require careful attention to shipborne equipment, space, and support.

Furthermore, the backbone of any long–term observing system into the next decade must be an *in situ* measurement array (Figure 2–2). Even for surface parameters (e.g., winds, air temperature, humidity, and sea surface temperature), *in situ* ground truth of satellite measurements will be required. The long lead time of satellite–borne sensors implies that improved technologies (e.g., a scatterometer with increased low wind resolution such as is required in the tropics) may be decades away. The only alternatives are the oceanographic arrays. Deployment and maintenance of these *in situ* arrays will require an operational use of oceanographic research ships at a level commensurate with the current EEZ mapping effort (in excess of 150 ship days per year).

Coastal Oceans and Great Lakes. Open–ocean moorings with physical sensors will continue to be a traditional approach, but in the future they may also include acquisition of biological and chemical data. Such information would ideally include oxygen, inorganic nutrients, suspended matter, and fluorescence. Moored acoustic sensors could assess pelagic stock size in a wide variety of targets. The data could be stored, or transmitted in real–time to ships or satellites. Experimental protocols and cruise plans could then be based on a combination of real–time satellite remote sensing, remote moorings or floats, and heuristic models of coupled physical and biogeochemical processes.

These are target objectives but for many of the chemical parameters are not yet obtainable. Remote sensing by means of *in situ* instrumentation can now be done for oxygen over short periods but not routinely over long periods as is being done for temperature, salinity, and current speed and direction. When this capability is fully developed much pressure will be relieved from the surface vessels for routine sampling, with a shift toward mooring deployment and maintenance. However, until this capability is developed the requirements for time on surface ships remain very high and will actually increase.

Seafloor Processes. Given that only a very small percentage of the global seafloor spreading centers have been mapped with even new swath–sonar technology, it is evident that there will not only be a continued need but also an increased need for standard as well as innovative shipboard observations. Included in the latter case are new–generation swath sonar mapping systems, sidescan sonars, and towed instrument packages capable of both reconnaissance and high–resolution sensing. Associated with these towed devices will be seafloor observatories used to collect time–series oceanographic and seafloor data. These observatories and other delicate *in situ* instrumentation may best be deployed and serviced by remotely operated vehicles (ROV's) and autonomous undersea vehicles (AUV's).

Short–Term Event Studies and Long–Term Monitoring

Climate and Global Change. To varying degrees, process studies and synoptic measurement programs have traditionally been segregated from long–term monitoring efforts, both operationally and in program planning and funding. This is beginning to change, both as environmental variability becomes a scientifically more important issue, and as the technical capability for monitoring improves and expands. Through long–term *in situ* monitoring the study of oceanography will move away from simple steady–state calculations of the ocean's behavior to more advanced non–steady–state general circulation models which more closely mimic the real world.

Two things will probably happen in the future. First, short– and long–term monitoring measurements will be tied more closely to each other, with monitoring activities assuming a greater research orientation than has been the case thus far. Second, the variety of parameters and processes being monitored will increase, as will the duration of the monitoring. This trend is already apparent in TOGA COARE planning where the western Pacific process study is tied to a basinwide observing system and in JGOFS where chemical measurements are linked to ongoing physical oceanographic studies.

A shift toward more extensive long–term monitoring will place increasing demands on the research fleet, both for ship time and for breadth of support. Data obtained from long–term monitoring will include more exact measurements and calibration for sea surface temperature, surface salinity, air temperature, wind speed and direction, surface humidity, sea level pressure, fluxes of heat, moisture, and momentum at sea surface, estimates of components of radiation and precipitation, sea state, and wave spectra.

Coastal Ocean and Great Lakes. To date, the nearshore studies have focused on providing information on specific variables, such as concentrations, standing fish stocks, chemical parameters, etc., and not on rates of processes. A trend has started, and is expected to continue, toward synoptic, cross–disciplinary observations over seasonal and annual event scales using remote and *in situ* measurements. Included in the types of long–term data sets now required for nearshore studies are: water levels, winds, waves, currents, water temperature, water quality, and sediment concentrations. When properly carried out, such approaches save ship time and manpower. To effectively accommodate this shift in research focus, the shipboard work must evolve from surveying along grids or transects for descriptive assessment to conducting experiments for determining rates of processes that give rise to change.

Seafloor Processes. In order to fully understand the chemical and thermal effects related to seafloor venting, a combination of long–term *in situ* monitoring and site–specific surveys are required. From this combination, an integrated data set will emerge allowing modeling of the chemical, physical, and biological processes active within the venting system. Therefore, future research into seafloor venting will entail both site–specific surveys and sampling, and the deployment and servicing of *in situ* instrumentation.

An important consideration in understanding the processes associated with seafloor venting is the episodic nature of underwater eruptions. *In situ* monitoring will collect certain data associated with these events. Other data can be collected, however, only through sampling from a ship or a remotely operated vehicle (ROV). To allow for such "unexpected" events, some degree of unscheduled ship time may be needed to allow improvisational or serendipitous observations on event–dominated processes.

Trends in Data Collection/Analysis

Climate and Global Change. Multidisciplinary research programs today not only require onboard investigators with a range of expertise but also inputs from remote sensors, other platforms (ships and aircraft), and land–based analyses. Future research will demand much greater interactions with data sources external to the ship. To accomplish this, researchers will require interactive access with computers and data sources ashore. The ability to access and interactively manipulate models of atmospheric and oceanic processes will be required on a routine basis to conduct future research programs.

One such data source will be from ocean arrays. In the future, moored and float data will be transmitted to ships in real–time to further assist in determining sampling strategies at sea. Examples of such monitoring and data transmission would be real–time data on oxygen concentrations from moored electrodes, accumulation of fluorescence near the bottom or on the pycnocline (in the study of microbial carbon recycling), variations in animal biomass as assessed by acoustic doppler profilers moored to the bottom, intensified bottom currents characterized by dense concentrations of suspended sediments, etc. These approaches improve research because they eliminate "blind" sampling and experimentation on processes in the ocean. Since a use of these figures is to serve as calibration values for remotely sensed or model quantities, it will be necessary to have frequent calibration information on each variable transmitted at some less frequent intervals than the regular flow of data.

From the vessel perspective, a larger number of basic variables will be needed from more–sensitive sensors than presently widely employed. Among these variables are: sea surface temperature, surface salinity, air temperature, wind speed and direction, a humidity variable, sea level pressure, and acoustic doppler current profiling. There will be a critical need in the next decade to provide ground–truth estimates for the fluxes of heat, moisture, and momentum at the sea surface. Estimates of various components of radiation and precipitation are required. Better estimates of sea state and wave spectra will be needed. For measurements of each of these variables, care needs to be taken to minimize or eliminate sampling problems introduced by the presence of the ship. Calibration information needs to be maintained. As much of the measurement, recording, and processing as possible needs to be automated and free from human intervention.

For high–latitude research, the shipborne instrumentation is of even greater importance than in other areas. In ice–covered regions, fewer environmental parameters are available from satellites. As a result complementary shipborne measurements will increase as the total research effort increases in both volume and diversity. For example, a continually–growing suite of oceanographic tracer measurements within the water column, many of which measurements hold great promise for dealing with polar ocean circulation issues, is beginning to be applied aggressively to polar research. The sampling and analysis of these tracers will require careful attention to shipborne equipment, space, and support. At the same time, nontraditional methodologies not directly based on board ship may place significant new demands on the ship and its equipment, e.g., instrument deployment of *in situ* calibration procedures within the ice. Among these are ROV's or AUV's with the capability of operating under the ice. Without such vehicles, sampling is restricted.

A related issue is the ready access to environmental data collected with the satellite sensors. Such information is of utmost value to several of the climate studies. The ability to directly download satellite sensor data to a research vessel for processing onboard will be a major requirement of all research programs, especially biogeochemical research. Presently not one U.S. research vessel routinely accesses imagery from NOAA–10 and –11 satellites to guide sampling strategies. This capability is expected to be a standard requirement in future research programs.

Multiple platform operations will be common in future global geoscience research programs. Even though concentrating on a certain process or region, the platforms will be spatially separated. Information and data exchange between platforms operating together will need to take place much more efficiently than at present. Enhanced communication in the form of rapid data transfer and high quality facsimile transmission for text and figures will be required on a routine basis.

Coastal Ocean and Great Lakes. In the coastal ocean, traditional shipboard collections for fish, plankton, benthic organisms, sediments, suspended particles, and water chemistry will continue to be made from ships using conventional gear (Figure 2–6). This capability will also extend to work in very shallow water with the use of launches. These

Figure 2–6. *Trawls of bottomfish supply samples for use in the research conducted by NOAA's National Status and Trends Program. Here a specimen is being examined for evidence of damage by contaminants. (Courtesy NOAA/NOS/Office of Oceanography and Marine Assessment)*

launches must be capable of working for 10–12 hours independent of the ship while collecting a broad suite of oceanographic measurements. Similarly, due to the analytical nature of the research, the launches must be constructed of "clean," e.g., plastic or stainless steel, material.

In addition, much greater use will be made of drifting or stationary buoys and ROV's. Therefore, the capability of easily deploying and retrieving such instruments will be especially important in the future. New coastal vessels will need to be equipped with continuous underway sampling instrumentation. It will be particularly important to collaborate with the UNOLS fleet and national and international oceanographic research programs (e.g., WOCE and JGOFS) in regard to standards for instrumentation and data handling and quality, and data exchange will be essential.

Seafloor Processes. Data will be processed and integrated into an on–site marine Geographic Information System (GIS) work station which will allow for real–time plotting of targets of hydrothermal vent sites and subsequent sampling of vent fluids.

A critical aspect of the study of chemical and thermal effects of venting is the intermittent nature of these events. It is not feasible to obtain continuous monitoring of the venting features from the relatively brief time on station now available with surface ships. Yet, without a time–series profile to "capture" an event, modeling and eventual prediction of the processes and effects are impossible. Seafloor observatories are required to achieve this time–series monitoring. These observations are analogous to observatories designed to collect other environmental data, e.g., solar and magnetic. A modern NOAA fleet will provide a critical resource in its anticipated ability to deploy and service such seafloor observatories.

Anticipated Growth in Need for Vessel Time

Climate and Global Change. Federal agencies, academia, and private environmental groups have precipitated a public and political awareness that industrialization and agricultural development can affect the ocean and climate on global scales. This awareness has resulted in new initiatives in all the relevant federal agencies. Cross–disciplinary faculties and curricula at academic institutions are being organized to assist these agencies, and analogous, cooperating global programs are being put in place in western Europe. For the first time in several years, an increase in the research budgets of some federal agencies is expected, driven by the anxiety over global change, especially global warming.

As a consequence of growing public and political awareness of the global climate change issue, there is a clear tendency towards increased support for deep ocean studies involving large ships. In the equatorial regions, oceanographic research supporting climate studies are expected to continue to grow for the next one to two decades. There are several reasons for this. The first is the relatively robust nature of the global consequences of ENSO variability. Compared to many signals in climate variability, the effects of ENSO are readily apparent and direct. Several countries are expanding their ENSO research programs. The second is that TOGA researchers have defined a basinwide Pacific Ocean real-time, *in situ* observing system which needs to be deployed, first in a research mode and then as an operational system. Support for this system will require expanded ship time, and expansion to the global tropics will occupy research efforts for several decades. Third, the combined chemical and physical studies required by climate change research have only begun. The equatorial regions will continue to be a major area of research because of the unique nature of the air-sea interactions in the tropics and the importance of cross-equatorial exchange. Lastly, the continued world population growth in the tropical regions will increase the importance of tropical climate fluctuations which are intimately linked to the coupled ocean-atmosphere system.

Likewise, polar oceanographic research is likely to experience higher-than-average growth during the next one to two decades (Figure 2-7). There are several reasons for this expectation. First, polar research is required to understand global climate and its change. Second, research in polar regions is significantly underexploited compared with those for much of the world ocean. Third, polar research is no longer a pronouncedly parochial activity, but is increasingly being incorporated into a global perspective. Fourth, continuing population growth is increasingly impacting polar regions, creating a concomitant need for a broad range of research.

Figure 2-7. *The exploration of polar ice and the waters beneath it is critical to understanding global climate. Deployment of in situ instrumentation in high latitudes requires surface ship support. (Courtesy NOAA/OAR)*

As reflected in the Committee on Earth Sciences submission to OMB for FY 1991-1995, there is a threefold increase in support for ocean programs in NSF (WOCE, JGOFS and TOGA) and NOAA (TOGA, Atlantic Climate Change and Ocean Carbon). This increase is in excess of existing base programs in NOAA/Office of Oceanic and Atmospheric Research and NSF Ocean Sciences. As with all government programs growth is only predicted, never assured. However, it is clear that the existing NOAA fleet is inadequate to satisfy the NOAA needs of the Global Change

Program, as envisioned, much less any additional requirements arising from growth in other program areas such as the Coastal Ocean.

Coastal Ocean and Great Lakes. Growth in this area, stimulated by increased awareness of the coastal ocean's value and susceptibility, is already apparent in NOAA's Coastal Ocean Program (COP) under the Coastal Ecosystem Dynamics theme. This program, plus parts of the Global Climate Change Program form an umbrella for coastal fisheries oceanography research that includes traditional resource surveys (e.g., groundfish and reef fish), monitoring (National Status and Trends), as well as ecological or process–oriented studies [e.g., Fisheries Oceanography Coordinated Investigations (FOCI) and Coordinated Ecosystem Research in the Great Lakes].

Significant growth in these areas and consequent increase in ship–time requirements will occur in the next one to two decades. Major expansion of programs in nutrients, coastal ecosystems, and physical impacts are planned. These programs will all require the utilization of NOAA research vessels if they are to meet their planned objectives. The nutrient research program is embodied in the Nutrient Enhanced Coastal Ocean Productivity (NECOP) program, which has as its objective, determining the impact of the flux of nutrients, both natural and anthropogenic, on the productivity, water quality, and carbon flow in our coastal waters. Large inputs of anthropogenic nutrients can lead to altered primary productivity, resulting in noxious algal blooms, anoxia, effects on secondary productivity, and changes in carbon flow through the system. The study of changes in carbon flow has assumed new importance in understanding the global carbon cycle. Recent calculations indicate that the uptake of CO_2 in the open oceans cannot account for the CO_2 emitted by man to the environment. Coastal oceans may prove to be a more important sink for anthropogenic CO_2 than originally thought. Currently, the NECOP program is only addressing the flux of nutrients in one coastal region, the Gulf of Mexico. Expansion of the program into other coastal areas is planned in future years.

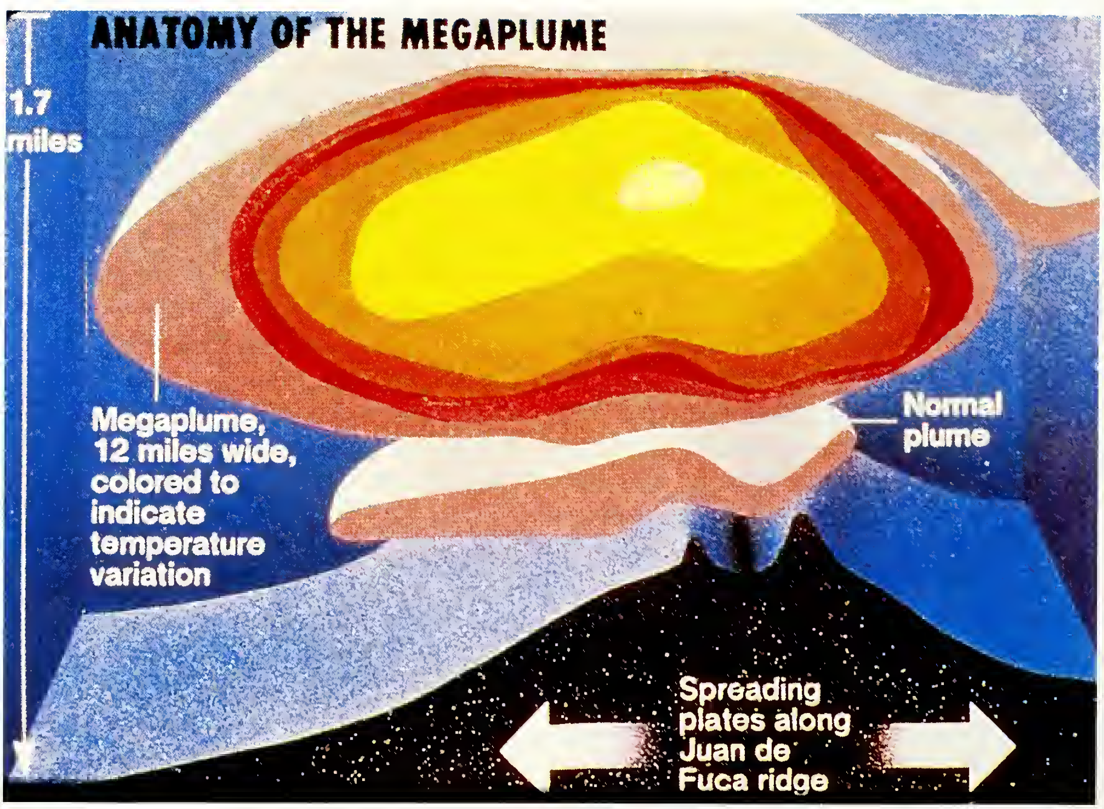
In addition to NECOP, the COP is proposing a major study of the causes and consequences of toxic and noxious algal blooms beginning in 1991. These blooms represent a human health problem in many coastal areas, are a threat to our living marine resources, and often severely impact the aesthetics of our coastal zone. The COP plans to conduct research, monitoring, and assessment studies in several of our coastal waters for the coming years.

A major new NOAA program in coastal ecosystems is planned for initiation in 1991 by the COP. Building on the very successful FOCI program in the Gulf of Alaska, NOAA plans to begin similar programs that address important recruitment problems in a variety of physical oceanographic regimes around our coasts. A significant commitment of NOAA ship time will be required if these programs are to be successful. Also, the Coordinated Ecosystem Research (CER) program now being initiated in the Great Lakes will significantly increase ship requirements for NOAA and the scientific community at large. The two primary parts of this study, ecosystem assessment and planktivorous forage fish variability, both involve ship support.

Other program areas, where ship needs can be anticipated but where actual requirements are less clear, include the Estuarine Habitat and Physical Hazards Programs. As the Habitat Program expands from shallow–water habitat research to studies in open estuarine waters, ship time will be need to accomplish program goals. The Physical Impacts Program's main focus is on the development of predictive models to improve NOAA warning systems. Extensive ship time for field data generation will be needed.

Seafloor Processes. For the next several years, there will be a critical requirement for ship–based reconnaissance and detailed surveys to statistically characterize the global hydrothermal environment, e.g., the extent and magnitude of active venting. Long–term monitoring is now beginning to become a reality as prototype seafloor instrumentation is being deployed by VENTS and other programs. As a consequence, the ship support will grow in relative importance during the coming decade. Another critical aspect of the need for a modern fleet in support of long–term monitoring will be the ability to respond to detected events. A major discovery of the VENTS Program has been the documentation of the occurrence of large–scale hydrothermal bursts. The major bursts (termed megaplumes) observed thus far each contained the mass and heat equivalent of the entire year's output of the essentially steady–state hydrothermal processes occurring along the ridge segment where the bursts originated (Figure 2–8). Megaplumes may be an important aspect of the global perspective of hydrothermal venting, but they occur episodically, as does seafloor volcanism, and long–term monitoring is being implemented to detect and locate these events in real–time. One of the anticipated highlights of NOAA's hydrothermal research in the coming years will be the ability not only to detect, locate, and remotely characterize episodic events, but

Figure 2–8. *Long–term ship monitoring of the vents along seafloor ridges will enhance our understanding of megaplumes like the one shown in this schematic. Understanding these major bursts of hydrothermal venting is important to our study of global climate change. (Courtesy NOAA/OAR/Pacific Marine Environmental Laboratory)*



also to respond with appropriate shipboard and ship-deployed instrumentation to quantitatively document, for the first time, the nature and evolution of such events and their effects on the ocean.

Specific Vessel Requirements for Science Needs

As identified by the Oceanographic Research Working Group, in summary, there are several trends in NOAA's oceanographic research which will impact vessel characteristics. These include:

Remote Operation. Global climate research will expand into the western Pacific basin, the Southern and Indian Oceans, and the Norwegian and Greenland Seas. More frequent and longer cruises will be made to the polar regions, especially the Arctic. In high latitudes, there will be increased pressure to work further into the ice and for a greater portion of the year. The remote operations will require vessels capable of long endurance (up to 60 days), range of 15,000 nautical miles, and carrying large science payloads (15 ocean moorings). To ensure maximum utilization of station time these vessels must have a degree of seakindliness (able to operate in high sea states). At least one vessel needs to be able to operate within the ice (ice capable, but not an icebreaker).

Multidisciplinary Research. In the areas of Global Climate, Seafloor Processes, and Coastal Ocean Programs, the research efforts are becoming progressively process-oriented. The processes which drive phenomena as diverse as climate and fisheries recruitment are quite complex, encompassing components of several science disciplines. The role and rate of biology, chemistry, physics, and geology in influencing global and regional oceanic circulation patterns, which in turn influence climate, have yet to be fully understood. Likewise the understanding of the climatic variability on fishery recruitment processes is in its infancy. This complexity requires multidisciplinary research efforts. Within various disciplines, such as chemical oceanography, several specialties are often involved. In order to support the wide-ranging research requirements the vessels must be able to berth large numbers of scientists. Dedicated analytical laboratories to support multidisciplinary research must be much more sophisticated than now exist on NOAA ships. These laboratories must be environmentally isolated from each other, possess a high degree of environmental control for specific analytical functions, and be equipped with input from a wide spectrum of environmental data. Also, the laboratories and deck equipment must be sufficiently flexible to accommodate a variety of science requirements.

Enhanced Sample Collection/Storage. With the advances in remote-sensing technology have come more varied and more demanding sampling protocols. We envision even greater use of new technology, especially remotely operated vehicles, *in situ* bottom instrumentation, and sophisticated buoy systems. The ROV's can provide access to heretofore inaccessible areas such as beneath the polar ice and spreading-center venting features. *In situ* instrumentation will provide much-needed time-series data. Ship capabilities need to be upgraded to more efficiently deploy and recover these instruments, and to better monitor the position and control the operation of ROV's. Another aspect of enhanced sampling is precision stationkeeping. Especially in the study of seafloor processes and around ocean fronts, the importance of precisely maintaining the ship's position is assuming even greater importance. With the development of global GPS, real-time navigation is now sufficiently exact to permit the required positioning. Required now is computer control of thrusters and main propulsion systems to fully utilize the GPS data input.

There is a need for real–time sampling while at sea. The sophistication of analytical tools now permits elucidation of chemical parameters which a few years ago were thought impossible. Unfortunately with few exceptions, and none within the U.S. civilian or military research fleet, this sophistication has not been incorporated into real–time sampling while at sea. Furthermore for certain chemical and biological species, without real–time processing, valuable data are lost. Vessels must be equipped with analytical facilities to perform these analyses. Such facilities would include, among others, precise temperature control (in the range of −25 to −2°C, −2 to +5°C, +5 to +25°C), ultra–clean laboratories, ability to process very–large–volume water samples, and the on–board production of liquid nitrogen and oxygen.

Continuous Collection of Data. The Working Group recognized the importance of continuous collection of environmental and physical data on a routine basis. The environmental data, collected and transmitted in near–real–time, serve two major functions: input into global and regional oceanic and atmospheric circulation models and verification of earth–observing satellites. Physical data, while not required in near–real–time, are used for a multitude of solid–earth studies and provide important collaborative input to satellite data.

Ship observations provide the only surface data over large portions of the earth. For these data to be effectively incorporated, the environmental and physical parameters must be collected digitally on a continuous basis. Required data streams include:

Positioning: X,Y, and Z

Meteorological: relative humidity, short– and long–wave insolation, visibility, water vapor

Water column: directional wave spectra, ocean skin temperature, surface temperature/salinity, chlorophyll, oxygen, subsurface current shear, mixed layer depth, particulates

Ocean Bottom: swath bathymetry, shallow sub–bottom, magnetic field, gravity field

At present, none of the NOAA ships provide these required data on a continuous basis.

Enhanced Communications. Communications falls into three categories of requirements. Internal communication is that into and between science spaces including van, key working areas, and selected staterooms. In addition to high–quality voice, the communication should include: real–time transmission, monitoring and recording systems of all data; closed–circuit television monitoring and recording of working areas; and monitoring of ship control, environmental parameters, and over–the–side equipment performance. For external communication, there must be high–speed data transmission to shore laboratories and other ships on a continuous basis, high–speed graphics and hard–copy text, and reliable voice channels. For satellite monitoring, there must be facilities to receive readouts of environmental remote sensing.

Tables 2–1 – 2–4 give a detailed list of the science requirements for four types of General Purpose Oceanographic Vessels: Long Endurance, Ice Capable, Medium Endurance, and Low Endurance.

Table 2–1. High–Endurance, Multidisciplinary Oceanographic Research Vessel: Scientific Requirements.

Purpose	Hydrographic/tracer sections, buoy maintenance/handling, air–sea flux, moorings, continuous water and air sampling, seafloor processes, cross–disciplinary process studies, bathymmetry, and remotely–operated vehicles.
Endurance	Sixty days; providing the ability to transit to the most remote area and work 3–4 weeks on station. 15,000 mile range at cruising speed.
Accommodations	30–35 scientific personnel in two–person staterooms. Expandable to 40 through the use of vans. Science library–lounge and separate conference room.
Speed	15–20 knots cruising; sustainable through sea state 4. Speed control plus/minus 0.25 knot in 0–6 knot range; and plus/minus 0.5 knot in range 6–20 knots.
Seakeeping	Maintain science operations in following speeds and sea states: 15–20 knots cruising through sea state 4 13–15 knots cruising through sea state 5 8–13 knots cruising through sea state 6 6–8 knots cruising through sea state 7 Allow normal station and deck work in sea states through SS 5 and limited work through SS 7.
Stationkeeping	Maneuverability that would assure relative positioning at best heading in 35–knot winds and SS 5 and 2 knot current plus/minus 150 ft maximum excursion from a point or trackline, and maintain plus/minus 5 degree heading. Maintain a precision trackline while towing at speeds as low as 0.5 knots with a heading deviation up to 45 degrees from the prescribed trackline using GPS or bottom navigation as reference. (See navigation and positioning.) Speed control along track should be maintained plus/minus 0.1 knot (averaged over one–minute intervals). Trackline requirements should be met 95% of time considering range of specified sea states.
Dynamic Positioning	Ability to maintain vessel in position to 1 percent of water depth greater than 2000 m.

Table 2-1, Continued.

Ice Strengthening	ABS Ice Classification 1A. Able to transit loose pack. Not intended for icebreaking or close pack work. Protection against encounters with growlers and other glacial ice difficult to detect.
Deck Working Area	Total deck space 7000 sq ft including spacious fantail area (3,000 sq ft minimum) with 2000 sq ft clear area readily accessible to fantail with contiguous work area along one side 12 x 100 ft minimum. Provide for deck loading up to 1,500 lbs/sq ft and an aggregate total of 100 tons. Oversize holddowns (1-inch bolts) on 2-ft centers. Highly flexible to accommodate large and heavy equipment. Removable bulwarks. Dry working deck but not greater than 10-15 ft above waterline. All working decks accessible for power, water, air, data, voice and alarm communication ports.
Boom	A boom on the foc'cle to extend to the water forward of the bow wave with an instrument loading of approximate 500 lbs. Manned-access to the end of the boom is required.
Cranes	A suite of modern cranes with constant tension capability including: a) One large crane for heavy equipment op to 30000 lbs. located to support the fantail working area and to site vans and • articulated to work close to deck and water surface • to handle oversize loads up to 10000 lbs. 24 m from center of crane • to have servo controls and motion compensation. b) Two cranes, one on each quarter, capable of towing with line pull of up to 5000 lbs. extending out to 20 ft for towed packages. c) One crane to service the bow working area (5000 lb capacity).
Winches	New generation of oceanographic winch systems providing fine control (0.5 m/min); constant tensioning and constant parameter. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems. Local and remote controls. Permanently installed general purpose winches include: • Two winches capable of handling 30,000 ft of wire rope or electromechanical cables having diameters from 1/4" to 3/8".

Table 2–1, Continued.

	• A winch complex capable of handling 40,000 ft of 9/16" trawling or coring wire and 30,000 ft of 0.68" electromechanical cable (up to 10 KVA power transmissions and fiber optics). This could be two separate winches or one winch with two storage drums. Additional special purpose winches may be installed temporarily at various locations along working decks with a footprint in accordance with tie–down locations. Winch sizes may range up to 40 tons (140 sq ft) and have power demands to 300 hp. Portable shelters available to winch work areas for instrument adjustments and repairs. Winch control station(s) located for optimum operator visibility with reliable communication to laboratories and ship control stations. A secondary winch control should be located on both the bridge and in one laboratory.
Overside Handling	Various frames and other handling gear and more versatile thank present to accommodate wire, cable and free launched arrays. Matched to work with winch and crane locations but able to be relocated as necessary. Stern A–frame to have 20–ft minimum horizontal and 30–ft vertical clearance; 15–ft inboard and outboard reaches; safe working load up to 60 tons. Midship J–frame with hydrowinch and adjacent to wet lab. Able to handle, deploy and retrieve 30 m piston cores. Control station(s) to give operator protection and operations monitoring and be located to provide maximum visibility of overside work.
Towing	Movable stern ramp capable of opening to facilitate trawling and deployment/recovery of ROV's. Capable of towing large scientific packages up to 10,000 lbs tension at 6–knots and 25,000 lbs at 2.5 knots in sea state 5, 35–knot wind, and 3–knot current.
Conference Room	Conference room with full communication with ship and deck operations (32 person capacity).
Laboratories	Approximately 4,000 sq ft of laboratory space broken down into approximately 12 individual laboratories which could include the following activities: including biological sample processing (flash freezing/washdown), trace chemistry (organic), trace chemistry (inorganic), biochemistry, radioisotope (low activity), radioisotope (high activity), wet lab, dry lab,

Table 2-1, Continued.

electronic repair shop, air chemistry, photography, sediment processing, acousitic, meteorological, gravity, liquid nitrogen/liquid air processing facility, mechanical and computer.

Two medium size general purpose wet labs to have large drains and associated strainers/cutters to accomodate sample residue.

Electronics/computer facility and associated user space.

A CTD prep room adjacent to midships J-frame connected by moving sidewalk through hinged door to ship interior. The CTD prep room must be capable of handling and storing 15 Gerard-type (200 liter) and 15, 20-30 liter water samplers. Multiple hose connectors in CTD prep room to enable water to be ported directly to other labs. A large drain will be placed in the floor for draining large volumes of water.

CTD prep room to have hose pumping system (inert inner walls) capable of delivering 50 liters/min of continuous and discrete depth samples down to 1000 m.

Special environmental lab conditions: One working lab to capable of being maintained at -2 to 25 plus/minus 1 degree C for low-temperature biological and chemical sample processing and flash-freezing samples.

Labs should be located so that none serve as general passageways. Access between labs should be convenient. Labs, offices, and storage to be served by a man-rated elevator having clear inside dimensions of approximately 3 ft by 4 ft and where appropriate, moving sidewalks.

All labs should have structured inserts in bulkheads and decks for removal and addition of interior furnishing.
Individual labs should be protected from cross-contamination through the ventilation system.

Labs to be fabricated using uncontaminated and "clean" materials and constructed to be maintained as such. Furnishings, HVAC, doors, hatches, cable runs, and fittings to be planned for maximum lab cleanliness.

Fume hoods to be installed permanently in Wet lab and Analytical lab. Main lab shall have provision for temporary installation of fume hoods.

Cabinetry shall be high-grade laboratory quality including through the use of unistruts and deck boltdowns.

Table 2-1, Continued.

	Heating, ventilation, and air conditioning (HVAC) appropriate to laboratories, vans, and other science spaces being served. Laboratories shall maintain temperature of 20-24 degrees C, 50% relative humidity, and 9-11 air changes per hour. Filtered air provided to interior analytical and instrument labs. Each lab area to have a separate electrical circuit on a clean but with continuous delivery capability of at least 40-volt amperes per square foot of lab deck area. Labs to be furnished with 110 v and 220 v AC. Total estimated laboratory power demand is 100 KVA.
	A central facility to manufacture and store liquid nitrogen, dry ice and distilled and distilled-deionized water.
	Seawater and "clean" seawater supplies to most laboratories, vans, and several key deck areas. Intakes should be from two areas: one on bow slightly below water line and the other midships on keel. Measurements that are required close to point of entry include: SST, salinity, chlorophyll, phaeophytin and particulates. Flow rate of 50 liters/min required for these systems. Compressed air supply to be clean and oil-free.
	Modular vans connecting to a central walkway may be substituted for certain internal labs. These vans should be fabricated as part of the ships construction and contain full power, ducting and plumbing.
Vibration Control	As much as feasible, an effort should be made to reduce vibrations through shock mounting engines and generators.
Vans	To carry at least four standardized 8 ft by 20 ft portable vans which may be laboratory, berthing, storage, or other specialized use. Hookup provision for power, HVAC, fresh water uncontaminated sea water, compressed air, drains, communications, data and shipboard monitoring systems. Van access direct to ship interior.
	Provision to carry up to four additional portable non-standard vans (600 sq ft total) on super-structure, foc'cle and working decks. Supporting connections at several locations around ship including foredeck.
	Ship must be capable of loading and offloading vans using own cranes.
Workboats	At least one and preferably two 18-20 ft semi-rigid boats located for ease of launching and recovery.
	A scientific work boat 25-30 ft LOA specially fitted out for supplemental operation at sea including collecting, instrumentation, and wide-angle signal measurement. 12-hour endurance including both manned accommodations and automated operation. "Clean" construction. To be carried as a one of

Table 2–1, Continued.

	four–van options above. Workboat to be equipped with own skids for easy tie–down to deck.
Science Storage	Total of 16,000 cubic ft of scientific storage accessible to labs by elevator (500 lb load capable), moving sidewalks and weatherdeck hatch(es). Half to include suitable shelving, racks, and tie downs; remainder open hold. Easily accessible storage in hold (4000 cubic ft) under fantail area for moorings and weights (comparable to 60,000 lbs).
Acoustical Systems	Ship to be as acoustically quiet as practicable in the choice of all shipboard systems and their location and installation. Design target is operationally quiet noise levels at 12 knots cruising in sea state 5 at the following frequency ranges: • 3 kHz – 500 kHz echo sounding and acoustic navigation • 75 kHz – 300 kHz doppler current profiling Ship to have 12 kHz, 3.5 kHz echo sounding systems and provision for additional systems. Phased array, very wide multibeam precision echo sounding system (equivalent to "Sea Beam"). Transducers appropriate to dynamic positioning system. Transducers wells (20") one located forward and two athwartships. Large pressurized sea chest (4 ft x 8 ft) to be located at optimum acoustic location for at–sea installation and servicing of transducers and transponders. Conformable arrays along hull to monitor and control ROV's.
Helicopter	A clear area to provide for helicopter hovering.
Navigation/Positioning	Global Positioning Systems (GPS) with appropriate interfaces to data systems and ship control processors in 3–dimensions. Short baseline acoustic navigation system. Selected vessels should be equipped with "dynamic positioning" capability to maintain the ship on station or on a trackline to the stationkeeping specifications under automatic control and appropriate navigational reference.

Table 2–1, Continued.

Routine Monitoring	Digital systems for routine environmental monitoring: a) Water column: Directional wave spectra, ADCP b) Bathymmetric: Multibeam, shallow sub–bottom profiling, gravity c) Meteorological: UV radiation, global radiation, insolation, upper air soundings with rawinsonde
Internal Communications	Internal communication system providing high–quality voice and visual communications throughout all science spaces, working areas and other selected spaces (e.g., conference room, chief scientist stateroom). Data transmission, monitoring and recording system available throughout science spaces (including vans and key working areas) networked through a central computing facility. Closed–circuit television monitoring and recording of all working areas including subsurface performance of equipment and its handling with readout on bridge and selected laboratories. Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in all laboratories and other selected spaces (e.g., conference room, chief scientist stateroom) with data ports located at all winches and cranes.
External Communications	Reliable voice channels for continuous communications to shore stations (including home laboratories), other ships, and aircraft. This includes satellite, VHF, and UHF. Facsimile communications to transmit high–speed graphics and hard–copy text on regular schedules. High–speed data communications (56K Baud) links to shore labs and other ships on a continuous basis. Antenna located to minimize EM contamination to portable and interior lab spaces.
Satellite Monitoring	Carry transponding and receiving equipment including antenna to interrogate and receive satellite readouts of environmental remote sensing.
Ship Control	Chief requirement is maximum visibility of deck work areas during science operations and especially during deployment and retrieval of equipment.

Table 2-1, Continued.

This would envision a bridge–pilot house very nearly amidships and with unobstructed stern visibility.

The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude, and positioning will often be integrated with scientific operations requiring control to be exercised from a laboratory area.

Table 2–1, Continued.

LABORATORIES AND ASSOCIATED SPACES

Laboratory	**Large Vessel Size (sq. ft.)**	**Medium Vessel Size (sq. ft.)**	
Wet Laboratory	200	200	S
Dry Laboratory	150	150	S
Dry Laboratory	150		SVM
Radioisotope Laboratory	150	150	VM
Clean Laboratory (Inorganic)	200	160	VM
Clean Laboratory (Organic)	200		VM
General Laboratory (Stable environment for S o/oo, tracers, Co_2, O_2 and nutrients)	250	250	S
Macrofauna	300	200	S
Geology	400	200	S
Climate Controlled Space(s)	300	150	S??
Atmospheric Chemistry Laboratory	120		S
Phototography Laboratory	120	80	SVM
Computer Room	300	200	S
Bottom Topography Data Acquisition and Plotting	150	150	S
Doppler Current Data Acquisition and Control and ROV Control	200	200	S
Gravity Room	50	50	S
Charting and Plotting	200		SVM
Scientific Electronics Shop	100	100	SVM
Scientific Office	150	100	S
Meteorological Center	64	64	S
Total	3754	2404	

Notes:

S (Ship) V (Van) M (Modular)

Climate Control space needs ship refrigerant.

Atmospheric Chemistry to be located near bridge.

The Meteorological Center is a permanent facility of the ship and would include atmospheric soundings feet with a balloon launch facility on the clear deck space on the fantail. All of hardware associated with the meteorological center would be part of the bridge or communications center.

Associated with all of the above would be a bow room and/or sea chest where the clean seawater intakes and some sensors are located as well as the acoustics equipment room(s).

NOTES:

Table 2-2. High-Endurance, Multidisciplinary, Ice-Capable Oceanographic Research Vessel: Scientific Requirements.

Purpose	Hydrographic/tracer sections, buoy maintenance/handling, air-sea flux, moorings, continuous water and air sampling, seafloor processes, cross-disciplinary process studies, bathymmetry, and remotely-operated vehicles in polar regions.
Endurance	Sixty days; providing the ability to transit to the most remote area and work 3-4 weeks on station. 15,000 mile range at cruising speed.
Accommodations	30-35 scientific personnel in two-person staterooms. Expandable to 40 through the use of vans. Science library-lounge and separate conference room.
Speed	15-20 knots cruising; sustainable through sea state 4. Speed control plus/minus 0.25 knot in 0-6 knot range; and plus/minus 0.5 knot in range 6-20 knots.
Seakeeping	Maintain science operations in following speeds and sea states: 15-20 knots cruising through sea state 4 13-15 knots cruising through sea state 5 8-13 knots cruising through sea state 6 6-8 knots cruising through sea state 7 Allow normal station and deck work in sea states through SS 5 and limited work through SS 7.
Stationkeeping	Maneuverability that would assure relative positioning at best heading in 35-knot winds and SS 5 and 2 knot current plus/minus 150 ft maximum excursion from a point or trackline, and maintain plus/minus 5 degree heading. Maintain a precision trackline while towing at speeds as low as 0.5 knots with a heading deviation up to 45 degrees from the prescribed trackline using GPS or bottom navigation as reference. (See navigation and positioning.) Speed control along track should be maintained plus/minus 0.1 knot (averaged over one-minute intervals). Trackline requirements should be met 95% of time considering range of specified sea states.
Dynamic Positioning	Ability to maintain vessel in position to 1 percent of water depth greater than 2000 m.

Table 2–2, Continued.

Ice Strengthening	Ice–capable – able to operate independently in open pack 4/10 – 6/10 concentration; first–year thin/medium level ice of not greater than 4 ft. thickness.
Deck Working Area	Total deck space 7000 sq ft including spacious fantail area (3,000 sq ft minimum) with 2000 sq ft clear area readily accessible to fantail with contiguous work area along one side 12 x 100 ft minimum. Provide for deck loading up to 1,500 lbs/sq ft and an aggregate total of 100 tons. Oversize holddowns (1 inch bolts) on 2–ft centers. Highly flexible to accommodate large and heavy equipment. Removable bulwarks. Dry working deck but not greater than 10–15 ft above waterline. All working decks accessible for power, water, air, data, voice and alarm communication ports. Work area equipped with steam deicing capability.
Boom	A boom on the foc'cle to extend to the water forward of the bow wave with an instrument loading of approximate 500 lbs. Manned–access to the end of the boom is required.
Cranes	A suite of modern cranes with constant tension capability and internal heating including: a) One large crane for heavy equipment op to 30000 lbs. located to support the fantail working area and to site vans and • articulated to work close to deck and water surface, • to handle oversize loads up to 10000 lbs. 24 m from center of crane • to have servo controls and motion compensation. b) Two cranes, one on each quarter, capable of towing with line pull of up to 5000 lbs. extending out to 20 ft for towed packages. c) One crane to service the bow working area (5000 lb. capacity).
Winches	New generation of oceanographic winch systems providing fine control (0.5 m/min); constant tensioning and constant parameter; internal heating. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems. Local and remote controls.

Table 2-2, Continued.

	Permanently installed general purpose winches include: ● Two winches capable of handling 30,000 ft of wire rope or electromechanical cables having diameters from 1/4" to 3/8". ● A winch complex capable of handling 40,000 ft of 9/16" trawling or coring wire and 30,000 ft of 0.68" electromechanical cable (up to 10 KVA power transmissions and fiber optics). This could be two separate winches or one winch with two storage drums. Additional special purpose winches may be installed temporarily at various locations along working decks with a footprint in accordance with tie-down locations. Winch sizes may range up to 40 tons (140 sq ft) and have power demands to 300 hp. Portable shelters available to winch work areas for instrument adjustments and repairs. Winch control station(s) located for optimum operator visibility with reliable communication to laboratories and ship control stations. A secondary winch control should be located on both the bridge and in one laboratory.
Overside Handling	Various frames and other handling gear and more versatile thank present to accommodate wire, cable and free launched arrays. Matched to work with winch and crane locations but able to be relocated as necessary. Stern A-frame to have 20-ft minimum horizontal and 30-ft vertical clearance; 15-ft inboard and outboard reaches; safe working load up to 60 tons. Midship J-frame with hydrowinch and adjacent to wet lab. Able to handle, deploy and retrieve 30 m piston cores. Control station(s) to give operator protection and operations monitoring and be located to provide maximum visibility of overside work.
Towing	Movable stern ramp capable of opening to facilitate trawling and deployment/recovery of ROV's. Capable of towing large scientific packages up to 10,000 lbs tension at 6-knots and 25,000 lbs at 2.5 knots in sea state 5, 35-knot wind, and 3-knot current.
Conference Room	Conference room with full communication with ship and deck operations (32 person capacity).

Table 2–2, Continued.

Laboratories	Approximately 4,000 sq ft of laboratory space broken down into approximately 12 individual laboratories which could include the following activities: including biological sample processing (flash freezing/washdown), trace chemistry (organic), trace chemistry (inorganic), biochemistry, radioisotope (low activity), radioisotope (high activity), wet lab, dry lab, electronic repair shop, air chemistry, photography, sediment processing, acousitic, meteorological, gravity, liquid nitrogen/liquid air processing facility, mechanical and computer. Two medium size general purpose wet labs to have large drains and associated strainers/cutters to accomodate sample residue. Electronics/computer facility and associated user space. A CTD prep room adjacent to midships J–frame connected by moving sidewalk through hinged door to ship interior. The CTD prep room must be capable of handling and storing 15 Gerard–type (200 liter) and 15, 20–30 liter water samplers. Multiple hose connectors in CTD prep room to enable water to be ported directly to other labs. A large drain will be placed in the floor for draining large volumes of water. CTD prep room to have hose pumping system (inert inner walls) capable of delivering 50 liters/min of continuous and discrete depth samples down to 1000 m. Special environmental lab conditions: One working lab to capable of being maintained at −25 to 2 plus/minus 1 degree C and another at −2 to 25 plus/minus 1 degree C for low–temperature biological and chemical sample processing and flash–freezing samples. Labs should be located so that none serve as general passageways. Access between labs should be convenient. Labs, offices, and storage to be served by a man–rated elevator having clear inside dimensions of approximately 3 ft by 4 ft and where appropriate, moving sidewalks. All labs should have structured inserts in bulkheads and decks for removal and addition of interior furnishing. Individual labs should be protected from cross–contamination through the ventilation system. Labs to be fabricated using uncontaminated and "clean" materials and constructed to be maintained as such. Furnishings, HVAC, doors, hatches, cable runs, and fittings to be planned for maximum lab cleanliness.

Table 2–2, Continued.

	Fume hoods to be installed permanently in Wet lab and Analytical lab. Main lab shall have provision for temporary installation of fume hoods.
	Cabinetry shall be high–grade laboratory quality including through the use of unistruts and deck boltdowns.
	Heating, ventilation, and air conditioning (HVAC) appropriate to laboratories, vans, and other science spaces being served. Laboratories shall maintain temperature of 20–24 degrees C, 50% relative humidity, and 9–11 air changes per hour. Filtered air provided to interior analytical and instrument labs. Each lab area to have a separate electrical circuit on a clean but with continuous delivery capability of at least 40–volt amperes per square foot of lab deck area. Labs to be furnished with 110 v and 220 v AC. Total estimated laboratory power demand is 100 KVA.
	A central facility to manufacture and store liquid nitrogen, dry ice and distilled and distilled–deionized water.
	Seawater and "clean" seawater supplies to most laboratories, vans, and several key deck areas. Intakes should be from two areas: one on bow slightly below water line and the other midships on keel. Measurements that are required close to point of entry include: SST, salinity, chlorophyll, phaeophytin and particulates. Flow rate of 50 liters/min required for these systems. Compressed air supply to be clean and oil–free.
	Modular vans connecting to a central walkway may be substituted for certain internal labs. These vans should be fabricated as part of the ships construction and contain full power, ducting and plumbing.
Vibration Control	As much as feasible, an effort should be made to reduce vibrations through shock mounting engines and generators.
Vans	To carry at least four standardized 8 ft by 20 ft portable vans which may be laboratory, berthing, storage, or other specialized use. Hookup provision for power, HVAC, fresh water uncontaminated sea water, compressed air, drains, communications, data and shipboard monitoring systems. Van access direct to ship interior.
	Provision to carry up to four additional portable non–standard vans (600 sq ft total) on super–structure, foc'cle and working decks. Supporting connections at several locations around ship including foredeck.
	Ship must be capable of loading and offloading vans using own cranes.

Table 2–2, Continued.

Workboats	At least one and preferably two 18–20 ft semi–rigid boats located for ease of launching and recovery. A scientific work boat 25–30 ft LOA specially fitted out for supplemental operation at sea including collecting, instrumentation, and wide–angle signal measurement. 12–hour endurance including both manned accommodations and automated operation. "Clean" construction. To be carried as a one of four–van options above. Workboat to be equipped with own skids for easy tie–down to deck.
Science Storage	Total of 16,000 cubic ft of scientific storage accessible to labs by elevator (500 lb load capable), moving sidewalks and weatherdeck hatch(es). Half to include suitable shelving, racks, and tie downs; remainder open hold. Easily accessible storage in hold (4000 cubic ft) under fantail area for moorings and weights (comparable to 60,000 lbs).
Acoustical Systems	Ship to be as acoustically quiet as practicable in the choice of all shipboard systems and their location and installation. Design target is operationally quiet noise levels at 12 knots cruising in sea state 5 at the following frequency ranges: • 3 kHz – 500 kHz echo sounding and acoustic navigation • 75 kHz – 300 kHz doppler current profiling Ship to have 12 kHz, 3.5 kHz echo sounding systems and provision for additional systems. Phased array, very wide multibeam precision echo sounding system (equivalent to "Sea Beam"). Transducers appropriate to dynamic positioning system. Transducers wells (20") one located forward and two athwartships. Large pressurized sea chest (4 ft x 8 ft) to be located at optimum acoustic location for at–sea installation and servicing of transducers and transponders. Conformable arrays along hull to monitor and control ROV's.
Helicopter	Helicopter pad (preferred with hangar).
Navigation/Positioning	Global Positioning Systems (GPS) with appropriate interfaces to data systems and ship control processors in 3–dimensions.

Table 2–2, Continued.

	Short baseline acoustic navigation system.
	Selected vessels should be equipped with "dynamic positioning" capability to maintain the ship on station or on a trackline to the stationkeeping specifications under automatic control and appropriate navigational reference.
Routine Monitoring	Digital systems for routine environmental monitoring: a) Water column: Directional wave spectra, ADCP b) Bathymmetric: Multibeam, shallow sub–bottom profiling, gravity c) Meteorological: UV radiation, global radiation, insolation, upper air soundings with rawinsonde
Internal Communications	Internal communication system providing high–quality voice and visual communications throughout all science spaces, working areas and other selected spaces (e.g., conference room, chief scientist stateroom).
	Data transmission, monitoring and recording system available throughout science spaces (including vans and key working areas) networked through a central computing facility.
	Closed–circuit television monitoring and recording of all working areas including subsurface performance of equipment and its handling with readout on bridge and selected laboratories.
	Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in all laboratories and other selected spaces (e.g., conference room, chief scientist stateroom) with data ports located at all winches and cranes.
External Communications	Reliable voice channels for continuous communications to shore stations (including home laboratories), other ships, and aircraft. This includes satellite, VHF, and UHF.
	Facsimile communications to transmit high–speed graphics and hard–copy text on regular schedules.
	High–speed data communications (56K Baud) links to shore labs and other ships on a continuous basis.

Table 2–2, Continued.

	Antenna located to minimize EM contamination to portable and interior lab spaces.
Satellite Monitoring	Carry transponding and receiving equipment including antenna to interrogate and receive satellite readouts of environmental remote sensing.
Ship Control	Chief requirement is maximum visibility of deck work areas during science operations and especially during deployment and retrieval of equipment. This would envision a bridge–pilot house very nearly amidships and with unobstructed stern visibility. The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude, and positioning will often be integrated with scientific operations requiring control to be exercised from a laboratory area.

Table 2–2, Continued.

LABORATORIES AND ASSOCIATED SPACES

Laboratory	**Large Vessel Size (sq. ft.)**	**Medium Vessel Size (sq. ft.)**	
Wet Laboratory	200	200	S
Dry Laboratory	150	150	S
Dry Laboratory	150		SVM
Radioisotope Laboratory	150	150	VM
Clean Laboratory (Inorganic)	200	160	VM
Clean Laboratory (Organic)	200		VM
General Laboratory (Stable environment for S o/oo, tracers, Co_2, O_2 and nutrients)	250	250	S
Macrofauna	300	200	S
Geology	400	200	S
Climate Controlled Space(s)	300	150	S??
Atmospheric Chemistry Laboratory	120		S
Phototography Laboratory	120	80	SVM
Computer Room	300	200	S
Bottom Topography Data Acquisition and Plotting	150	150	S
Doppler Current Data Acquisition and Control and ROV Control	200	200	S
Gravity Room	50	50	S
Charting and Plotting	200		SVM
Scientific Electronics Shop	100	100	SVM
Scientific Office	150	100	S
Meteorological Center	64	64	S
Total	3754	2404	

Notes:

S (Ship) V (Van) M (Modular)

Climate Control space needs ship refrigerant.

Atmospheric Chemistry to be located near bridge.

The Meteorological Center is a permanent facility of the ship and would include atmospheric soundings feet with a balloon launch facility on the clear deck space on the fantail. All of hardware associated with the meteorological center would be part of the bridge or communications center.

Associated with all of the above would be a bow room and/or sea chest where the clean seawater intakes and some sensors are located as well as the acoustics equipment room(s).

NOTES:

Table 2–3. Medium–Endurance, Multidisciplinary Oceanographic Research Vessel: Scientific Requirements.

Purpose	Hydrographic/tracer sections, buoy maintenance/handling, air–sea flux, moorings, continuous water and air sampling, seafloor processes, cross–disciplinary process studies, bathymmetry, and remotely–operated vehicles.
Endurance	Thirty days; providing the ability to transit to the most remote area and work 3–4 weeks on station. 8,000 mile range at cruising speed.
Accommodations	20–25 scientific personnel in two–person staterooms. Expandable to 30 through the use of vans. Science library–lounge and separate conference room.
Speed	15–20 knots cruising; sustainable through sea state 4. Speed control plus/minus 0.25 knot in 0–6 knot range; and plus/minus 0.5 knot in range 6–20 knots.
Seakeeping	Maintain science operations in following speeds and sea states: 15–20 knots cruising through sea state 4 13–15 knots cruising through sea state 5 8–13 knots cruising through sea state 6 6–8 knots cruising through sea state 7 Allow normal station and deck work in sea states through SS 5 and limited work through SS 7.
Stationkeeping	Maneuverability that would assure relative positioning at best heading in 35–knot winds and SS 5 and 2 knot current plus/minus 150 ft maximum excursion from a point or trackline, and maintain plus/minus 5 degree heading. Maintain a precision trackline while towing at speeds as low as 0.5 knots with a heading deviation up to 45 degrees from the prescribed trackline using GPS or bottom navigation as reference. (See navigation and positioning.) Speed control along track should be maintained plus/minus 0.1 knot (averaged over one–minute intervals). Trackline requirements should be met 95% of time considering range of specified sea states.
Dynamic Positioning	Ability to maintain vessel in position to 1 percent of water depth greater than 2000 m.

Table 2–3, Continued.

Ice Strengthening	ABS Ice Classification 1A. Able to transit loose pack. Not intended for icebreaking or close pack work. Protection against encounters with growlers and other glacial ice difficult to detect.
Deck Working Area	Total deck space 7000 sq ft including spacious fantail area (3,000 sq ft minimum) with 2000 sq ft clear area readily accessible to fantail with contiguous work area along one side 12 x 100 ft minimum. Provide for deck loading up to 1,500 lbs/sq ft and an aggregate total of 100 tons. Oversize holddowns (1 inch bolts) on 2–ft centers. Highly flexible to accommodate large and heavy equipment. Removable bulwarks. Dry working deck but not greater than 10–15 ft above waterline. All working decks accessible for power, water, air, data, voice and alarm communication ports.
Boom	A boom on the foc'cle to extend to the water forward of the bow wave with an instrument loading of approximate 500 lbs. Manned–access to the end of the boom is required.
Cranes	A suite of modern cranes with constant tension capability including: a) One large crane for heavy equipment op to 30000 lbs. located to support the fantail working area and to site vans and • articulated to work close to deck and water surface • to handle oversize loads up to 10000 lbs. 24 m from center of crane • to have servo controls and motion compensation. b) Two cranes, one on each quarter, capable of towing with line pull of up to 5000 lbs. extending out to 20 ft for towed packages. c) One crane to service the bow working area (5000 lb capacity).
Winches	New generation of oceanographic winch systems providing fine control (0.5 m/min); constant tensioning and constant parameter. Wire monitoring systems with inputs to laboratory panels and shipboard recording systems. Local and remote controls. Permanently installed general purpose winches include: • Two winches capable of handling 30,000 ft of wire rope or electromechanical cables having diameters from 1/4" to 3/8".

Table 2-3, Continued.

	• A winch complex capable of handling 40,000 ft of 9/16" trawling or coring wire and 30,000 ft of 0.68" electromechanical cable (up to 10 KVA power transmissions and fiber optics). This could be two separate winches or one winch with two storage drums.
	Additional special purpose winches may be installed temporarily at various locations along working decks with a footprint in accordance with tie-down locations. Winch sizes may range up to 40 tons (140 sq ft) and have power demands to 300 hp.
	Portable shelters available to winch work areas for instrument adjustments and repairs. Winch control station(s) located for optimum operator visibility with reliable communication to laboratories and ship control stations.
	A secondary winch control should be located on both the bridge and in one laboratory.
Overside Handling	Various frames and other handling gear and more versatile thank present to accommodate wire, cable and free launched arrays. Matched to work with winch and crane locations but able to be relocated as necessary.
	Stern A-frame to have 20-ft minimum horizontal and 30-ft vertical clearance; 15-ft inboard and outboard reaches; safe working load up to 60 tons.
	Midship J-frame with hydrowinch and adjacent to wet lab.
	Able to handle, deploy and retrieve 10 m spar buoy.
	Control station(s) to give operator protection and operations monitoring and be located to provide maximum visibility of overside work.
Towing	Movable stern ramp capable of opening to facilitate trawling and deployment/recovery of ROV's. Capable of towing large scientific packages up to 10,000 lbs tension at 6-knots and 25,000 lbs at 2.5 knots in sea state 5, 35-knot wind, and 3-knot current.
Conference Room	Conference room with full communication with ship and deck operations (32 person capacity).
Laboratories	Approximately 3,000 sq ft of laboratory space broken down into approximately 8 individual laboratories which could include the following activities: including biological sample processing (flash freezing/washdown), trace chemistry (organic), trace chemistry (inorganic), biochemistry, radioisotope (low activity), radioisotope (high activity), wet lab, dry lab,

Table 2–3, Continued.

electronic repair shop, air chemistry, photography, sediment processing, acousitic, meteorological, gravity, liquid nitrogen/liquid air processing facility, mechanical and computer.

Two medium size general purpose wet labs to have large drains and associated strainers/cutters to accomodate sample residue.

Electronics/computer facility and associated user space.

A CTD prep room adjacent to midships J–frame connected by moving sidewalk through hinged door to ship interior. The CTD prep room must be capable of handling and storing 15 Gerard–type (200 liter) and 15, 20–30 liter water samplers. Multiple hose connectors in CTD prep room to enable water to be ported directly to other labs. A large drain will be placed in the floor for draining large volumes of water.

CTD prep room to have hose pumping system (inert inner walls) capable of delivering 50 liters/min of continuous and discrete depth samples down to 1000 m.

Special environmental lab conditions: One working lab to capable of being maintained at –2 to 25 plus/minus 1 degree C for low–temperature biological and chemical sample processing and flash–freezing samples.

Labs should be located so that none serve as general passageways. Access between labs should be convenient. Labs, offices, and storage to be served by a man–rated elevator having clear inside dimensions of approximately 3 ft by 4 ft and where appropriate, moving sidewalks.

All labs should have structured inserts in bulkheads and decks for removal and addition of interior furnishing.

Individual labs should be protected from cross–contamination through the ventilation system.

Labs to be fabricated using uncontaminated and "clean" materials and constructed to be maintained as such. Furnishings, HVAC, doors, hatches, cable runs, and fittings to be planned for maximum lab cleanliness.

Fume hoods to be installed permanently in Wet lab and Analytical lab. Main lab shall have provision for temporary installation of fume hoods.

Cabinetry shall be high–grade laboratory quality including through the use of unistruts and deck boltdowns.

Table 2–3, Continued.

	Heating, ventilation, and air conditioning (HVAC) appropriate to laboratories, vans, and other science spaces being served. Laboratories shall maintain temperature of 20–24 degrees C, 50% relative humidity, and 9–11 air changes per hour. Filtered air provided to interior analytical and instrument labs. Each lab area to have a separate electrical circuit on a clean but with continuous delivery capability of at least 40–volt amperes per square foot of lab deck area. Labs to be furnished with 110 v and 220 v AC. Total estimated laboratory power demand is 100 KVA. A central facility to manufacture and store liquid nitrogen, dry ice and distilled and distilled–deionized water. Seawater and "clean" seawater supplies to most laboratories, vans, and several key deck areas. Intakes should be from two areas: one on bow slightly below water line and the other midships on keel. Measurements that are required close to point of entry include: SST, salinity, chlorophyll, phaeophytin and particulates. Flow rate of 100/50 liters/min required for these systems. Compressed air supply to be clean and oil–free. Modular vans connecting to a central walkway may be substituted for certain internal labs. These vans should be fabricated as part of the ships construction and contain full power, ducting and plumbing.
Vibration Control	As much as feasible, an effort should be made to reduce vibrations through shock mounting engines and generators.
Vans	To carry at least two standardized 8 ft by 20 ft portable vans which may be laboratory, berthing, storage, or other specialized use. Hookup provision for power, HVAC, fresh water uncontaminated sea water, compressed air, drains, communications, data and shipboard monitoring systems. Van access direct to ship interior. Provision to carry up to four additional portable non–standard vans (600 sq ft total) on super–structure, foc'cle and working decks. Supporting connections at several locations around ship including foredeck. Ship must be capable of loading and offloading vans using own cranes.
Workboats	Two 25–30 ft semi–rigid boats located for ease of launching and recovery specially fitted out for supplemental operation at sea including collecting, instrumentation, and wide–angle signal measurement. 12–hour endurance including both manned accommodations and automated operation. "Clean" construction. To be carried as a two of two–van options above. Workboats to be equipped with own skids for easy tie–down to deck.

Table 2–3, Continued.

Science Storage	Total of 10,000 cubic ft of scientific storage accessible to labs by elevator (500 lb load capable), moving sidewalks and weatherdeck hatch(es). Half to include suitable shelving, racks, and tie downs; remainder open hold.
Acoustical Systems	Ship to be as acoustically quiet as practicable in the choice of all shipboard systems and their location and installation. Design target is operationally quiet noise levels at 12 knots cruising in sea state 5 at the following frequency ranges: • 3 kHz – 500 kHz echo sounding and acoustic navigation • 75 kHz – 300 kHz doppler current profiling Ship to have 12 kHz, 3.5 kHz echo sounding systems and provision for additional systems. Phased array, very wide multibeam precision echo sounding system (equivalent to "Sea Beam"). Transducers appropriate to dynamic positioning system. Transducers wells (20") one located forward and two athwartships. Large pressurized sea chest (4 ft x 8 ft) to be located at optimum acoustic location for at–sea installation and servicing of transducers and transponders. Conformable arrays along hull to monitor and control ROV's.
Helicopter	A clear area to provide for helicopter hovering.
Navigation/Positioning	Global Positioning Systems (GPS) with appropriate interfaces to data systems and ship control processors in 3–dimensions. Short baseline acoustic navigation system. Selected vessels should be equipped with "dynamic positioning" capability to maintain the ship on station or on a trackline to the stationkeeping specifications under automatic control and appropriate navigational reference.
Routine Monitoring	Digital systems for routine environmental monitoring: a) Water column: Directional wave spectra, ADCP b) Bathymmetric: Multibeam, shallow sub–bottom profiling, gravity c) Meteorological: UV radiation, global radiation, insolation, upper air soundings with rawinsonde

Table 2–3, Continued.

Internal Communications	
	Internal communication system providing high–quality voice and visual communications throughout all science spaces, working areas and other selected spaces (e.g., conference room, chief scientist stateroom).
	Data transmission, monitoring and recording system available throughout science spaces (including vans and key working areas) networked through a central computing facility.
	Closed–circuit television monitoring and recording of all working areas including subsurface performance of equipment and its handling with readout on bridge and selected laboratories.
	Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in all laboratories and other selected spaces (e.g., conference room, chief scientist stateroom) with data ports located at all winches and cranes.
External Communications	
	Reliable voice channels for continuous communications to shore stations (including home laboratories), other ships, and aircraft. This includes satellite, VHF, and UHF.
	Facsimile communications to transmit high–speed graphics and hard–copy text on regular schedules.
	High–speed data communications (56K Baud) links to shore labs and other ships on a continuous basis.
	Antenna located to minimize EM contamination to portable and interior lab spaces.
Satellite Monitoring	
	Carry transponding and receiving equipment including antenna to interrogate and receive satellite readouts of environmental remote sensing.
Ship Control	Chief requirement is maximum visibility of deck work areas during science operations and especially during deployment and retrieval of equipment. This would envision a bridge–pilot house very nearly amidships and with unobstructed stern visibility.
	The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude, and positioning will often be integrated with scientific operations requiring control to be exercised from a laboratory area.

Table 2–3, Continued.

LABORATORIES AND ASSOCIATED SPACES

Laboratory	Large Vessel Size (sq. ft.)	Medium Vessel Size (sq. ft.)	
Wet Laboratory	200	200	S
Dry Laboratory	150	150	S
Dry Laboratory	150		SVM
Radioisotope Laboratory	150	150	VM
Clean Laboratory (Inorganic)	200	160	VM
Clean Laboratory (Organic)	200		VM
General Laboratory (Stable environment for S o/oo, tracers, Co_2, O_2 and nutrients)	250	250	S
Macrofauna	300	200	S
Geology	400	200	S
Climate Controlled Space(s)	300	150	S??
Atmospheric Chemistry Laboratory	120		S
Phototography Laboratory	120	80	SVM
Computer Room	300	200	S
Bottom Topography Data Acquisition and Plotting	150	150	S
Doppler Current Data Acquisition and Control and ROV Control	200	200	S
Gravity Room	50	50	S
Charting and Plotting	200		SVM
Scientific Electronics Shop	100	100	SVM
Scientific Office	150	100	S
Meteorological Center	64	64	S
Total	3754	2404	

Notes:

S (Ship) V (Van) M (Modular)

Climate Control space needs ship refrigerant.

Atmospheric Chemistry to be located near bridge.

The Meteorological Center is a permanent facility of the ship and would include atmospheric soundings feet with a balloon launch facility on the clear deck space on the fantail. All of hardware associated with the meteorological center would be part of the bridge or communications center.

Associated with all of the above would be a bow room and/or sea chest where the clean seawater intakes and some sensors are located as well as the acoustics equipment room(s).

Table 2–4. Low–Endurance, Multidisciplinary Oceanographic Research Vessel: Scientific Requirements

General	This ship will serve as a general purpose research vessel with limited endurance and maximum flexibility of operations. Vessel will provide access to shallow waters with launches. It is fully capable of continuous 24–hour operations. The primary design requirement is to combine multi–disciplinary capability with small size and cost effectiveness. For this vessel, endurance and cruising speed are secondary to broad operational capabilities and seakeeping qualities.
Endurance	15–21 days. Endurance formula should include 50% cruising and 50% on–station. RANGE = 5,000 nautical miles.
Accommodations	12 to 16 scientific personnel in two–person cabins, under research cruise conditions. Expandable to 24 with a van.
Speed	12–13 knots cruising; sustain 10 knots through sea state 4. Maximum speed = 14 knots. Speed control +– 0.1 knot in speed range from 0 to 6 knots. Design trade–offs should favor seakeeping over speed.
Seakeeping	Maintain science operations at these speeds and sea states: 9 knots in sea state 4 7 knots in sea state 5 4 knots in sea state 6 Allow normal station and deck work in sea states through SS4 and SS5.
Stationkeeping	Maintain station and over–the–side vertical operations in sea state 4, without dynamic positioning. Bow thruster.
Ice–Strengthening	ABS Class C (ability to transit loose pack ice) may be desirable for one or more vessels of this class as a Great Lakes research vessel.
Deck Working Area	Approximately 1500 sq. ft with contiguous work area along starboard waist = 8 ft. x 20 ft. minimum for CTD and rosette sampler handling. Deck loading at 1500 lbs/sq. ft. Heavy duty holddowns on 2–ft. centers. Able to accommodate at least one (preferably two) 8 ft. by 20 ft. van yet retaining clear access to stern and waist work areas. Removable bulwarks with hinged freeing ports to provide dry deck conditions in beam or quartering seas.

Table 2–4, Continued.

	All working decks with multiple access for power, fresh and salt water, air and cable–ways for data and voice communication lines. Low freeboard at fantail (3 to 5 ft.), with a stern ramp.
Cranes	(2) – One articulated crane to handle large and heavy (up to 10,000 lbs.) gear over both sides, on station and underway, with lateral motion damping, and an outboard reach of 14 ft. on one side. This crane also capable of reaching all working deck areas for loading and off–loading of equipment (including empty van). Man–rated for launch and recovery of small submersibles and ROVs. A second, smaller crane with re–location sites forward, midships and aft; articulated for work at deck level and at the sea surface, with weights up to 4,000 lbs., also usable as over–the–side, cable fairlead for vertical work and light towing.
Winches	Two modern winches with state–of–the–art controls providing fine control (0.5 m/min); constant tensioning or with tension accumulator. Wire monitoring systems on both winches, with readouts on laboratory panels and shipboard recording systems, as well as on the bridge. Local and remove control boards. Winches to be re–locatable (in port) to allow reconfiguration of deck layout. Capable of transferring winch drums at sea.
	Hydrowinch with interchangeable drums capable of handling up to 5,000 ft. of wire rope. Kevlar synthetic line or elecromechanical cables having diameters from 1/4" to 3/8" or 11 mm standard (e.g. Markey DES–5 or equivalent). Slip rings with 6 conductors.
	Trawling winch capable of handling 20,000 ft. of 1/2" trawling or coring wire or 20,000 ft. of 0.68" electromechanical cable (up to 10 KVA power transmission) or fiber optics cable. A traction winch is a possible alternative. Some flexibility in winch location is desired.
	All weather winch control station(s) located for optimum operator visibility of all work area and overside gear, with fail–safe communications to deck level, laboratories, and bridge. A–frame controls included.
Overside Handling	Various frames, davits and other handling gear to accommodate wire, cable and free–launched arrays. Matched to work with winch and crane locations, and with moveable capstans, but able to be relocated as necessary.
	Stern A–frame to have 15–ft. throat (horizontal width at deck level and up to 15 ft. off deck) and 20–ft. vertical clearance, 12–ft. inboard and outboard reaches. Man–rated for launch and recovery of small submersibles/ROVs. Safe working load of 20,000 lbs. Controls to be located at A–frame and at winch control station.

Table 2–4, Continued.

Trawling	Capable of trawling midwater and benthic gear at speeds up to 4 knots with line tensions of 20,000 lbs.
Laboratories	Minimum of 1,000 sq. ft. of laboratory space allocated: 75% main lab (including separate electronics lab capability), and reconfiguration into smaller specialized labs. Wet lab to be located contiguous to sampling areas; main lab with temperature and humidity precisely controlled. Labs to be located so that none serve as general passageways. Access between labs to be convenient. Dry lab and electronics lab areas with door sills to keep water out. Main lab access to be large enough to accommodate transfer of large equipment items. To ensure as much flexibility as possible modular laboratory units or vans are encouraged rather than fixed ship units. Labs to be fabricated using uncontaminated and "clean" materials and constructed so they can be easily maintained in an uncontaminated condition. Furnishings, HVAC, doors, hatches, cable runs, plumbing, and fittings to be planned for maximum lab cleanliness. Fume hood to be installed permanently in one of the laboratories or vans. Main lab to have provision for temporary installation of fume hood. Hood flues able to withstand acid fumes and situated so no fumes can be drawn back to occupied areas inside or on deck. Cabinetry shall be of high grade laboratory quality including flexibility through the use of unistruts and deck boltdowns on 1 ft. centers. Heating, ventilation, and air conditioning (HVAC) capabilities as follows: Labs shall maintain temperature of 70–75 degrees F in all weather conditions; 25% relative humidity; and 9–11 air changes per hour. Each lab area to have a separate electrical circuit on a clean bus with continuous delivery capability of at least 40–volt amperes per square foot of lab deck area. Labs to be furnished with 110 v and 220 v AC. Maximum estimated laboratory power demand is 50 KVA. Uncontaminated sea water supply to wet and dry labs, and deck areas (including anywhere on the fantail). Compressed air supply to all labs and deck area; supply to be clean and oil free, with 100 lbs. service pressure at outlets.
Special Science Facilities	Science shop with workbench, vise, and basic hand and power tools. Scientific freezer space = 36 cubic ft. @ –20 degrees C, and 50 cubit ft. @ –5 degrees C.

Table 2–4, Continued.

	SCUBA support facilities--compressor, water entry platform and ladder, tank storage racks.
	Space and capability for setting up an operating station for a small ROV; with deck space for cable payout and coiling, launch and recovery. ROV control center with video monitor, recording gear and communication in the main lab or on the bridge.
	Undisturbed air flow at bow for air–sea interaction studies.
Van	Capable of handling and carrying at least one standard 8 ft. by 20 ft. portable deck van, which may be laboratory, berthing, storage or other specialized use. Hookup provision for power, HVAC, fresh water, uncontaminated sea water, compressed air, drains, communications, data and shipboard monitoring systems. Van should have close, if not direct, access to ship's interior. Ship should be capable of loading and off-loading empty van using its own crane at dockside.
Workboats	Two 20–25 ft. semi–rigid boats, fitted for supplemental operation at sea including collecting, and instrumentation with a 12–hour endurance. "Clean" construction workboats should be equipped with own skids for easy tie–down to deck.
Acoustical Systems	Ship to be as acoustically quiet as possible in the choice of all shipboard systems and their location and installation. Ship to have conventional 12 kHz, and 3.5 kHz echo sounding systems and provision for additional systems as needed. Transducers to be mounted so as to provide clean transmission and reception from both lateral (tracking) and vertical signals. Three transducer wells with at sea access for servicing and installation.
Navigation/Positioning	Global Positioning System (GPS) and Loran C with appropriate interfaces to data systems in lab and ship control processors.
	Short baseline acoustic navigation system.
Internal Communications	Internal communication system providing high quality voice communications throughout all science spaces and working areas.
	Data transmission, monitoring, and recording system available throughout science space including van and key working areas.

Table 2–4, Continued.

	Closed circuit television monitoring of all outside working areas including subsurface performance of equipment and its handling.
	Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in all, or most, science spaces.
Exterior Communications	Reliable voice channels for continuous communications to shore stations (including home laboratories), other ships, boats and aircraft. This includes satellite, VHF and UHF.
	Facsimile communications to transmit high speed graphics and hard–copy text on regular schedules.
	High speed data communications links to shore labs and other ships on a continuous basis.
	Capability to receive real–time or near real–time satellite imagery.
Ship Control	Chief requirement is maximum visibility of deck work areas and adjacent sea surface, during science operations and especially during deployment and retrieval of equipment.
	The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude, and positioning will often be integrated with scientific operations requiring control to be exercised from a laboratory or deck working area.

Fishery Research

NOAA research on fisheries and other living marine resources (LMR) will continue to place a major focus on improving the scope and accuracy of assessments of exploited and protected species. These studies are essential for documenting the relationship between population changes and exploitation rates, and they represent a critical part of the data base needed for achieving conservation and management objectives. In addition, there is a need for significant augmentation of research on ecological processes controlling abundance of LMR's, and dynamic properties of the marine ecosystems supporting them, for developing predictive models of the long–term effects of exploitation, habitat degradation and natural environmental trends. Attaining each of these goals will require improved technology and vessel design so that the same ship can carry out concurrent multi–disciplinary studies in an efficient manner. Advances in remote–sensing technology (e.g., high–resolution acoustics as well as satellite imagery) and real–time data acquisition/processing together with acoustically quieter hulls will, for example, make it possible to increase the efficiency of pelagic resource assessments (from whales to zooplankton). The same vessel upgrades will greatly extend the scope and efficiency of studies of the marine ecosystem which must be conducted aboard ships, particularly in the mode of clarifying the relative importance of the wide range of spatial scales in the ocean which control the dynamics of LMR populations. Increases in research vessel commitments will be needed to develop and calibrate new biological measurement techniques, and to utilize these techniques for more comprehensive assessment, monitoring, and process–oriented studies on LMR's.

Background of Study

As we approach the 21st century, it is with a rapidly growing awareness that man is not only putting great stress on exploited animal populations, but even more important, he is degrading the earth's environment for living organisms. This has been clearly documented on local and regional scales, and now seems to be apparent on a global scale as well. In the marine environment, the environmental effects so far have been largely in the form of degradation of coastal and estuarine waters, where physical loss of habitat and pollution have directly or indirectly resulted in significant losses in productivity of fish and shellfish populations. It is likely that further productivity losses of these resources will occur, particularly in heavily populated coastal regions; and exploitation of natural populations is expected to increase along with the projected increases in human populations and the concomitant demand for food and recreation from the sea. The potential effects of long–term climate change on distribution and productivity of fishery resources could be even greater, resulting in large–scale economic and social impacts. These scenarios underscore the critical importance of NOAA's mission as the Nation's Earth Systems Agency which seeks to understand the dynamic linkages between climate and ocean processes, and the combined effects of natural and anthropogenic stresses on living marine resources and the ecosystems supporting them (Figure 3–1). Achieving these goals will require a greatly expanded array of monitoring and research activities into the next century by modern NOAA vessels equipped with new technology.

Activities of the Working Group

This report is a summary of the deliberations of the Fishery Research Working Group. A list of participants is given in Appendix B. The Working Group included fishery scientists and oceanographers from a variety of subdisciplines in those fields, and collectively represented a wide range of shipboard experience on research vessels. It also included a good mix of scientists with responsibilities for planning and implementing the full range of research programs required to meet NOAA's mission requirements relative to fisheries and other living marine resources (LMR). The report focuses on the fishery–research vessel capabilities necessary to meet these mission requirements into the next century. It represents a synthesis of Working Group discussions and material from a number of separate position papers prepared by

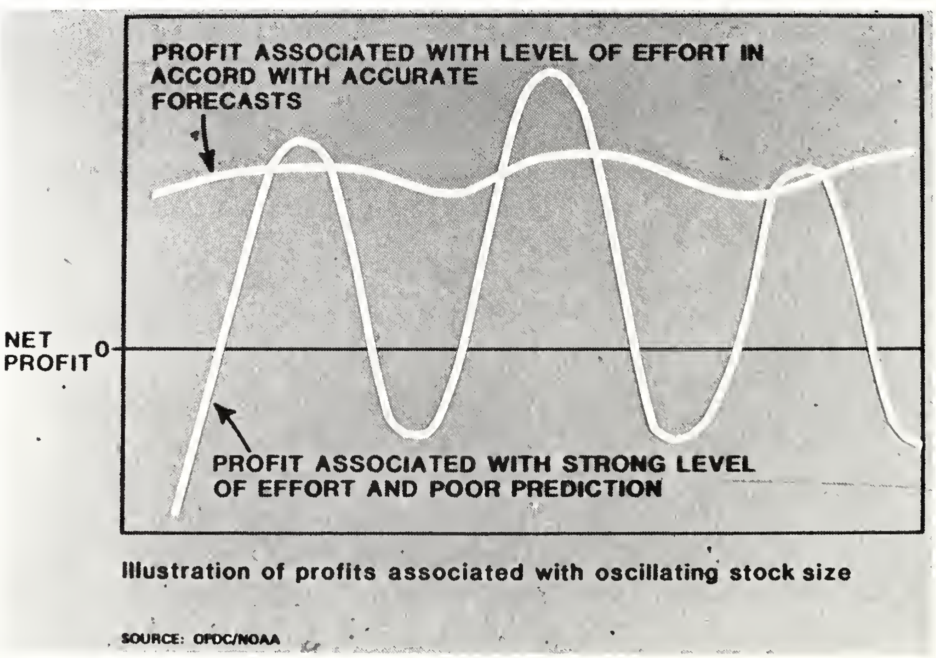


Figure 3–1. *Accurate prediction of fish stocks, made possible by NOAA fishery research will aid the fishing industry to operate more profitably. This curve shows how profit is related with level of effort in accord with accurate forecasts. (Courtesy NOAA/NMFS)*

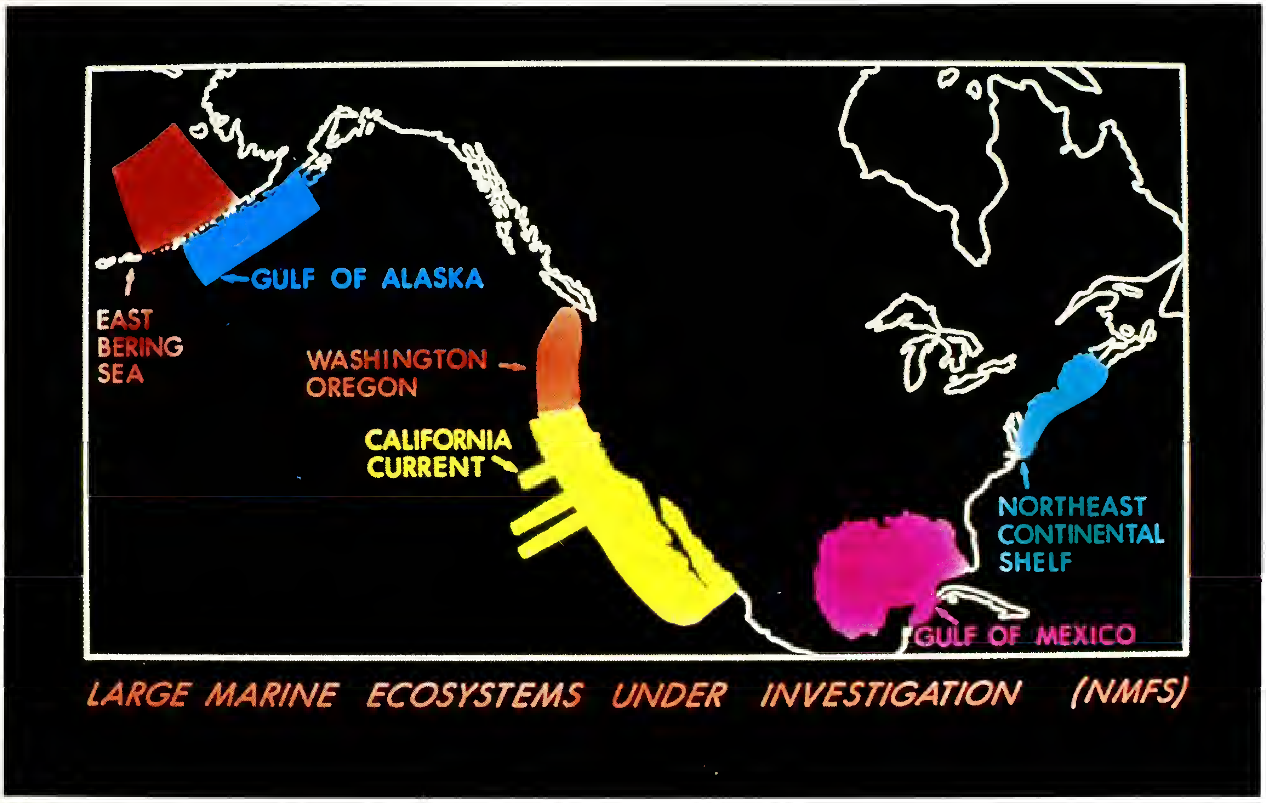


Figure 3–2. *Research conducted from NOAA vessels will be needed to investigate both the long– and short–term processes at work in marine ecosystems. (Courtesy NOAA/NMFS)*

individual members of the Working Group. These position papers appear in Appendix A and give more detailed descriptions of research problems and associated vessel needs.

Vessel design characteristics of unique importance to fishery research operations are given principal focus in the final section of this report, although operational requirements common to other oceanographic research are also covered. Operational requirements are described for three generic vessel classes (oceanic, coastal, and estuarine), with detailed specifications presented in Tables 3–1 – 3–3. A range of values exists for many operational requirements and there are some differences in requirements among the various regions. In general, the more stringent requirements appear in the tables.

Current Mission Requirements

The mission of NOAA relative to living marine resources (LMR) is to achieve continued optimum utilization of LMR for the benefit of the Nation. A critical objective is maintaining the productive potential of these resources through management of fishing and other human activities which affect biological productivity. This requires an understanding of the dynamic properties of the marine ecosystems supporting the LMR as well as man's effects on them. This understanding can only be achieved through a broad array of physical and biological studies, many of which require research vessels (Figure 3–2). These studies focus on assessing and predicting changes in the abundance and structure of LMR and associated biological communities with which they interact, studying ecological processes controlling production potential of LMR, and documenting the range of natural variability observed in the marine ecosystem.

The scope of activities by NOAA is very broad, and the agency pursues its mission under an umbrella of more than 100 federal statutes. Some of the most important of these relative to vessel needs for fisheries research include the Magnuson Fishery Conservation and Management Act, the Endangered Species Act, the Anadromous Fisheries Conservation Act, the Marine Mammal Protection Act, and the Driftnet Act. In addition, the U.S. is a party to many international agreements governing LMR's both within and outside the EEZ. These and other statutes mandate the collection of a wide array of information on LMR's and their environment from estuaries to the open oceans (and also the Great Lakes).

A fleet of research vessels equipped with modern technology will be needed to assess marine resources and their environment. These vessels will also be needed to meet the demands for information on LMR stock assessments by Fishery Management Councils, develop a fundamental understanding of the ecosystems supporting LMR's, and respond to new mandates, e.g., marine mammal/fishery interactions. Limited amounts of these NOAA/NMFS functions are currently performed on foreign research vessels or vessel charters, but the backbone of our future fisheries science will continue to depend upon NOAA research vessels.

Further, major new programs (Global Climate Change, Coastal Ocean Program) will require both qualitative and quantitative increases in vessel support. There will also be development in the direction of increased multidisciplinary and collaborative effort among NOAA line organizations, universities, and other marine research institutions.

Future Directions

Fishery Resource Assessments

1. LMR Stock Assessment. Stock assessment is a traditional research responsibility of NMFS involving the collection of standardized fishery-independent data on the distribution, abundance, and population structure of exploited populations. These data are a critical part of the information needed for forecasting future population trends and evaluating effects of fishing on LMR's. Although vessel charters or future charter-for-quota schemes may be most cost-effective in some cases, research vessels are required for a significant part of this stock assessment time-series.

Research vessels provide standardized abundance indices of exploited and unexploited species which are necessary for accurate analysis of population trends, and they must be done regularly to monitor changes, particularly those resulting from highly variable recruitment. Relative abundance measures (e.g., catch per standard trawl haul) are the only feasible way devised so far which can provide reliable indices of population abundance for the wide variety of fish species for which assessments are required. Broad experience of fishery scientists around the world has demonstrated that a time-series of such standardized indices is essential for assessing the relation between fishing and yield, and for many species it is the only consistent measure of population change available. When combined with accurate statistics on the magnitude and age composition of catches, these research vessel time-series provide a powerful basis for evaluating the basic dynamics of exploited populations.

Although progress is being made in development of more direct methods of estimating abundance, particularly bioacoustic biomass assessment techniques, these still have serious limitations particularly for demersal species which make up a significant share of the fishery resources. Thus, for the foreseeable future we shall have a continuing need for regular standardized trawl surveys. At the same time, trawl surveys provide a large array of other essential data (e.g., prerecruit indices, predator–prey interactions, growth, age at maturity, etc.). These latter studies are crucial for developing the ecological basis for improving predictions of long–term effects of fishing and environmental change on LMR's.

With continued growth of the human population there will be increasing demands on LMR for food and recreation. This will result in continuing demands for improved assessments and management of LMR involving more species/stocks, and greater accuracy of information to permit more precise and timely forecasting, resolution of resource allocation conflicts, and development of multispecies management plans. In order to meet these demands, we foresee expanded research to improve assessments and to design more efficient surveys. For the next decade, more research vessel coverage will be needed to improve assessments, e.g., special purpose surveys will be needed to investigate sources of bias in survey sampling technologies and estimation procedures. At the same time, studies need to be done on alternative methods such as acoustic and visual ROV systems that eventually should improve the efficiency of vessel use as well as the precision and accuracy of abundance estimates.

Recent advances in echo–integration technology, including hardware and software, have led to significant improvements in assessment methods for pelagic and semi–pelagic fish stocks. Norwegian scientists have designed an advanced scientific echo–integrator/sounder incorporating split–beam technology to measure target strength ***in situ*** that outputs to a powerful workstation computer. This provides the capability for rapid and sophisticated analyses to be conducted during the survey. With the addition of new standard sphere calibration procedures, pre– and post–cruise system calibrations can be conducted aboard ship relatively easily. This remote–sensing methodology of assessing off–bottom fish allows the survey vessel to steam at 9 to 10 knots collecting acoustic data. So far, the method has been most successful for off–bottom schools of fish where only a single species is present. It is much more difficult where there is a significant mixture of schooling species, as is often the case. However, direct sampling with nets is always necessary to confirm species identification, and there is as yet no foolproof way of knowing the actual acoustic target strength of fish under varying behavioral and environmental conditions in the sea.

Certain vessel design requirements are critical for successful application of an echo–integration acoustic system. These include an acoustically quiet ship, deck space for acoustic van or electronics lab, and wire tunnel ways for data transmission free from electromagnetic fields. The vessel should also be equipped with a retractable transducer housing, and a small deck crane and winch to tow a transducer on a dead weight fin. A useful feature on the MILLER FREEMAN has been a retractable stabilizing centerboard which has the dual purpose of serving as a mount for transducers. To conduct the standard sphere calibration, the vessel must maintain a stable precise position for 24 hours using a two–point anchor.

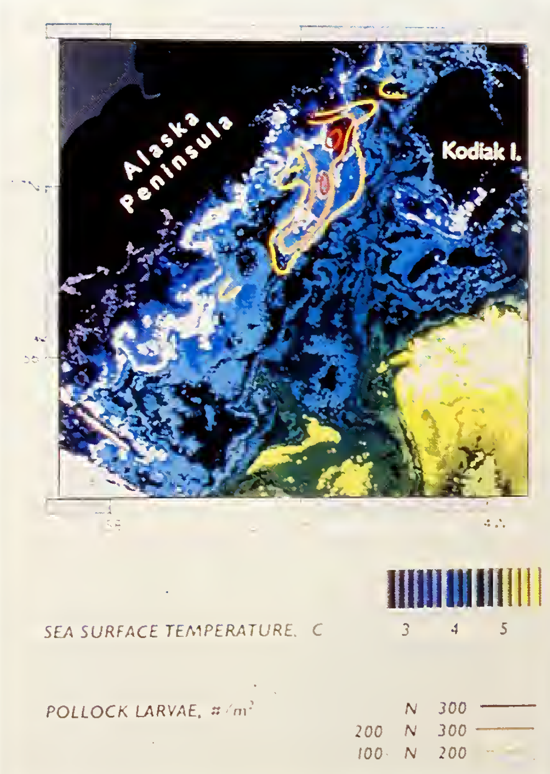
2. *Fisheries Oceanography*. As a discipline, fisheries oceanography goes beyond the traditional role of fisheries research to

integrate physical oceanography and climatology with biological oceanography, ecology, and fisheries biology to better understand dynamics of exploited populations in the context of their environment. At present, there are two somewhat different types of investigation in fisheries oceanography. The first, currently receiving the greatest attention, focuses on identifying the mechanisms controlling abundance and species composition both in the short–term (interannual) and the long–term (interdecadal) and is often termed recruitment fisheries oceanography. The second is more general and seeks to understand how the spatial and temporal distribution of fishes is controlled by physical features of the ocean.

Recruitment fisheries oceanography is devoted to understanding processes leading to recruitment and the physical and biological factors that cause spatial and temporal variability on several scales. Past research examining strictly predation, starvation, or advection of early life history stages has not been markedly successful in explaining recruitment variation at the population level. However, present technology and extrapolations for the next two decades clearly indicate that such process–oriented field experiments can lead to improved understanding of fishery variability. Current studies are multidisciplinary in focus and require intensive experiments at sea over various temporal and spatial scales, utilizing research vessels with capability for deploying a wide array of fisheries and oceanographic sampling gear.

The recruitment process is complex, involving multiple interacting physical and biological factors, impacting many life stages and species of fish as well as other trophic components of the marine ecosystem. Investigations tuned to fishery processes can employ sampling strategies with high spatial and temporal resolution combined with wide areal coverage. Observations often will be centered on an advected and evolving transient physical feature and require quasi–synoptic observations with several kinds of biological sampling devices. Seagoing efforts pertinent to such recruitment research include several projects either underway (e.g., SARP, FOCI, SEFCAR) or proposed for future funding. Figure 3–3 is an example of such research. Within the next five years there will be recruitment studies in most of the major ocean areas of interest to NOAA, with a broad range of non–NOAA scientific participation. All share commonalities that have implications for the design of research vessels.

Figure 3–3. *The coordination of satellite measurement of sea surface temperature with ship–conducted sampling of concentrations of fish larvae is necessary for adequate precision of fish stock estimates. Such coordination was achieved in this study of pollock larvae. (Courtesy NOAA/OAR/Pacific Marine Environmental Laboratory)*



Studies typically begin with larger spatial–scale sampling often narrowed by remotely–sensed information. Remote sensing of the environment (from the ship, remote instrument moorings, and satellites) is absolutely necessary to ensure mission success. Future efforts to develop remote–instrumented drones may also be beneficial to this effort. Regardless of source, continual updates of remotely–sensed data will make at–sea satellite downlink and image processing a necessity. Defining environmental features and distribution patterns of eggs and larval stages will require new sampling technologies, which are likely to involve *in situ* measurement, as in Figure 3–3. High vessel speed will be important to quickly characterize the critical spatial patches and to track and characterize the specific features of interest as they evolve.

Shipboard laboratory facilities to conduct experimental work (e.g., nutrient analysis, primary productivity measurements, copepod egg production rates, and larval feeding studies) will increasingly be complemented by new *in situ* technology. New sampling equipment, including large midwater trawls, ROV's, and acoustics, will be required to follow the progress of successively later stages of development of young fish. The relationship of these studies to fisheries–dependent and –independent stock assessments becomes evident as the latter provide the baseline of year–class–strength data from which to evaluate relative recruitment strength.

The second type of study in fisheries oceanography concerns the dynamics of distribution and movements of resource species. Demersal resources may shift spatial distributions in response to temperature or oxygen variations on temporal scales ranging from daily to climatic. Similarly, pelagic species such as tunas undergo migrations often subject to variations in large–scale oceanographic patterns, particularly frontal regions. Understanding these movements is important for interpreting catch rates and fleet dynamics. Higher vessel speeds, remote–sensing capability, and rapid environmental data collection, including profiling, are all important to these studies. Advances in fisheries oceanography research will thus require significant improvements to NOAA's research fleet.

3. Gear Research. The development of new gear for both fishing and research sampling needs will require some research vessel time. Important vessel design considerations for this type of work involve flexibility and space, including open fantail area and appropriate suite of winches, cranes and A/J frames. With ever–increasing exploitation pressure on LMR's and increasing public interest in conservation, there is an increasing need for fishing gear that is more selective for target species or size categories, thereby reducing undesirable by–catch. For example, so–called "savings gear" is becoming more important as fishing mortality rates approach or exceed recommended maximum values and the numbers of user groups continue to increase.

Also, the problems of incidental catches of non–target species (e.g., porpoises, turtles) in various fisheries are increasing along with general public concern for conservation of LMR (Figure 3–4). In addition, there is a need for measuring the sampling efficiencies (catchability coefficients) of existing standard survey gear and for development of better survey gear (including hydro–acoustics, ROV's, submersibles) for stock assessments to improve accuracy of estimates. Improving sampling capabilities is important for studies in fisheries oceanography, ecosystem research, and fisheries habitat to provide rapid quantitative samples of micronekton, larval/juvenile fish, benthos, and other ecosystem components. Research on improving our sampling methods with new technology will be important to insure efficient use of research vessel time.

Environmental Assessment

There is now a clear recognition that in order to estimate the effects of fishing and habitat degradation on the productive potential of LMR's, a much better understanding is needed of the natural ecosystems supporting LMR's, particularly the interdependence among ecosystem components and their environment. For example, in order to estimate the effects of marine pollution and eutrophication of coastal waters on LMR productivity, we need to better understand the way in which changes at the bottom of the food chain (phytoplankton) may affect secondary producers (zoo–plankton, benthos) and fish, and ultimately apex predators. Also, we need to better under–stand the effects of natural physical environmental changes on various components of the ecosystem as a basis for predicting effects of climate change.

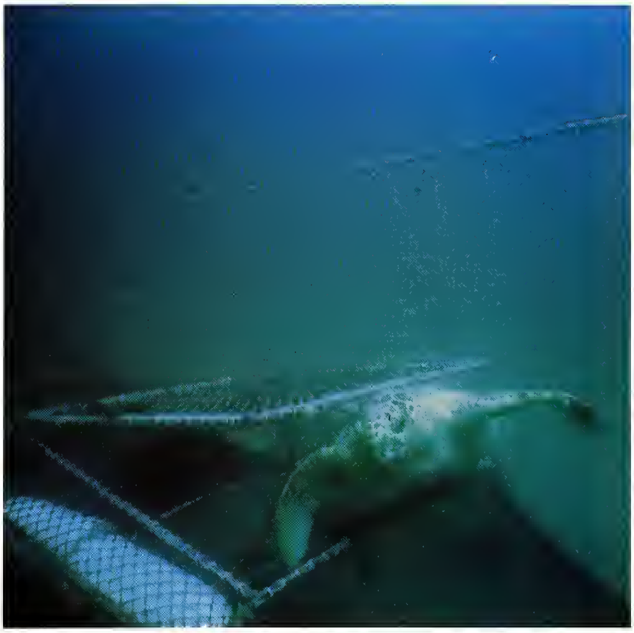


Figure 3–4. *NOAA's responsibility for protection of endangered species has involved its vessels in monitoring these species' activities. Here a protected sea turtle is shown leaving a device (commonly called a turtle excluder device, TED) designed to allow it to escape from commercial trawls. (Courtesy NOAA/OAR/National Sea Grant College Program)*

The same basic research strategy applied to fishery science is required for ecosystem studies, namely monitoring the changes in ecosystem properties and structure, and conducting process–oriented studies to clarify mechanisms linking causes and effects. Clearly, this problem will require research indefinitely into the future in view of the complexity of marine ecosystems and the importance of potential effects of global climate change on productive potential of LMR's. NOAA vessels will continue to play a lead role in this effort and, thus, the next generation of NOAA ships should be designed and equipped for multidisciplinary research. This implies overall enhancement of size, speed, endurance, and seakeeping ability as well as significant space for scientific laboratories and berthing. Also, it will require that there be significant deck space, electrical and hydraulic power, and an adequate suite of winches, cranes, etc. for developing and deploying new kinds of sampling technology as it evolves. Also needed is the capability for simultaneous over–the–side deployment of more than one type of equipment.

Protected Species Assessments

Significant additional requirements for research have been generated by public concern and federal statutes on protected/endangered species, particularly marine mammals, and these have required either minor modification of vessel design or, in some cases, minor compromise of research design. There is a need to monitor population distribution and abundance, and clarify ecological interactions with fisheries and their interdependencies on other LMRs. Similar questions need to be addressed for sea turtles.

Regional Fishery Research Problems and Associated Vessel Requirements

Fishery research vessel requirements vary somewhat by region. Some highlights of the principal research problems and vessel needs of each of the five NMFS Regional Fishery Science Centers, and the Great Lakes, are outlined below. Further details are available in the appended position papers.

1. *Alaska*. The Alaska Fisheries Science Center currently has resource assessment responsibilities for the waters of the U.S. EEZ off Alaska, Washington, Oregon, and California. The west coast responsibilities are coordinated with scientists of the Southwest Fisheries Science Center and support the fishery management needs of the Northwest and Southwest Regions.

The marine resource issues in these regions have grown rapidly in recent years along with rapid expansion of west coast domestic fisheries and replacement of foreign fisheries off Alaska by domestic fisheries. A relatively rapid growth in research programs is anticipated in the 1990's to augment ongoing fishery assessments on a large number of demersal and pelagic fishes as well as crabs and shrimp, and to begin major new initiatives to address problems related to high-seas drift nets, by-catch in the commercial fisheries, Bering Sea pollock, and marine mammal assessments. Research in these areas is highly seasonal corresponding with the large-scale migration patterns of most LMR's driven by strong seasonal weather cycles. Efficient and safe operations off Alaska and on the high seas will require vessels capable of extended endurance and ice-strengthened hulls, particularly for wintertime operations in the Bering Sea.

Future research in all the programs will increasingly rely on utilization of new technologies in remote sensing. For example, fishery acoustic methods for assessing midwater fish will have major applications for Pacific hake and Alaska pollock. Other applications include the need for improved shipboard communication with satellites for following oceanographic buoys and transmitter-equipped marine mammals. Fishery oceanography experiments will rely more and more on remote sensing from oceanographic moorings and drifting instruments, particularly in the Alaska region where year-round ship operations are difficult. Utilization of these new technologies will require special design features on research vessels, such as an acoustically quiet hull, deck space for portable instrumentation laboratories (vans), and communication/ computer packages for real-time satellite downlink and processing of remote-sensing data.

2. *Northwest Region*. Present vessel requirements of the Northwest Fisheries Science Center (NWFC) are related to contaminant surveys on the Pacific and Atlantic coasts funded under NOAA's National Status and Trends Program (NS&T). Much of the NS&T sampling occurs in protected estuaries with launches (25'), but general-purpose coastal vessels are needed which are large enough (25-30 m) for carrying the launches and for operations in larger sounds (e.g., Puget Sound) and bays, and for transit along the coasts. The vessels (and the launches) need the capability for deploying small trawls, dredges, sediment and water samplers, etc., and they need space for vans (special contaminant chemistry requirements) as well as regular shipboard lab facilities. The vessels also need good stationkeeping ability and maneuverability for operating in inshore waters.

Currently, the NWFC requires 40-50 days per year vessel-time on each coast for NS&T

work. Added emphasis on habitat and coastal ecosystem studies is anticipated in future years, which will expand the Center's need for coastal research vessel support.

3. Southwest and Antarctic. Research activities requiring NOAA vessel support for the Southwest Fisheries Center (SWC) encompass the widest ocean areas of any Center. The principal geographic areas of interest are coastal waters of California, Oregon, Washington, Hawaii, and the U.S. flag states of the Pacific. Farther–reaching programs include those for tunas throughout the Pacific and Indian Oceans: the North and South Pacific transition zones (for albacore resources), the tropical Pacific, and the tropical Indian Ocean. The Antarctic Ecosystem Research Group conducts research in the Antarctic, representing the U.S. contribution to the Commission for Conservation of Antarctic Marine Living Resources.

SWC research on fisheries resource assessment will require both oceanic– and coastal–class vessels. Assessment responsibilities include groundfish and coastal pelagics on the west coast; lobster, shrimp, bottomfish, seamount groundfish, and pelagics in the central and western Pacific; and to a lesser extent, krill and fishes in the Antarctic. Further, in the future, additional assessment responsibilities for tunas may require activities throughout the subtropical and tropical Pacific and conceivably into the Indian Ocean. Vessels will require trawling capability and the entire range of modern oceanographic equipment, including acoustics, discussed in this report. Remote–sensing downlink and processing capabilities will be of particular importance for tuna assessment.

Fisheries oceanography and recruitment studies will continue to be an important part of SWC research. Successful recruitment research pioneered at the SWC with coastal pelagics will be extended to west coast groundfish and insular species in the future. Tuna fisheries oceanography will also emerge in future SWC programs as an integral part of expanding tuna research.

Interactions of marine mammals with fisheries have prompted a great deal of research at the SWC and will probably continue to do so. Research on coastal marine mammals will probably increase. Current needs for research vessel–based population assessment and monitoring of marine mammals may continue over the next decade, but should decrease thereafter with improved capabilities in remote sensing and increased observer coverage (where fishery interactions occur). The next–generation NOAA vessels, however, will require design features allowing efficient visual transecting methods for marine mammals and other marine animals (turtles, birds).

Habitat and ecosystem–related programs in the SWC will require oceanic–class vessels for research throughout the Pacific, coastal vessels for the west coast and insular Pacific, and an estuarine vessel for San Francisco Bay and other estuaries on the Pacific Coast. Need for the latter two will increase as activities in the Coastal Ocean Program expand. The research program in the Antarctic takes an ecosystem approach, but is presently hindered by the lack of trawling capability on available vessels. Thus, a large, oceanic class vessel with ice–strengthening and trawling capability will be critical for research in that program.

4. Southeast. The Southeast Fisheries Center area of responsibility extends from Cape Hatteras to the U.S.–Mexico border, encompassing the South Atlantic Bight (Cape Hatteras to Cape Canaveral), U.S. EEZ portion of the Gulf of Mexico, and the FCZ zones around Puerto Rico and U.S. Virgin Islands in

the Caribbean. A wide diversity of resource species occur in these areas, including many which are dependent on estuaries for nursery grounds and which are subject to heavy exploitation by coastal/estuarine fisheries. Major species include menhaden, the Nation's largest–volume fishery, and shrimp, which are the Nation's highest–value fishery. Also, there are many reef fishes and pelagics of both commercial and recreational importance, e.g., mackerels, sea basses, tunas, billfish, and large sharks.

All of these resources are under heavy exploitation, and there is a rapidly increasing need for NOAA research vessel support for both fishery resource assessments and fishery ecology/environmental studies. The bulk of vessel usage is now allocated to resource assessment, but expanded fishery assessment surveys are needed because more and more species are coming under fishery management plans, and fishery managers are requiring more accurate information on stock abundance and population structure. Additional vessel support is needed to carry out fishery oceanography and environmental studies to determine natural ecological factors affecting resource fluctuations and trends. Rapid growth is expected in research directed at linking an understanding of physical processes that affect survival of early pelagic life stages at mesoscales (eddies, fronts, etc.) with those that operate at large scales (Gulf Stream, Loop Current, Mississippi River plume). Biological processes of major interest are spawning, growth and survival of larvae, larval transport into estuarine nursery areas, and growth and survival of juveniles in nursery zones.

The above research program will require additional sea time on oceanic–, coastal–, and estuarine–class vessels, suitably equipped with modern instrumentation and over–the–side sampling capability for deploying high resolution sonic and optical sensors and receiving satellite imagery. This new remote–sensing capability is needed for definitive research on the links between the physical environment and the dynamics of micronekton communities. It is also needed to help document spawning areas (optical particle counters for counting/ measuring/sizing eggs) and estimating biomass and movements of pelagic fish species (high–resolution acoustic arrays), to name a few examples.

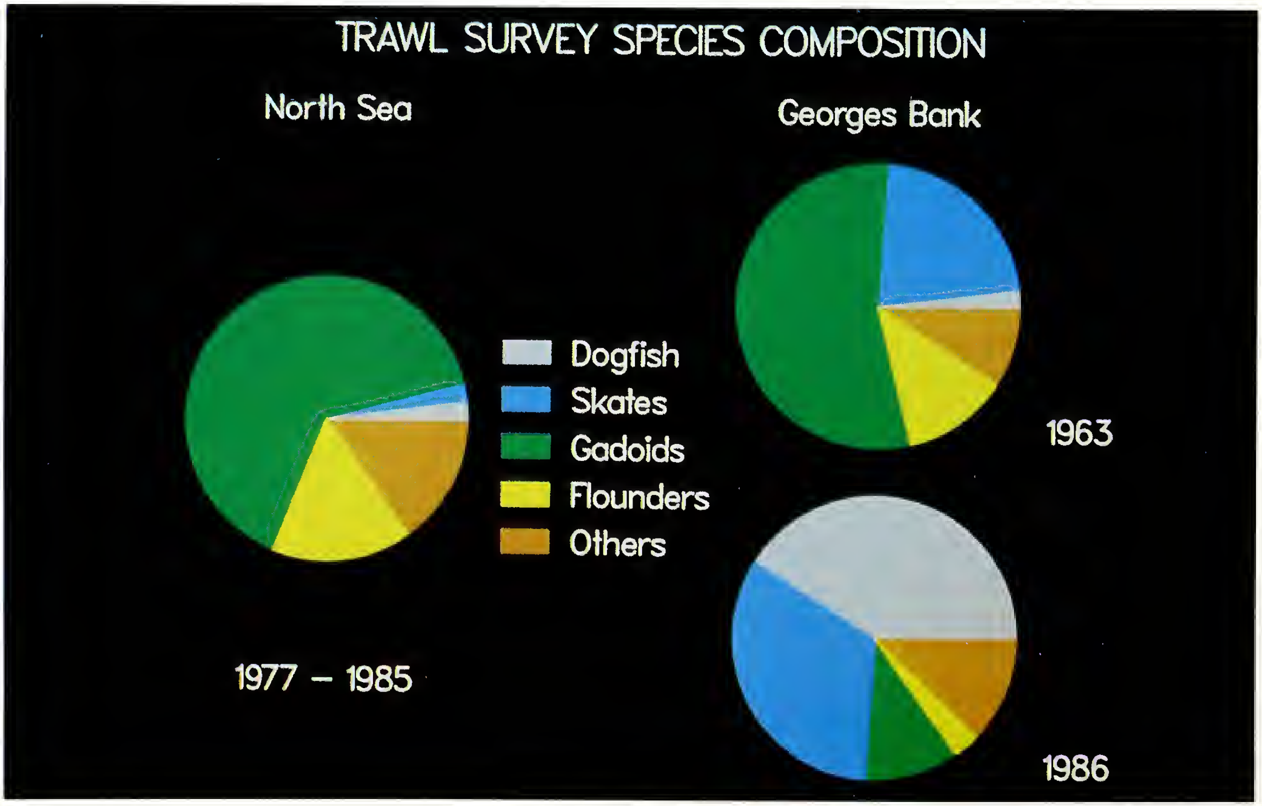
5. Northeast. The area of responsibility of the Northeast Fisheries Science Center extends from Cape Hatteras to western Nova Scotia, and includes the Middle Atlantic Bight, Georges Bank, the Gulf of Maine, and slope waters out to the Gulf Stream. The region supports a highly diverse fish and shellfish fauna with major species spawning in every month of the year. The heavy mix of species results in many mixed fisheries with significant by–catch problems and a need for multispecies assessment and management approaches. Also, many species of both commercial and recreational importance found in the EEZ depend on estuaries and coastal waters as nursery grounds; thus, assessment involves integration of inshore and offshore components, and it involves up to a dozen states and two Fishery Management Councils. In addition, a number of U.S./Canada transboundary stocks exist on Georges Bank and in the Gulf of Maine requiring joint research and management interactions with Canada.

Many fish stocks of the Northeast Shelf ecosystem are seriously depleted. Abundance of primary groundfish and flounder stocks are at historic low levels. Conversely, unexploited or lightly–fished species such as dogfish, skates, and mackerel have increased to record levels, and there is growing evidence that these predator species may adversely affect recovery of the depleted groundfish and flounders (Figure 3–5). Additional NOAA vessel support is needed to clarify these food–web dynamics, and provide more accurate and timely assessments of the aggregate finfish biomass. Ongoing multispecies resource surveys need to be augmented with special prerecruit and single–species surveys. New instrumentation (particularly state–of–the–art acoustics) is needed to help develop more efficient gear and survey strategies for groundfish and pelagic stocks, and improve the accuracy of information on species mixtures and distribution patterns. New sampling methods (photographic) and strategies need to be evaluated for major shellfish resources.

Fishery oceanography studies need to be initiated on: 1) the role of small–scale turbulence and stratification on the survival of pelagic early life stages, 2) effects of variability in the Georges Bank gyre on retention and survival of eggs and larvae, and 3) importance of predation on larval and juvenile stages by predator species (e.g., mackerel, dogfish) on gadid recruitment levels. In addition to shipboard acoustic capability, new sensors (optical image analysis, high–frequency acoustics with multichannel and/or dual–beam capability) will be needed in towed bodies and ROV's to provide the fine–scale resolution required for studying small–scale dynamics of micronekton communities.

New NOAA vessel support is also needed in the Northeast for mandated assessments of marine mammals. Surveys of marine mammals and their associated prey (pelagic fish and squid) and competitors (large pelagic

Figure 3–5. *The trawl surveys conducted by NOAA reveal important changes in species composition over time. As we see here, between 1963 and 1986 the finfish biomass on Georges Bank became increasingly dominated by underexploited predator species. (Courtesy NOAA/NMFS/Northeast Fisheries Science Center)*



sharks, billfish, tunas) are needed from the shelf waters off the Middle Atlantic Bight region to the Gulf Stream. Shipboard instrumentation for satellite downlink is needed for helping calibrate satellite telemetry of tagged whales, and advanced acoustic systems are needed for studying whale feeding behavior and their prey in relation to ocean frontal systems. Other required features include suitable lookouts for visual sightings and capability for towing large midwater trawls, long-lining, and standard oceanographic sampling.

There is also a need to augment habitat and ecosystem studies, primarily in inshore waters of the Northeast, to assess effects of pollution on fishery resources in the most heavily-populated section of the country. These studies will require coastal- and estuarine-class vessels with significant improvements in speed, scientific complement, sampling capabilities, and laboratory space for a wide variety of onboard analysis and/or preservation of samples (water, sediments, marine animals), and holding of live specimens.

6. *Great Lakes.* The Great Lakes Environmental Research Laboratory (GLERL) does not have a responsibility for research on exploited LMR's in the Great Lakes, but it does conduct ecosystem-oriented studies of nutrient and contaminant flux impacts on lower trophic levels including forage fish (Figure 3-6). Scientists at GLERL are currently conducting programs titled Coordinated Ecosystem Research (CER), Pollutant Effects, Exotic Species, and Large Lake Climate and Global Change. Studies are planned on physical-biological interactions and ecosystem variability mechanisms that require co-located and simultaneous measurements of a broad range of physical, chemical, optical and biological variables guided by near-real-time satellite imagery and meteorological data. The programs all

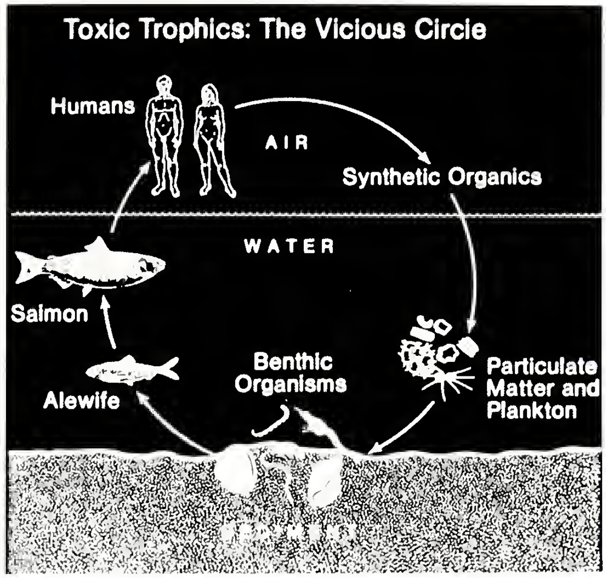


Figure 3-6. *Anthropogenic inputs to the marine environment create a vicious cycle of toxic trophics. NOAA marine research, supported by its fleets, constantly monitors the results of these interactions. (Courtesy NOAA/OAR/Great Lakes Environmental Research Laboratory)*

treat aspects of food-web dynamics in relation to environmental variability, and have substantial field components that must be supported by research vessels.

In order to successfully carry out this research in the 1990's, significant NOAA vessel support will be required on both coastal- and estuarine-class vessels. Approximately one half of the total requirement of 200-300 days is for a coastal vessel (70-100') and the remainder can be supported by smaller, higher-speed "work boats." Both vessel types should be fully equipped for biological and oceanographic sampling (see A. Bratkovich position paper in Appendix A), and should be relatively high speed (15 knots or greater).

Operating conditions vary significantly with seasons in the Great Lakes. Ship operations are generally not feasible in winter months with the current vessels. The remainder of the year tends to be fully scheduled, and concurrent multilake ship operations are not uncommon on the research agenda. At present, a second "work boat" with split crew is being employed to cover such research requirements.

Geographic/Seasonal Considerations

Each region has its own set of geographic and seasonal characteristics unique to the ecosystems and LMR's it includes. These characteristics are referred to in the discussion of Regional Fishery Research Problems and Associated Vessel Requirements above, and in the separate position papers.

Year–round studies are conducted in all regions except in Alaska and the Great Lakes where autumn– and winter–weather conditions restrict operations of existing vessels, and in the Antarctic where operations are conducted only in the Austral summer. Future research needs may require vessels able to work in these more rigorous conditions, both in rougher weather and near ice–edge regions. Consequently for selected future vessels, design considerations should take into account overcoming stability and size features that have heretofore constrained research in these locations and seasons. In general, vessels for offshore and oceanic research should be capable of carrying out most functions effectively through sea state 6. Seakeeping should not be compromised near the end of endurance when fuel is low.

Every region has seasonal time constraints linked to the biological timing of critical events, e.g., spawning and migrations. These events can vary significantly from one year to the next and, therefore, some surplus vessel time needs to be scheduled to account for these variations when a critical series of experiments is involved, e.g., recruitment studies where a particular life stage of a year class can only be sampled once a year. In addition, some surplus time should be included in vessel schedules at least on a regional basis in order to cover inevitable contingencies such as oil spills, LMR die–offs, and other situations.

Shipboard Observations and Remote Sensing

As described in the various position papers by Fisheries Research Working Group members, the importance and utilization of remote sensing will increase substantially in virtually all components of fisheries and oceanographic research. These developments will affect both research vessel design and usage. For example, efficient utilization of real–time transmission of satellite imagery of sea–surface conditions will require appropriate shipboard receivers, data loggers, computers, etc. These data can then be used to make real–time adjustments to cruise operations for more precise positioning of sampling in relation to important physical/ biological features. Communication with other types of remote sensors will also become more important, for example, oceanographic buoys, moorings, drifters, ROV's, AUV's, etc. Efficient utilization of these remote–sensing capabilities for shipboard operations will require that vessels be outfitted with the sophisticated instrumentation needed for communicating with these sensors. Shipboard acoustic systems are another form of remote sensing which will see much greater use in the future for a wide variety of real–time purposes including mapping bottom characteristics, current measurements, gear performance, and distribution and abundance of marine organisms from plankton to fish. This will require special design features in research vessels relative to deployment, calibration, and maintenance of acoustic systems, as well as low hull noise characteristics.

In general, shipboard utilization of remote–sensing technology will not decrease needs for vessel time for the foreseeable future. Sea–truth data from vessels will be essential for calibrating remotely–sensed data, and real–time availability of the remote–sensing data onboard ship will make it possible to conduct shipboard sampling at finer levels of resolution. New sensors will continue to be developed along with new uses, and requirements for accuracy and power of resolution will continue to increase.

There will undoubtedly be a need for increasing the level of process–oriented studies aboard ships as the dynamics of ecosystem properties begin to unfold through application of subsurface remote sensing and improved reliability of data products. Thus, remote sensing will change and improve the manner in which we conduct research, but will not markedly decrease vessel needs.

Short–Term Event Studies and Long–Term Monitoring

A successful strategy for assessing the effects of natural ecological factors and anthropogenic impacts on living marine resources will require a long–term research program consisting of both monitoring and short–term studies. Broad–scale monitoring with research vessels will be needed indefinitely (although efficiencies of methods will increase) to document changes in the structure of the fishery resources and the other ecosystem components and properties which affect them. Similarly, short–term studies using research vessels will be needed long into the future in order to clarify the functional forms of ecological relationships controlling fish production. The long–term need for process–oriented studies exists because these processes are very complex and because the ecosystems will be changing in response to environmental change and anthropogenic impacts, thereby altering the functional form of the controlling relationships.

The ideal mix between process–oriented and monitoring studies may vary somewhat among regions, but a properly–balanced research program will have a significant component of ship time for both. At the present time in all regions the greatest use of vessel time is for assessing exploited fisheries. Adequate assessment programs for other ecosystem components and properties are not yet established in most regions; they will be dependent on new funding from the Coastal Ocean and Global Climate Change Programs. Thus, significant amounts of additional ship time will be needed over present levels for the foreseeable future, despite expected improvements in remote–sensing capabilities. Similarly, additional ship time is needed in all regions to support process–oriented studies on ecological mechanisms controlling recruitment, interactions among ecosystem components, and linkages with the physical environmental and habitat quality. It will take a long time to establish cause/effect linkages with the degree of certainty desired for socio–economic decisions, and they will be complicated by changes in the natural environment, degraded habitats, and shifts in the ecosystem related to changes in exploitation patterns.

Trends in Data Collection/Analyses

Significant improvements will be required in shipboard data acquisition/processing systems in order to achieve the greater efficiency needed in fishery resource surveys and to effectively utilize remote–sensing capability for studying complex and rapidly–changing dynamic ecosystem processes. Specifically, integrated data acquisition systems with work–station–level computing capability will be needed, which can receive and process large amounts of digital data from a variety of vessels and remote sensors to provide real–time guidance of shipboard sampling in relation to dynamic physical and biological properties of the ocean.

For example, development of acoustic biomass survey techniques will require the ability to receive, display, process and store large volumes of multifrequency acoustic signals from biological targets such as fish and zooplankton, and at the same time receive and process digital data on the environmental fields (current, temperature, light) of the sampling area as well as the real–time performance of towed and remotely–operated sensors and sampling gear used to identify the targets. Other examples include process–oriented studies of plankton patches and mapping of plankton communities over various temporal and spatial scales, which are important components of fishery oceanography investigations. These types of research will often be multiship operations and will generate very large data bases with real–time analysis requirements using continuous flow–through systems with chemical/optical/acoustic sensors of temperature, salinity, nutrients, oxygen, chlorophyll (fluorescence), and associated planktonic organisms. Optical and acoustical mapping of zooplankton alone requires a computer capacity capable of handling a large volume of data involving density and composition (size frequency and species identification via pattern recognition) of zooplankton populations; and using hull mounted or towed instruments such as particle counters, image analyzers, dual–beam high frequency sounders, and underwater multi–spectral video cameras. At the same time vessels will require the capacity for simultaneously receiving, integrating and processing of data from moored or drifting buoys with their own sensors.

Additional areas of research requiring large data–handling capability are habitat and pollution studies where automated and/or complex chemical and physical sampling and analysis systems are involved (e.g., scintillation counters, spectroradiometer, transmissometer, autoanalyzer, experimental chambers with monitors and automatic feedback controls, etc.) and inshore and estuarine studies of rapidly–changing dynamic processes such as plumes, tidal fronts, etc., which may require shipboard integration of satellite/aircraft/vessel/moored–array sensors.

Still another operational mode which will require expanded data–handling capability is the shipboard monitoring and control of towed sampling gear or independent samplers under control of the ship as in the case of ROV's. Monitoring sampling gear performance and providing precise control of underwater samplers is critical to improved accuracy and efficiency of resource assessment surveys and biological sampling in general. Net opening, depth, towing tension and vertical profile, attitude and stability of gear in relation to flow fields and ship's speed can all be critical to the performance of sampling gear. This information derived from a variety of gear–mounted sensors (with hard wire or acoustic links to the ship) must be integrated with other data such as that from a doppler current profiler and fish–finding and bottom–sounding acoustic arrays.

Larger scale real–time studies such as the distribution of migrating populations of marine animals (e.g., tunas, mackerels, whales) in relation to major ocean features (fronts, eddies, currents, plankton blooms, etc.) will require shipboard receiving and processing of satellite data on SST and ocean color, as well as other data from meteorological buoys and subsurface oceanographic buoys. Improved navigation (GPS) systems will also add to the data acquisition and computer capability needed on the next generation of NOAA research vessels.

Anticipated Growth in Need for Vessel Time

A significant increase in NOAA research is projected for fisheries and related marine ecosystem studies. This increase is driven largely by expansion of domestic fisheries, public and Congressional concern for protected species, new NOAA emphasis on ecosystem and process–oriented research, and new national programs arising from concerns over global climate change and degradation of marine coastal waters.

In all five NMFS Fishery Research Centers, research utilizing vessel time is largely directed at resource assessment at the present time. We foresee expansion of stock assessment research to meet demands by the Fishery Management Councils for assessments of previously unregulated species/stocks, and more accurate assessments particularly for the most–valuable traditional fisheries which are under heavy exploitation. In particular, this research will focus on developing more accurate forecasts of trends, and evaluating effects of management decisions. Significant new research programs will be necessary to implement the environmental assessment and fisheries oceanography studies needed to document changes in the structure and properties of the marine ecosystems, and to determine the causal linkages between ecosystem components, and to sort out the natural environmental effects from man's impacts.

Vessel Requirements for Science Needs

The Working Group considered the full range of LMR–related research requirements and identified vessel characteristics relevant to those requirements. A clear consensus emerged regarding the need for improved versatility of NOAA vessels to provide multidisciplinary oceanographic research capabilities as well as enhanced capabilities for fishery assessment work on the same ship. Major functional improvements needed to achieve this versatility included greater endurance, additional space for scientist berthing and laboratories, more open deck space and equipment for efficient handling of fishery assessment and multidisciplinary oceanographic gear, as well as acoustically–quiet hulls and modern instrumentation for utilizing the wide array of new technology presently available and under development. A summary of these improvements is given below, and more detailed vessel design and operational specifications are presented in the tables of the following section.

Endurance. Greater endurance is necessary to accommodate the need for more comprehensive assessments of LMR involving more species and different kinds of sampling gear deployed on a single cruise. Endurance is of particular importance for research in the Pacific and Antarctic regions where LMR are distributed over vast areas, and transit distances to study sites are great.

Seakeeping. Significant upgrades are needed to the seakeeping capabilities of NOAA vessels for LMR research so that critical resource assessment surveys can be carried out in rough sea conditions throughout the year. These surveys represent a substantial part of the LMR research vessel needs, and thus, even a modest increase in seakeeping ability will result in significant gains in the resource assessment mission over the operational life of the vessel.

Accommodations for Scientists and Technicians. Berthing as well as lab space for larger scientific parties is essential to permit the wide array of multidisciplinary studies needed in LMR and marine ecosystem research. Added space will also be necessary for technical personnel to maintain and troubleshoot a rapidly–expanding array of instrumentation, computers, etc.

Laboratory Spaces. Individual laboratories should be designed and equipped to serve their specific science functions efficiently, but allow for some versatility relative to placement of portable equipment and arrangement of cabinets, benches, etc. For example, a large wet lab is essential for processing and handling large catches of fish or other biological samples, and it has key fixed requirements including mechanical conveyors for transporting catches from the deck to the lab, ease of discarding processed specimens, hose–down cleaning, etc. However, versatility can also be achieved through the use of a matrix of threaded tie–downs on the walls and floor to allow secure installation of portable equipment that may change from cruise to cruise. Given a standard tie–down matrix in all the labs, modules of equipment can be added or removed easily, and yet be structurally attached to the ship. On the other hand, the use of modular wall partitions should be avoided due to their non–structural nature and the certainty of their becoming loose and rattling.

Specific equipment within "specialized" laboratories refers to items like fume hoods in the chemistry and plankton laboratories; overhead tracks for the movement of equipment in and out of an instrument lab to a hero's platform; hose–down capabilities and powered conveyor belt and gurry scuppers in the wet lab; 19–inch racks in the electronics laboratory, etc. The vessel should have open and accessible wire races to allow for the inevitable need for new equipment. Stuffing tubes from lab to lab and from lab to deck must be available.

Main Deck and Equipment. The main deck should be open and free of raised hatches as much as possible because every general purpose vessel should be capable of stern trawling and handling a full range of fisheries as well as oceanographic sampling gear. The deck should be covered with a nonslip surface and a mosaic of threaded tie–downs for temporary instrument, van, or equipment support. Winches should all be hollow cored for the use of conductor wire, and be located to minimize fair–leading to the A–frames or gantry that they service. It may be desirable to have some of the smaller winches mounted on turntables to allow rotation for other uses. Winches should have adjustable levelwinding equipment to accept wire of various sizes. Capstans positioned around the main deck allow for the handling of heavy equipment both at sea and during loading/offloading. Cranes should be positioned to have full deck coverage and reach outboard on both sides of the vessel. Lifting capacities should match or exceed the rated working strength of the winches that would be used with the cranes (i.e., do not let the cranes lifting capacity be the limiting factor). The overall deck space must be sufficient to allow a range of multipurpose oceanographic sampling without compromising the ability to carry out fishery assessment work on the same cruise.

Scientific launches should be available to allow sampling the environment remotely from the large vessel, to track and tag marine mammals, or perhaps to work in areas too shoal for the mother ship.

Speed Control. Fine control at low vessel speed is of critical importance. The ability to be able to track a submersible, a ROV, an AOV, perhaps divers, or tagged marine animals will certainly be required. This either calls for an adjustable–pitch propeller with bow and stern thrusters or perhaps some auxiliary electric propulsion system. This fine control would also allow one to remain "on station" to very fine tolerances which are required for some operations and which are now possible with the precision of satellite navigation. Fine–speed control in the range of 1 to 5 knots also allows for the fine–tuning of the shape of bottom and midwater trawls as well as the handling of the various

MOCNESS–type sampler systems which require very fine speed control at slow speeds for extended periods (2–3 hours).

Acoustics. Full utilization of hydroacoustic technology either for fish–finding, bottom–profiling, sidescanning, or seabeam–type systems, will require an acoustically quiet vessel. This will involve hull and propeller design as well as the mounting and support structures for the engines and generators. It also will require a retractable transducer head for at–sea maintenance and accessibility of the various systems. "Acoustically quiet" refers to the general noise level of the interior of the vessel, not just for human comfort, but for the use of sensitive electronic equipment and sensors.

Communication. Internal shipboard communication for high-quality voice transmission to any location on the vessel is a must. All too often internal communications appear to be an after–thought instead of an integral part of a vessel's equipment. Internal communications should not be seen as a convenience item but as a necessity for safety and operational efficiency. Additional internal communication comes via a shipboard centralized data–acquisition system. This allows all available shipboard systems to be monitored from anywhere on the vessel, and logs this information as a record for reference in retrospective analysis.

External communications will certainly require satellite receivers and transponders, both for voice and for data transmission. Satellite navigation systems backed up with LORAN will be necessary for precise stationkeeping and the ability to return to an exact location repeatedly.

These details in ship design and construction will make for a vessel capable of carrying out missions of a constantly–changing nature well into its working life span. The inherent flexibility of such a vessel will allow it to adapt to demands not yet foreseen.

Vans. Vans are perhaps best used for highly–specialized sampling functions. Examples of this would be some need for an extremely dust–free environment, perhaps a teflon–coated interior to avoid metals contamination, or SCUBA–diving equipment handling and storage, decompression chamber, etc. This is in contrast to the suggestion that the maximum flexibility for a vessel would be to have a "bare–bones" ship and simply add on the modular components needed for any one cruise. There are several problems with this bare–bones concept: 1) the basic weight distribution and ballasting of the vessel would be different on every cruise, and stability of the vessel would surely suffer; 2) common internal passageways would be lost, requiring an exterior entrance to each of the laboratories, or making passageways internal through vans, which would severely limit the useful space inside; and 3) the installation of HVAC, AC, communications (both voice and data) and alarms would be made much more tenuous. Similarly, large items like cranes and winches should be permanently mounted and not modular for removal when not needed.

Preliminary vessel specifications needed for the full range of fishery research activities were prepared for three general classes of vessel: 1) oceanic, 2) coastal, and 3) estuarine (see Tables 3–1 – 3–3). The specifications often cover a range of requirements; in cases where only one quantity is given (e.g., speed) the upper limit of the range discussed was generally chosen.

NOTES:

Table 3–1. **General Specifications for Oceanic Class Vessel Required for Fisheries Research.**

Purpose	Conduct full range of resource assessment for LMR's, and wide range of fishery oceanographic and environmental studies (sometimes piggyback on assessment cruises) in shelf and open ocean waters.
Propulsion	Main propulsion system capable of very low speed, high power drive for trawling, but must not compromise cruise speed. Special low–speed, omni–directional propulsion system integrated with SPD or acoustic positioning system is needed for automatic dynamic vessel positioning and stationkeeping. Main propulsion propellers should be variable pitch (manual control option and nozzle) and variable RPM with independent control to provide adequate power at low pitch settings; back–up propulsion for emergency. Bow thrusters for maneuvering. All propulsion systems designed for low noise and vibration.
Speed/Power	16 knots cruise (±0.1 knot in 0–5 knot range), low noise engine, with vibration reducing foundations.
Endurance	31–45 days, full complement at 24 hour/day operation 12,000 mile range, adequate freshwater storage or distilling capability for up to five days independent of main engine use.
Seakeeping	Maintain trawling operations, and towing plankton and micronekton nets through sea state 6 at speeds up to 4 knots, and allow associated station and deck work through sea state 6. Deploy other towed samplers or gear (CTD's, XBT's, fluorometer, neuston, CPR's, image analyzers) through sea state 5. Allow normal oceanographic station and deck work through sea state 5. Maintain steerage at 1 knot. Stability requirements must be met through full range of endurance.
Stationkeeping	Maintain station and over–the–side vertical operations in 3 knot current, 35 knot wind, and sea state 5, with dynamic positioning or bow thrusters.
Accommodations	16–20 scientists, 2–man rooms, 1 head/shower for each 2 rooms; 1 single berth, chief scientist; library/lounge with conference capabilities; science office with computer workstation.
Ice–Strengthening	ABS Class C (transit loose pack ice) should be minimum for one or more vessels for high latitude work in Pacific.
Waste Management	A shipboard waste management system that consists of incineration, compaction, and recycling is essential. Minimum 3–4 day holding capacity of sewage system.

Table 3–1, Continued.

Deck Space	2,000 sq.ft. clear fantail, flush non–skid, non–corrosive, seawater washdown deck, minimum number of hatches, deck tie–downs (2 ft. on center). Removable bulwarks along 20 ft. of rail, hero or hydro platform, >6' and <8' freeboard, have 120/240 VAC, fresh and salt water, compressed air on deck. Hands–free communications. Completely accessible to cranes. Bridge video observation of deck activity areas. Hull and deck design suitable for hauling longline, pot gear, and gillnets; line haulers for crab pots, sablefish and large shark longline gear; net haulers for gillnets. Vessel configuration to deploy gillnet from stern, retrieve gillnet forward, and store net in stern well. Deck machinery must include net pullers and cylindrical tube for transfer net from forward deck to stern.
Crane/Frames	1) Suite of hydraulic cranes/booms a) one to reach center of ramp @ 15,000 lbs b) one to reach 20 ft. outboard @ 10,000 lbs (40,000 lbs maximum line pull) c) able to load & off–load 20' vans d) full deck coverage 2) A or J frames (both same side of vessel) 8' outboard and 4' inboard reach, 15' vertical 6' wide, working/towing loads of 4,000 lbs 3) Hydraulic Gantry over ramp 15' in/out reach at 20 tons
Trawlway	Vessel outfitted with stern ramp (slope <45°) at least 12' wide with hydraulic tailgate and cover.
Winches	All main winches are hollow cored for slip rings/ conducting cables, all have adjustable levelwinding gear, all are metered for tension, wire out, wire angle and rate. Winches are to be mounted on vibration dampening foundations. Control stations located for maximum visibility, direct communication to deck, labs and bridge. Plumb hydraulic systems away from work and living spaces. Winch hydraulic whine noise must be minimized to meet OSHA standards for the unprotected ear. 1) Main trawl winches––paired, programmable hydraulic, metered, clutched (power out with freespooling option), 3,000 meters of 1" trawl warp. Line speed of 300 ft./min. and line pull of 25,000 lbs. on each winch at half wrap.

Table 3–1, Continued.

	2) Two oceanographic winches for the A/J frames, constant tension, metered, 2,500 and 4,000 meters of .25" and .322" on one and .322" and .5" on other. 4,000 lbs of torque, 50 meters/min in/out plus free-spooling; all UNOLS standard conducting cable. Deploy CTDO's to 3,000 meters; the winch dedicated to this task should be capable of variable speed operation and equipped with UNOL's standard .322" multi–conductor cable. These winches should be multi–purpose to allow for the oblique deployment and retrieval of ichthyoplankton samplers such as bongo nets, Mocness nets, and Tucker trawls. These winches should be hydraulic with a line speed of 350 ft./min., line pull of 3,000 lbs, minimum capacity 5,000 meters .322" UNOLS multi-conductor cable and slip ring assembly. Also need capability for deploying 4,000 m of fiber optics cable. A third backup hydrographic winch using 3/16" or 1/4" 6 X 19 construction cable. This cable is a better choice if one is clamping collecting gear to cable. 3) Third wire winch for trawl instrumentation packages. Constant tension, metered, 3,000 meters .5" wire. 4) Several small deck winches and capstans. 5) Two removable net reels (each 10 ft. wide), split–reel type with removable divider with capacity for large rope trawls, hauling capacity 15,000 lbs. each reel.
Laboratories	<u>General</u>: uninterrupted stable 120/240 VAC with power loss protection, HVAC for 70° F, 50% relative humidity, sinks, safety washes, running uncontaminated ambient salt and hot and cold fresh water, distilled water, compressed air, tie–downs (floor and walls), stainless steel walls and counters, low point drains, well–ventilated and fume hoods in chemical and biological labs, meets OSHA acoustic standards. Quality voice communications with the entire ship, including decks. Computer ports for all labs to access or data dump to central DAS system. 1) Wet lab––large (600 sq.ft.), clutter–free, sinks and fume hood, hose–down, direct access to main deck. Powered conveyor belt/gurry scupper for hauling catches of a ton or more. Flexibility for portable aquaria, freezers, movable counter tops. 2) Oceanographic plankton lab and Instrument lab (400 sq.ft.)––near A/J frames, fume hoods, trolley for instruments and adjacent to CTD or hydro platform.

Table 3-1, Continued.

	3) Bio/chem lab--adjacent to instrument lab (300 sq.ft.). Fume hood, filtered air, dust-free construction, workstation.
	4) Electronics lab (400 sq.ft.)--3 full-size 19" racks, non-static floor covering, counters.
	5) Walk-in environmental chamber--approximately 100 sq. ft., programmable light and temperature, running water, power, and deck drains.
	6) Freezers--100 sq.ft. walk-in freezer off wet lab, racks and shelves covering most area, tie-downs, access to hatch for unloading. A small chest type flash freezer is desireable.
	7) Refrigerators--75 cubic ft. in 3 or four units (ie., one each in wet, chem, plankton labs).
	8) Information processing lab (200 sq.ft.); dedicated workstation, signal processing, video/optical disk, data logging.
	9) Labs could be below deck if dumbwaiters and/or chutes were built into ship to transfer samples, catches from one level to another.
	10) Need large total lab space (about 2,000 sq.ft.) area to insure capability for 24-hour simultaneous multi-disciplinary activities, including oxygen titration, salinity determination, chlorophyll extraction, nutrient analysis, primary production, respiration, examination of fresh biological samples, processing and preserving specimens, etc.
Water Intake	Flow-through multiport seawater system near bow of ship should have a thermosalinograph and fluorometer attached and logged by shipboard data acquisition system.
Shipboard Sensors	Vessel outfitted with a complete XBT system, with two launchers (one fixed) and the SEAS transmitting system; acoustic doppler current profiler, CTDO with transmissometer, fluorometer, rosette, profiling photometer.
Stowage	Total of 10,000 cu.ft. scientific stowage, part shelved and part open, tie-downs. A toxic chemical storage locker should be available on deck (10 sq.ft.).
Hazardous Materials Storage	Hazardous materials lockers (formalin, acetone, alcohol, acids, radioisotopes).

Table 3-1, Continued.

Vans	Should be able to carry at least one 8 X 20 ft. van without compromising normal trawling or science activities. Hook-ups for AC, HVAC, water, communications, and ship's computer available. Space for additional vans but with some loss of function.
Acoustic	Ship should be generally acoustically as quiet as possible. Bow design should reduce bubble retention for higher quality acoustics. Propeller should be of a low-cavitation design. Should have a retractable transducer head within a transducer well for at-sea maintenance. Fish finding and bottom sounding equipment should include shallow and deepwater fish finders, including 12 KHz PDR/UGR sounders and recorders and 12 KHz high resolution bottom pingers. Scientific echo sounder with signal processor to provide density estimates from midwater signals, "EK-500 type" with 3 cards for 38, 120, and 200 KHz transducers. Links to navigation systems for automatic recording of position with other data such as bottom type and depth, off bottom signals, etc. Also acoustic link net mensuration system with operational capability to 700 fathoms.
Communication	Internal--quality voice throughout the vessel, including all staterooms. Hands free voice on decks, laboratory repeaters of all vessels instruments. Computer--shipboard data acquisition and analysis system for all ship's instruments and scientific data logging; terminals in variety of locations and linked with scientific workstation(s). External--Voice communication via satellite, VHF, UHF., High speed data communication (56K Baud), and facsimile communication for weather and data. Satellite links for environmental remote sensing data, XBT/SEAS system, telecommunications, rapifax, weatherfax, SST, color, etc.
Navigation	Precise positioning with LORAN and GPS (latter w/in 20 m); also, capability to deploy and use acoustic arrays for precise localized relative positioning of vessels, bottom moorings, divers, ROV's, etc.
Small Boat	Capable of safe launch at sea, for carrying 5-6 people.

NOTES:

Table 3–2. General Specifications for Coastal Class Vessel Required for Fisheries Research.[1]

Purpose	Conduct full range of resource assessment for LMR's, and wide range of fishery oceanographic and environmental studies (sometimes piggyback on assessment cruises) in shelf and coastal waters.
Propulsion	Main propulsion system capable of very low–speed, high–power drive for trawling; but must not compromise cruise speed. Special low–speed omni–directional propulsion system integrated with SPD or acoustic positioning system is needed for automatic dynamic vessel positioning and stationkeeping. Main propulsion propellers should be variable pitch (manual control option and nozzle) and variable RPM with independent control to provide adequate power at low pitch settings; back–up propulsion for emergency. Bow thrusters for maneuvering. All propulsion systems designed for low noise and vibration.
Speed/power	14–15 knots cruise (±0.1 knot in 0–5 knot range), low– noise engine, with vibration reducing foundations.
Endurance	21–30 days, full complement at 24 hour/day operation 5,000 mile range, adequate freshwater storage or distilling capability for up to five days independent of main engine use.
Seakeeping	Maintain trawling operations, and towing plankton and micronekton nets through sea state 6 at speeds up to 4 knots, and allow associated station and deck work through sea state 6. Deploy other towed samplers or gear (CTD's, XBT's, fluorometer, neuston, CPR's, image analyzers) through sea state 5. Allow normal oceanographic station and deck work through sea state 5. Maintain steerage at 1 knot. Stability requirements must be met through full range of endurance.
Stationkeeping	Maintain station and over–the–side vertical operations in 3–knot current, 35–knot wind, and sea state 5, with dynamic positioning or bow thrusters.
Accommodations	10–12 scientists, 2–man rooms, 1 head/shower for each 2 rooms; 1 single berth, chief scientist; library/lounge with conference capabilities; science office with computer workstation.

[1]A variant of this class is needed for S&T work, with more deck space (1,200–1,500 sq.ft.) for two large 29' launches and capability for their deployment and retrieval, and maximum draft of 12'. Besides trawl winches and articulated crane, only need one traditional hydro winch. Other specs of coastal vessel similar. Another option may be "low endurance" oceanographic class.

Table 3–2, Continued.

Waste Management	A shipboard waste management system that consists of incineration, compaction, and recycling is essential. Minimum 3–4 day holding capacity of sewage system.
Deck Space	1,000 sq.ft. clear fantail, flush non–skid, non–corrosive, seawater washdown deck, minimum number of hatches, deck tie–downs (2 ft. on center). Removable bulwarks along 20 ft. of rail, hero or hydro platform, >6' and <8' freeboard, have 120/240 VAC, fresh and salt water, compressed air on deck. Hands–free communications. Completely accessible to cranes. Bridge video observation of deck activity areas. Hull and deck design suitable for hauling longline, pot gear, and gillnets; line haulers for crab pots, sablefish and large shark longline gear; net haulers for gillnets. Vessel configuration to deploy gillnet from stern, retrieve gillnet forward, and store net in stern well. Deck machinery must include net pullers and cylindrical tube for transfer net from forward deck to stern.
Crane/Frames	1) Suite of hydraulic cranes/booms a) one to reach center of ramp @ 10,000 lbs b) one to reach 20 feet outboard @ 5,000 lbs c) able to load & off load 20' vans d) full deck coverage 2) A or J frames (both same side of vessel) 8' outboard and 4' inboard reach, 15' vertical 6' wide, working/towing loads of 4,000 lbs 3) Hydraulic Gantry over ramp 15' in/out reach at 20 tons
Trawlway	Vessel outfitted with stern ramp (slope <45°) at least 10' wide with hydraulic tailgate and cover.
Winches	All main winches are hollow cored for slip rings/ conducting cables, all have adjustable levelwinding gear, all are metered for tension, wire out, wire angle and rate. Winches are to be mounted on vibration dampening foundations. Control stations located for maximum visibility, direct communication to deck, labs and bridge. Plumb hydraulic systems away from work and living spaces. Winch hydraulic whine noise must be minimized to meet OSHA standards for the unprotected ear. 1) Main trawl winches––paired, programmable hydraulic, metered, clutched (power out with freespooling option), 3,000 meters of 1" trawl

Table 3–2, Continued.

	warp. Line speed of 300 ft./min. and line pull of 25,000 lbs. on each winch at half wrap.
	2) Two oceanographic winches for the A/J frames, constant tension, metered, 2,500 and 4,000 meters of .25" and .322" on one and .322" and .5" on other. 4,000 lbs. of torque, 50 meters/min in/out plus free–spooling; all UNOLS standard conducting cable. Deploy CTDO's to 3,000 meters, the winch dedicated to this task should be capable of variable speed operation and equipped with UNOL's standard .322" multi–conductor cable. These winches should be multi–purpose to allow for the oblique deployment and retrieval of ichthyoplankton samplers such as bongo nets, Mocness nets, and Tucker trawls. These winches should be hydraulic with a line speed of 350 ft./min., line pull of 3,000 lbs., minimum capacity 5,000 meters .322" UNOLS multi–conductor cable and slip ring assembly. Also need capability for deploying 4,000 m of fiber optics cable. A third backup hydrographic winch using 3/16" or 1/4" 6 X 19 construction cable. This cable is a better choice if one is clamping collecting gear to cable.
	3) Third wire winch for trawl instrumentation packages. Constant tension, metered, 3,000 meters .5" wire.
	4) Two small deck winches and capstans.
	5) Two removable net reels (each 10 ft. wide), split–reel type with removable divider with capacity for commercial size trawls, hauling capacity 15,000 lbs. each reel.
Laboratories	General: Uninterrupted stable 120/240 VAC with power loss protection, HVAC for 70° F, 50% relative humidity, sinks, safety washes, running uncontaminated ambient salt and hot and cold fresh water, distilled water, compressed air, tie–downs (floor and walls), stainless steel walls and counters, low point drains, well ventilated and fume hoods in chemical and biological labs, meets OSHA acoustic standards. Quality voice communications with the entire ship, including decks. Computer ports for all labs to access or data dump to central DAS system. Approximately 1,000 sq. ft. lab space in total.
	1) Wet lab––largest, clutterfree, hose–down, direct access to main deck. powered conveyor belt/gurry scupper. 2) Dry lab––used for computers and recordkeeping. Ships instruments repeated here.

Table 3–2, Continued.

	3) Bio/chem lab--adjacent to wet lab. fume hood, filtered air, dust–free construction. 4) Freezers--25 sq.ft. walk–in freezer off wet lab, racks and shelves covering most area, tie–downs, access to hatch for unloading. Small flash freezer desireable. 7) Refrigerators--40 cubic ft. in 2 units (i.e., one each in wet/chem labs). Flow–through seawater system should have a thermosalinograph,CTD, and flurometer attached and logged by shipboard data acquisition unit. Vessel should be outfitted with a complete XBT system with 2 launchers (one fixed) and the SEAS transmitting system.
Stowage	Total of 5000 cu. ft. scientific stowage, part shelved and part open, tie–downs; accessible to main deck via elevators, dumbwaiters, etc.
Vans	Should have adequate deck space for one 8 X 20 ft. van with only moderate impact on trawling or science activities. Hook–ups for AC, HVAC, water, communications, and ships computer available. Additional vans possible but with loss of function.
Water Intake	Flow through multiport seawater system near bow of ship should have a thermosalinograph and fluorometer attached and logged by shipboard data acquisition system.
Shipboard Sensors	Vessel outfitted with a complete XBT system, with two launchers (one fixed) and the SEAS transmitting system; acoustic doppler current profiler, CTDO with transmissometer, fluorometer, rosette, profiling photometer.
Hazardous Materials Storage	Hazardous materials lockers (formalin, acetone, alcohol, acids, radioisotopes).
Acoustic	Ship should be generally acoustically as quiet as possible. Bow design should reduce bubble retention for higher quality acoustics. Propeller should be of a low cavitation design. Should have a retractable transducer head within a transducer well for at–sea maintenance. Fish finding and bottom sounding equipment should include shallow and deepwater fish finders, including 12 KHz PDR/UGR sounders and recorders and 12 KHz high resolution bottom pingers. Scientific echo sounder with signal processor to provide density estimates from midwater signals, "EK–500 type" with 3 cards for 38, 120, and 200 KHz transducers. Links to navigation systems for automatic recording of position with other data such as bottom type and depth, off bottom signals, etc. Also acoustic link net mensuration system with operational capability to 700 fathoms.

Table 3–2, Continued.

Communication	Internal--Quality voice throughout the vessel, including all staterooms. Hands–free voice on decks, laboratory repeaters of all vessels instruments. Computer--Shipboard data acquisition and analysis system for all ship's instruments and scientific data logging; terminals in variety of locations and linked with scientific workstation(s). External--Voice communication via satellite, VHF, UHF., High speed data communication (56K Baud), and facsimile communication for weather and data. Satellite links for environmental remote sensing data, XBT/SEAS system, telecommunications, rapifax, weatherfax, SST, color, etc.
Navigation	Precise positioning with LORAN and GPS (latter w/in 20 m); also, capability to deploy and use acoustic arrays for precise localized relative positioning of vessels, bottom moorings, divers, ROV's, etc.
Small Boat	Capable of safe launch at sea, for carrying 5–6 people.

NOTES:

Table 3–3. General Specifications for Estuarine Class Vessel Needed for Fisheries Research.

Purpose	Conduct resource assessment of LMR's and wide range of biological and environmental sampling in inshore and estuarine waters, including S&T and other habitat studies.
Propulsion	Variable pitch and variable RPM, low–speed power and fine control (± 0.25 knot in 0–5 knot range).
Speed	12–15 knots
Draft	10' maximum
Endurance	4–10 days with full complement at 14–18 hour/day operation.
Seakeeping	Maintain trawling operations, towing plankton/micronekton gear (at 4 knots), and associated station and deck work through sea state 4. Deployment of water/sediment samplers, video gear, LCROV's, etc. through sea state 4.
Stationkeeping	Variable need. Minimum requirements, maintain position within three boat lengths in 20 knot winds (implication twin screw).
Accommodations	6–8 scientists for 14–18 hr/day operations. Berths for 5 crew.
Deck Space	600 sq.ft. fantail; 4' freeboard; deck and van tie–downs across deck 2' on center, have 120/240 VAC, fresh and salt water, compressed air on deck. Hands–free communications, completely accessible to cranes, flush with a minimum of openings/hatches.
Cranes/Frames	1) articulated crane or moveable boom a) outboard reach of 20' @ 8,000 lbs. b) reaches boat deck for semi–rigid handling c) able to load and off–load 10' vans d) full deck coverage 2) A or J frame 8' outboard and 4' inboard reach, 15' vertical 6' wide, working/towing loads of 4,000 lbs.
Stern Ramp/Gantry	Hydraulic gantry over stern 15' in/out reach at 10 tons

Table 3–3, Continued.

Winches	All winches are hollow cored, all have adjustable level–winding gear, all are metered for tension, wire out, and rate. Control stations located for maximum visibility, direct communication to deck, labs and bridge. Sound buffered to meet OSHA standards. 1) Main trawl winches––paired, metered, clutched (power out with freespooling option), 700 meters of 1/2"–5/8" trawl warp. Line pull of 10,000 lbs. on each winch. 2) An oceanographic winch for the A/J frame constant tension, metered, 500 meters of .25" or .322". 3,000 lbs. of torque, 50 meters/min in/out plus freespooling. 3) Two small deck winches and capstans. 4) Two removable net reels (each 4 ft. wide); hauling capacity 5,000 lbs. each reel.
Laboratories	General: Clean, stable 120/240 VAC, HVAC for 70° F, 50% relative humidity, sinks, safety washes, running salt and fresh water, compressed air, tie–downs (floor and walls), stainless steel walls and counters, low point drains, well–ventilated, meets OSHA acoustic standards. Quality voice communications with the entire ship, including decks. Total of about 500 sq.ft. lab space. 1) Wet lab––largest, clutter–free, hose–down, direct access to main deck, powered conveyor belt/gurry scupper. 2) Dry lab––used for computers and recordkeeping. Ships instruments repeated here. 3) Bio/chem lab––adjacent to wet lab, fume hood, filtered air, dust–free construction. 4) Freezers––25 sq.ft. walk–in freezer off wet lab, racks and shelves covering most area, tie–downs, access to hatch for unloading. 5) Refrigerators––40 cubic ft. in 2 units (i.e. one in wet/chem labs).
Stowage	Total of 2000 cu.ft. scientific stowage, part shelved and part open, tie–downs.
Vans	Should have adequate deck space for one 8 X 10 ft. van with only moderate impact on trawling or science activities. Hook–ups for AC, HVAC, water, communications, and ships computer available. Additional vans carried but with loss of function.
Launches	Carries one 6 meter semi–rigid workboat for diving operations and inter–tidal science.

Table 3–3, Continued.

Acoustic	Ship should be generally acoustically as quiet as possible. Should have a retractable transducer head within a transducer well for at–sea maintenance. A 38, 50, 100, and 200 KHz available.
Communication	Internal--quality voice throughout the vessel, including all staterooms. Hands–free voice on decks, dry laboratory repeaters of all vessels instruments.
	Computer--shipboard data acquisition system for all ships instruments and scientific data.
	External--voice communication via VHF, UHF. High–speed data communication (56K Baud), and facsimile communication for weather and data.
Navigation	Precise positioning with LORAN and GPS (latter w/in 20 m); also, capability to deploy and use acoustic arrays for precise localized relative positioning of vessels, bottom moorings, divers, ROV's, etc.

Charting and Applied Oceanographic Research

The past decade has been a time of transition in the technology for charting and applied oceanographic research. That period of transition is likely to continue through the next decade and perhaps beyond. This is a time of "accelerated application of ocean science to other fields, as well as a time when technology derived from space research, electronics and computer science have found uses in oceanography." (Treadwell, et al., 1988) Ships that serve during this period, and the equipment that they carry, should reflect this transition and be able to accommodate and exploit evolving technology. Some established, traditional techniques, such as water samplers, will persist at the same time as futuristic systems, such as autonomous vehicles acting as remote data gatherers (RDG's), are adopted.

Background of Study

Today's budgets demand that faster and more efficient ways be found to map the seafloor. A large portion of our coastal area is charted with only lead-line data obtained more than a century ago. These data are neither sufficiently accurate nor complete enough to meet present requirements. With the proclamation of the Exclusive Economic Zone (EEZ) (see Figure 1-6, p. 10) in 1983, approximately 60% of the national domain was underwater and largely unmapped. Heightened awareness of change processes both globally and along our coasts has made it increasingly important that regular resurveys be conducted. New technology in vessels and equipment offers an opportunity to better meet those needs within budget constraints.

Activities of the Working Group

To determine the expected mission requirements for NOAA in the area of charting and applied oceanographic research into the next century and the fleet requirements necessary to carry out these missions, a Charting and Applied Oceanographic Research Working Group was formed along with those in Oceanographic Research and Fishery Research. The Working Groups were asked not to devote attention to the status of existing ships. The objective of the fleet study to which the Working Groups were to contribute was to determine the hull characteristics, instrumentation, and size of the oceanographic fleet to meet NOAA's requirements for the next ten to thirty years.

The Charting and Applied Oceanographic Research Working Group felt that two points, closely but not strictly related to the fleet assessment, deserved prominent mention. These were:

First, mission accomplishment will depend, in part, on availability of platforms other than ships. Remote-sensing techniques and equipment miniaturization have made it possible, and economically attractive, to use other platforms under some circumstances. Overall agency planning should include provisions for such support. Aircraft, in particular, are likely to become cost-effective alternatives to ships for near-shore surveying. Small vessels, less than 65 feet in length, also have not been included in fleet planning. Field parties, operating with small boats, carry out a substantial portion of the hydrographic surveying today and are likely to in the future. These vessels and their associated equipment will require modernization. Other work, such as circulation studies, often requires intermittent use of properly equipped, small vessels. One suggestion was that a mechanism be established through state relationships or through Sea Grant institutions for accommodating some of these needs with small vessels belonging to universities or state organizations. Cooperative arrangements were thought to be the preferred mechanism should NOAA missions require use of platforms such as icebreakers, submersibles, or hovercraft.

Second, data management requires planning and support. A major change accompanying new technology has been an enormous increase in the volume of data collected at sea. Some data are collected to fulfill the needs of sharply defined programs. Often other data are gathered to meet less clear requirements but to more fully exploit ship availability. Data management run by programs tends to be effective in producing specific products but is narrow in scope. Data management supported by base funds tends to be broad in scope but less effective. The ultimate effectiveness of ships and the sensor systems aboard them depends, in large part, on thought and investment in data management. Data should be in digital form with standardized formats. As much data processing as possible should be done in near-real-time aboard the ship.

Current Mission Requirements

Charting and applied research is oriented toward the missions of providing for safe navigation and developing scientific and engineering knowledge of the conditions and processes at the seafloor (Figure 4-1). Measurements that are required and may need ship support include the depth of the water, state of the tide and current, and the general shape and composition of the seafloor.

NOAA's work in this area is presently carried out under the following authorizations:

33 U.S.C. 883 charges NOAA with the responsibility to provide charts and related information for "the safe navigation of marine and air commerce, and to provide basic data for engineering and scientific purposes, and for other commercial and industrial needs"

33 U.S.C. 1701 (The National Ocean Pollution Planning Act of 1978) authorizes NOAA to "develop the necessary base of information to support, and provide for, the rational, efficient

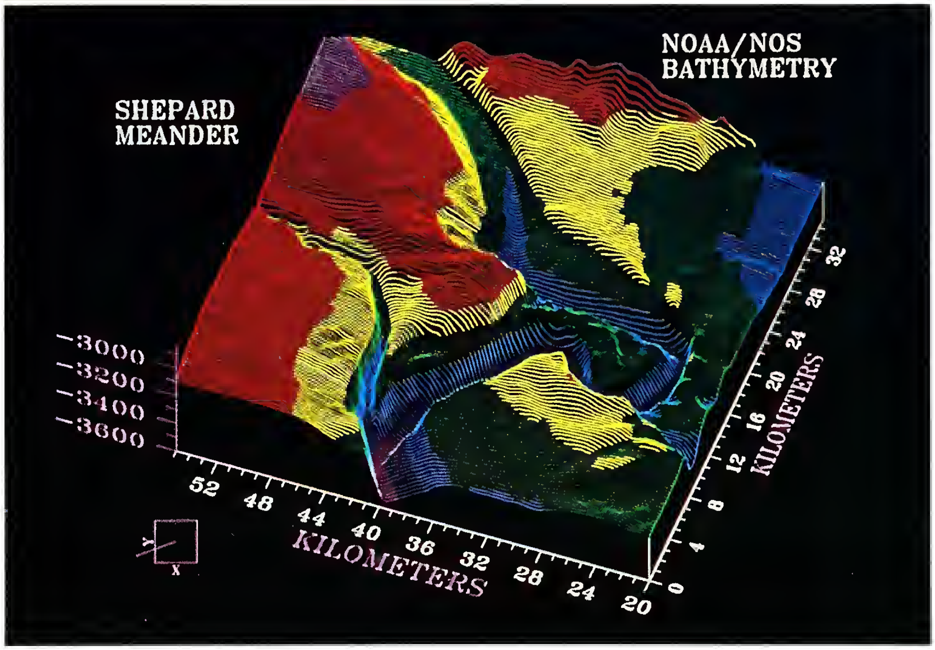


Figure 4–1. *Through SeaBeam monitoring from NOAA vessels the geologically complex Monterey Canyon along the California coast, for the first time, can be accurately viewed. (Courtesy NOAA/NOS/Office of Charting and Geodetic Services)*

and equitable utilization, conservation and development of ocean and coastal resources"

30 U.S.C. 1419 (The Deep Seabed Hard Mineral Resources Act of 1980) authorizes NOAA to conduct ocean research that "shall include the development, acceleration, and expansion, as appropriate, of the studies of the ecological, geological, and physical aspects of the deep seabed in general areas of the ocean where exploration and commercial development are likely to occur"

33 U.S.C. 1441 (The Marine Protection, Research and Sanctuaries Act of 1972) authorizes NOAA to "conduct a continuing program of monitoring and research regarding effects of the dumping of material into ocean waters"

16 U.S.C. 1451–1456 (The Coastal Zone Management Act Amendments of 1976) authorized NOAA to conduct a program of research, study and training to support the development and implementation of management programs

NOAA's missions in carrying out these mandates are service–oriented and driven by the need for the information products that are generated. Surveys and other data collection efforts are generally designed to cover areas systematically. NOAA's missions in charting and applied oceanographic research are sufficiently distinct from those of other agencies and organizations that NOAA must provide the infrastructure to carry out this work.

Research efforts associated with this work are generally designed to apply to specific objectives as opposed to pure research seeking general expansion of knowledge. There is, however, increasing need to coordinate with other scientists and to accommodate the needs of basic science as much as possible. There is also a large degree of overlap between research interests related to NOAA programs and those of other federal agencies and academia. Coordination offers the opportunity not only to more efficiently achieve national goals but also serves to enrich efforts on NOAA's missions. The goals today are not only to map and describe the existing environment, but also to understand processes, develop models, and predict changes and responses (Figure 4–2).

Monitoring of the marine environment for pollution–related status and trends is a NOAA mission which is very similar because of its systematic nature and service orientation. Although this work may be more properly categorized as applied research, it was considered in the other working groups. Supporting ship requirements for that mission are not included in this report.

Future Directions

NOAA ship requirements will continue to grow in amount and diversity over the next 30 years. The nation is drawn to the oceans for direct commercial exploitation, for interpretation of world environmental concerns, and for defense. No panacea will be forthcoming over the life of the next generation of the NOAA fleet that will preclude an aggressive ship operations concept. Ships which can satisfy the demands of NOAA's mission in ocean surveying and applied oceanographic research will remain the essential instrument of data collection.

Nautical charting and bathymetric mapping is, and will remain, the most stressing requirement for the fleet. The regions needing immediate survey in coastal areas and offshore

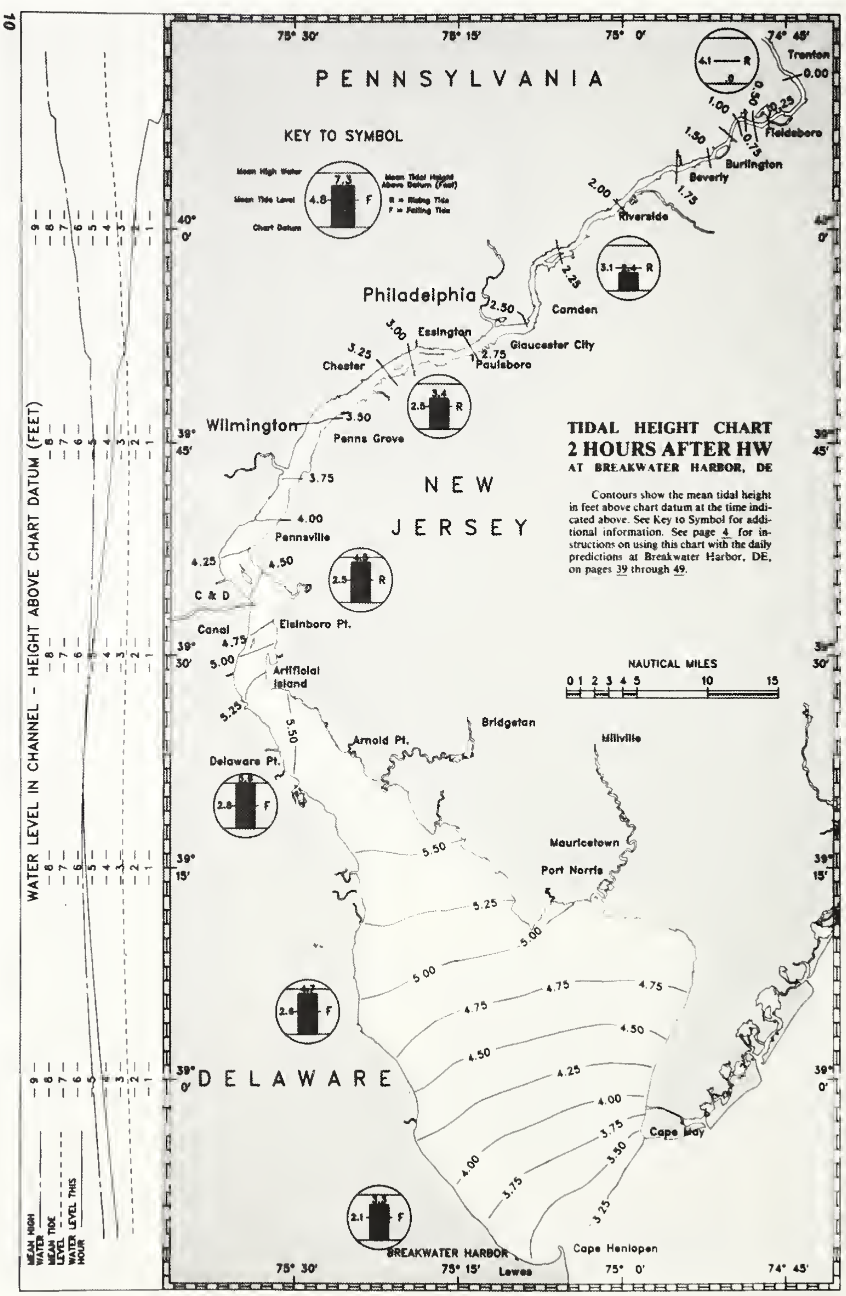


Figure 4–2. *NOAA's Coastal Ocean Circulation program provides users with the best available estuarine and coastal circulation information from a variety of advanced scientific tools. These two plates from the* *Delaware River and Bay Tidal*

in the EEZ are vast, with estimates of hundreds of ship–years to meet just the known responsibilities. From the shoreline to the EEZ's edge, data collected from a single "complete" survey will not answer all the needs over the time period. Such data is perishable, depending on the natural dynamic processes, human development activities, and the changing application of the data to solve new problems.

Circulation and Water Level Forecast Atlas provide tide and tidal current prediction information for the time period two hours after high water at Breakwater Harbor, DE. (Courtesy NOAA/NOS/Office of Oceanography and Marine Assessment)

Allocation of ships to satisfy NOAA's data collection and monitoring role in fundamental oceanic and atmospheric processes will increase. Both near our coasts and around the world, NOAA will need to remain responsive to providing platforms that will be able to carry out multiple missions in the water column and bottom.

Geographic/Seasonal Considerations

The largest area of uncharted waters or sparsely sounded waters within NOAA's responsibility, besides the deep ocean off–shore EEZ region, is in Alaska. Shipping to and from Alaska is likely to increase, requiring improved charts of routes and harbors in Alaska (Figure 4–3). Demands for greater productivity are likely to lead to vessels operating with smaller draft margins in and out of many ports. Fishing and offshore energy exploration and production will require increased charting activity.

Figure 4–3. *The continued development of Alaskan shipping and fishing will require NOAA to increase its charting activities in many areas that have yet to be surveyed. (Courtesy NOAA/NOS/Office of Charting and Geodetic Services)*

Defense needs for adequate charting in the Aleutian Islands will play a significant part in placing charting resources. Pacific rim trade is likely to grow, creating demand for surveys in Hawaii and the U.S.–affiliated Pacific territories.

On the east coast, areas still remain that have only sparse lead–line soundings. However, the areas of concern on the east coast are focusing on traffic lanes, safety zones, and approaches to major ports as shipping continues to increase both in number and draft. In addition, demand will continue for investigation of reported obstructions to navigation which outnumber current resources to resolve. Harbor improvement projects can be expected, with accompanying survey demands.

Coastal processes are of increasing priority. Monitoring of sediment transport, erosion, deposition, and coastal flooding will require resources along the Nation's coast areas and in the Great Lakes. This work should be closely coupled with NOAA's and other agencies' roles in environmental monitoring. Knowledge of bottom processes is often critical in management of hazardous material, dredging operations, and oil spills, as well as monitoring of waste discharges and dumpsites.

Offshore, the available bathymetric database is very poor. Management and development of the resources of the EEZ will depend on improved bathymetric maps and more complete characterization of the seafloor. Priorities from the energy sector are likely to be potential oil and gas regions in the Gulf of Mexico, off the west coast and Alaska, and off the east coast.

The highest priority of the Defense Department is in the Aleutian area, but it also has requirements for a number of areas around the continental U.S., off Hawaii and off the U.S. affiliated territories in the Pacific. Priorities for scientific investigations are likely to be on the continental slopes and other areas of high–dynamic geologic processes, as well as historic and potential dump sites. Fishermen and fisheries managers need maps of deep water fishing grounds and need to locate areas of high biological productivity (hard– or live–bottom areas). Industry seeks bathymetric data to aid in the search for sand, gravel, placer, phosphorite, or other mineral deposits.

Global change studies will require access to the global ocean. Designated study areas, such as the Juan de Fuca Ridge, will continue to be the focus of more intense studies and technology development. Since the polar areas are a primary regulator of global climate, access to ice–covered areas may also be required.

Time constraints are minimal in the Gulf of Mexico and along the east coast. Hurricane season and winter storms influence the choice of optimum survey times. In the Great Lakes, ice cover is the limiting factor. On the west coast, including Hawaii and the affiliated territories in the Pacific, yearly tropical storm periods are of concern.

Of NOAA's area of responsibility, surveying is most constrained in Alaska. Extreme cold, icing conditions, and/or dangerous sea states are encountered over much of Alaska from approximately October through March. In the Bering Sea and north, the optimal surveying time is reduced to two or three summer months at most, unless special platforms (e.g., ice-strengthened hull) are available.

NOAA's fleet needs to have the capability of working in more extreme weather and sea state conditions. Much ship time is wasted transiting to catch optimum weather windows thousands of miles away. Even within selected weather windows, weather often causes operations to be suspended and productivity to be lost.

Remote Sensing and Shipboard Observations

Shallow water (20–30 m to the coastline) is a region where airborne techniques are becoming operational and more efficient. Ships move relatively slowly and shipboard acoustic systems have a narrow swath-width in shallow water. Consequently the area coverage rate is lower than airborne systems. Those areas that have clear water windows should be mapped using airborne lasers. For certain areas turbidity limits the use of lasers year-round, and these will continue to require ship and launch surveys, as will ground truth and item investigations in areas swept by laser systems. Laser profilers with centimeter resolution allow beach profiles to be determined so that aerial photography of the shoreline can be flown at any stage of the tide and corrected. This would help maximize use of aircraft when the weather is appropriate.

The Global Positioning System (GPS) is expected to make a substantial effect on ship productivity by relieving the need for setting and tending shore-based positioning equipment and periodically calibrating it. Developing techniques may make it possible to determine a ship's attitude (roll, pitch, heading, heave, and, perhaps, even the state of the tide--all important to sonar and some geophysical measurements) through use of the GPS signals. Obtaining vertical accuracy of better than 5 cm using GPS would have important implications for determining the tidal correction for bathymetry data. A local determination of the tidal height in the survey area could be determined without going to a tide gauge at the beach.

Coastal and estuarine current measurement techniques have evolved from direct measurement with mechanical meters to remote acoustical measurements with acoustic doppler current meters (either shipboard or bottom-mounted) coupled with modeling. These combinations of techniques have reduced requirements for ship support of circulatory surveys (Figure 4-4).

Acoustic techniques are developing the capability to classify seafloor materials based on absolute reflectivity, backscatter texture, or acoustic absorption. Sub-bottom profilers are capable of centimeter-level vertical resolution. These techniques can eliminate or reduce the need for actual bottom samples. Acoustic techniques can also be used to track and measure suspended sediments and estimate biomass. An acoustic system called the "echometer" was proposed several years ago to measure the temperature profile in the water column. The Hydrosweep swath mapping system employs a technique to remotely determine the sound velocity profile beneath the ship. These procedures have the potential to reduce the need for CTD casts.

As part of global change, many parameters of the earth's surface will be measured using satellites. Ships allow for verification or quantification of satellite measurements. Ships should carry as many different sensors as possible to provide *in situ* measurements. Satellite data can provide a complementary role with respect to shipboard measurements. Charting operations require that a ship be geographically located in a small area for long periods of time, which would provide repetitive sampling or measurement over that period. A limited time series of information would be developed for future reference in determining variability of events or processes.

Short–Term Event Studies and Long–Term Monitoring

Repeat surveys are required at a time scale necessary to identify changes in bottom topography that are related to catastrophic events (e.g., landslides and tsunamis) and to bottom processes (e.g., currents). As long as it takes 50 to 100 years to conduct a repeat bathymetric survey, it will be very difficult to identify, quantify, and understand the processes leading to change. Airborne measurements allow rapid, repetitive response to sudden events. Laser altimetry information just before and immediately after a storm will allow net change calculations to be made in the coastal zone. In the case of coastal studies using airborne laser techniques, even if the absolute depth is not verifiable, just being able to identify change will be a significant contribution. In the context of global change, coastal erosion in response to sea–level change and storm intensification due to global warming require short–term event studies.

A rapid–deployment circulation information system would provide a mechanism for improved predictions in response to emergencies such as oil and hazardous material spills, storm evacuations, and search and rescue operations. The fully integrated system would include real–time measurements of winds and currents, data processing, hydrodynamic modeling and data display. The components would include helicopter–deployable instrument buoys with sensors and telemetry transmitters, microwave or UHF radar for measuring surface currents (deployable by helicopter, small boat, or shore party), telemetry receivers, and data acquisition and processing equipment with access to historical circulation data and the capability of real–time quality assurance and modeling. Several such systems should be maintained for deployment anywhere in the U.S. within 12 hours.

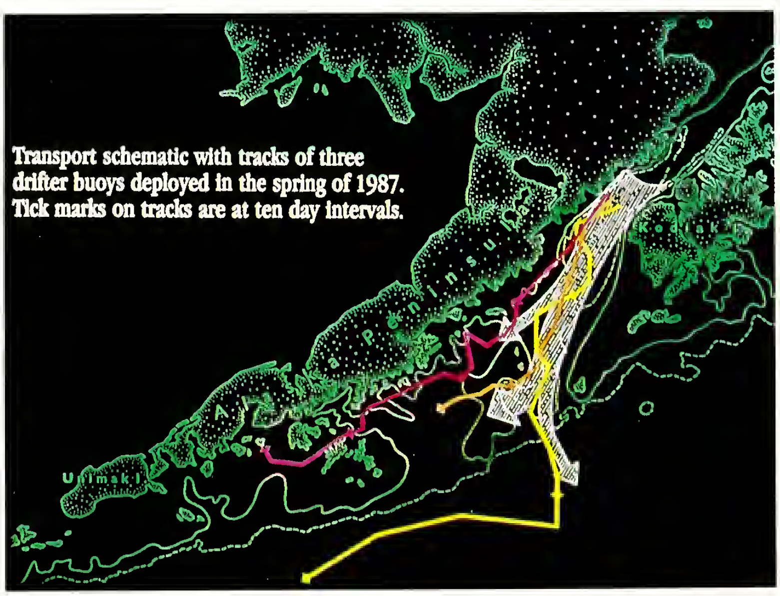


Figure 4–4. *Drifter buoys deployed by NOAA vessels were used to study the transport of fish larvae. Such multidisciplinary research is a significant part of the Agency's research in living marine resources. (Courtesy NOAA/NMFS)*

The RIDGE program (Ridge Inter-Disciplinary Global Experiments component of the U.S. Global Change Research Program) has a goal of predicting, identifying and monitoring mid-ocean ridge crest venting processes. If the eruptive event, releasing fluids and energy from the seafloor, can be identified as occurring, event monitoring will be attempted. Mapping of the seafloor topography to identify change (e.g., lava flows, faulting) will be required. Acoustic techniques would be used to look at the water column structure to identify change (e.g., particulates, thermal differences).

Seafloor observatories are being proposed to monitor processes over long time periods. "Ocean stations," somewhat akin to the proposed space station, could be envisioned. Ship support would be required for construction and servicing of such a facility.

Trends in Data Collection/Analysis

The Working Group debated alternatives of science and mission complement at sea. Technology is available to permit data transmission to shore-based mission control facilities alleviating the necessity for ships to carry large numbers of personnel. However, the group decided that, for the foreseeable future, there were significant advantages in having personnel aboard. Among these were better quality control, enhanced flexibility and general familiarity with circumstances surrounding the data. The fact that scientific personnel are available at sea is important and should be capitalized upon. This philosophy means that as much real-time data processing as possible needs to be done while data collection is underway. On the other hand, the most demanding communications requirements are to handle bursts or segments of data occasionally rather than continuous capacity for full data transmission.

Attention should be given to at-sea data collection and processing to maximize use of personnel time at sea and reduce backlogs of data. Data management and handling should be a priority on ships.

Anticipated Growth in Need for Vessel Time

In order to meet its responsibility to provide up-to-date charts and other navigation information, it has been a goal of NOAA to sustain a basic resurvey cycle of 50 years in all areas of moderate-to-heavy marine activity, and more frequent surveys in important areas of rapid change (see U.S. Commission on Marine Science, Engineering and Resources 1969). NOAA has not met that goal and is increasingly drawn into disputes over liability concerning its products. At the same time, the level of expectation on the part of the mariner is likely to increase. The Global Positioning System (GPS) is scheduled to be fully operational by 1993. It will provide a low-cost means of accurately determining location with respect to the chart and, consequently, increase reliance on the charted information. Electronic charts and semi-automated navigation systems appearing in the near future will continue this trend (Figure 4-5). Tide and current information will find similar scrutiny. Approaches to U.S. ports are being deepened to accommodate deeper draft ships. In order to maximize productivity, ships ride the tide--a practice that requires both accurate bathymetry and accurate tide prediction.

In the offshore areas, important national decisions about matters ranging from energy supply to waste disposal depend on having a base of information about the physical characteristics of the EEZ. Bathymetric maps of these areas are essential as base maps for all ocean research and are required by all ocean users, federal and state agencies, academia and the private sector. After nearly twelve ship-years of effort, only a little more than 2% of the EEZ has been covered. The pace of progress in surveying these areas must be accelerated.

NOAA will be asked to improve the cost effectiveness of its operations by extracting more information from its surveys and by applying improved technology in conducting them.

Figure 4–5. *New computer–based systems now being developed will make the navigation of vessels easier, more accurate, and safer. In this artist's rendition the helmsman utilizes a variety of navigation aids including electronic charts. Such tools will place increasing demands on marine bathymetric surveys. (Courtesy NOAA/NOS)*

In shallow water, remote–sensing techniques, such as airborne laser systems, offer the promise of significant improvements in coverage rate and costs. These will reduce, but not eliminate, the need for acoustic mapping from surface vessels. Swath acoustic mapping technology developed over the last decade allows total coverage of the seafloor as opposed to single point values along widely spaced track lines. This technology has greatly improved the quality of bathymetric data being collected. Future technology must target collection of this information faster by increasing ship speed during surveying and increasing the swath width mapped (Figure 4–6). The capability to broaden the swath width to three times the water depth is now available and needs to be incorporated in NOAA's fleet. Ship speed needs to be increased. Ability to work in rough seas, at least to sea state 5, needs to be attained. In order to broaden the swath further, autonomous remote vehicles ("remote data gatherers"), such as the Canadian Dolphin system, should be considered.

The mission of NOAA and our national needs go beyond determining the shape of the seafloor. In general, the goal should be to define the characteristics of the bottom in order to advance development of marine resources and promote protection of the marine environment. Ancillary measurements that are compatible with hydrographic and bathymetric surveying, such as sub–bottom profiles, side–scan images, gravity and magnetic measurements, should be gathered simultaneously. These data must be processed to extract information which is required for traditional NOAA products, such as bottom type, as well as more recent demands such as sediment transport models related to pollution and coastal processes.

It is important that we recognize the need for a NOAA fleet of greater capacity than today's to address the historical missions of basic hydrographic and bathymetric surveying as well as the new ones being assigned. The game is not zero sum. Monitoring and mapping pollution, coastal erosion, oceanic indicators for climate and global change, geological and energy resources will all stress limited ship platform availability.

Specific Vessel Requirements for Science Needs

The specific ship requirements developed by the Working Group reflected several basic premises:

1. *Efficiency*. Ships should be designed to maximize mission productivity. Ships should be able to transit rapidly and to survey rapidly. They should accommodate broad swath sonars, remote vehicles and/or launches. Ships must be designed so that personnel and equipment can continue to operate over a broad range of weather conditions. Automation and remote monitoring systems should be incorporated in ship designs to reduce crew manpower requirements. Consideration should be given to increasing the number of days per year that ships are operated and including within the design provisions for exchange of crews.

Figure 4–6. *This bathyscan device is an example of a new technology being applied to NOAA's charting and mapping efforts in order to increase the efficiency of the survey vessels. (Courtesy NOAA/NOS)*

2. *Acoustic Conditions*. Acoustical systems generally provide the most effective means for shipboard data gathering and development of such systems is likely to continue. Present systems can be grouped into several frequency ranges:

a) *Sub–bottom profiling*––nominally 3.5 kHz but more advanced systems actually using wider range of frequencies from approximately 2 to 10 kHz

b) *Echosounding*––nominally 12 kHz for deep ocean systems but often using higher frequencies (as high as 200 kHz) especially in shallow water in order to achieve high directivity without large arrays

c) *Acoustic positioning and communication with sub–sea instruments and remote vehicles*––in the range from 15 to 50 kHz with lower frequencies used in deeper water for longer range but requiring larger arrays

d) *Water–column characterization*–– typically in the 100–300 kHz range for current measurements, biomass estimation, and suspended sediments

Ships need to be designed to accommodate these systems. Machinery must be installed so as to minimize interference due to radiated or structure–born noise. Hull shapes and propulsion must be designed to avoid disruption to acoustic sensors due to noise, bubble sweepdown, or other phenomena. Access to transducers or transducer spaces without hauling the ship is desirable.

3. *Flexibility*. The Working Group discussed the issue of specialization vs. flexibility in ship designs. It was generally concluded that the larger ships should be flexible, probably through a design utilizing replaceable modules (not "vans" or "containers"). These should be fully environmentally controlled (power, heat, air conditioning, waste disposal, etc.). They should mate with the ship structure in a way that provides for inside passage and complete communication including access to the ship's navigation, systems status, and possibly sonar suite via a local area network. The modules should be standardized to be easily transportable (including air transport if possible). Deck equipment might also be interchangeable through standardization by incorporating a deck grid accepting one–inch bolts on 18–inch centers for example. Although flexibility is highly desirable, it can increase costs and impede efficiency. The degree to which flexibility is designed into a ship should reflect its expected utilization. Dedicated arrangements for charting missions are likely to be appropriate particularly in intermediate size and smaller vessels.

Tables 4–1 – 4–3 list specific requirements for large–, medium–, and small–size vessels. In cases where ship requirements were felt to be driven by considerations outside the realm of charting and applied oceanographic research, those requirements are denoted with an asterisk.

References

Treadwell, T. K., D. S. Gorsline, and R. West (1988), "History of the U.S. Academic Oceanographic Research Fleet and the Sources of Research Ships," UNOLS Fleet Improvement Committee Report (UNOLS Fleet Improvement Committee Office, Texas A&M University, College Station, TX), p. 14.

U.S. Commission on Marine Science, Engineering and Resources (1969), **Our Nation and the Sea: A Plan for National Action** (U.S. Government Printing Office, Washington, D.C.), pp. 212–214.

Table 4-1. Requirements for Large-Size Vessels.

General	Large, stable, high-endurance vessel for world-wide cruising in ice-free (or loose ice?) areas. Characteristics would be driven by such present and potential mapping missions as EEZ mapping in remote areas such as the Pacific Islands, mid-ocean ridge mapping and research, Antarctic surveys, deep seabed hard minerals support, etc. This type vessel would likely be designed to accommodate pure oceanographic research, as well as charting and applied oceanographic research missions through the use of flexible, interchangeable modules.
Endurance	40 days (* 60 days desirable)
Accommodations	10 personnel involved in mapping missions (* with 20-25 other scientists for multi-disciplinary missions). Two-person staterooms with head shared by two staterooms. Lounge as well as library/study/conference space. Exercise area.
Speed/Seakeeping	Transit: as fast as possible Cruising: as fast as 15 knots without loss of data collection capability through sea state 4 (SS4) Deep Tow: as slow as 2 knots Stationkeeping

Data Collection Systems

acoustically quiet, with minimal bubble sweepdown over arrays, and provision for sequencing systems

o wide swath bathymetric mapping and imaging system
  approx. 12 kHz, full ocean depth capability
  spatial resolution better than 5% water depth
  minimum swath width = 3 x water depth,
  desirable = 10 x water depth (perhaps using remote data gatherers (RDGs), each carrying independent swath systems, or acting in coordination using forward scatter)
  ship system preferably hull mounted
  data acquisition/processing capability adequate for logging and presentation of echo waveforms and water reverberation as well as derived depth contours and imagery (up to 20 Megabytes/hr)

o velocimeter (acoustic echometer, expendable probes and/or CTD system with 10,000 m capacity)

* Desirable

Table 4-1, Continued.

	o	sub-bottom profiler < 10 kHz, preferably wide-band, beamwidth as narrow as possible digital data acquisition and presentation with capability for bottom material classification coordinated with bathymetric/imaging data system
	o	gravimeter digital acquisition and processing system integrated with bathymetric/imaging data system
	o	magnetometer same acquisition and processing system
	o	environmental - SEAS
	*	CTD and water sampling system for physical oceanography 6000 m depth capability
	o	deep-towed system 30-100 kHz bathymetric mapping and imaging system low-light level video and still camera fiber optic cable digital data acquisition and display system
	o	doppler current meter 75-300 kHz digital data acquisition and presentation system
	*	acoustic water quality and biomass system
Navigation	o	GPS (precise positioning service + differential capability)
	o	attitude measurement system (roll, pitch and heave) with minimum sensitivity to horizontal acceleration
	o	heading gyro - accuracy 0.1 degrees (possibly GPS derived)
	o	short baseline acoustic navigation (for location of deep tow system and shallow towed system, if used)
Cranes/Handling Systems		
	o	dedicated launch and recovery equipment for RDGs with swath mapping systems or other large towed systems (including any necessary winches)

* Desirable

Table 4–1, Continued.

	*	crane capacity for deploying and retrieving deep–sea moorings and long–term observatory instrumentation
Winches	o	CTD (* and water sampling)
	o	capable of ship motion compensation and precise control of cable for near–bottom work
	o	design for handling of conducting/fiber–optic cables avoiding unnecessary wear or stress on the cable
Deck Space	o	towed systems (if used) require substantial deck space (footprint of SeaMARC II deck equipment, for instance, is 8 x 12 meters) at the stern with minimum freeboard
Laboratories	o	mapping laboratory >100 square meters (plotter, chart table, computer systems) power conditioning air conditioning
	o	electronics shop
	o	oceanographic (wet) laboratory
	o	ROV control center (if remote vehicles used for data collection)
Internal Communications		
	o	high quality voice communication through all work spaces
	o	high speed LAN for data (carrying navigation, monitoring of ship control functions, environmental parameters, ongoing operations, etc.)
	o	closed circuit TV monitoring of deck areas
External Communications		
	o	reliable continuous communication, with voice and facsimile capability to other vessels, and with capability for voice, graphic facsimile and data segments to and from shore. Satellite and VHF.
	*	high resolution picture transmission system (HRPT)

* Desirable

Table 4–1, Continued.

Launch/Workboat	o	although routine launch survey operations are not expected with this vessel, its launch/workboat should be designed to be equipped as a survey vessel in circumstances such as Antarctic work or other similar cruises.
Storage		

Table 4-2.	**Requirements for Medium-Size Vessels.**
General	Medium size, medium endurance, stable vessel for use in remote areas both near shore and to the edges of the continental shelf. Ice-free or loose ice areas. Missions would include nautical charting in Alaskan areas distant from resupply and bathymetric/geophysical mapping on the shelf. Design would be driven by the need to carry launches (for shallow < 20 m, complicated areas) and/or ROV's (for extension of the mapping swath in open areas). Perhaps two sizes -- one carrying four launches or equivalent, and one carrying two launches or equivalent.
Endurance	25 days for four-launch size 20 days for two-launch size
Accommodations	20 personnel involved in mapping missions with four launches, 12 with two launches, plus 5-10 scientists and crew. Lounge/conference space. Exercise area.
Speed/Seakeeping	Transit: as fast as possible Cruising: as fast as 15 knots without loss of data collection capability through SS4

Shipboard Data Collection Systems

acoustically quiet, with minimal bubble sweepdown over arrays, and provision for sequencing systems

o wide swath bathymetric mapping and imaging system
  dual frequency (separate arrays for each)
  approx. 12 kHz for full ocean depth capability and 20-40 kHz, 1000 m depth capability
  spatial resolution better than 5% water depth
  minimum swath width = 3 x water depth, desirable = 10 x water depth (perhaps using ROVs, each carrying independent swath systems, or acting in coordination using forward scatter)
  ship system preferably hull mounted
  data acquisition/processing capability adequate for logging and presentation of echo waveforms and water reverberation as well as derived depth contours and imagery (up to 40 Megabytes/hr)

o velocimeter (acoustic echometer, expendable probes and/or CTD system with 10,000 m capability)

o sub-bottom profiler
  < 10 kHz, preferably wide-band
  beamwidth as narrow as possible

Table 4–2, Continued.

		digital data acquisition and presentation with capability for bottom material classification coordinated with bathymetric/imaging system
	o	gravimeter digital acquisition and processing system integrated with bathymetric/ imaging data system
	o	magnetometer same acquisition and processing system
	o	environmental – SEAS
	o	doppler current meter 75–300 kHz digital data acquisition and presentation system
	*	CTD and water sampling system for physical oceanography
	*	acoustic water quality and biomass system
Shipboard Navigation		
	o	differential GPS (laser range–azimuth systems for some unusual applications)
	o	heading gyro – accuracy 0.2 degrees (possibly GPS derived)
	o	attitude measurement system (roll, pitch, heave) with minimum sensitivity to horizontal acceleration
Launches		shallow mapping, turbid water, ground truth –– 0–20 m
	o	30 ft length
	o	two person operation
	o	interferometric mapping system –– hull mounted; or simpler multibeam echosounder (3–5 beams)
	o	navigation by differential GPS or laser range–azimuth
	o	heading gyro – accuracy better than 1.5 degrees
	o	attitude measurement system

* Desirable

Table 4–2, Continued.

	o capability to tow small side–scan (possibly interferometric)/sub–bottom profiler system
	o velocimeter
	o rugged digital acquisition and processing system capable of largely automatic operation, capable of handling echosounder and sidescan data at rates of up to 40 Mbytes per hour, and exercising at least minimal quality control
ROV's	remote data gatherers for use in relatively unconstrained waters with depths > 20 meters to extend the ship's mapping coverage in lieu of manned launches
Cranes/Davits/Handling Systems	
	o launches or ROV's, perhaps using a stern capture arrangement but more likely davits and side–capture arrangement
	o bottom sampling systems and sediment traps
	o intermediate depth moorings
	o dedicated, removable launch and recovery equipment for large towed systems if used
Winches	o CTD and water sampling
Laboratories	o mapping laboratory >100 square meters (plotter, chart table, computer systems) equipped to handle multiple streams of data from launches and/or ROV's as well as ship systems power conditioning air conditioning
	o ROV control center if remote vehicles used
	o electronics shop
	o oceanographic lab
Internal Communications	
	o high quality voice communication through all work spaces

Table 4–2, Continued.

	o	high speed LAN for data (carrying navigation, monitoring of ship control functions, environmental parameters, ongoing operations, etc.)
	o	closed circuit TV monitoring of deck areas
External Communications		
	o	reliable continuous communication, with voice and facsimile capability to other vessels, and with capability for voice, graphic facsimile and data segments to and from shore. Satellite and VHF.
	o	dedicated telemetry links for complete data streams from launches and/or ROV's
Diving	o	provision for frequent SCUBA diving operations generally from launches
Storage	o	diving gear
	o	spare equipment
Workboat	o	for tide work (GPS possibility? -- 5 cm accuracy requirement)
	o	define zero fathom curve
	o	general utility boat

Table 4-3. Requirements for Small-Size Vessels.

General	Smaller, stable, low endurance vessel capable of 24 hr/day survey operations and some multidisciplinary (but not interdisciplinary) work. Typical missions would item investigations and East Coast survey work. Draft would be as shallow as practical.
Endurance	10 days
Accommodations	10 scientists or other mission personnel plus crew
Speed/Seakeeping	Transit: as fast as possible Survey: as fast as 15 knots or faster Stationkeeping: using GPS signal or taut-wire for reference, hold position in winds to 35 knots

Data Collection Systems

- o acoustically quiet
- o multibeam side-scan sonar with digital acquisition and processing system capable of indexing contacts, recalling images and processing images for obstacle detection (80 Megabytes per hour)
- o inspection system – sonar and optical system for inspection of contacts with remote control (special ROV with less emphasis on manuverability and more on sensing to avoid getting entangled in obstructions) and capability of determining least depth
- o broad swath bathymetric mapping and imaging system
  50-200 kHz, >100 m depth capability
  swath width >8 x water depth
  preferably hull mounted
  interfaced to same data acquisition/processing system as used for the multibeam sidescan sonar
- o velocimeter
- o sub-bottom profiler
  <10 kHz, preferably wide-band
  interfaced to the same data acquisition/processing system as used above with software for bottom material classification
- o doppler current meter
- o acoustic water quality system

Table 4–3, Continued.

Navigation	o differential GPS
	o heading gyro – accuracy 0.75 degrees (possibly GPS derived)
	o attitude measurement system (roll, pitch, heave) with minimum sensitivity to horizontal acceleration
	o short baseline acoustic navigation for tracking towed systems or inspection system
Launch	for shallow water work
Cranes/Davits/Handling Systems	o remote acoustic current meters
	o launch
	o inspection system
	o towed systems
Winches	o CTD and water sampling
	o bottom sampling (up to large, 1 ton box core?)
Laboratories	o mapping laboratory >30 square meters (plotter/chart table, computer systems) power conditioning air conditioning
	o inspection system control center
	o electronics repair area
	o oceanographic (wet) laboratory
Internal Communications	o high quality voice communication through all work spaces
	o LAN for data (carrying navigation, monitoring of ship control functions, environmental parameters, ongoing operations, etc.)
	o closed circuit TV monitoring of deck areas

Table 4–3, Continued.

External Communications		
	o	reliable continuous communication, with voice and facsimile capability to other vessels, and with capability for voice, graphic facsimile and data segments to and from shore. Satellite and VHF.
Diving	o	provision for frequent SCUBA diving
	o	some capability for surface supply
	o	divemaster + alternate, 6 qualified divers aboard
Storage		
Workboat		

Glossary

ABS	American Bureau of Shipping
ADCP	Acoustic Doppler Current Profiling
ADEOS	Advanced Earth Observing Satellite
AKFC	Alaska Fisheries Science Center (NOAA)
AMC	Atlantic Marine Center (NOAA)
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
ARCSS	Arctic System Science
ATSR	Along–Track Scanning Radiometer
AUV	Autonomous Undersea Vehicles
AVHRR	Advanced Very–High–Resolution Radiometer
^{14}C	Carbon 14
CalCOFI	California Cooperative Fisheries Investigations
CAOR	Charting and Applied Oceanographic Research
CD–ROM	Compact Disk–Read Only Memory
CER	Coordinated Ecosystem Research
CES	Committee on Earth Sciences
CGS	Charting and Geodetic Survey
CNES	Acronymn for the French Space Agency
COARE	Coupled Ocean–Atmosphere Response Experiment
COP	Coastal Ocean Program
CPR	Continuous Plankton Recorder
CSTD	Conductivity, Salinity, Temperature, and Depth Measurements
CTD	Conductivity, Temperature, and Depth Measurements
CTDO	Conductivity, Temperature, Depth, and Oxygen Measurements
CZCS	Coastal Zone Color Scanner
DAS	Data Acquisition System (Shipboard System)
DMS	Dimethylsulfide
DMSO	Dimethylsulfate
DOD	Department of Defense
DOE	Department of Energy
DSRV	Deep Submergence Research Vessel
DSV	Deep Submergence Vessel
EEC	European Economic Community
EEZ	Exclusive Economic Zone
ENSO	El Niño/Southern Oscillation
Eos or EOS	Earth Observing System
EPA	Environmental Protection Agency
EPOCS	Equatorial Pacific Ocean Climate Studies
ERS–1	European Remote–Sensing Satellite
ERTS–E	Earth Resources Survey Satellite

FCMA	Fishery Conservation Management Act, i.e., Magnuson Act
FCZ	Fisheries Conservation Zone
FNOC	Fleet Numerical Oceanography Center (DOD)
FOCI	Fisheries Oceanography Coordinated Investigations
FURUNO	Trade name for a chromoscope echo sounder
GCM	General Circulation Model
GEBCO	General Bathymetric Chart of the Ocean
Geosat	Geodetic Satellite
GIS	Geographic Information System
GLERL	Great Lakes Environmental Research Laboratory (NOAA)
GLOBEC	Global Ecosystem Dynamics
GMCC	Geophysical Monitoring for Climate Change
GOES	Geostationary Operational Environmental Satellite
GOM	Gulf of Mexico
GPS	Global Positioning System
GTS	Global Telecommunications System
HRPT	High-Resolution Picture Transmission
HVAC	Heating Ventilation Air Conditioning
ICES	International Council for the Exploration of the Sea
ICNAF	International Commission for the Northwest Atlantic Fisheries
ID	Identification Number
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IGOSS	International Global Ocean Services System
INMARSAT	International Marine Communications Satellite
IOC	International Oceanographic Commission
IR	Infrared Satellite Measurement
JERS-1	Japanese Earth Resources Satellite
JGOFS	Joint Global Ocean Flux Study
KVA	Kilo Volts Amperes
Landsat	Land Remote-Sensing Satellite
LAN	Local Area Network
LCROV	Low Cost Remotely Operated Vehicle
LMR	Living Marine Resources
LOA	Length Overall (of Vessels)
LORAN	Long Range Navigation
MARMAP	Marine Resources Monitoring Assessment and Prediction
MEXUS-GULFO	Name for the United States/Mexico Cooperative Fishery Agreement
MET	Meteorological
MOCNESS	Multiple Opening Closing Environmental Sampling System
MODIS	Moderate Resolution Imaging Spectrometer
MW	Midwater Trawl
NAFO	Northwest Atlantic Fisheries Organization
NASA	National Aeronautics and Space Administration
NECOP	Nutrient Enhanced Coastal Ocean Productivity
NECOR	Northeast Consortium for Oceanographic Research
NEC or NEFC	Northeast Fisheries Science Center (NOAA)

NESDIS	National Environmental Satellite, Data and Information Service
NMFS	National Marine Fisheries Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service (NOAA)
NOSS	National Oceanic Satellite System
N–ROSS	Navy–Remote Oceanographic Sensing System
NS&T	National Status and Trends
NSCAT	NASA Scatterometer
NSF	National Science Foundation
NWFC	Northwest Fisheries Science Center (NOAA)
NWS	National Weather Service (NOAA)
OAO	Office of Aircraft Operations (NOAA)
OAR	Office of Oceanographic and Atmospheric Research (NOAA)
OCI	Ocean Color Instrument
OCTS	Ocean Color and Temperature Scanner
ODAS	Ocean Data Acquisition System
ORA	Office of Research and Applications (NOAA)
PAH	Polynuclear Aromatic Hydrocarbons
PDR	Precision Depth Recorder
PICES	Pacific International Council for the Exploration of the Sea
PMC	Pacific Marine Center (NOAA)
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PP	Primary Production
PPS	Precise Positioning Service
PSP	Paralytic Shellfish Poison
Radarsat	Synthetic Aperature Radar Satellite Mission sponsored by Canada (not an acronymn).
RIDGE Program	Ridge Inter–Disciplinary Global Experiments component of the United States Global Change Research Program
RITS	Radiatively Important Trace Species
ROV	Remotely Operated Vehicle
SABRE	Southeast Atlantic Bight Recruitment Experiment
SAIL System	Serial ASCII Instrumentation Loop System
SAR	Synthetic Aperture Radar
SARP	Sardine Anchovy Recruitment Program
SARSAT	Search and Rescue Satellite
SAT–NAV	Satellite Navigation
SEABEAM	A shipboard multi–transducer swath echo sounding system.
SEAGRID	A grid of the sea used for analytical purposes (not an acronymn).
SEAMAP	Southeast Area Monitoring and Assessment Program (NMFS)
"SEAMAP" project	Scientific Exploration and Mapping Program (NOS, 1965–1972)
SeaMARC	Trade name of a sidescan sonar: MARC = Marine Resource Characterization
SEAS	Shipboard Environmental (Data) Acquisition Systems
Seasat	Sea Satellite
SeaWIFS	Sea Viewing Wide Field Sensor

SEC or SEFC	Southeast Fisheries Science Center (NOAA)
SEFCAR	Southeast Florida/Caribbean Recruitment Project
SIMRAD	Trade name for a multibeam bathymetric system
SMMR	Scanning Multichannel Microwave Radiometer
SOOP	Ship-of-Opportunity
SPD	Satellite Positioning Data
SPOT	Système Probatoire d'Observation de la Terre (France), a satellite system
SPS	Standard Positioning Service
SS	Sea State
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature
STACS	Subtropical Atlantic Climate Studies
STARFIX	Trade name for a high-resolution navigation system
STD	Salinity Temperature Depth Measurements
SWATH	Small Waterplane Area Twin Hull-type Vessel
SWC or SWFC	Southwest Fisheries Science Center (NOAA)
TAO Array	Tropical Atmosphere-Ocean Array
TIROS-N	Television Infrared Observing Satellite (N = latest series)
TOGA	Tropical Ocean/Global Atmosphere
UCAR	University Corporation for Atmospheric Research
UGR	Universal Graphic Recorder
UNOLS	University National Oceanographic Laboratory System
UOR	Undulating Oceanographic Recorder
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
VAC	Voltage alternating current
VENTS	Name of hydrothermal venting research program (not an acronym).
WCR	World Climate Research
WOCE	World Ocean Circulation Experiment
XBT	Expendable Bathythermograph
XCP	Expendable Conductivity Profiler
XCTD	Expendable Conductivity Temperature Device
XCTP	Expendable Conductivity Temperature Profiler

Appendix A

Position Papers

Oceanographic Research and Monitoring Working Group

Fishery Research Working Group

Charting and Applied Oceanographic Research Working Group

NOAA Oceanographic Fleet Needs: Polar Physical Oceanography

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Research Directions

Increasingly, polar oceanographic research is being focused on global issues such as climate change and geochemical fluxes. Since the polar regions play a unique role in the workings of the planet, this trend is likely to continue. For example, the ventilation of the deep and intermediate world ocean is driven from high latitudes, and the mechanisms appear to be both complex and variable. Furthermore, the stability of the resulting circulation is questionable.

Along with the emphasis on incorporating polar conditions and processes into a larger-scale perspective comes the need for the detailed process- and dynamically-oriented studies which give substance to the larger perspective. Coincidentally, such studies provide the research base for dealing with more regional issues, e.g., those relating to resource harvest and extraction, environmental protection, and transportation. Many of these issues loom large over the foreseeable future.

Very recently under the Arctic Research and Policy Act there have been serious attempts to coordinate arctic research between the various federal agencies, including budgetary cross-cuts. It's likely that this trend toward greater interagency cooperation will continue, and with it will come a need for expanded and thoughtful planning and for flexible attitudes and new procedures. Ship issues will probably be affected.

It's also likely that a significantly greater diversity of disciplines and methodologies will be represented as polar research expands. The active development and encouragement of such scientific pluralism is, in fact, essential to the overall health of the nation's research endeavors, but it will also place new demands on the research fleet and its technical support capability and capacity.

Growth

Polar oceanographic research is likely to experience higher-than-average growth during the next one to two decades. There are a number of reasons for this expectation. First, research opportunities in polar regions are significantly underexploited compared with those for much of the world ocean. Second, polar research is no longer a pronouncedly parochial activity, but is increasingly being incorporated into a global perspective. Third, continuing population growth is increasingly impacting polar regions, creating a concomitant need for a broad range of research.

Role of Shipboard Observations

None of the anticipated advances in remote sensing or automated technology are likely to diminish the need for high-quality shipborne research over the foreseeable future. Rather, the need for complementary shipborne measurements will probably increase as the total research effort increases in both volume and diversity. For example, a continually growing suite of oceanographic tracer measurements within the water column, many of which hold great promise for dealing with ocean circulation issues, is beginning to be applied aggressively to polar research. The sampling and analysis of these tracers will require careful attention to shipborne equipment, space, and support.

At the same time, non-traditional methodologies not directly based onboard ship may place significant new demands on the ship and its equipment, e.g., in instrument deployment or *in situ* calibration procedures.

Process Studies and Monitoring

To some extent, process studies and synoptic measurement programs have traditionally been segregated from monitoring efforts both operationally and in program planning and funding. This is beginning to change as environmental variability becomes a scientifically more important issue and as the technical capability for monitoring improves and expands.

It's therefore likely that two things will happen. First, short- and long-term measurements will be tied more closely to each other, with monitoring activities having a greater research orientation than has been the case so far; they will no longer primarily be operational activities. Second, the variety of parameters and processes being monitored will increase, as will the duration of the monitoring. These developments will place increasing demands on the research fleet, both for ship time and for breadth of support.

Geographic and Seasonal Distribution

Shipborne high-latitude research efforts by the United States have in the past been almost entirely limited to the polar margins, and they have also been primarily conducted during the summer and fall, when conditions for navigation are most favorable. This is not a desirable state since many of the most important scientific issues require measurements within the ice pack and during the cold seasons. Our present situation is, in fact, a prime example of science being driven by logistics, in this case in a highly limiting way.

As a result, our nation's marine scientists have increasingly been forced to work from more-capable foreign vessels, particularly those of western European nations, but also those of Canada and the Soviet Union. In this situation, our overall scientific capabilities will be increasingly vulnerable, and our choices of scientific problems and geographic areas in which to work will be limited. This will, in turn, affect recruitment and retention of competent personnel. To reverse this downward spiral will require significant improvements in the ability of the research fleet to operate within the ice and during cold and stormy weather. These improvements relate both to the ships and to their deck configurations and equipment.

Onboard Data Analysis

Two distinct sets of issues are involved:

1. Observations which are substantially routine and/or primarily the responsibility of the ship, e.g., standard meteorological observations; and

2. More specialized measurements or those specific to a particular cruise, e.g., water column chemistry.

There is also a third, hybrid, category, which arises because the necessary instrumentation is carried permanently onboard ship, while the measurements themselves are part of the core program for a cruise. A prime example is CTD observations and their supporting measurements, which require constant attention to instrumental and processing quality, system maintenance, and personnel training.

With respect to the first set of issues, the goal should be to make a first-class supporting data set quickly and easily available to onboard investigators. Quality and adequacy of the underlying instrumentation (including sampling frequency), the optimal use of automation, strict quality control of the data, and efficient data processing are all involved.

The second set of issues leads to rather different expectations. While both technical advances and the desire to improve experimental and personnel efficiency are driving investigators toward data processing and analysis at sea, this trend will probably not substantially increase direct demands on the ship's computing facilities. Rather, investigator-driven processing and analysis will tend to become more efficient and self-contained, and thus less dependent on permanent shipborne facilities. On the other hand, the increasing ability to analyze newly acquired data will likely create greater needs for flexibility in amending ship's operations as the developing data stream suggests changing strategies and tactics during a cruise.

Still another need for onboard data analysis is created by the trend toward greater diversity in the investigations carried out at sea. Many of these require specialized laboratory space, e.g., "clean laboratories," often in the form of self-contained laboratory van units. Adequate provision must be made for such temporary installations in safe and convenient locations and for necessary services to be supplied, e.g., electrical power and potable or clean seawater.

Ship and Technical Requirements

Hull strength and endurance are particularly important considerations in polar operations. A suitable research vessel should be capable of working in 9/10 ice, and also of being beset. It should have an endurance of at least 60 days, with an additional margin, under reduced service, if beset by ice.

There are also a number of specialized service requirements for polar operations. For example, protection and heating of staging and sampling spaces becomes very important. Similarly, there are additional requirements to protect the water supplies to laboratory vans, as well as discharges, from freezing.

A much-discussed topic is the desirability of moon-pools from which to sample or install sensors, and while there are definite advantages to these in high-latitude work, there are significant tradeoffs in cost and structural complexity, and to some extent also in operational care. For example, such wells have to be closed off while transiting in ice. The problems of access to the ocean in ice-covered waters remains, however. In general, working in ice requires special consideration for protection of equipment and instruments, both hull-mounted and over-the-side. The stationkeeping characteristics of the vessel, and the patterns of water flow past it, will to some extent determine the best strategies.

Several recent studies of high-latitude research vessel requirements, which go into considerable scientific and technical detail, are available to guide and stimulate thinking on these issues. An example is the April 1989 UNOLS report, "Scientific Mission For An Intermediate Ice-capable Research Vessel." The U.S. Coast Guard's design studies of ice breakers for research purposes are also helpful.

NOAA Climate and Global Change Program: Vessel Requirements

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Oceanographic research will occupy a central position in the NOAA Climate and Global Change Program and in the overall national Global Change effort as well. This is because the ocean's role in global climate change is recognized as one of the central uncertainties in our ability to predict climate. The vast heat capacity of the ocean and its ability to take up large amounts of atmospheric carbon dioxide will certainly influence the timing and extent of global warming. For this reason, studies of ocean circulation and heat flux and of biosphere/atmosphere/ocean fluxes of trace species are among the highest priorities of the U.S. Global Change Research Program (USGCRP; see Figure 1). As will be detailed later, this suggests that oceanographic research will be well supported over the next 5–10 years at least.

Program Requirements

Specific long–term observational and process study requirements *relevant to vessel use* center in the following areas:

Tracer Studies. Monitoring of the distribution of oceanographic tracers such as chlorofluorocarbons (freons), carbon–14, and tritium is the only practical way to describe the ocean's response to (and interaction with) climate change on long time scales. These tracer fields are essential for comparison to the output of coupled ocean–atmosphere models. Interpretation of these fields is difficult without the standard oceanographic observations of temperature, salinity, and nutrients. Tracer studies could take place in all three ocean basins.

These transoceanic measurements require large vessels with deep ocean winch capability and environmentally controlled laboratory space. The PMEL Tracers Program and the World Ocean Circulation Experiment (WOCE) are two programs for these measurements in which NOAA will have a continued heavy involvement. It should be noted that endurance is a significant requirement. This year's WOCE cruise to the south Pacific/Southern Ocean has 59–day legs; endurance of a Class II NOAA ship is 24 days. Even following WOCE, NOAA will be engaged in monitoring the distribution of tracers in the water column for a long time.

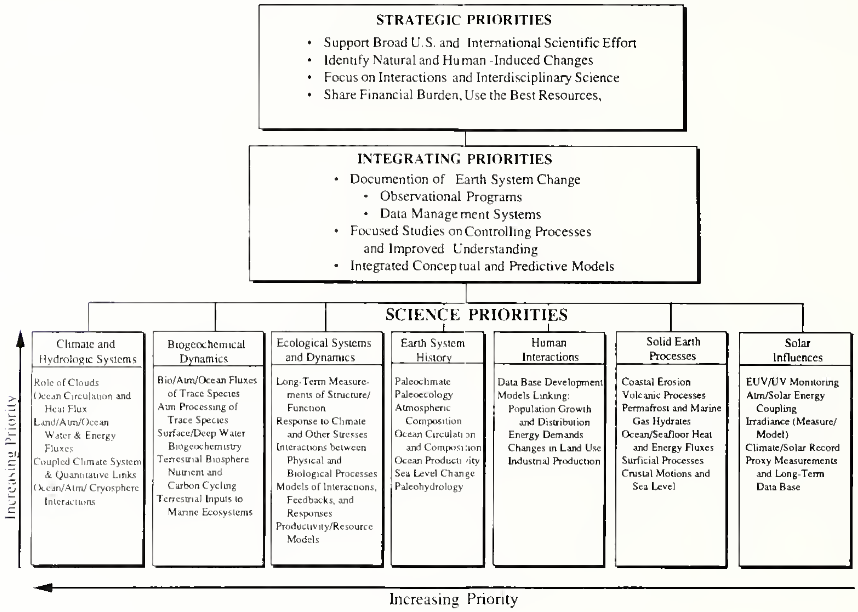
Air–Sea Fluxes. The fluxes of heat, water, and momentum across the air–sea interface is a central issue in climate change studies. Wind stress over the ocean is a central parameter here. NOAA has undertaken a long–term commitment to maintain a gridded network of moored buoys in the equatorial Pacific (the TOGA TAO array) to measure wind speed, humidity, and atmospheric and upper–ocean temperature. This array is part of the observational network which the TOGA Program will leave in place to provide some of the baseline data for the prediction of El Niño/Southern Oscillation events. Thus, there is the requirement for a large vessel to service these moorings on a regular basis, which implies a winch/crane/A–frame capability and substantial deck space.

Estimates of sea surface temperature and upper ocean heat content are also needed for large areas of the world ocean, but these can largely be accomplished by deployments of drifters and XBT's from volunteer ships. The exception is in areas of the world ocean where merchant traffic is infrequent, such as the Southern Ocean.

CO_2 Distribution. The exchange of carbon dioxide between the ocean and the atmosphere requires measurements of dissolved CO_2 in the ocean. This is an evolving observational need of the Joint Global Ocean Flux Program (JGOFS) and the NOAA Ocean Carbon Program, both funded initiatives under the USGCRP. This implies much of the same deep–ocean sampling capability as the tracer measurements.

Process Studies. While planning and development of localized research projects in different ocean basins will be a continuing process, it can be said with confidence that research vessel support for NOAA–sponsored efforts will be needed in the next five years in several specific regions. The TOGA COARE (Coupled Ocean–Atmosphere Response Experiment) will focus on processes controlling formation of the warm water mass in the western tropical Pacific. Vessel requirements are expected to peak in FY92–93. The Atlantic Climate Change Program will require continuing vessel time to support Subtropical Atlantic Climate Studies (STACS) commitments while expanding research activities on the interaction of the large–scale circulation of the Atlantic with climate change. Expansion of activities will most

Figure 1
U.S. Global Change Research Program Priority Framework



likely come in the North Atlantic and Greenland/ Norwegian Sea areas. Capability to work in pack ice would likely not be required.

Support Trends

There is a clear tendency towards increased support for deep ocean studies requiring the support of large vessels. As reflected in the Committee on Earth Sciences submission to OMB for FY 1991–95, support for ocean programs in NSF (WOCE, JGOFS and TOGA) and NOAA (TOGA, Atlantic Climate Change and Ocean Carbon) increases significantly through this period, as follows:

Support for Ocean Programs of NOAA & NSF ($/Million)

	FY91	FY92	FY93	FY94	FY95
NSF	11.2	24.6	32.2	31.7	38.9
NOAA	11.2	18.4	25.9	30.5	32.4

These figures do not reflect existing base program efforts of NOAA/OAR/Environmental Research Laboratories and NSF/Division of Ocean Sciences. Note that these increases are not all associated with research programs requiring large oceanographic vessels, as some can be done with volunteer ships (e.g., float and drifter deployments, XBT measurements). There is a clear and increasing need for vessel time, however, by Global Change oceanographic programs, some of which have been in planning for five years or more.

A Note on Long-Term Prospects

It is conceivable in the 10–20 year timeframe that needs for deep ocean vessels could be reduced somewhat by combined developments in autonomous vehicles and sensor technology. Engineering studies are underway in the United Kingdom for an autonomous vehicle with sampling capability to several hundred meters and basin-scale range. Coincidentally, fiber optic technology for measurement of pCO_2 in seawater is currently promising, and it is conceivable that other compounds could be measured using this technology as well. The obstacles are daunting. It should be remembered that electrode measurements of dissolved oxygen have been widely used for at least 15 years but have not removed the need for classical Winkler titration methods. A prudent strategy would be to invest in these developing technologies, but not to risk the future of the field by allowing seagoing capability to deteriorate.

NOAA Fleet Needs and Geological Oceanographic Research

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Introduction

The following responses address the needs and requirements for the NOAA fleet in support of anticipated NOAA/OAR geological oceanographic research during the next 10–20 years. Most of these geological oceanographic needs and requirements are encompassed within NOAA's interdisciplinary hydrothermal research program (VENTS). (There may be seagoing geological needs associated with other programs as well, however, such as the Nutrient Enhanced Coastal Ocean Productivity (NECOP) program. It is felt that other programmatic needs will be well represented by the perspective developed in the context of VENTS, a long–term research program presently in its sixth year of focused effort in the northeast Pacific.) While the specific definition of NOAA's mission in hydrothermal research during the coming decade is still under consideration, it is certain that this mission will, in part, involve an expansion of NOAA's present hydrothermal research efforts, which are largely focused on the northeast Pacific Ocean. Other NOAA hydrothermal research is also being carried out in the North Atlantic and it is planned that an expanded, global VENTS program will involve the study of hydrothermal venting at other study sites at new locations in these and other oceans as well.

Because NOAA/OAR geological oceanographic, i.e, VENTS Program, fleet needs and requirements are so closely tied to the fleet needs and requirements for VENTS Program chemical and physical oceanographic research, I have chosen to also include them in this overview. This document therefore reflects the seagoing priorities of a NOAA program rather than of a single scientific discipline. Contributors to the following outline of needs, requirements, and priorities are all of the NOAA scientists working in hydrothermal research at Pacific Marine Environmental Laboratory and Atlantic Oceanographic and Meteorological Laboratory.

Seafloor Processes Research for the Next 10–20 Years

NOAA's hydrothermal oceanographic research in the present context includes geological oceanography as well as chemical and physical oceanography. This integrated research is focused on determining the oceanic chemical and thermal effects of hydrothermal venting along the global system of sea floor spreading centers. Within the past decade, it has become apparent that hydrothermal venting processes function as both important chemical sources as well as chemical sinks, particularly for elements that are important in oceanic biochemical cycles. The oceanic impact of hydrothermal heat is not yet well understood, but may be a significant driving force for intermediate–depth ocean circulation. Assessing both of these oceanic impacts constitutes NOAA's role in hydrothermal research, but other agencies have major hydrothermal research programs as well which are focused on other, complementary, objectives. These include the NSF's RIDGE program, which is scientifically broad–based but with a major emphasis on deep–earth volcanic and magmatic processes. The USGS supports hydrothermal research which focuses on assessing the hard mineral resources associated with hydrothermal precipitates. The Navy has several programs which involve spreading centers and hydrothermal research, notably efforts in sea floor monitoring instrumentation and acoustic–image processing and enhancement.

Seafloor Spreading Center Research

Although hydrothermal processes have been actively influencing ocean chemical and heat budgets for hundreds of millions of years, these processes were only discovered a little more than ten years ago. Since that time, new seagoing technology has made it possible to obtain wide–scale, high–resolution images of the sea floor and the insights gained from such mapping technology have, in turn, sparked the development of other new instrumentation to explore for, and study, active vent sites. Both the scale and activity of sea floor volcanism and its associated hydrothermal activity are now recognized to be much more widespread and vigorous than previously thought. The NSF has established seafloor spreading–center research as a key element in its Global Change Program and there is a growing recognition among earth scientists, both in the U.S. and abroad, that seafloor volcanic and hydrothermal activity not only have major impacts on the ocean but that these effects may occur over relatively short intervals of time, i.e., on the order of days to years. There is a rapidly growing recognition of the importance of spreading–center research––particularly in the context of Global Change––and it is clear that such research will undergo considerable expansion during the next decade. At present, well less than ten percent of the entire global sea floor spreading-center system has been studied in even broad detail. This, coupled with the relevancy of this research in the context of understanding the range of naturally occurring chemical and thermal variability in the global ocean, will engender an increasing need for suitable seagoing research platforms and both ship and submersible-deployed instrumentation and remotely-operated and autonomous vehicles.

Advanced Technology. Given that only a very small percentage of the global sea floor spreading center has even been mapped using new swath-sonar technology, it is very clear that there will not only be a continued need, but also an increased need for standard as well as innovative shipboard observations, including in the latter case, new-generation swath-sonar mapping systems, sidescan sonars, and towed instrument packages capable of both reconnaissance and high-resolution sensing.

Another critical aspect of the study of chemical and thermal effects of venting is that sea floor observatories will be required to obtain the long time-series that are needed to model and eventually predict the processes and effects--exactly analogous to observatories dedicated to collecting other environmental time-series such as solar observatories, magnetics observatories, atmospheric observatories, etc. It will not be possible to achieve the objectives of this research by simply sampling from ships (or submersibles) for the relatively very limited periods of time associated with conventional shipboard field seasons. The NOAA fleet will be a critical resource in the ability to deploy and service such sea floor observatories and the technologies necessary to do these tasks must strongly influence the modernization of the fleet.

Fleet Needs for Researching Spreading Centers

For the next several years, there will be a critical requirement for ship-based reconnaissance and detailed surveys in order to statistically characterize the global hydrothermal environment, e.g., the extent and magnitude of active venting. Long-term monitoring is now beginning to become a reality as prototype sea floor instrumentation is being deployed by the VENTS Program and other programs. The ship support mentioned above in support of these long-term monitoring activities will grow in relative importance during the coming decade. Another critical aspect of the need for a modern fleet in support of long-term monitoring will the ability to respond to detected events. A major discovery of the VENTS Program has been the documentation of the occurrence of large-scale hydrothermal bursts. The major bursts (termed megaplumes) observed thus far each contained the mass and heat equivalent of the entire year's output of the essentially steady-state hydrothermal processes occurring along the ridge segment where the bursts originated. Megaplumes may be an important aspect of the global perspective of hydrothermal venting but they occur episodically---as does sea floor volcanism---and long-term monitoring is being implemented to detect and locate these events in real-time.

It is interesting, as well as significant, to note that while three quarters of the Earth's surface has been created at seafloor spreading centers, no one has ever observed such an eruption (along with the hydrothermal activity such an eruption undoubtedly generates). One of the anticipated highlights of NOAA's hydrothermal research in the coming years will be ability to not only detect, locate, and remotely characterize episodic events, but to respond with appropriate shipboard and ship-deployed instrumentation to quantitatively document, for the first time, the nature and evolution of such events and their effects on the ocean.

Given the global scope of the studies, it is anticipated that the geographic location of designated study areas will vary from tropical to polar latitudes. Megaplumes which originate along spreading centers at high latitudes, for example, may be capable of reaching the sea surface. During the next decade, however, it is anticipated that most of the research will be conducted at mid-to-tropical latitudes. Present (and continued) emphasis on the northeast Pacific will constrain ship operations to summer months. Work at sites where NOAA is concentrating most of its efforts on the Mid-Atlantic Ridge is constrained to exclude months of high risk of hurricanes. (It should be noted here that there may be other NOAA programs which will encompass geological oceanographic investigations, such as studies of seasonal runoff patterns from the Mississippi Delta, under the auspices of the NOAA Coastal Ocean Initiative, which may have seasonal weather windows.)

It is unlikely that shipboard use of satellite data transmission will increase dramatically within the next few years. Rather, there is an increasing utilization of seagoing computer systems to both sense, reduce, and analyze data as they are collected.

Vessel Requirements

The following is a list of shipboard equipment, facilities, and capabilities deemed of highest priority for support of NOAA's hydrothermal research mission:

- Both wet- and dry-lab space, air-conditioned and vibration-damped floors and/or benches for computerized systems; conditioned/clean power sources.

- Precise stationkeeping and maneuvering capability.

- Ability to stage/de–stage multiple laboratory vans.

- Capabilities for both long– and short–based navigation.

- Motion–compensated, full–ocean depth capacity, oceanographic and hydrographic winches equipped with optical–conductor cables for use with deep– and shallow–towed acoustic, electromagnetic, light–sensitive, and water–sampling sensors; specific types of winches will be required to include hydrographic and main (heavy capacity) winches. (In the latter instance, these winches will need to be configured to easily switch from electrically–conducting cables to standard 1/2" – 9/16" non–electrically–conducting cable.)

- In–hull swath bathymetric and acoustic backscatter sonar.

- Shipboard sampling systems should include a source of clean seawater and "clean" laboratory spaces for chemical studies; clean seawater streamflow should be continuously monitored for temperature and salinity and these data integrated and stored with navigation information.

- Standard shipboard equipment should include state–of–the–art CTD samplers which, along with the hydrographic winch, are controlled by chemistry–lab computers.

- Shipboard computer systems should be configured to provide integrated navigation information to all underway surveys and systems, such as swath–bathymetric surveys, as well as to provide complete data logging of high–density positioning information.

NOAA Oceanographic Fleet Needs: Equatorial Physical Oceanography

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Research Directions

NOAA research into the role of the oceans in climate change began with the study of the El Niño Southern Oscillation (ENSO) problem in the Pacific Ocean. Recognition of the importance of ENSO to year-to-year changes in the global climate has led to continued focus on this problem. Obviously, the tropical oceans play a unique role in the coupled ocean-atmosphere system. Heat received in low latitudes is stored in the deep tropical mixed layers and transported poleward in the surface currents. This warm water and the resultant atmospheric convection drives the Hadley and Walker circulations of the atmosphere. The interannual zonal and perhaps meridional redistribution of the tropical Pacific ocean warm water is critical to ENSO, and it may also be important on longer time scales.

In many ways ENSO research can be considered to be an example of a mature climate study. Much of the basic phenomenology of the processes has been described. Numerical general circulation models (GCM) are now able to simulate, reasonably well, the tropical ocean response given the atmospheric forcing and the atmospheric response given the ocean SST. A prototype operational ocean GCM is being run in near real-time. Simple models of the coupled system are routinely used to obtain pilot forecasts and experiments with coupled GCM's are promising. The crucial observational need at present is an adequate observational array in order to drive the models and to quantitatively assess their validity. Progress on improved ocean model simulations cannot be made without adequate forcing fields (winds and surface fluxes) and improved data sets for diagnosing the model performance and assimilation. Progress on improving the atmospheric models requires improved measurements for data assimilation and model validation.

A major thrust of TOGA research in the next 10 years is the development of a real-time, long-term, ocean-observing system. Providing requisite data for ENSO forecasting is the primary motivation. These data are also required in order to improve understanding of the physical processes and provide a comprehensive description of the phenomena. Specific, shorter-term process studies will continue, but these will be embedded in the long-term observing array.

As the research emphasis expands to include interdecadal climate variability and climate change, the role the deep equatorial circulation will play becomes more critical. In addition, the interaction of the air-sea exchange and oceanic circulation of CO^2 and trace gases will require development of joint physical and chemical oceanographic and atmospheric studies. Examples of this research are the WOCE and JGOFS programs which are already underway and the plans for NOAA's Climate and Global Change Program.

Growth

Equatorial oceanographic research is likely to continue to grow in the next 1-2 decades. There are several reasons for this. The first is the relatively robust nature of the global consequences of ENSO variability. Compared to many signals in climate variability, the effects of ENSO are readily apparent and direct. Several countries are expanding their ENSO research programs. The second is that TOGA researchers have defined a basin-wide Pacific Ocean real-time, *in situ* observing system which needs to be deployed, first in a research mode and then as an operational system. Support for this system will require expanded shiptime, and expansion to the global tropics will occupy research efforts for several decades. Third, the combined chemical and physical studies required by climate change research have only begun. The equatorial regions will continue to be a major area of research because of the unique nature of the air-sea interactions in the tropics and the importance of cross-equatorial exchange. Lastly, the continued world population growth in the tropical regions will increase the importance of tropical climate fluctuations which are intimately linked to the coupled ocean-atmosphere system.

Role of Shipboard Observations

Advances in remote sensing and automated observing systems will influence the shipboard research, but not decrease its importance. The availability of complementary remote sensing and *in situ* automated observing systems will permit shipboard measurements to be made in the context of the large-scale variability. Shipboard profiling of tracers in both the ocean and atmosphere will continue to be critical to tropical research. New technologies for underway shipboard measurements will actually increase the need for ships.

Furthermore, the backbone of any long-term observing system for the next decade, at least, must be an *in situ* measurement array. Even for surface parameters (e.g., winds, air temperature, humidity, and SST), *in situ* ground truth of satellite measurements will be required. The long lead time of satellite-borne sensors implies that improved technologies (e.g., a scatterometer with increased low wind resolution, such as is required in the tropics) may be decades away. Deployment and maintenance of the *in situ* array will require an operational use of oceanographic research ships at a level commensurate with the current EEZ effort.

Process Studies and Monitoring

As noted above, the monitoring programs form the requisite broad time-and-space scale description needed to interpret the process studies. These two activities will be increasingly linked in future research. The process studies will become more intense with greater variety of measurements (physical, chemical, atmospheric, and oceanographic), and will be of longer duration. This trend is already apparent in COARE planning where the western Pacific process study is tied to a basin-wide observing system and in JGOFS where chemical measurements are linked to ongoing physical oceanographic studies.

Geographic and Seasonal Distribution

TOGA research has concentrated on the tropical Pacific for the last decade. The first efforts towards a basin-wide real-time observing system will be in this ocean. However, research efforts in the Atlantic and Indian Oceans can be expected to expand. The former has a direct connection to the Atlantic Climate Change study being developed by the Climate and Global Change Program. One should anticipate increased demands for tropical Atlantic research from U.S. ships. The Indian Ocean is relatively poorly explored, especially in terms of long-time series of *in situ* observations. Research in this region will also require U.S. ships although attempts will be made to involve foreign research vessels. There is no seasonal limitation to tropical research programs.

Onboard Data Analysis

These data sets fall into three categories: (a) basic shipboard data acquired routinely such as meteorological observations, SST, XBT's; (b) research observations which are reasonably standard, e.g., CTD's; and (c) specialized studies on a cruise, e.g., tracer profiling. These measurements at present all require, to a varying degree, systems resident on the ships and those brought aboard by specific investigators.

The basic shipboard data must be of high quality, using calibrated instruments. Automated procedures are recommended to the extent possible. These systems should be monitored by competent, skilled support staff. Edited and calibrated data files should be quickly available to onboard scientific staff and should be disseminated to the operational centers over GTS.

The research systems maintained by the ship must be available to the scientific users for calibration and quality control. Data from these systems will likely be acquired on a shipboard computing system. If this is maintained by the ship, full documentation must be available to the user and maintained by the ship, full documentation must be available to the user and the ability to supplement his own requirements on a specific cruise must exist. Given the advances in computer technology, increases in shipboard facilities are not necessarily required. Individual investigators will become more self-contained and less dependent on the shipboard systems. However, specialized processing will require flexibility, and the shipboard systems must accommodate this.

The research components brought aboard by the investigators will likely be self-contained. The ship should provide flexible space and adequate environment for the systems. This may involve clean power, temperature control, or clean laboratories. Vans may be the most efficient way to achieve this flexibility.

Perhaps, the issue to be stressed is that the basic shipboard facilities such as navigation, meteorological equipment, ADCP, salinometer, fathometers, etc., must be maintained at the highest levels. The data from these systems must be reliable and readily available to the scientists. The final cruise data set from these instruments must be a product which can be displayed with confidence. The basic shipboard data needs to receive high priority in the management of the fleet.

Ship and Technical Requirements

The ship must have a deep ocean winch with conducting cable capable of CTD/chemical profiling to at least 6000 m. The cable must be capable of lowering and retrieving a CTD/rosette package with 36-10 L Niskin bottles. The winch must be reliable and capable of working in reasonably heavy seas. Profiling must be accomplished in a timely manner (say three hours for a 5000 m cast). The wire must be inspected before each cruise and replaced if damaged. Winch operation should be convenient so that the operator can view the package as it comes in and out of the water.

Increased use of moored arrays in the long-term observing system require improved vessels for mooring operations. Up to 10 moorings may be set and retrieved in a single cruise. Low feedboard, easy access to the fantail with cranes, and specialized mooring winches should be considered. Attention should be given to availability of storage space for anchors, flotation, and mooring hardware.

Several recent studies of oceanographic fleet requirements should be consulted for further technical details. For example: "Scientific Mission Requirements for Oceanographic Research Vessels" by the UNOLS Fleet Improvement Committee provides most of the information needed for the spectrum of research requirements.

NOAA's Fleet Mission and Programs Within the Next Two Decades: The Perspective Of Plankton Dynamics

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Introduction

During the past two decades the focus of research programs examining the role of plankton dynamics in oceanic ecosystems has undergone a profound change. Prior to the early 1970's, research on oceanic plankton concentrated on aspects of their taxonomy, physiology, distribution and productivity, primarily within individual trophic levels of bacteria, phytoplankton, and zooplankton. With the advent of large, interdisciplinary programs, the need arose to define the function of plankton communities within the ecosystem, particularly in relation to physical forcings. Subsequent studies, such as those in the Middle Atlantic Bight and South Atlantic Bight and the Warm Core Rings Program, integrated observations on plankton dynamics into physical and chemical field programs. These field studies were made possible, to a large extent, by the development of remote-sensing capabilities for several important oceanographic parameters. Without the capacity to monitor at least surface temperature on a synoptic scale in near real-time, for example, it is unlikely that such large, interdisciplinary ocean studies could be successfully completed.

It is now clear that future research on plankton dynamics must address the functioning of these organisms within biogeochemical processes. This emphasis is clearly defined by the Committee on Earth Sciences in the document, "Our Changing Planet: The FY1990 Research Plan (1989)." The document addresses the need to improve our understanding of biological processes as factors in global climate, particularly with regard to "Scientific Priorities" in biogeochemical dynamics, ecosystem functioning, and anthropogenic impacts. The future role of NOAA in addressing these priorities, in terms of plankton dynamics, can be perhaps best defined as quantitatively determining the role of plankton processes in the flux of biogeochemical constituents (especially carbon, nitrogen, sulfur, phosphorus, and possibly radiatively-important trace species) in the oceans and atmosphere. Additionally, the impact of anthropogenic activities on coastal oceans is already defined as an objective of NOAA's Coastal Ocean Program. These studies concentrate on nutrient-enhanced primary productivity, water quality, and potential impacts on fisheries. It is expected that the Working Group on Fisheries will address most of the latter issues, thus the major emphasis of this paper is directed towards the fleet needs in relation to plankton process studies within global climate programs.

Biological Oceanography

During the next one to two decades the major emphasis on plankton dynamics research, and biological oceanography in general, will undoubtedly be guided by the need to quantify the action of organisms as sources, sinks, and mediating factors in the flux of important biogeochemical constituents. While the role of plankton dynamics in the "biological pump" (mediating the biogenic transfer of carbon dioxide to the deep sea) is qualitatively known, the Joint Global Ocean Flux Study (JGOFS) will seek to quantify the importance of these processes in terms of the Earth's carbon budget. Specifically, how do rates of plankton processes regulate the fixation of carbon, its transformation and subsequent transport to the deep ocean? A NOAA complementary effort could be suited to monitor long-term (several years) changes and dynamics in surface and deep $pC0_2$ concentrations over broad oceanic regions in conjunction with surface-layer productivity. While JGOFS programs are mainly concentrating on site-specific process studies, there exists a need to describe the short- and long-term variations in inorganic carbon dynamics over large areas of the ocean, and ultimately to relate these to oceanic and atmospheric processes. The large-scale sampling aspects of many existing, and proposed future, NOAA programs implies that NOAA Climate and Global Change and Coastal Ocean Programs can fulfill an important requirement in the interagency approach to global climate programs. Based on this scenario, it is suggested that NOAA's oceanic programs would concentrate on large-scale surveys, while coastal studies might emphasize more regional surveys and short-term studies.

Another interdisciplinary research program within NOAA potentially involves joint studies between plankton ecologists and atmospheric chemists. The role of plankton in modulating climate is not understood, but may be significant. As an example, oceanic biogenic dimethylsulphide (DMS) production accounts for 25 – 50% of global atmospheric sulfur. The Charlson hypothesis (Charlson et al., 1987, Nature, 326: 655–661) suggests that biogenic DMS production acts as a negative feedback mechanism; production of cloud condensation nuclei from plankton DMS influences local climate through cloud formation and reduction of sunlight. Future plankton and atmospheric chemistry studies must be coordinated to address such hypotheses, most likely in large-scale surveys and a few site-specific studies.

Future NOAA Fleet Needs

The potential funding to support NOAA's Global Change studies is currently estimated at $60 million. That for the Coastal Ocean Program is around $10 million. At present the fleet capabilities are inadequate to address research programs at this level of effort. Most NOAA vessels are not equipped to routinely sample and record the basic physical, chemical, and biological parameters in surface waters while underway: time, position, temperature, salinity, currents (via the Acoustic Doppler Current Profiler, which may also provide an indication of zooplankton biomass within the upper 100 meters), surface fluorometry, incident irradiance, and, in the future, surface nutrients and atmospheric gases. Increasing the global database on these parameters will be essential to address climate change issues.

Future ships should be designed to routinely record both underway and water column parameters with systems that are compatible with those routinely used in the UNOLS "academic fleet," such as the present SAIL system configuration. This uniformity would enable NOAA and visiting scientists from different labs to readily transfer instrumentation from ship to ship. In order to meet the objectives of both global climate and coastal ocean programs, the NOAA fleet requires Class I vessels for open ocean studies and smaller Class II vessels for nearshore work. Both ship designs should be able to accommodate 20 to 24 scientists, with a minimum capability of 21 days at sea for Class II and 30 days at sea for Class I. Both designs should be acoustically quiet, possess the capability for CTD, ADCP, and trace metal clean sampling (to minimize metal contamination for biological process studies). These capabilities now reside on many UNOLS ships. In summary, there must be coordination among the various agencies to insure that all future vessels within the U.S. fleet have similar sampling and operational capabilities, if field observations are to be of a uniform quality.

NOAA Class I vessels now have the deck space to take several laboratory vans, but this is lacking on Class II vessels. When it became necessary to fit five laboratory vans on the Class I vessel MT. MITCHELL for an extensive oceanographic–atmospheric research cruise in 1988, four launches and their supports had to be removed. This required an expensive period (in both time and money) in the yard. Most NOAA researchers have now located instruments in laboratory vans. It should be possible to place a minimum of four 10 x 15 laboratory vans on Class I ships and a minimum of three such vans on Class II ships. It is no longer feasible to expect that a common, large laboratory space will accommodate all scientists when state-of-the art instruments must be isolated in terms of electrical and environmental conditions. It is suggested that ocean-going programs within NOAA be standardized, as far as possible, in terms of van electrical requirements. A common problem among all NOAA ships is that modern instrumentation is susceptible to electrical noise. This is derived from both electrical line noise and radio interference. Future ship designs should be uniform in terms of electrical supply for scientific instrumentation.

The projected requirements of a modern fleet of NOAA ships to monitor physical, chemical, and biological parameters over large tracts of the oceans should include one ship for work at high latitudes. At present Class I and II vessels are sent as far north and south as 65° latitude during the spring to summer months. The projections for NOAA's role in Arctic Ocean research is detailed in a report by the Interagency Arctic Research Policy Committee titled, "Arctic Oceans Research: Strategy for an FY 1991 U.S. Program." Within this proposed interagency program the largest budgetary expenditures are designated for ecosystems and biogeochemical dynamics studies, with NOAA's present Arctic budget (about $7 million) increased to $10.2 million in FY 1991. The major emphasis is on achieving a predictive capability for living marine resources, especially in marginal ice zones, the Arctic Basin, and Bering Sea shelf. The future design of at least one NOAA research vessel should, therefore, take into consideration capabilities for plankton productivity studies, biomass sampling, and basic physical and chemical observations at high latitudes. Since the success of each year class of fish populations may be dependent upon the timing of plankton blooms, the vessel should be able to work in high latitudes from spring to fall. The past experience of the MILLER FREEMAN in the Fisheries Oceanography Coordinated Investigation (FOCI) in Alaskan coastal waters can serve as a guide for the requirements of a high-latitude ship with respect to plankton process studies.

An additional requirement is that each ship within the fleet be equipped to determine position via GPS, as well as Loran and Transit systems. Ships should be able to receive satellite SST and surface altimetry imagery, as well as transmit data to shore via satellite data channels. In any synoptic-scale survey, ship-based satellite IR capability has evolved into a basic necessity, as demonstrated on most UNOLS ships. Presently satellite data is received and processed ashore, then transmitted to ships via satellite facsimile transmissions or as compressed data files for processing on-board ship. The development of PC-based processing capabilities suggests that future field programs may be able to receive satellite transmissions directly and process imagery at sea. This would considerably reduce the time required to plan sampling strategy while at sea, and thereby optimize ship use.

The requirement for coordinating atmospheric sampling with water column sampling (whether biological, chemical, or physical) dictates that future ship designs should incorporate automatic sampling instrumentation for atmospheric gases. At present atmospheric chemists must assemble bow towers and locate sampling gear on the foredeck of each ship. In most instances, when the ship is on station for water column sampling, the atmospheric sampling must be suspended. Stack gases contaminate atmospheric samples if the ship cannot be positioned into the wind while on station. Recent ship designs have demonstrated that it is feasible to position the ship into the wind while on station; this capability minimizes potential gas sample contamination and provides an opportunity to conduct simultaneous measurements of volatile gases, such as DMS, in both the water column and atmosphere (marine boundary layer). The ability to conduct simultaneous sampling would improve the resolution of atmospheric-ocean process studies in the future.

Present and Future Needs for Coastal Monitoring and Research Vessels

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Introduction

The coastal ocean from a depth of 100 m on the continental shelves and all shallower depths to the heads of estuaries contains the vast majority of the valued commercial, recreational, and aesthetic resources of the sea. It is also the coastal ocean that is susceptible to man-induced change. Monitoring change and understanding processes through which the ocean responds to man's activity are the central themes of NOAA's coastal research and monitoring programs.

The types of work to be done include routine monitoring where, in order to establish a temporal record, a small and standard set of samples (e.g., fish, sediment, or water) are collected at prescribed locations and on a prescribed schedule. At the other extreme of complexity, explaining fluctuations in fisheries resources, a goal of the GLOBEC program, requires simultaneous collection of hydrographic and current data along with measurements of biological productivity and of the survival of larval and juvenile stages of economically important species.

Measuring and modelling global climate change is often considered the purview of open-ocean science but there are important coastal aspects. Exchanges of heat, moisture, and radiativity of important trace gases (e.g., methane, carbon dioxide, nitrous oxide, and dimethylsulfide) between the ocean and atmosphere are intense on the continental shelves and more subject to human influence than in deeper water. Exchanges of radiatively important carbon and nitrogen compounds are accentuated in coastal zones where man is impacting the environment and where the primary productivity that supports food chains and fishery recruitment is highest.

Coastal areas are subject to events of degradation that need to be assessed under emergency conditions. The most obvious of these are oil spills, but other episodic discharges of hazardous materials also demand urgent attention. Spills in the open ocean need be monitored only to the extent that we know the material does not reach the coastal zone but, in the coastal zone, damage to resources can occur. As a federal trustee of natural resources NOAA must assess such damage. Anoxic episodes in the New York Bight and the Gulf of Mexico are types of events that stimulate research aimed at predicting their occurrence and the extent to which they are caused by man's activities. Whenever such episodes occur, whether predicted or not, NOAA needs to be able to respond by quantifying their extent and their consequence on resources. Predicting habitat alterations and chemical distributions resulting from slow, continuous migration of sediments is a topic of coastal oceanography but so is reaction to massive, episodic changes in coastal morphology brought about by storms.

Future Research and Need

The ultimate goal of fisheries research in the coastal ocean is to protect the environment, including threatened and endangered species, and at the same time optimize the yield obtainable from fisheries. Where possible prediction of variability in resource production would be highly desirable. Even where such prediction is impossible, fisheries research can still be very useful to management by partitioning variation in resource production into understandable components – e.g., variability caused by physical dynamics, biotic interactions or large-scale climatic fluctuations. The essence of fisheries oceanography, as distinct from traditional fisheries science, is the recognition that this objective implies an effort to better understand the fundamental linkages between population variability and the physical environment, which, in turn, implies utilization of the theoretical and technical advances being made within the wider oceanographic community. The logistic demands of fisheries oceanography are, therefore, essentially similar to those mandated by modern interdisciplinary process studies.

During the next 10 to 20 years marine research in the coastal ocean will become increasingly interdisciplinary. Specifically, there will be a bringing together of the fields of physical oceanography, meteorology, fishery population biology, and ecology in an effort to better understand the regulation of productivity in the sea and the variability in abundance of marine populations.

Growth in this area, stimulated by increased awareness of the coastal ocean's value and susceptibility, is already apparent in the Global Change Program and the Coastal Ocean Program under the Coastal Ecosystem Dynamics theme. These programs form an umbrella for coastal fisheries oceanography research that include traditional resource surveys (e.g., groundfish and reef fish) and monitoring (National Status and Trends), as well as ecological or process-oriented studies (Fisheries Oceanography Coordinated Investigations).

Changes from Traditional to Remote Sampling

In the coastal ocean traditional shipboard collections for fish, plankton, benthic organisms, sediments, suspended particles, and water chemistry will continue to be made from the ship using conventional gear. The capability will also be needed to work in very shallow water from launches.

In addition, much greater use will be made of drifting or stationary buoys and ROV's and the capability of easily deploying and retrieving such instruments will be especially important. New coastal vessels will have to be equipped with continuous underway sampling instrumentation. It will be particularly important to follow the developing standards being used throughout the UNOLS fleet in regard to such systems since data exchange will be essential.

Because of advances in remote sensing, doubts have been raised on the necessity of ships. The promise of remote sensing, though, is not to replace ships but to greatly increase our ability to monitor conditions and processes. In the last decade, remote sensing from satellites has introduced a quantum leap in the spatial and temporal extent of our sampling ability. Remote sensing from moored arrays does not provide the wide-scale synoptic spatial coverage of satellites but does afford even denser temporal coverage and sampling at depths inaccessible to satellites. The variables subject to remote sensing are presently limited but will no doubt increase in the future. Ships, though, will never be replaced because there are myriad chemical and biological variables whose quantification requires manipulation of samples; whenever samples are needed, ships are essential. Also, the more valuable remote sensing becomes the more ships will be needed to provide ground truth and to deploy and service moored arrays.

Geographic Extent and Seasonality

A coastal ocean research vessel should be able to work in all of the territorial coastal waters of the U.S. and its possessions. It should also be able to work throughout the year (excluding the Alaskan winter).

Summary

Future research in the coastal ocean will become increasingly interdisciplinary and complex. Remote sensing and continuous sampling will become more important but will supplement, not replace, traditional shipboard sampling methods. The present NOAA coastal ocean ships do not have the capability to meet projected needs. In most cases, these ships were designed with a single function in mind (e.g., hydrography, fishing, etc.).

Most coastal ocean fishery vessels are poorly equipped for interdisciplinary cruises. In general, they are deficient in some or all of the following areas:

- Satellite monitoring including communications
- Scientific accommodations including staterooms, lounges, and conference space
- Scientific storage including freezer space
- Speed
- Booms and winches other than trawl winches
- Scientific laboratory space and computer facilities
- Deck space for portable vans including hookup provisions
- Workboats
- Routine scientific monitoring equipment

An Assessment of NOAA's Fleet Requirements as They Relate to Satellite Remote Sensing

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Abstract

The world is focusing considerable attention on the detection of global change and the underlying processes responsible for driving such change. In response, the initial planning is underway to identify and implement a worldwide ocean-measurement system that would, on an operational basis, monitor important oceanographic and marine meteorological parameters. This will accompany a rapid growth in the volume of satellite ocean remote-sensing data over the next decade. However, a carefully implemented ocean-observing network will require a balance of remote and *in situ* sensing. There will be a corresponding role for quality shipboard, moored buoy, and drifter observations to serve two obvious needs: (1) to provide for validation and calibration of the satellite measurements, and (2) to furnish complementary kinds of data which remote sensors cannot provide. This report recommends that NOAA fleet operations establish a program of significantly expanding the set of routine observations made at sea. These are discussed in detail herein, as well as the potential demands on ship systems and design. Such a program will demonstrate NOAA's commitment to developing a viable ocean-observing system for global change and will serve equally the needs of ocean remote-sensing and broader requirements for oceanic and climatologic measurements.

Overview

The next few decades will witness an increasing role for ocean remote-sensing from satellite platforms and a concomitant impact of satellite data analyses on new knowledge of the ocean. This will couple directly with the long-term and large-scale research being conducted to understand global change and climate processes. Ocean remote-sensing, however, will not make the surface platform obsolete. On the contrary, a balance of orbiting and surface platform observations are needed for a rigorous ocean-sampling strategy to support climate monitoring, process-oriented analysis, and modeling. While satellites can provide globally synoptic surface measurements, *in situ* observations are needed to measure the deep circulation, vertical structure, geochemistry, and other variables not observable from space. It may even be safe to predict that an increasing need for complementary *in situ* data will accompany the growing wealth of satellite data over the next few decades.

Research projects are now underway (for example, WOCE, TOGA, and JGOFS) which rely both on satellite data and shipboard observations. In addition to these ongoing efforts, programs such as ARCSS (Arctic System Science) and GLOBEC (Global Ocean Ecosystem Dynamics) will utilize both surface and satellite observations. These represent major international field-measurement programs which will extend well into the next decade as elements of the overall research on global change. In addition, there is an ever-increasing awareness of the need for accelerated research in the U.S. coastal zone, extending from the estuaries and wetlands to well beyond the continental shelves and covering numerous scales. Shipboard and buoy observation platforms will be required for many facets of this work.

An important legacy of WOCE, TOGA, JGOFS and other programs, will be the groundwork laid for building regional and global ocean-observing and predictive systems. This will entail international commitments and embody a blend of remote-sensing, *in situ* observations, and numerical modeling. One of NOAA's unique future roles vis-a-vis its fleet, will be in providing major contributions in an evolving shipboard, drifter, and moored observation program. Measurements will be carefully conducted according to standard protocols and with a concern to calibration and quality control, as required to develop data sets for reliably detecting global change. Data provided by NOAA ships, and automated platforms they deploy, will support remote-sensing both directly and indirectly. Often, these data are useful for calibration and validation of remote-sensing observations. However, as satellite data quality steadily improves, the more important contribution of surface and subsurface *in situ* observations will be to provide the essential kinds of data which cannot be obtained from satellites.

NOAA's commitment in developing, deploying, and maintaining, for the long term, components of an ocean-observing system will be critical drivers for the fleet requirements in the future. One could project that a future NOAA fleet will be comprised, as today, of a mix of ships primarily outfitted for different missions: oceanography, hydrography (i.e., bathymetry), and fisheries. The oceanographic ships will likely play the most visible and direct role in an ocean and climate research, with activities such as repeat transects, maintenance of long-term moorings, geochemical tracer surveys, etc. It is important to emphasize, however, the potential contribution of routine ocean observations by the hydrographic and fisheries components of the fleet. These ships often make long ocean transits between ports and operating areas, and often visit regions which are out of the major shipping lanes, and thus not sampled by other volunteer programs. High-quality measurements of a variety of parameters are valuable, whether from planned experiments or from opportunistic and routine observations. Consequently, a strong recommendation of this report is that all NOAA ships be outfitted and mandated to make routine observations of a set of essential ocean, atmospheric, and geophysical parameters when underway.

In developing these recommendations, we have sought advice from several scientists, representing NOAA, NASA, and academia, who are familiar with both remote-sensing and *in situ* observations. Suggestions were often made for observations not normally of direct interest to the individual, but recognized as being of immense general value. The unifying theme is clearly the recognition that there is a great deal of useful data which should be collected by NOAA ships whenever they are at sea. These observations are further described below, and include: standard meteorological data(pressure, wind speed and direction, air temperature, humidity), short- and long-wave radiation, sea-surface skin temperature, sea-surface (bulk) temperature and salinity, upper-ocean optics, standard CTD and bottle samples, XBT's and XCTD's, surface currents (ADCP), atmospheric profiling (mini-sondes), deepsea bathymetry, gravity, magnetics, and, of course, GPS (Global Positioning System) navigation. The NOAA fleet is an important national resource, and high quality marine observations are a very expensive commodity. It makes very good sense that NOAA should optimize the costs of sending ships to sea by providing a broad spectrum of routine marine observations which will serve the needs of multifaceted ocean-observing and prediction system.

Trends In Satellite Oceanography

Ocean remote-sensing techniques presently consist of a mix of sensors and spacecraft, which supply different kinds of information about the ocean. As noted above, both *in situ* and satellite-based measurements are required for a fully-implemented, ocean-observing system. To understand this synergism, it is necessary to describe the nature and future direction of ocean remote-sensing capabilities.

Over the next 8-10 years a variety of planned research and operational satellite missions will carry ocean remote-sensing instruments. Commencing in the late 1990's will be the Earth Observing System (EOS), which will embark on a planned >15-year mission. EOS will consist of four large polar-orbiting observatories, two from NASA and one each from Europe and Japan, carrying a diverse array of sensors covering a broad spectrum of earth observations including atmospheric and terrestrial as well as oceanic. Complementing EOS is the proposed Earth Probes program; a series of small, dedicated earth science missions which are precursor to EOS or whose measurement and orbit requirements are incompatible with the EOS observatories. The ocean-related sensors on EOS will consist of essentially state-of-the-art technology, by today's standards, with incremental improvements in sensor design, accuracy, resolution, etc. In other words, the types of ocean observables to be provided by EOS into the next century will be extensions of the present-day and near-term satellite capabilities, which are summarized here:

Altimeters. These measure sea level relative to a geocentric coordinate system, and are used to map the marine-geoid and the sea-level variability associated with geostrophic currents, eddies, and tides. They also return information on the wind speed (but not direction) and wave height. A major goal is to derive increasingly more detailed information about the mean oceanic surface circulation with altimeter data. This will require improved knowledge of the marine gravity field, combined analyses with *in situ* measurements, model assimilation and model-inversion techniques. Past altimeters include Geos3 (1975-1978), Seasat (1978), and Geosat (1985-1989). Near-term planned missions with altimeters are: US Navy SALT (late 1990), European ERS-1 (early 1991), NASA/CNES Topex/Poseidon (1992), ERS-2 (~1995 or 1996). With the inclusion of altimeters on EOS, there is an excellent prospect of uninterrupted altimeter ocean-circulation observations extending from late this year through the next two or three decades; clearly a valuable climatological data set.

Scatterometers. These use radar backscatter to measure the marine surface wind speed and direction, usually within wide (>1000 km) swaths and with a spatial resolution of about 50 km square. Satellite scatterometers will provide global (>90%) coverage of the ice-free ocean every two or three days. Scatterometer surface wind observations provide direct estimates of the Ekman flux and Sverdrup transport, and are essential for understanding the oceanic response to wind forcing and air-sea interactions across many space and time scales. A scatterometer was first tested in space aboard Seasat in 1978. The next will be on the European ERS-1 (early 1991), followed by NASA's NSCAT on the Japanese ADEOS satellite in 1995, ERS-2 and EOS in the late 1990's.

Visible and Infrared Radiometers. Radiometers, such as NOAA's AVHRR on the operational polar-orbiting meteorological satellites, can be used to derive sea-surface temperature (SST) with 1 km spatial resolution. Present-day absolute accuracies are to about 1°C, and precision about 0.1°. Data is often obscured by clouds and accuracy is limited by uncertainties in atmospheric absorption of infrared and sample aliasing. Nevertheless, these images reveal a great deal of information about the ocean's thermal and dynamic structure and variability. The data now extend over the past decade and are anticipated to continue operationally in the future. A similar instrument, ATSR, will fly on ERS-1. The next generation sensor, MODIS, will observe SST on EOS.

Ocean-Color Sensors. These sensors measure surface chlorophyll pigment concentrations, which are directly related to phytoplankton biomass. These data reveal the spatial and temporal structure of oceanic primary production, critical to understanding the fluxes of carbon, nutrients, and biomass within the ocean. The first color sensor was the CZCS from 1978-1986. The next planned sensor will be SeaWifs (~1993), followed by the Japanese OCTS on ADEOS (1995). The MODIS will also be the ocean-color sensor for EOS.

Microwave Radiometers. Microwave radiometers provide a variety of information of the ocean surface, marine atmosphere and sea ice, as well as snow cover on land and other data. For the ocean, the principal retrievable parameters, depending on which radio frequencies (channels) are observed, are sea-ice concentration in polar seas and, for ice-free areas, surface wind speed (not direction), atmospheric water vapor, atmospheric liquid water, surface temperature, and perhaps precipitation rate. These parameters are critical for the remote-sensing estimation of air-sea fluxes, particularly latent heat and moisture flux. In the future (>10 years hence), satellite microwave measurements of sea-surface salinity may be also be possible. The NASA SMMR instrument provided data from 1978-1986 on sea ice, wind speed, atmospheric vapor and liquid water, and SST. The SMMR temperature data are at a very coarse ~300 km resolution and are fraught with sensor calibration problems. Nevertheless, microwave temperature measurements are not subject to the cloud interference which obscures much of the data from the infrared radiometers. The present-day Defense Department sensor SSM/I provides data similar to SMMR plus a new channel for precipitation, but without the temperature channel. The EOS radiometer will have channels similar to SSM/I and will include an SST channel with a spatial resolution of about 50 km.

Synthetic Aperture Radar (SAR). This produces a high-resolution image of radar reflectance of a ~100 km square patch of the earth surface. The principal oceanic application for SAR is imaging of sea ice, to recover ice concentration, ice motion, morphology, and ice type. Over the open ocean, SAR has revealed patterns of surface waves, internal waves, shear flows, and other phenomena. However, progress in quantitatively relating these patterns to geophysical parameters has been slow, and SAR's high data rate and small (per scene) geographic coverage have not made it suitable for systematic global observations of the ocean. Consequently, SAR has not been a primary instrument for research over ice-free oceans. An exception will be the ERS-1 SAR (launch 1991), which will provide low data-rate estimates of the directional wave spectra globally every 100 km. Other future SAR missions are JERS-1 (1992) by Japan and Radarsat (1994) by Canada.

Proposed Measurement Requirements

The following is a list of generic and specific instruments and capabilities recommended for future NOAA operational oceanographic, hydrographic, and fisheries survey vessels. Where appropriate, the relevance of the requirements to remote sensing is discussed and suggested operational procedures are given. However, it must be re-emphasized that these recommendations are not limited to support for ocean remote-sensing, but rather serve much broader needs for ocean observations in support of global change research. In some cases generic examples are used because the state-of-the-art of the class of sensor is rapidly improving and is sure to change over the next few decades. It is recommended that NOAA employ these capabilities on all the ships, although it is recognized that this may not be practical due to cost, available space, and specific mission constraints.

Meteorological Observation Package. Ship-mounted MET observation devices including but not limited to such parameters as vector-averaged wind speed and direction, pressure, temperature, relative humidity, and utilizing state-of-the-art sensor technology. The WOCE MET package is a current example. Data should be logged into a computer network and available for transmission to shore or passing to other onboard sensors and their analysis.

Short Wave (Solar) and Long Wave Radiometers. To be used in heat-flux computations with the AVHRR and microwave radiometer data, and to establish a climatological heat flux data base critical to understanding heat transport within the ocean-atmosphere system and the earth's radiation budget. Sensors must not be shaded by the ship's structure and must be cleaned hourly. Data should be logged with MET package.

Surface (Bulk) Temperature and Salinity. This will require a continuous monitor with computer-controlled sampling and recording. Sea intakes with thermistors should be in the bow, but flow can be piped to a separate salinity (temperature and conductivity) sensor set in a ship's lab to allow easier maintenance and quality control. Data should be logged and inspected onboard and merged with MET data and navigation and time data. These are needed for comparison with satellite SST data, and measuring the air-sea temperature difference which govern sensible and latent heat fluxes and wind stress. Surface salinity is far less sampled than SST and routine observations are needed to build the climatological data base and to serve as validation data for potential future salinity remote-sensing.

Skin Temperature Radiometer. Satellite infrared radiometers, such as AVHRR, actually sense the "skin" temperature of the upper millimeter of the sea surface. However, SST retrievals are generally calibrated against the "bulk" SST measured over the upper few meters or so of the ocean from ships and buoys. The skin temperature is more directly related to air-sea exchange processes, whereas bulk temperatures are more indicative of mixed layer and upper-ocean dynamics. The two indices of SST can differ by more than a degree. Developing statistics of how they vary is important in interpreting satellite and *in situ* SST measurements and require routine independent shipboard measurements of bulk SST (see above) and skin SST using a radiometer. A simple self-calibrating infrared radiometer can be mounted on the flying bridge of most ships and requires an unobstructed viewing angle of about 45 degrees, and sea water flow through for calibration.

Expendable Profilers. Such devices as XBT's, XCTD's, and XCP's or their follow-on generations are used to measure water column properties from moving ships. These are a relatively inexpensive means of obtaining important data of the upper-ocean variability, which are used to monitor seasonal and inter-annual climate anomalies, such as El Niño, verify and update numerical models, and provide SST, dynamic-topography, and vertical-profile data to complement satellite altimeter and SST observations. XBT's should be deployed every 12 hours or as required by IGOSS, and at specific locations when ships routinely transit an area in order to build long-term time series. There will be requirements for power and space for shipboard segments of such systems which might include a PC and data logging and transmission ashore, such as the NOAA SEAS package.

Ocean Station Equipment. Ability to occupy an ocean station including, but not limited to, CTD device with water samples under sampling control from on deck, with requisite deep-sea oceanographic winch and a minimum of 6000 meters of conducting cable. A midships station to deploy and recover CTD's with minimal surge to the instruments is recommended, as is the ability to deploy tow nets or lower other biological sampling devices at appropriate locations. This equipment serves a variety of requirements in physical, chemical, and biological oceanography. Relative to remote sensing, for example, the dynamic height calculations from CTD casts are important to the analysis of satellite altimeter sea-level data. In an effort to develop climatological data records in certain frequently visited areas, we recommend a set of ocean stations be established at specific locations to be routinely sampled with CTD or XCTD whenever a NOAA ship transits the vicinity. These could be located in deep water adjacent to ports frequently visited by NOAA ships, such as the Strait of Juan de Fuca, Norfolk, Miami, Honolulu, Kodiak, and others. Sites such as Ocean Station Papa, where long time series already exist, should be occupied at every opportunity. NOAA ships should also run CTD, XCTD or XBT transects across major ocean currents when in transit, such as the Gulf Stream or the Alaska Stream.

Optics Package. A lightweight, rapidly deployable profiling optics/CTD package is presently available, capable of being lowered to 300 meter depth, for measuring upwelling and downwelling irradiance at specific optical frequencies. This would provide valuable climatological information on the penetration (heating) of solar insolation, primary productivity, and verification data for satellite ocean color and infrared sensors. A small dedicated winch with a few hundred meters of conducting cable would be ideal and would not need to compete with heavier-duty, ocean-station equipment described above. A viable sampling strategy would have NOAA ships, whenever underway, take a station every day at local apparent noon (time of meridian transit of the sun). This random-sampling approach would observe a variety of locations, seasons, cloud cover, and ocean optical conditions, and only require stopping the ship for about 15 minutes per day of observation.

Atmospheric Profiling. Rawinsonde data over the ocean is very sparse and is critical for humidity, temperature, and wind profiles. These data are needed for meteorological analyses and forecasts, serve to verify atmospheric vapor estimates from satellite microwave radiometers, and are necessary for the estimation of air–sea fluxes. We understand that a new "mini–sonde" is presently under development which will include GPS for tracking and use smaller balloons to facilitate deployment from a variety of platforms. Ability to launch and track mini–sondes and transmit atmospheric profile data to shore by rapid satellite communication links is recommended. Deployment should be routinely scheduled consistent with operational forecasting requirements.

Acoustic Doppler Current Profiling (ADCP). As shipboard ADCP systems become more reliable, they will provide valuable routine observations of the upper ocean drift when coupled with GPS. These observations are valuable input to ocean models and for analysis with satellite–derived estimates of upper–ocean currents. Complete systems will require input from time and navigation system, fathometer, roll pitch and yaw, and require onboard quality control and data logging.

Narrow Beam Echo Sounder. The advent of a fully functioning worldwide GPS will make obsolete almost every chart based wholly or in part on random track bathymetry. This will require a dedicated and long–term charting effort to incorporate new surveys into charts for mariners of all types who use both GPS navigation and an echo sounder to navigate safely in U.S. and international waters. One can easily postulate the mariner carrying a dangerous or environmentally deleterious cargo deciding to cut closer to a charted hazard or shoal (surveyed or charted in the past) to save a little time since he "knows where he is" via GPS. NOAA has historically been a pioneer in the implementation of along–track precision bathymetric survey systems coupled to time and position systems with onboard computers.

Gravity and Magnetic Data. Accurate measurements of the marine–gravity anomaly field are valuable in separating the mean dynamic height from the marine gravimetric geoid as observed in satellite altimeter data. This is important to both oceanographic and geophysical studies. It would be particularly useful to run gravity transects along select altimeter orbit paths which cross high gravity gradients, such as midocean ridges, trenches, and seamounts. A well–thought–out strategy for routine marine gravity and magnetic measurements, coupled with multibeam and single–beam bathymetry, would be greatly beneficial to geophysical research, particularly within the EEZ.

Other Recommendations Or Requirements Affecting Ship Design

There is every reason to believe that current trends in computer design and software coupled with global and regional communications will make possible significant changes in how data is collected, analyzed, quality controlled, and communicated from oceanographic vessels. The cornerstone of a good long–range plan would be to allow flexibility for these changes. Initial designs that have plenty of stable buffered power, allow for smooth transition from shore to ships power, mitigate against power surges, and provide for graceful shutdown in emergency should be incorporated. Plenty of clean, dry, environmentally–controlled space should be planned for computers which control sampling, data analysis, and integration. One would expect the powerful PC of the 90's and beyond to replace the concept of shipboard central computers. Satellite wide–band communications to and from the ship and the ability to read GPS and other satellite systems onboard should be expected. Space and moment should be left in the design for numerous antennas. All vessels should carry proficient electronics technicians for the computer and communications environment for both ship and research systems. Ships should have a network which allows data logging, analysis, and transmission devices to access navigation, time, and fixed environmental parameters. Ships will access raw or partially–analyzed satellite data for use in research, data analysis, or shipboard management. Expect ships company and many ship systems to be linked by computer networks for routine operations, data logging, navigational safety (such as electronic charts), and personal use. Scientists onboard will use PCs and have to communicate via modem–to–shore systems at will. Many operations, such as monitoring data from expendables and sampling ship installed MET equipment, and other sensor data will be PC–controlled, including extensive quality control of data, and data will be transmitted ashore automatically for NOAA/NWS and Fleet Numerical Oceanography Center (FNOC) processing and then archiving. Flags and alarms will alert when human intervention is needed. Future research ships may carry extensive historical oceanographic and MET data on CD–ROM.

Some specific considerations are suggested below:

Navigation/Time Standard System. Onboard, fully–redundant GPS navigation system with time standard, data logging, and ability to pass refined position to all other sensor systems needing the input. For some Class A ships this might include an inertial system and gravimeter or some linkage to a bathymetric survey system.

Ships Digital Interface System. A shipboard system to pass digital data between sensors systems and to provide navigation time and other shipboard data to all research and survey systems will be needed. Consideration should be given to fiber optic systems with minimum interference problems, high bandwidth and room for growth.

Direct Readout HRPT Receiver. The ability to receive and display direct transmission AVHRR image data from NOAA satellites would be extremely useful in a number of ways. Real-time SST images could be used to monitor ocean circulation features, such as fronts, eddies, upwelling filaments, and the like, which are relevant to ongoing scientific operations. In remote areas, such as the southern hemisphere, the images will assist in monitoring developing weather patterns which will affect ships operations. The cost of such systems is steadily decreasing, and are presently available for less than $100,000.

High Bandwidth Communication Systems. The ability to rapidly transmit operationally important observations via GOES/GTS or other telecommunications links is a technological area where NOAA can continue to show leadership. The present capabilities for data-buoy telemetry and the SEAS/XBT system can be extended to include other important parameters discussed above. This should include standard meteorological data, sondes, CTD, XBT, XCTD, SST, solar flux, and possibly others.

Ability to Change Out Most Through-Hull Sensors Without Drydock. This could include ADCP transducers, fathometer transducers, and the like.

Stationkeeping Ability. Ability to take expendables, station data, and integrated ship system data to 45-knot wind speed. Ability to take MET package data to 90-knot wind speed. Ability to maneuver ship to make oceanographic stations at 45-knot wind speed. Ability to launch and recover buoys and drifters at winds speeds to 35 knots.

Ability to Plant and Recover Buoys. Both surface and subsurface buoys, i.e., recover swallow-type floats and other buoys or instrument packages recovered by acoustic or time release.

Electrical Power. Ability to provide stable, buffered power for all research and shipboard navigation, time, and installed instruments. System to allow for controlled shutdown in the event of power loss. Ability to shift from shore to ship's power without power loss or spikes to onboard electronics.

Weight and Moment. Allow ample space and weight for antennas and changes in number and types of antennas. Satellite receivers for ocean data, communications, and navigation will be expected as well as for high bandwidth communications to shore via satellite and other systems.

Geographical Considerations

Geographical areas of interest to NOAA will certainly include those waters included in the U.S. Exclusive Economic Zone (EEZ); the waters of the tropical, western and north Pacific; the tropical and north Atlantic; and the Polar regions.

One must not be tempted to draw sharp boundaries on the geographical limits of these areas for scientific study since the forcing geophysical parameters which one must study to understand what is happening (or will happen) to the ocean and atmosphere within the EEZ or on the land may well require study at distant geographic points. Hurricanes, typhoons, the El Niño and management of fisheries stocks are graphic current examples. NOAA should by no means be restricted to a nearshore or coastal fleet of research or survey vessels. Even what we know today about geophysical processes indicates that such a fleet would lack the necessary high-seas capabilities critical for effective research on many large-scale problems vital to U.S. interests.

If one views future shipboard measurements from a temporal viewpoint, often the most interesting or critical parameters to measure for calibration and validation of satellite data or general understanding of an oceanographic problem require the ability to make measurements in fairly high sea-state conditions, for example winter months in the North Atlantic or Gulf of Alaska. Also the prevalent cloudiness in some regions makes year-round sampling by surface platforms necessary until we can develop satellite sensors not impaired by total cloud cover. Areas of the Gulf of Alaska and between Iceland and Greenland are examples.

Another consideration that may call for NOAA platforms to deploy considerably farther than our EEZ would be in support of global operational ocean measurements. As stated above, the U.S. and other governments are now trying to put together a worldwide ocean measurement program. While NOAA will certainly be required to make such operational measurements in our EEZ, the U.S. will likely accept responsibility for areas in a distant ocean area where no other nation can or will take the responsibility.

Ship Requirements for Oceanographic Research

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Introduction

One can anticipate that in the future, interdisciplinary programs, especially those dealing with climate and global change will become more important. Of these, the important ones will be those linking the biology, chemistry, and physics of the oceans with the atmospheric circulations. Phenomena on almost all space scales--from the smallest to global--will be important. This will place extreme demands on sampling abilities, the need for rapid transfer of data, and the ability to synthesize the various data sets in close to real-time. It is clear that various classes of oceanographic and meteorological models will play a central role in synthesizing this information. It is also evident that remote sensing is essential to providing high resolution data on the global scales. Despite the rising importance of the use of numerical models and remote sensing, shipboard sampling will continue to play an important role. Profiling of the subsurface structure of the ocean will need to be done by ships and moored arrays. The latter will need to be serviced by ships. Providing ground truth for remotely-sensed information and ground truth and input for fields produced by atmospheric and oceanographic models will become an increasingly important role for ships and will require specialized sampling and equipment. Some of the requirements this class of activity places on future NOAA ships will be discussed in more detail in the following sections. No doubt other position papers will discuss the requirements for profiling, specialized measurements, and mooring maintenance.

General Requirements

Climate problems require study of the global ocean. Consequently, the endurance and sea-keeping capabilities of these ships have to be such that extended cruises can be carried out in weather conditions ranging from tropical ones to severe conditions in polar regions. Voice and data communications capabilities have to be such that 24-hour, reliable service is available globally. The use of models to synthesize data puts a premium on close-to-real-time transmission of information. Preferably this would be by satellite to some central location. (At present much of the surface marine data is transmitted by radio to regional centers to be inserted on the Global Telecommunications System (GTS). Because of various problems much of what is transmitted does not make it onto the GTS or has introduced errors.) Errors in position and time need to be minimized. (At present we reject about one-sixth of the ship information which we use in estimating global sea-surface-temperature fields because of bad positions or times, duplicate positions, or duplicate times.) Some onboard computing capability will be required to process, transmit, and log the various data sets.

Routine Measurements

Standard shipboard sampling of various parameters must be a central part of environmental sampling for documenting global change. Shipboard measurements are the only means for providing ground truth over three quarters of the globe. However, at present, this potential is not properly utilized because of poor or improper measurement techniques and sampling and inadequate reporting. Consequently, this information is of marginal use for climate problems. For example, sea surface temperature (SST) is a key environmental variable for monitoring climatic variability, and it is this property of the ocean that interacts with the atmosphere. Presently, of the various techniques for estimating SST, ship estimates are the worst by far. Average rms errors for ships in the tropics are around 1.2 deg C. Averages of satellite data have errors of the order of .5 deg C. Both of these can have bias problems of the order of a degree C. These two data sets provide the bulk of the information on SST globally. Since we anticipate climate signals to be of the order of .25 to .5 deg C over the next 10-30 years, it is clear that our estimates need to improved in quality. Global SST estimates will be dominated by satellite estimates. However, these MUST be verified by *in situ* measurements. At present this is not feasible.

Although SST was used as an example, the same sampling problems probably exist for the other parameters being measured not only in terms of the basic quality of the measurements but also in terms of the sampling. The variables that need to be "ground truthed," i.e., those measured remotely or estimated by models, represent areal averages. Hence, shipboard techniques need to be developed to derive similar quantities. At present shipboard estimates are point samples in space and time. In the future they need to be sampled frequently and then averaged in space or time. These averages are then the quantities that are telemetered. Since one use of these quantities is to serve as calibration values for remotely-sensed or model quantities, it would be useful to have calibration information on each variable also transmitted at some less frequent intervals.

Some of the basic variables that will need to be measured by ships are: sea surface temperature, surface salinity, air temperature, wind speed and direction, a humidity variable, and sea-level pressure. Other variables are also desirable. There is a critical need in the next decade to provide ground truth estimates for the fluxes of heat, moisture, and momentum at the sea surface. Estimates of various components of radiation and precipitation are required. Future satellites will measure ocean color. Better estimates of sea state and wave spectra will be required. (Remotely-sensed wind/stress information depends on the radar backscatter from the sea surface.) Biological and chemical parameters no doubt will also need to be measured.

For measurements of each of these variables care needs to be taken to minimize or eliminate sampling problems introduced by the presence of the ship. Calibration information needs to be maintained. Probably adequate sensors for many of these variables do not at present exist, and they need to be developed. As much of the measurement, recording, and processing as possible needs to be automated and free from human intervention.

In addition to surface variables, there is a need for underway sampling of subsurface parameters in the upper ocean. Upper-ocean velocity profiling is by now a routine measurement. This information needs to be telemetered to a central site in real-time. XBT and XCTD information is also valuable on selected sections.

Impacts of Charting and Data Management on Oceanographic Research

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Introduction

The purpose of this position paper is to highlight the status of ocean charting as it relates to oceanographic research, identify the nature of research in the next decade, and suggest issues relating to the management of charting data. The intent is to provide additional background, along with others in the oceanographic research working group, for assessing the requirements for the NOAA oceanographic fleet for the next century. The approach taken is based upon personal knowledge coupled with general literature on the subject of ocean charting. Where practicable and useful, references, quotations and graphical depictions have been included to reinforce certain points.

The paper has been prepared in three parts. The first deals with the general subject of charting, the second with the data management aspects. The final section deals with some of the specific requirements needed on ships, based upon reasonably anticipated technology, to satisfy NOAA's mission in charting into the next century.

Part 1 - Charting as It Relates to Oceanographic Research

Charting includes the location of seafloor features, determination of depth and, to some extent, characterization of the surface sediment. Historically, it has been primarily oriented to the surveying and subsequent mapping of hazards to navigation or to identify seafloor features, e.g., submarine canyons, in sufficient detail such that they could be used as an aid to the navigator. It does not normally include penetration of the seafloor. It is primarily concerned with that aspect of scientific research dealing with determining the morphology (undersea topography) of the ocean floor.

Even though bathymetric mapping (charting) is concerned only with the surface morphology, the best interpretative bathymetry results when processes of tectonic evolution and sedimentary history are understood through the use of seismic reflection, ocean drilling, and ocean sediment sample information. One hundred percent bottom coverage through the use of sidescan and multibeam systems has alleviated this somewhat; however, subbottom profiling and other geophysical observations greatly enhance the ability to interpret the bathymetric data set.

Results are normally presented as a three-dimensional description of the bottom, usually as a contour map. The quality of the map is a function of the accuracy of the depth measurement, the position of the ship, and the sonic "foot print" of the sounding instrument. As a rule, accuracy and resolution decrease with increasing water depth. Increasing emphasis is being put on digital maps and using maps in conjunction with GIS and computer applications.

Techniques used in charting the seafloor range from single-beam (wide and narrow) echo sounders, sidescan sonar, multibeam echosounders, and optical imaging of the seafloor with cameras. Techniques selected reflect the research objectives of the project. The soon-to-be-universally-available Global Positioning System (GPS) will improve greatly the accuracy (and resolution) of midoceanic charting. Data management aspects include the collection, processing, plotting maps, long-term storage and retrieval capabilities (archive), and the use of these data to integrate (or overlay) other research applications.

We are at a point in time where we can be more selective in our choice of technology to match research objectives. We have a host of tools to select based upon our understanding of the shape of the seafloor. Presently, much of this can be determined with sidescan combined with multibeam swath bathymetric systems. However, improvements in *efficiently* surveying features in the 10-100 m dimension (especially in deep water) are not generally available. There have been significant advances in determining the relief of the seafloor by several agencies of the United States Government, the academic community, and foreign countries. The majority of ocean charting has been conducted by organizations within the United States Department of Defense. The Department of Defense, especially the U.S. Navy, has been the major sponsor of research and development into advances in charting technology.

Certain areas, e.g., continental shelves, areas high in resource potential or navigational interest, have been charted in greater detail, however, this is not the case for the vast majority of the ocean floor. In regard to continental margins specifically: "The continental margins of the world constitute the most impressive and largest physiographic features of the earth's surface, and one of fundamentally great geological significance. Continental margins have been the subject of increasing attention in recent years, and interest focused by a body of new data that has provided new insights into their character. This interest was further stimulated by the realization that, in addition to the abundant living resources, continental margins contain petroleum and mineral resources that are accessible with existing technology. This realization, along with their basic geological importance, has provoked further research into the nature of continental margins throughout the world." (Burke and Drake, 1974). While somewhat dated the statement can probably be equally applied to today's situation.

For example, the estimated coverage of the seafloor from modern observing techniques is:

- Single beam 70% (sounding/sq mi)
- Sidescan 10%–15% (varying frequencies)
- Multibeam 1% (total all systems exclusive of classified surveys)
- Photographs and video – .5%

In many respects this still allows us to draw only a very generalized picture of the seafloor. Bathymetric information from GEBCO maps supplemented by nautical charts and other maps show the present state of our knowledge of the topography of the seafloor to be adequate for 16% of the ocean; sufficient for major features only 22%; and too sparse to determine for 62%.

In 1979, the National Academy of Sciences convened a committee to evaluate the status of current understanding of continental margins and recommend elements of a long–term research strategy to study geological and geophysical research needs of the margins. The study acknowledged the lack of sufficient data for defining smaller–scale relief forms (1 m vertical x 100 m horizontal). They stated that, "The principal problem, however, is still outstanding, i.e., the lack of detailed bathymetric information for the deeper parts of the shelf, the slope, and the upper rise regions of the world." They recommended an intensive study of morphology and the deposition and erosion of surficial sediments on slopes and upper rise of both passive and active margins.

Additional research objectives relating to ocean mapping are derived from the Global Change Research Program, the Deep Sea Drilling Program, Ocean Flux and Circulation studies, and the Continental–Oceanic Crust Program. While mapping, *per se*, is not the primary research objective of those projects, it should be noted that virtually every research project in the ocean requires an accurate bathymetric base map so as to sufficiently display and interpret results. For example, see: UCAR, 1988; RIDGE, 1989; CES, 1989.

In the RIDGE research strategy plan a number of research topics were identified for a ten–year approach. In regard to charting the plan stated that, "...it would not be unreasonable to aim for greater than 50% coverage of the global system by the end of the century, with particular emphasis on eliminating major gaps in terms of thousands of kilometers of ridge length for which there is no data whatever." This aim would be much facilitated if multi–beam data were collected routinely on oceanographic expeditions, if ships of opportunity could be guided to follow the most essential ship tracks, and if there were an archiving system that processed and catalogued the data in an orderly fashion.

Our objective over the next 10–30 years should be to chart (map) the morphology of the ocean floor to a standard which will allow certain fundamental research questions to be answered. NOAA's goal should be to advance the analysis of the ocean floor such that there is no area of the ocean floor that does not have an accurate sounding for each minute of latitude and longitude. Sidescan coverage should be nearly 100% of the seafloor utilizing systems like GLORIA or SeaMARC for deep ocean coverage. Multibeam – swath – bathymetry should be approaching 30% of the world's oceans, primarily continental margins and midoceanic ridge systems, thus allowing us to "zoom in" on certain research targets.

Our long–term research objectives should be to focus, in an orderly fashion, on priority research targets in the following physiographic provinces:

- Sedimentation
  Continental Shelves and Upper Slope: 0m–2,000m
  Submarine Fans
  Continental Margins

- Tectonic/Volcanic
  Midoceanic Ridge Systems
  Plate Boundaries
  Trenches
  Subduction Zones
  Submarine Volcanoes
  Seamounts and Midocean Islands

Additional Requirements

In addition, certain aspects of charting/research require ships to revisit sites with change potential--earthquakes, high rates of sedimentation, lava flows, or fast-moving spreading centers (in conjunction with seafloor bench marks). This may also include areas that are susceptible to periodic scouring of the seafloor and the occasional deposition of thick layers of sedimentary material caused by landslides or other episodic oceanographic events. There is evidence to suggest that the role of fish and mammals in shaping seafloor topography may be significant in certain environments. (Twitchel, et al., 1985). Gouging by icebergs is an important concern in the Arctic regions.

A regional focus/priority should be given to the Arctic Region. The Arctic basin is the least well known of all ocean floors and has great potential for many applications.

Part 2 - Data Management Aspects

Data management is a critical part of any charting effort. In many respects it is the most critical element to the success of a research project. It is extremely important with fully automated digital systems. including onboard processing, data exchange, and onboard storage and retrieval. Some of the critical aspects of next generation shipboard data management capabilities include:

1. More and faster shipboard (nearly real-time) analysis. Direct links to shore laboratories and data bases of a communications drop to a "mother" ship for central processing in remote areas. Clearly a more efficient shipboard data collection system would greatly enhance the ability and usefulness of data in the long run.

2. Absolutely no analog data collection systems; magnetic tape will be replaced with optical recording equipment.

3. Fully automated capability including quality assurance of data via integration with historical data sets on CD-ROM and ready availability of source documentation to survey personnel.

4. Field editing and verification, with the objective of "intelligent" charting, i.e., a variety of techniques and approaches available to the ship: swath widths, frequencies, etc. dependent on water depth, slope, roughness, hardness, water column characteristics, etc., including the integration of satellite data, with scarce bathymetric information from surface ships.

5. "Heads up" data display 3-D GIS for intelligent surveying and sampling, support for submersible and ROV operations.

6. Coordination, communications and personnel ramifications will have to be carefully evaluated.

7. Multidisciplinary, integrated research projects, with the objective of collecting high resolution multibeam data on an ancillary or a ship of opportunity basis.

8. Standardization of data collection procedures, software for editing, processing, and handling the data between NOAA, university, and other government ships, private sector, etc. will facilitate the exchange and use of data sets between and among researchers. A data collection approach, suggested by Vogt and Tucholke, 1986, is to establish a standardized survey grid for the "uncharted" areas of the ocean floor. Survey and research vessels would be requested to follow any grid lines not previously surveyed, and so, in time, a systematic and homogeneous seafloor image could be developed. They suggest that, "...the long-term result of such a `SEAGRID' program would be to have images of the ocean floors more cheaply and efficiently and to have created a more homogeneous data base. With the introduction of GPS navigation, which will allow data collection precisely along predetermined tracks, it is not unrealistic to begin considering the design and implementation of such a program." Clearly, such an approach would have significant ramifications upon the management of bathymetric data (both onboard and ashore).

Part 3 - Specific Requirements Needed On Ships

Without getting too far involved in future phases of this study, the following are a few general recommendations regarding the nature of the ships required to conduct ocean charting and research into the next century.

Ships. Three classes of ships should be considered:

1. Class A: Large - 120 m - General Purpose/ Integrated Oceanographic Research Ships - Full Ocean Capability.

2. Class B: Small - 40 m - General Purpose/ Integrated Oceanographic Research Ships - Primarily for Continental Shelf Research.

3. Specialized Applications: It is not unreasonable to consider Arctic and deep-ocean research projects being conducted by a high-endurance submarine. There are several advantages to this type of platform including stability and under-ice capability; however, from a

research standpoint the greatest gain would be in being nearer the seafloor and beneath the thermocline. Both factors would significantly improve the accuracy of charting results.

The nature of the operations involved with charting will require continuous underway operations. The present ship capability is restricted to speeds of 10–14 knots. Charting efficiency would increase significantly with increased speed and sea-keeping ability of charting vessels. Consideration should be given to ships capable of 30 knots in sea state 4 and 15 knots in sea state 5–6. Significant efficiencies would be shown in survey coverage as well as reduction in transit time between survey locations.

Ships should be capable of carrying a scientific party of 30+ members and ship's crew of about 20. Certain ships should be selected for integrated projects/multiple missions. There should be a capability of "conversion" of laboratory space to accommodate various requirements.

Conclusion

"Charting of the ocean floor is now done with an accuracy thought impossible just a decade ago. We are witnessing an explosion of knowledge about the world's oceans. Each new survey, each new dive of increasingly sophisticated deep submersibles and ROV's reveals significant new information valuable for commercial applications and increasing our understanding of earth processes. For lack of proper tools, this vast undersea frontier has defied exploration until very recently. Now that new technology is at hand, slowly, earth's underwater realm is beginning to emerge." (Pittenger, 1989).

The mission of NOAA in regard to "charting" stems from several sources. Early responsibility is derived from the Charting and Geodetic Survey's (CGS) organic act oriented toward charting for navigational interests. While this was the main purpose for conducting surveys, there was often a scientific mission accompanying the surveys. (See Veatch and Smith, 1939; Mallahoff, Hammond, Perry, Embly, and others.) In 1947, CGS's mission was clarified with regard to science and engineering studies. In 1960, the responsibility was clarified to include global (worldwide and international) responsibilities. CGS has conducted many charting surveys on an international basis. The "Seamap" project, 1965–1972, produced a special series of ocean floor maps, accompanied with magnetic and gravity overlays, showing many new understandings of the marine geology (Cohen, 1981; Fefe, 1982). Other responsibilities relate to charting under the IOC/GEBCO project through the International Hydrographic Organization. Specifically, the United States' responsibility extends to the Mid-Atlantic Ridge and the Caribbean Sea in the Atlantic and to the date line in the Pacific. All of these responsibilities should be carefully evaluated as we design the appropriate fleet mix for the next century.

References

American Geophysical Union, 1990. Sidescan Sonar Images of an Active Mud Volcano, *EOS*, January 30, 1990.

Bishop, Charles, editor. *Sonar Technology for Science and Commerce,* Marine Technology Society, 1986, Washington, D.C., 80 pp.

Burke, Creighton A. and Charles Drake, 1974. *The Geology of Continental Margins,* New York: Springer, Verlan, 1009 pp.

Cohen, Phillip M., 1981. Observations on a SEAMAP, *International Hydrographic Review,* LVIII (I): 127–133.

Committee on Earth Sciences, 1989. Solid Earth Processes, *Our Changing Planet – FY 1990 Research Plan,* Washington, D.C., 78–90.

Couper, Alastair, 1983. *The Times Atlas of the Oceans,* New York: Van Nostrand Co., 272 pp.

Department of Energy, 1988. *Coastal Ocean Margins Program*, Office of Energy Research (DOE/ER–0402), Washington, D.C., 19 pp.

Emèry, K.O., 1969. The Continental Shelves, *Scientific American,* 41–52.

Fefe, Carl, 1982. The Bathymetric Mapping Program of the National Ocean Survey, *Oceans 82 Conference Proceedings,* Marine Technology Society, Washington, D.C., 778–780.

International Hydrographic Bureau, 1983. Chart indicating the adequacy of available bathymetry for determining seafloor topography. Monaco.

Heezen, Bruce and Charles Hollister, 1971. *The Face of the Deep.*

Hekinian, Roger, 1984. Undersea Volcanoes, *Scientific American,* 251:1, 46–55.

Hollister, Charles D., A. Nowel, et al., 1984. The Dynamic Abyss, *Scientific American*, 250:3.

Menard, William H., 1986. *The Ocean of Truth*, Princeton University Press, 353 pp.

Moore, J.D., D.A. Clague, et al., 1989. Prodigious Submarine Landslides on the Hawaiian Ridge, *Journal of Geophysical Research*, December 10, 1989, 95:B12, 17,465–17,484.

National Academy of Sciences, 1979. *Continental Margins--Geological and Geophysical Research Needs and Problems*, National Research Council, Washington, D.C., 302 pp.

National Research Council, 1989. *Our Seabed Frontier, Challenges and Choices*, Marine Board, Commission on Engineering and Technical Systems, National Academy Press, Washington, D.C., 138 pp.

Palmer, Harold D., 1976. Erosion of Submarine Outcrops, La Jolla Submarine Canyon, California, *Geological Society of America Bulletin*, 87, 427–432.

Paulet, Steven B., 1989. Integrating Navigation and Data Management for ROV's and Ships, *Sea Technology*, February, 1989, 49–51.

Pittenger, Richard F., 1990. Exploring and Mapping the Seafloor, *National Geographic*, Washington, D.C.

Prior, David B., et al., 1989. Evidence of Sediment Eruptions on Deep Sea Floor of the Gulf of Mexico, *Science*, January 27, 1989, 517–519.

RIDGE, 1989. *Working Group Reports*, Ridge Office, University of Washington, School of Oceanography.

Rona, Peter A., and Robert P. Lowell, 1980. *Seafloor Spreading Centers--Hydrothermal Systems*, Stroudsburg, PA: Dowden, Hutchinson, and Rodd, Inc., 424 pp.

Scholl, David, Arthur Grantz, and John Vedder, 1987. Geology and Resource Potential of the Continental Margin of Western North America and Adjacent Ocean Basins--Beaufort Sea to Baja, California. In Circum-Pacific Council for Energy and Mineral Resources, *Earth Science Series*, Vol. 6.

Schwing, Franklin B., Jerrold G. Norton, and Cynthia H. Pilskaln, 1990. Response of Monterey Bay to the Loma Prieta Earthquake, *EOS*, American Geophysical Union, 250–262.

Sheridan, Robert, and John Grow, 1988. The Atlantic Continental Margin, *The Geology of North America*, Vol. 1.

Twichell, David C, et al., 1985. The Role of Erosion by Fish in Shaping Topography Around Hudson Submarine Canyon. *Journal of Sedimentary Petrology*, 55:5, 712–719.

University Corporation for Atmospheric Research, 1988. *Ocean System Studies, NOAA Office of Oceanic and Atmospheric Research, Research Strategy I*, 80 pp.

Veatch, A.C., and P.A. Smith, 1939. Atlantic Submarine Valleys of the United States and the Congo Submarine Valley, Geological Society of America, *Special Paper 7*, 101 pp., 17 plates.

Vogt, Peter R, and Brian Tucholke, 1986. Imaging the Ocean Floor: History and State of the Art, *Geology of North America*, Vol. M, The Western North Atlantic Region, Geological Society of America, pp. 19–44.

Vessel Requirements for Nearshore Physical Processes Research

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Direction of Research

Large, multi-agency, process-oriented experiments on physical transport mechanisms important to biological populations and anthropogenic water quality issues will increasingly be conducted over the next 20 years.

Powerful numerical modeling schemes (i.e., nested grid models for coarse and fine-scale resolution of physical processes) will require extensive, high-quality data sets for calibration, verification, and updating.

Deployment of long time-series measurement systems will provide data for monitoring of coastal water quality and transport and will also be used to obtain data useful in defining interannual variability in coastal forcing, scale of episodic events, and boundary conditions for numerical models.

In shallow regions where bottom elevation changes can be rapid and dramatic, long-term monitoring and shorter process-oriented experiments will enhance our understanding and predictive capability related to shoreline erosion and nearshore sediment transport.

In deeper ocean waters and estuaries, monitoring, research, and prediction of fine-grid sediment transport processes will greatly increase, particularly concerning mechanisms of toxic contaminant dispersal and effects on biological populations.

Anticipated Rate of Growth

Overall, growth in resources to conduct the above studies will depend largely on the Administration's agenda. However, nearshore oceanographic research has historically been underfunded. Decreasing defense budgets and probable degradation of coastal ocean resources could generate significant additional research funding in this area over the next 10 to 20 years.

By and large, instrumentation capabilities are reasonably adequate to measure physical forcing. However, the comprehensive, interdisciplinary, long-term monitoring and prediction systems envisioned will be costly to deploy and maintain, but cheaper than ship operations.

Shipboard Observations vs. New Technologies

As ship operation costs increase and satellite sensors become increasing versatile and accurate, the mix of capability will shift more towards remote sensing. The mix will change in that fixed *in situ* measurement systems will increase and replace ship-based measurements. Both *in situ* and shipboard observations will continue to be required to calibrate satellite-borne sensors. Overall there will be little change in the requirements for ocean-based systems.

Short- and Long-Term Data Sets

As mentioned above, historically inadequate funding of nearshore research has precluded collection of adequate long-term data for defining coastal-ocean variability as well as detailed understanding of processes. Both types of data are urgently required.

The types of long-term data sets required for nearshore processes include: water levels, winds, air temperature, relative humidity, incident irradiance, atmospheric pressure, spectral wave properties, currents, water temperature and salinity, and sediment concentrations.

Regions and Timescales

Programs are now developing in various regions depending on the forcing criteria. The entire U.S. coast is subject to enhanced research on a regional basis, since different processes dominate different regions.

In terms of seasonal requirements, long-term measurements have none: they must simply operate reliably throughout the year. Process-oriented research tends to focus on times of large signals, which for the nearshore means during large natural events (hurricanes, storms, etc).

In order to interact with biological studies, physical processes studies should also examine phenomena on timescales similar to the generation times of the organisms of interest. For example, primary production studies would need daily variability monitored, while seasonal and event- scale information may be sufficient for fisheries studies.

Real-Time Data Analyses

In nearshore research, the emphasis on *in situ* real-time measurement systems will grow. These data will be complemented by satellite data to enhance the synoptic coverage of large areas and interpret *in situ* results. Some ship time may be required for data collection to calibrate satellite sensors. Remotely-sensed data provide a synoptic-scale coverage for ship-based observations obtained over much smaller scales, and are increasingly being used to direct ships to sampling sites. Real-time data analyses via satellite will be of increased importance because of the smaller temporal and spatial scales of nearshore processes.

Ships Requirements for Physical Processes Research Missions

In view of the emphasis on ***in situ*** systems, primary use of NOAA vessels for nearshore research will be for installation and maintenance of buoys and bottom-mounted sensor packages and sophisticated measurement/communications buoys (much like existing NWS data buoys). Small (less than 3 m square) lightweight (less than 5000 lbs) bottom-mounted current-meter and water-level measuring systems will probably be hardwired to surface buoys for data transmission to satellite.

Some ship time will be required for quasi-synoptic event-scale coverage of coastal circulation and water property characteristics, as well as non-routine mapping and geophysical surveys of shallow coastal regions. Thus, remote acoustic doppler systems and conventional water sampling equipment (e.g., CTD's) should be available on all NOAA vessels. However, there will be little use for ships to define the large amplitude signals in currents, waves, winds, and water levels, since these periods are extremely hazardous to relatively small vessels.

Anticipated nearshore research requirements for the requested vessel characteristics are provided:

Endurance. Relatively short periods (about 3-4 weeks) required for ***in situ*** system support and process studies.

Size of Scientific Berthing. Commensurate with month-long cruises of up to 5 scientists and 10 technical support personnel.

Overside Gear and Small Boat Handling. Winches, davits, and A-frames capable of safely offloading/onloading instrument packages ranging from 2000 to 5000 pounds and setting them on or removing them from bottom; primary small boat of choice: Zodiac or similar inflatable for small tasks, launches or catamarans for mapping, coring, etc.

Type of Laboratory Space. Must maximize flexibility; fixed-space vessel construction should consist only of generic spaces which can support all disciplines, such as the following: machine shop; standardized, well-equipped computer room; electronic shop.

Laboratory Space. Since there is a wide range of specific storage and operational requirements depending upon the type of studies being conducted, a container concept should be developed for design of modular laboratory spaces that are outfitted for specific disciplines and prepped onshore by the principal investigators (PI's), then loaded onto vessel for period of cruise, then offloaded. The exterior dimensions of these containers would be standardized, but different interior layouts would be built based on the purpose of the cruise: physical oceanography; geological sampling (sediment lab, core analysis, etc.); water chemistry studies. The modular labs must be an integral part of the vessel design, not mere appendages. They should also be part of the vessel's complement, not provided by the PI. At least 3 containers for each space aboard ship will be required. The benefits of this concept include reduced mobilization and de-mob times and costs, greater flexibility in space allocation, and reduced vessel construction and operational costs.

Free Deck Space. Low (less than 3 ft freeboard) afterdeck at least 700 sq ft in size; sufficient storage space for cores (100) up to 30 ft long.

Dynamic Positioning. Some shallow-water coring work will require stable positioning of vessel.

Navigational Positioning. Links to GPS are a must for all vessels and launches.

Instrumentation and Sampling. Real-time shipboard measurements should include seawater properties determined with a "clean" flow-through system; relevant information would include dissolved oxygen, chemical tracers such as nutrients, chlorophyll fluorescence and suspended sediments.

NOTE: Pages F-1 through F-5 of UNOLS "Scientific Mission Requirements for Oceanographic Research Vessels" (September 1988) describe specific requirements for a typical coastal vessel equipped for interdisciplinary studies.

Scheduling

If available, University of Southern Mississippi PI's could use the support of properly-designed research vessels in the following size categories as indicated:

Vessel Length	Decadal Projected Use		
	1990-2000	2000-2010	2010-2020
20-50 ft	25	30	35
50-100 ft	28	35	35
100-200 ft	30	35	40
200+ ft	21	28	35

Assessment of NOAA's Fleet Requirements: Physical/Satellite Oceanography

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Introduction

The material in this document is a compilation of inputs from several physical scientists and engineers at the Atlantic and Oceanographic Meteorological Laboratory (AOML). The report is broken down into requirements in physical oceanography and satellite oceanography. As often as possible the informal inputs from individuals was used (plagiarized, with permission) with only minor revision.

Physical Oceanography

For at least the next ten years, and possibly twenty, physical oceanography in NOAA will be directed at *climate and coastal* problems. This implies a wide range of areas to study, from the polar regions because of its importance to climate questions to tropical areas for the same reason, to river outfalls for their input to the coastal ocean. Also implied is a wide range of oceanographic observations including all the subdisciplines of the field. These requirements indicate the need for a fleet of research vessels that has the *flexibility* to operate in all these areas taking all the required data, a flexibility which is not presently a characteristic of the NOAA fleet. Most NOAA ships can do only one job and even the Class I's, which are supposed to be multipurpose, are sorely lacking in capability to perform even the most basic physical oceanography task (e.g., none have lab space adequately temperature controlled for salinity, oxygen, nutrient, etc. analysis).

If present plans are correct, the rate of growth of NOAA programs and seagoing requirements will be dramatic. In particular, the Global Change Program is expected to be a $60 million plus effort in FY 91, implying considerable additional pressure on the NOAA fleet. The present fleet is definitely inadequate to satisfy the needs of the Global Change Program much less any *additional requirements* from a large coastal program. Technological advances are also expected to be rapid with over-the-side instrumentation planned that will greatly reduce on-station time (e.g., Pegasus-like CTD's and faster Pegasus).

The question is what should the NOAA fleet look like and how to get there. One opinion is that NOAA needs a fleet of more *versatile* research vessels which can collect data in all the disciplines of oceanography. The vessels should be approximately 200-250 feet, have at least 15 knot capability, with scientific berthing of at least 20 people. Endurance should be at least 30 days and total number of at-sea days/year should be at least 270 days (accomplished with a rotating crew). The ships should be able to collect state-of-the-art data in all areas, which will require better temperature and pollutant-controlled lab space for chemical as well as physical observations. The ships should be able to operate from the tropics to the subpolar regions, with a portion of the fleet able to operate in the polar regions. Although satellite imagery can provide information about the sea surface, there will always be a need for over-the-side observations from a research vessel.

Satellite Oceanography

In the next twenty years, satellites will routinely observe ocean-surface wind velocity (from scatterometers), sea surface height (from altimeters), waves and roughness (from synthetic aperture radars), chlorophyll + phaeophytin and diffuse attenuation coefficient (from visible color scanners), sea surface temperature (from infrared and microwave scanners), rainfall (from microwave scanners), insolation, and a host of other products, some of which aren't yet imagined. The *most critical need* in satellite oceanography will be verification and calibration of the remotely-sensed data. Because of local effects, continental and island stations will not provide this verification data at the accuracies required in the coming decades; moored buoys will be necessary.

Satellite data verification buoys are envisioned to be spar buoys with meteorological towers at least 10 meters high, so as to obtain wind shear profiles. The subsurface elements will be thermistor/conductivity chains extending to the bottom where an anchor/instrument package will keep the unit on station and measure bottom pressure among other things. Optical sensors over a range of one optical depth are required; optical depths in deep water are typically 100 m. One can envision other sensors to place on such buoys, but the point from a ship requirement perspective is that they will be long (perhaps 30 meters in length or more), they will have delicate instruments on the mooring cable, and they will have to be serviced, probably annually. No single NOAA ship could handle all the buoys needed, and therefore many NOAA ships should have the capability.

Although spar buoys are argued for, there are other designs worth considering. The point, however, is that a *systems engineering* approach is required. The ships must be designed to handle the buoys, and the buoys must be designed to be handled by the ships. For such a commitment, we should begin a building program of one new ship every two or three years. Design and program continuity is critical.

Mooring systems and the required ship capability will be in two geographic locations: in the EEZ and in those regions where ship-of-opportunity observations are minimal. The different geographical regions suggests NOAA needs two classes of ships: coastal and long-endurance deepsea vessels. To maximize flexibility, these ships should be designed with portable laboratory facilities that are standard commercial containers in dimension. Research ship requirements are distinctly different from hydrographic ship requirements, and NOAA must remodel their officer/crew design accordingly; the OAO model for pilots is an example. Ships should supply mechanical and electrical support for research requirements, but not attempt to have excessive fixed scientific facilities. *Flexibility* is the key issue.

All NOAA ships should automatically transmit via satellite oceanographic and atmospheric data required in forecasting and nowcasting. This is more of a retrofit issue no matter what the ship's design, but NOAA should set the standard for a new generation of passive, digital, satellite-reporting instruments, not only for our fleet, but for UNOLS and commercial vessels. Ships should be outfitted with satellite image reception and display electronics so that real-time imagery may be used quantitatively to fine tune the data collection.

General Requirements

Standardized Instrumentation. All ships should have standardized equipment so that no compromises are necessary when changing ships. This should include acoustic profilers, computers, meteorological sensor systems, data acquisition software and support for all cruises. AOML, PMEL, PMC, and AMC put together a measurements list several years ago which should still be valid. Technical support for the systems has been and will still be a problem in the future and must be worked out between the labs and ship bases. Equipment that is mission-specific should be designed to be modular and standardized so that it can be easily installed and removed and so that there is no interference between users. Computers should be available to all users that board the ship.

Laboratory Space. All ships should have dedicated lab space for salinity work, for instance, with adequate temperature controls to do it properly. Freon and other trace elements work should also be able to be done on the ship without possibilities of contamination. Environmental controls of lab spaces on all ships is not adequate at present. Labs on newly-designed ships should provide space for common functions (i.e., wet/dry facilities for CTD/rosette observations), but rely on roll-on/roll-off standardized portable labs for specialized functions.

Winches and Cranes. These should be sufficient to handle and deploy the packages we are now using. The largest CTD configuration we now use is roughly 6 feet in diameter, 6 feet high, and weighs approximately 1500 lbs in air, although there is some talk of going to even larger packages in the future. All ships should be capable of carrying at least 7000 meters of UNOLS standard wire (.322" dia., 11000 lbs breaking strength), and it should be replaced promptly when required, i.e., an inventory of spare wire and drums should be maintained on both coasts. A-frames and other handling gear should be capable of handling these packages. Winches should be capable moving these packages at 150 meters per minute at all depths and have precise control when bringing them aboard.

Berthing for Scientific Parties. The NOAA fleet should work toward the capacities that are available on comparable UNOLS ships. Class I NOAA ships should be designed to accommodate a minimum of 25 scientists with minimal interaction with the ship's crew and officers; scientist/crew ratios of 1:1 are standard on many UNOLS ships. Class II ships, which are comparable with the OCEANUS (WHOI) and ENDEAVOR (URI), should be capable of scientific parties of 20 or more in relative comfort with little impact on the crew and officers. This may mean reducing and/or giving additional assignments for the crew, which may not be possible.

Improved Communications. NOAA should try to provide a relatively high-capacity data communications link to the ships. It is unknown how this would be accomplished since it will require access to a satellite data channel, but it is envisioned that real-time data transfer between the labs and ships is becoming increasingly important. One possibility is renting a complete INMARSAT channel for voice and data to/from the ships; installation of a transponder for voice and data on GOES is another possibility. The UNOLS fleet can and should be included in our communication plans. Real-time interaction between the scientists in the lab and the data being acquired at sea will enable the users to examine the data without distraction, modify cruise tracks, and work on short notice if required.

Navigation. All ships should have LORAN, Transit, and GPS receivers with high-precision clocks until the full GPS satellite constellation is available to the users. The LORAN and Transit may not be necessary after full implementation of GPS, but adequate navigation has been a problem for the labs in the past on some ships. An uninterrupted power supply for computers and other scientific/ship electronics is required on all vessels.

Ship Requirements for Coastal and Estuarine Monitoring

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Extrapolating the Present

I am addressing future fleet requirements from the view of coastal and estuarine monitoring. The platform needs of the National Status and Trends (NS&T) Program are being met by two NOAA ships, the 130' FERREL and the 175' McARTHUR. These ships usually carry scientific parties of five and spend one to two months traversing the west, northeast, and southeast coasts sampling fish and sediments at preselected sites. The only other NS&T use is for sampling water in a trace-element clean fashion for analysis and for toxicity testing. In total, about 150 ship days per year are devoted to the NS&T Program.

The FERREL and McARTHUR are too large for many of the shallow areas being sampled, and it is the launches on these ships that are really the sampling platforms. Those launches, 20 to 25 feet long, are equipped to trawl for benthic fish and to collect box cores of sediment. Trawls and box cores are retrieved by hand to the launch on the FERRELL. The launches on the McARTHUR carry 200 m of 5/16" cable on hydraulic winches. When depths allow, it is convenient to sample directly from the FERRELL and McARTHUR. Nevertheless, to a large extent, these main vessels are serving as ferries for the launches, as laboratories in which samples are processed and preserved, and as living space. In principle, they could be replaced with towed 25' vessels and trailers containing laboratory and living space that are trucked along the U.S. coast.

There are so many coastal locations that are hard to reach from the road, especially with a truck in search of a launching ramp, that replacing ships with trucks seems inefficient. However, the existence of that alternative demonstrates that a future NOAA fleet should have vessels that have laboratories and carry small boats. If such vessels were designed *de novo* they could incorporate efficient methods for frequent deployment and retrieval of the boats. The McARTHUR, the longer of the two presently-used ships, carries two launches. That is an obvious advantage and should be an attribute of any new ship. The launches themselves could be designed with power winches and A-frames.

The laboratory spaces on the FERREL and McARTHUR are sufficient for current purposes, but, again, if designed anew, those laboratories could be removable vans. The advantage of laboratory vans is their great flexibility. Simply changing vans can convert a vessel capable of manipulating water samples under ultra-clean conditions to a vessel capable of testing with all the latest in electronic hardware. Moreover, when not aboard ship the vans are still usable laboratories. The ideal ship need have no laboratory at all; nor does its design need anticipate future uses of a laboratory. It does need to have electrical and plumbing connections conveniently arranged to accommodate vans. The electrical connections should satisfy heavy power needs of heaters and air conditioners and "clean" voltage needs of electronic instrumentation and computers. The plumbing connections should supply both fresh and salt water.

The design and ownership of vans can be left in the hands of individual scientific users of the vessels. The external sizes of vans can also be flexible within limits imposed by the ship. For example, a ship should be able to accommodate two 10x12 foot vans or one van of twice that size. Since some users of a ship will not be regular users, there should be a pair of bare-boned utility vans that are considered part of the ship's equipment.

Future Requirements

I am confident of the future need for shallow water work. The ocean within 10 km of shore and shallower than 100 m is the entire ocean to most people, and maintaining its aesthetic and recreational resources will always be high on the political agenda. I am not confident that future monitoring will be limited to or even include collecting the types of samples being taken today. The flexible type of vessel just described with its removable vans and well-equipped launches will be valuable under any future conditions.

A central question, though, is to what extent should a future vessel be able to do more than provide launches and space for vans. Continuous sampling over a cruise track cannot, obviously, be done from launches. The main vessel, itself, needs to be equipped with at least a one winch and boom for towing any continuously sampling device. That device could be sampling acoustically, it could be collecting particles from the water, or it might be pumping water to instruments in a van. The details will change with the mission, but the ship needs to be able to sample while underway. Given that, any needs for sampling on station will be easily met.

I do not anticipate the need for direct measurements of chemical contaminants, or nutrients or oxygen being replaced by remote sensing from satellites. As desirable as that would be there are, except for oxygen, no sensors now that can measure these things without manipulation of water samples. Remote sensing by leaving instrumentation *in situ* with signals either saved or transmitted via satellite would be invaluable. That can be done now for oxygen over short times but not routinely for long periods as are the cases for temperature, salinity, and current speed and direction. The prospects for *in situ* sensing of chemicals are themselves remote. Ideas abound, but the need to actually collect samples for analysis will still exist in thirty years. I see no chance of vessels like those I have described becoming obsolete because everything can be done from the sky or with instruments moored in place.

Oceanographic Fleet Requirements for NOAA to Support Marine and Atmospheric Chemical Research

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Introduction

As is true throughout the geosciences today, two words are dominating discussions of the future objectives and requirements in Marine Chemistry and Atmospheric Chemistry: " Global" and "Multidisciplinary." The scientific issues and global perspectives of marine oceanic and atmospheric processes are critical components of the tightly coupled ocean–atmosphere–geosphere–biosphere system. Within this system are the range of questions being addressed by programs in global tropospheric chemistry, dynamics of global ecosystems and biogeochemical fluxes as well as their relationship to climate variability. The following will, primarily, deal with the projected requirements in support of marine chemical/biochemical research. Some projected requirements for atmospheric chemical research will be included. Projected growth figures will be based on United States data with global estimates being qualitative.

Marine Chemistry

Future basic (core) marine chemical research programs will be directed towards providing an understanding of how oceans and estuaries function as chemical systems and how they respond when subjected to either natural or anthropogenic perturbations. This will provide the basis for addressing socioeconomic problems such as pollution, deepsea mining, waste disposal, and scientific problems such as sediment diagenesis, climate, ocean circulation and biological productivity. In order to meet these objectives, marine chemistry will need to:

- Quantitatively describe the reactions (processes and mechanisms) that occur between the various species and phases that exist in the marine environment

- Determine the fluxes (rates and pathways) of material to and removal from the ocean, and the transformations that occur during transit

In order to accomplish these goals, marine chemistry will continue programs in:

1. Chemical equilibria and physiochemical properties

2. Material transformations and transfers at the land/sea boundary

3. Fluxes of material, transport through and alterationas in ocean basins

4. The role of biochemical processes in determining the chemical nature of seawater

5. The use of chemical tracers in the study of large–scale processes in the oceans.

Chemical programs within the context of a global program will include major programs in ocean fluxes which have both open–ocean and coastal components, oceanic lithosphere and ridge crest processes, chemical research to assess food chain shifts (biological processes) and tracer studies, especially within the context of WOCE:

Open Ocean Fluxes. At least through the decade of the 1990's a major goal of marine chemical research will be to determine biogeochemical cycles and budgets over extended spatial and extended temporal scales. Some of the questions to be addressed include:

- What is the magnitude of oceanic productivity? How does it vary with time? What are the roles of physical processes in determining oceanic productivity?

- How much oceanic production represents recycled material and what are the processes involved in this recycling? What are the fluxes of organic matter out of the euphotic zone of the oceans?

- What are the rates of transfer between chemical phases in biogeochemical systems and what are the processes involved in this transfer?

- What are the fluxes at the ocean/sediment interface?

To accomplish the above will require:

1. Remote–sensing data to provide synoptic, global data on boundary conditions and primary productivity

2. Extensive field observations of processes, especially in critical regions and at critical times of the year

3. Interactions with programs such as WOCE for physical dynamics as well as the continuation of tracer studies.

Coastal Ocean Fluxes. The objective of programs under this topic will be to determine the nature and extent of material being injected into the ocean across the coastal boundary. This includes the two major modes of transport across the boundary, air and water. Some of the questions to be addressed include:

• How do dynamic forces (e.g., winds, pressure fields and river flows) interact with boundaries (e.g., continental margins, topographic features) to determine major regions of chemical transformation and transport (e.g., upwelling, eddies, surface currents) to the ocean basins?

• What are the fluxes of dissolved and particulate material brought into the coastal zone and what is the transport from the coastal zone to the open ocean?

To accomplish this will require:

1. Multidisciplinary field programs in representative and/or critical coastal regions

2. Extensive use of remote-sensing imagery coupled with *in situ* observations of biological, chemical, and physical processes

Lithosphere and Ridge Crest Processes. As far as marine biogeochemical programs are concerned, research in this area will probably focus on vent water chemistry, seawater interactions with crustal material, and mineralization processes. Some of the major questions are:

• What are the chemical (and thermal) properties of hydrothermal fluids from vents? What is the contribution of hydrothermal fluids to the chemical balance of the oceans?

• What is the role of hydrothermal fluids in mineralization and scavenging of chemical species? What chemical reactions occur between fluids and dissolved species in seawater?

• What are the temporal and spatial scales of oceanic crustal evolution (alteration)?

• What are the geochemical processes operating in the benthic boundary layer to remove and/or remobilize chemical species?

To accomplish this will require:

1. An increase in the number of field programs designed to quantify the extent of hydrothermal venting as well as the volume of oceanic systems influenced by venting

2. Development of long-term monitoring techniques (either platform or *in situ*) to assess the temporal (and, to some extent, spatial) variability and influence of both high- and low-temperature crustal processes on oceanic chemical composition

Biological Processes. Much of the chemical research in the area of marine biological processes is covered under open-ocean fluxes. It is likely, however, that there will be demands for a chemical component to biological research on food-chain dynamics and recruitment to answer such questions as why relatively small (two- to four-fold) changes in primary production can be magnified by one to two orders of magnitude in fish recruitment. (See Fisheries Research.)

Tracer Studies. Chemical tracers provide the best means of establishing the boundary conditions for models of ocean circulation and mixing. Providing this data will require the development of three-dimensional pictures of tracer distributions throughout the world ocean.

To accomplish this will require:

1. Large, field-intensive field programs with onboard facilities for the collection and analysis of samples as well as the development of *in situ* sensors

2. Development of onboard data handling-equipment to process and interpret this data

3. The maintenance of a full-time, shipboard staff to operate this sampling program

Atmospheric Chemistry

Atmospheric chemical research will be aimed at developing a thorough understanding of the fundamental processes controlling global tropospheric biogeochemical cycles. These processes include the input of species into the atmosphere, their long-range transport and distribution, their transformations and their removal.

This will be accomplished through:

1. Investigations of sources and sinks of chemical substances to the atmosphere

2. Determinations of the global distributions of gases and aerosols and their physical properties

3. Extensive laboratory investigations into fundamental photochemical processes followed by field studies to verify the results of such research

4. The development of systems models

Primarily, the subject of oceanic platforms deals with the requirements of numbers 1 and 2 above, however, some components of 3 will require oceanic platforms. To address this subject, the atmospheric chemistry community has adopted two concepts: the establishment of networks for long-term monitoring and research and the conduct of intensive experiments to address specific questions (e.g., sources, sinks, transformations).

Networks. Networks will be established for three purposes:

• A Long-Term Trends Network would consist of a few stations located in remote environments that are unaffected by local sources it is felt that existing, land-based stations are probably adequate to meet these requirements.

• A Global Distributions Network would consist of a larger number of stations operating over a relatively limited period of time (a few years) to establish distribution patterns of species with tropospheric residence times of weeks to months that are important in both transport and chemical cycles. Land-based stations may serve these requirements; however, there are major oceanic regions that are globally significant and yet do not have suitable terrestrial locations for establishment of stations. Among these are the Northeast Pacific (Asian transport investigations); the Eastern, Tropical Pacific (investigations of transport to and photochemical destruction within); the Southeast Pacific basin and South Indian Ocean ("non-anthropogenically" impacted, southern hemisphere sites).

• A Surface Source/Receptor Network would be a large network with relatively inexpensive and low technology techniques in critical source and sink regions. As far as marine systems are concerned, we are primarily concerned with the Eastern Tropical Pacific as regions of upwelling and downwelling are more the subject of intensive experiments than monitoring.

Intensive Experiments. These consist of concentrated experiments involving extensive resources (personnel and equipment) brought to a specific site for a limited duration to study a specific process or group of processes. These may often involve multiple platforms including aircraft and ships. The focus of these experiments will be biological sources with the major questions addressing: the chemical fluxes to the troposphere from critical biomes and determining the factors controlling these fluxes.

As far as marine systems are concerned, the major species of importance in tropospheric chemical processes that will be initially investigated (critical regions) are:

• Reduced sulfur species (Equatorial and North Pacific)

• Carbon dioxide (Equatorial Pacific and Indian Oceans, bottom and deepwater forming regions of the oceans)

• Low-molecular weight halogenated (i.e., containing chlorine, bromine and iodine) species with a special emphasis on organo-bromine species (regions of increased biological productivity)

• Methane and nitrous oxide (productive oceanic regions)

Anticipated Growth Rates

Anticipated growth-rate data for academic marine and atmospheric chemical research programs for the United States are available for funding levels but not personnel into the second half of the decade of the 1990's. Personnel growth rates are available for atmospheric programs. Anticipated global rates in funding and personnel are available in atmospheric chemical programs. From that data, the following conclusions appear valid:

Marine Chemistry.

Core Programs:

• Funding will keep place with inflation, approximately doubling between 1988 and 1996 (i.e., approximately 7% per year growth).

• Funding for support of those programs (e.g., ships, new technology) will slightly exceed that growth rate, more than doubling between 1989 and 1996.

• Personnel will probably remain somewhat static over that period.

Global Programs:

• Funding in support of the Global Program (primarily Open Ocean Fluxes) is projected to quadruple between 1988 and 1996 in the academic community.

• Funding in support of these programs is expected to increase sixfold in the same period. Included in this is the proposed construction of four large research vessels (one ice-strengthened); one small, ice-capable vessel; and the present modernization of KNORR and MELVILLE. Beyond 1995, the academic fleet is projected to acquire four more large, six intermediate, and five small vessels.

• Personnel requirements for Global Programs will dramatically increase the need for new researchers probably to a level equivalent to the present Core Program staffing for an overall increase of a factor of two in personnel.

In my opinion, I believe that you can extrapolate the above numbers internationally. Of the programs that I am familiar with (Open Ocean Fluxes) some programs will remain static (e.g., United Kingdom), some will grow dramatically (e.g., Federal Republic of Germany, Japan, Soviet Union, Australia and the Netherlands) and some moderately (e.g., France and Canada). A potential source of increased demands on the research fleet will be increasing participation by what are termed "eastern-block" countries. This is already beginning in the FRG/DDR and Poland.

Atmospheric Chemistry. The following only apply to the two research topics requiring field investigations: Sources and Sinks, Global Distributions and Budgets:

• Funding for research on Sources and Sinks is specifically identified as occurring over the World's Oceans, especially high latitudes. It is expected to more than double in the period from 1987 through 1990 but then remain constant through the remainder of the decade.

• Personnel-years devoted to this research will only increase by 20-25% over the same four-year period and then remain constant.

• Most of the funding increases in Distributions and Trends will be in the Global Distributions Network stations rather than Long-Term Trends. Large, initial costs are associated with these stations so it is difficult to assess a growth rate. The U.S. is projected to be the major contributor to the establishment of new stations while existing stations will be maintained by the international community. It is projected that $2-4M per year for four years will be spent to establish these. Once established the funding for maintenance will keep place with inflation.

• A similar, rapid increase in personnel (50% over three years) is expected to accompany the establishment of stations followed by static staffing levels.

The Global Tropospheric Chemistry Plan for Action specifically addresses shipboard platforms, primarily for Source/Sink research. In summary they believe that platforms can be found to conduct the research (even at high latitudes). What is lacking is the funding to keep these vessels operating at the levels necessary to conduct the research programs. The plan does not address the probability of platforms in regions where suitable, terrestrial sites are not available.

Additionally, the plan does not go into a great deal of detail on carbon dioxide because of its extremely long residence time. It only states that present sampling programs are inadequate in the temperate northern hemisphere and at low latitudes, the locations detailed under the section Atmospheric Chemistry, Networks.

NOAA's platforms are a resource for the academic community and, as such, the above requirements apply to NOAA. Growth rates within NOAA directly for this research will probably be at levels less than the academic community; potentially considerably less. Platform requirements will increase because of new technology allowing increased productivity and requiring real-time data acquisition and interpretation in critical regions of the world's oceans.

Temporal And Spatial Requirements

A common theme in marine biogeochemical research programs, at least into the next century, is a focus on dynamic oceanic regions. Present participants in Open Ocean Flux research have programs outlined as far as the year 2001 (The Netherlands). Continental margins will not be ignored nor will open ocean areas subject to continental influence (e.g., equatorial Atlantic). Some published schedules addressing Open Ocean Fluxes include the Federal Republic of Germany, The Netherlands, and United Kingdom. Within these three, something like 50% of the marine biogeochemical research time through this decade will be spent in the Southern Ocean and South Atlantic with major programs in the Indian Ocean (FRG and Netherlands) to look at monsoonal-driven circulation in the equatorial and northwest Indian Ocean. The next international experiment in the Joint Global Ocean Flux Study will be in the western tropical Pacific in 1992/93. For both chemical and biological research programs, high-latitude oceanic regions (i.e., ≥ 60°) will be a major focus. Specific regions in no particular order will be: Southern Ocean; Indian Ocean in general with major emphasis on tropical regions; Southern hemisphere convergence zones; tropical Pacific; pelagic South Pacific; deep- and bottom-water forming regions.

All of these regions will require platforms capable of long cruises without replenishment or the need to ballast.

Temporal requirements will demand further capabilities. In addition to many of the above regions being too remote for past routine research programs, there is a strong tendency to conduct that research in periods of reduced dynamic and biological activity (i.e., summer). Deep- and bottom-water forming regions are going to need to be visited when those processes are active (e.g., boreal spring for North Atlantic deep water). Biogeochemical process research will require studies before, during and after periods of high productivity. Vessels will have to be capable of year-round operations in (nearly) all regions.

Atmospheric chemical research requirements have been outlined. Research on processes (e.g., gas exchange at the air/sea interface) will require either new technology to directly measure exchange rates or very stable platforms operating for extended periods of time.

Miscellaneous Requirements

A number of topics will be briefly addressed in this section:

Remote Sensing. There will be a dramatically increased need for real-time acquisition and reduction on board ship of data from satellite-borne sensors. To the best of my knowledge, only the POLARSTERN (FRG) routinely accesses data from NOAA-10 and -11 for such purposes as sea surface temperature and to define regions of high reflectivity which may indicate increased productivity. Once the SeaWIFS sensor is operating, the demands for both ocean color and AVHRR data directly by the ships will increase dramatically. This type of data will often guide future field operations.

Communications. Researchers will be demanding greater interactive access with computers ashore and with data sources ashore. Routine satellite linkage with ground stations will be mandatory. In the Joint Global Ocean Flux Study, the FRG's Weather Bureau supplied data to meteorologists on METEOR which was invaluable to the decision-making process of the Chief Scientist. A key to this was access to meteorological data sources on a real-time basis.

Oceanic GMCC's. Biogeochemical process research requires extended station time. The JGOFS North Atlantic Pilot Study succeeded in investigating the progression of the spring bloom in the vicinity of 47° and 60°N along 20°W by having three different ships from three nations scheduled so as to occupy those sites nearly continuously for two and one-half months. These may take the form of surface moorings with appropriate sensors or permanent platforms. At this point it is doubtful that a complete set of sensors necessary to study processes will be available over the next two decades to permit unmanned platforms.

Sampling Contamination. If anything has been learned over the past two decades in biogeochemical research it is the need for both accurate and precise measurements. This includes such items as trace metal contamination of productivity samples and exhaust contamination of atmospheric samples. Over-the-side handling equipment will need to reevaluated as to contamination control (e.g., titanium or Kevlar "wires," coated rosettes). The location of atmospheric and hydrographic sample intakes with relation to exhausts and discharges needs to be evaluated.

Laboratory Contamination. Very minor fluctuations in laboratory environments can lead to major analytical problems in determining both physical and chemical properties of seawater. This raises the entire question of small, discipline-specific, laboratories versus large, open laboratories and/or vans. There is definitely a need for both (three). A specific recommendation cannot really be made. I think we need to look at ships with both concepts and develop suitable options. My feeling is that returning to individual, small laboratories will definitely control contamination and, therefore, is probably more desirable.

Personnel and Support. Research cruises of the future are going to require the ability to carry and support (computers) 20+ researchers. WOCE demands 25 berths, of which three are really biogeochemical in nature. A minimum of 25 is what vessels should be designed for.

Specific Requirements

In my opinion, the best guidelines for future research vessels are in the U.S. plan for its large research vessels and in the R/V METEOR (FRG) launched in 1986. My experiences with METEOR this year indicated that it has been designed to operate in nearly all conditions, except ice, and can support atmospheric as well as oceanographic research with specific sampling facilities meeting the particular needs of atmospheric programs.

In my opinion, NOAA will require two all-weather, large research vessels in the near future; a vessel capable of operating in ice (e.g., POLARSTERN) and a FLIP-type vessel capable of operating as a station for extended periods of time in dynamic regions of the oceans.

I will only go into detail on the large vessels. Approximate specifications:

Overall Length (ft)	300
Beam (ft)	60
Draft (ft)	16
Displacement (tons)	4,000
Speed (knots)	15
Range (nautical miles)	13,000
Endurance (days)	60
Scientists	28
Lab Space (sq ft)	4,000
Deck Space (sq ft)	5,000
Science Storage (cu ft)	16,500

Caveat

The specifications for the academic fleet requirements in support of Global Programs call for large research vessels to operate at sea 270 days per year. The United Kingdom (specifically DISCOVERY after it is modified), The Netherlands, and the Federal Republic of Germany all plan to operate their vessels at levels in that area to accomplish the goals of their national programs. The Global Tropospheric Chemistry Experiment Plan for Action specifically cites ship time as opposed to ship type as the major constraint on oceanic data acquisition in support of the program.

The financial commitment to operate these vessels at a minimum level of 240 days per year needs to be made at the same time as a construction commitment is made. Such an operating level is the minimum required to meet the spatial and temporal scale demands of global research programs in the foreseeable future.

Meeting the Needs of Benthic Ecology and Ecosystems Research

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Direction of Benthic Ecology and Ecosystems Studies

The general emphasis in the future will be on process-oriented studies, many of which will be incorporated into cross-disciplinary approaches to understanding the workings of whole ecosystems. Where appropriate, these "whole ecosystem function" studies will be incorporated into global problems, or be of those particular ecosystems which appear to have some global significance in terms of climate change (WOCE, JGOFS), ocean margin enrichment and environmental degradation (NECOP), or fisheries, the latter with a probable emphasis on recruitment (GLOBEC).

Growth in Studies

Federal agencies, academia and private environmental groups have precipitated a public and political awareness that industrialization and agricultural development can affect the ocean and climate on global scales. This awareness has resulted in new initiatives in all the relevant federal agencies (EPA, NOAA, NASA, DOE, and NSF). Cross-disciplinary faculties and curricula at academic institutions are being organized to assist these agencies, and analogous, cooperating global programs are being put in place in western Europe, as well. We are expecting for the first time in several years to see an increase in the research budgets of some federal agencies, and this has been justified by anxiety over global change, especially global warming. The funding can be expected to lead to technological advances in remote sensing, data transmission and storage, real-time shipboard and *in situ* experimentation and data gathering, and geographic information systems.

Traditional Observations vs. Remote-Sensing Observations

Ecological studies, including those of the benthos, will change from statistical descriptions of standing stocks and zoogeographic distributions of species and assemblages to studies which characterize the dynamic processes of functional components of whole ecosystems. Biologists will emphasize bioenergetics (using *in situ* and laboratory techniques developed by physiologists) and biomass production within each functional component of a system (or at each level of a food chain). Chemists will use natural and introduced tracers in collaboration with the biologists to determine transfer rates between the living and nonliving components in the same systems, also using *in situ* as well as shipboard laboratory experimentation. The information generated will be utilized in time-dependent models which, when coupled with physical flow fields, will aid in experimental design, portray our understanding of important processes, and ultimately with some hindcasting, allow prediction of global climate or biogeographic (fisheries) trends.

Examples of such process studies could include trace gas generation that is a function of grazing on blooms of particular groups of phytoplankton, as appears to be the case with DMS generation, molecules of which (as DMSO) in the atmosphere are cloud condensation nuclei; use of experimental enclosures or flumes on the seafloor or the sea surface to measure interfacial gas fluxes; long-term monitoring of routinely-measured variables, such as plant pigments, to assess changes on decadal time scales, as observed in the central Pacific; manipulation of an environment's chemical biological components by ROV or submersible; etc.

Open-ocean moorings with physical sensors will continue to be a traditional approach, but in the future they will also include acquisition of biological and chemical data. Such information will include oxygen, inorganic nutrients, suspended matter, and fluorescence, for example. Moored acoustic sensors will assess stock size in a wide variety of targets. The data will be stored, or transmitted in real time to ships or satellites. From satellites it will be distributed around the world on a semi-real-time basis. Experimental protocols and cruise plans will be based on a combination of real-time satellite remote-sensing, remote moorings or floats, and heuristic models of coupled physical and biogeochemical processes.

Periodicity

The trend will continue toward making synoptic, cross-disciplinary observations over seasonal and annual events (months to biannual) using remote approaches (satellite EOS's (Earth Observing Systems), remote moorings, and floats). When properly carried out, such approaches save ship time and manpower.

Such approaches to date, however, provide information on "state" variables (concentrations, standing stocks, etc.), and not on rates of processes. Shipboard work will therefore evolve from its previous major role of surveying along grids or transects in order to assess state variables, to conducting experiments to help determine rates of processes that give rise to changes in the state variables. The biggest impact of this in the recent past is to necessitate greater lab space, berthing capacity, and a constantly evolving set of analytical capabilities over the side and aboard ship.

As a number of important processes that couple transfers between land, the ocean and the atmosphere will be driven by "unexpected" physical events, some degree of heretofore unavailable ship time may need to be flexible, thus allowing improvisational or serendipitous observations on event-dominated processes.

Geographic Areas of Interest

Areas for such emphasis would be:

1) River mouths (NECOP's emphasis on the Mississippi)

2) Shelf-slope frontal exchanges (DOE's SEEP program)

3) High latitudes where deep water is formed (NSF's Polar Programs, and the JGOFS experiments on the spring bloom)

4) Productive fishing areas (Georges Bank, Grand Banks, etc.)

5) Hydrothermal vents

6) Cold seeps of reduced compounds (Gulf of Mexico by ALVIN, SEA LINK and NR1)

7) Equatorial divergence zones (TOGA)

8) The deep, open ocean [JGOFS time series studies (both Atlantic and Pacific), and work in the Gulf of Mexico using artificial islands]

In general, these would, in the future, include any area identified as important as a sink or source of "trace" gases [such as new deepwater formation on the poles, areas of divergence (equatorial), coastal upwelling, etc.], important to the global heat or hydrological cycles, or which play a role in fisheries recruitment.

Real-Time Data Needs via Satellite

Real-time AVHRR temperature data are now being used to direct sampling patterns by ships at sea. Color would be used too if it were available. In the future, moored and float data will be transmitted to ships in real-time to further assist in determining sampling strategies at sea. Examples of such monitoring and data transmission would be real-time data on oxygen concentrations from moored electrodes (in the study of hypoxia), accumulation of fluorescence near the bottom or on the pycnocline (in the study of microbial carbon recycling), variations in animal biomass as assessed by acoustic doppler profilers moored to the bottom, intensified bottom currents characterized by dense concentrations of suspended sediments, etc. These approaches improve research because they eliminate our heretofore "blind" sampling and experimentation on processes in the ocean.

Specific Requirements Needed on Ships

The trend to cross-disciplinary studies of ecosystem processes will require an increase in several characteristics of NOAA vessels. At least one large research vessel should be available on the east and west coasts, plus Alaska, for a total of three such major vessels. For such a large, high-endurance, general-purpose research ship capable of carrying out missions outlined above, berthing for scientists and their technical support should be 30 to 35. Laboratory space should be on the order of 4,000 sq ft. LOA should be on the order of 250 to 300 LOA. Endurance should be 60 days or 15,000 mi, with a cruising speed of 13 knots in sea state five. At least one of these vessels needs to be ice strengthened.

A spacious fantail will be required of all the vessels, with about 3,000 sq ft of unimpeded space. A suite of two to three cranes should be able to reach all areas of the main deck and deck space on the O2 level. Winches should be available to handle two spools of 30,000 ft. of 1/4" or 3/8" wire rope or conducting cable. A deepsea trawling winch with 40,000 ft of 9/16" cable and 30,000 ft of 0.68" conducting cable (up to 10 KVA power transmission and fiber optics) should be available.

Consideration should be given to even greater strength and length for future deep ocean operations, especially trawling. Exceptionally large nets cannot be used on any U.S. research vessel at the present time (ref. D. Stein, Oregon State University). Likewise, large-diameter piston coring presently available cannot be accomplished on any U.S. government or academic research vessel currently. The "large diameter coring facility" at the University of Rhode Island, for example, has been used only on the Department of Fisheries and Oceans (DFO) of Canada's R/V HUDSON because it cannot be used on any present U.S. vessel (ref. A. Driscoll).

Provision should be made in the stern of these vessels for a flexible (movable) A-frame that can accommodate launching and use of deep-towed devices such as acoustic, single-channel seismic or water-sampling fish.

State-of-the-art acoustics for mapping (phased array, very wide multibeam precision echo-sounding system) should be available (e.g., Sea Beam, GLORIA, TAMU2, etc.), along with hardware and plotting capabilities to provide semi-real-time visual displays of bottom topography.

Laboratory space should total 4,000 sq ft, divided into wet lab, dry lab, acoustics lab, dark room, a freezer (100 sq ft), a climate (temperature) controlled space (100 sq ft), a well-equipped dive locker (including medium capacity compressor), a "clean" laboratory, and an area designated for the use of radioisotopes. Some of these areas could be portable labs., and space in any case should be available for up to four 8 x 20 ft vans without impinging on the fantail space.

An easily deployed work boat (25 – 35 ft LOA, with a draft of about 3 ft) should be available, in addition to a 17 ft inflatable boat equipped with a large (50 to 100 hp) outboard. A single continental-shelf-depth ROV (300 m) with umbilicus should be available for use as needed on one of these vessels on an as-needed basis.

Communications should include facsimile to transmit high-speed graphic and hard-copy texts, high-speed data communications (56K Baud) links to shore labs, with transponding and receiving equipment including antenna to interrogate and receive satellite readouts from remote-sensing sources.

Medium size and medium endurance vessels in any fleet would have capabilities which would be subsets of the above capabilities. NOAA's role in U.S. marine science relative to that of the academic fleet, and NOAA's needs in fisheries and mapping, will dictate the need for such vessels. My (GTR) prognosis above considers basic ocean research in general and assumes that NOAA and its ship support will take a major role in it. Greater detail on the scientific requirements suggested for all size classes of the U.S. academic fleet (UNOLS) is available in "Scientific Mission Requirements for Oceanographic Research Vessels," by the UNOLS Fleet Improvement Committee, 1989. 52 pp. (available at the UNOLS FIC, Dept. Oceanography, Texas A&M, College Stations, TX 77843).

Special Considerations

Polar Research. New deep water is formed at high latitudes. Understanding the ocean as a global whole will require a significant increase in investigations of polar oceans, but the U.S. presently lacks an ice-capable research vessel in its federal or academic fleet. Polar programs must be done in collaboration with countries, such as West Germany using the POLAR STERN, in order to conduct high-latitude work when ice is present. The BERNIER was purchased from Canada by NSF for UNOLS and it is ice-strengthened. If NOAA wants a role in global studies, one of its new vessels should be ice-capable.

Small Drill Ships. The European Economic Community (EEC) is considering building a small drilling ship as a joint venture. The ship would not be used for drilling but for conducting near-bottom sampling, observations, and environmental experimentation. This project, called NEREIS, had a predecessor in the ALCOA SEA PROBE. In use about a decade ago, SEA PROBE has since been abandoned as a research vessel. Such a capability should be considered somewhere in the U.S. research fleet, but could be utilized on a leased basis. Such an approach could be of great value in geographic surveying of vent communities and mineral deposits; a "pod" could transmit video pictures up a drill string while it simultaneously "sniffed" for vent fluid tracers.

Very Deep Ocean In Situ Platforms – ROV's or DSRV's. The U.S. ocean research community presently lacks any capability to experiment, manipulate, or observe in real time in the deep ocean past a depth of 4,000 m, ALVIN's present depth limit. IFREMER, the French counterpart to NOAA, now operates the DSRV NAUTILE, capable of work at 6 km depth. A legitimate role of NOAA, as NASA's counterpart in the ocean, would be the design, construction, and operation of a 6 km DSRV, thus extending our depth range for direct observation and experimentation for direct observation and experimentation from the continental rises out across the abyssal plains and thus allowing the U.S. to regain its preeminence in the study of fundamental processes in the ocean. If NOAA does not take that role, it should support, as it has in the past, the involvement of the academic fleet (UNOLS) in such initiatives.

The ALVIN's sister sub, the DSV SEA CLIFF, owned and operated by the U.S. Navy, has been upgraded to reach 6,000 m. A further-enhanced sub which would reach 10,000 m would weigh on the order of 25 tons. Any ambition by NOAA for having one of its surface vessels act as a tender to such a submarine would need to take this into consideration.

One of the larger UNOLS vessels (ATLANTIS II, presently) is dedicated to supporting ALVIN. As NOAA continues to purchase dive time on ALVIN, perhaps utilizing a large NOAA vessel to support ALVIN should be considered. A 10 km ROV system would be an alternative to deeper DSRV's which could be incorporated into NOAA's plans.

Assessment of Oceanographic Fleet Needs: Chemical Oceanographic Requirements in Climate and Global Change Research

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Direction of Chemical Oceanography as It Pertains to Climate and Global Change Research

The field of chemical oceanography has and will continue to grow into highly-specialized subdisciplines. Over the last half-century, we have learned a tremendous amount about the behavior of chemical constituents in the ocean and atmosphere. One of the weaknesses in the field has been the ability to generate large quantities of data, in near real-time that must be obtained if we are to understand the dynamics of chemical transport and behavior in the oceans on a three-dimensional scale. With each space dimension, the data required to satisfy the needs of computer models is greatly increased. Therefore, in the next 10-30 years, chemical oceanographers will strive to increase the data flow by employing improved instrumental capabilities and increased numbers of shipboard analyses (as opposed to storing samples for analysis at shore-based laboratory facilities). Highly-selective chemical sensors will be developed in order to provide rapid, inexpensive chemical data for many oceanic tracers on unattended buoy systems that are linked by satellite to ship- and shore-based facilities. The World Ocean Circulation Experiment (WOCE) and Joint Global Ocean Flux Study (JGOFS) research programs are envisioned as lasting through the next decade and will require incorporation of large data sets into general circulation models. Next-generation research programs are envisioned to be built upon the success of these two global ocean programs and will undoubtedly require more highly-refined data sets.

Anticipated Rate of Growth in the Field of Chemical Oceanography

While the importance of chemical oceanography is very apparent, and the numbers of Ph.D. graduates in the field have increased, the rate of growth of the job market has been stalled due to lack of funding for basic research. The physical oceanographic community has not experienced this effect. Assuming that more positions can be created for chemical oceanographers, then the field will grow. At the present time, however, it is very difficult to place numbers on this projected growth rate.

Traditional Shipboard Observations versus Remote Sensing

Over the next few decades, there will be a progression from traditional shipboard observations to those measurements that can be made by unattended *in situ* technology; by instrumented buoys, for example. Information gathered from these systems will be relayed to ships and shore-based facilities via satellite in near real-time. It must be recognized, however, that traditional shipboard observations serve an extremely important function in oceanographic research by providing "ground-truthing."

Long- vs. Short-Term Monitoring

With the advent of unattended *in situ* biogeochemical observing systems, the field will flourish due to the ability to make measurements more frequently over longer time-scales. This will allow us to move away from simple steady-state calculations of the ocean's behavior to more advanced non-steady-state general circulation models which more closely mimic the real world. Electronic miniaturization will provide us with the capability of placing small, but highly-instrumented buoys in the ocean for the purpose of data collection.

Atmospheric and Oceanic Sample Acquisition

Over the past 20 years, the availability of high-precision, low-detection limit analytical instrumentation has become available to researchers in the field of chemical oceanography. With the increased instrument sensitivity, researchers have learned that a very significant problem to overcome has been that of sample contamination. This problem first manifested itself in the study of oceanic trace-metal distributions. Research platforms are notoriously burdened with an infinite source of contamination (both organic and inorganic). Until the mid-1970's, depth profiles of various trace metals, including iron, manganese, zinc, lead, and copper, to name a few, showed dramatic changes (i.e., scatter) with depth that were difficult to attribute directly to major hydrographic properties/features in the water column such as salinity, temperature, density, and nutrient fields. These data were heatedly debated in the oceanographic community since it was thought that they should follow the major hydrographic properties; that is, the trace metal distributions should be "oceanographically consistent." With the advent of cleaner analytical chemistry procedures, it was eventually realized that the previously measured oceanic trace metal distributions were not entirely natural, having been compromised by contamination of the samples during retrieval and subsequent preparation for analysis. Hence, it is now the consensus of the chemical oceanographic research community that oceanic trace metal distributions reported prior to the mid-1970's suffered from contamination and are not reliable estimates of the natural levels of these constituents. Both the oceanographic and atmospheric chemistry community presently devote a tremendous amount of effort in striving to minimize, or remove altogether, the potential for contamination in oceanographic and atmospheric samples.

Due to the problems mentioned above, it is of the utmost importance that contaminant-free oceanic and atmospheric samples be obtained from shipboard platforms. Analytical detection limits for various chemical constituents place the major constraint on the quantity of water or air that is sampled at a particular location. Concentrations of chemical constituents in the atmosphere are typically found to be quite different than those found in the ocean. While the volumes necessary for many chemical analyses have been drastically reduced over the past 20 years for many constituents due to a lowering of detection limits offered by various instrumentation, still others presently require the same volumes. For example, water column samples of one liter or less per sample typically satisfy the sample volume requirements for nutrients (phosphate, silicate, nitrate, nitrite, ammonia), trace metals, stable isotopes, and chlorofluorocarbons (CFC's). However, for various oceanic radionuclides such as radon-222, carbon-14, krypton-85, radium-226, and radium-228 volumes of 30 to 200 liters are presently required because of the detection limits presently available and the concentrations of these constituents in seawater. It is anticipated that detection limits will continue to decrease the need for large-volume water samples. This is certainly the case with carbon-14, which previously required 200 liters of water per sample for measurement by beta-counting, but now can be measured by accelerator mass spectrometry on samples of 1 liter or less. Until such detection limits can be decreased by the advent of analytical instrumentation, the research fleet should have the capability of obtaining large-volume water samples from the 30-liter Niskin bottles to the 200-liter Gerard barrels [used during the Geochemical Ocean Sections Study (GEOSECS) in the 1970's and the Transient Tracers in the Ocean (TTO) Program in the 1980's]. Large-volume water sampling will require heavy cranes, winches, and appropriate hydrowire. A larger deck working area is also required with heavy instrument/water sampling packages (including submersible pumping systems, discussed later).

In order to facilitate clean surface water sampling underway, bow-pumping systems will be required. The bow pumps and pipe/tubing must be comprised of an appropriately inert inside material (e.g., teflon) in order to minimize contamination. Water obtained from the bow pump systems must be accessible to the clean chemistry laboratories onboard. The pumping systems should be capable of delivering up to 50 liters/minute of surface seawater to the wet laboratories. This will aid in the reduction of sample alteration during its passage from the ships bow to the wet lab (i.e., "residence time" effects will be minimized).

The ship should have the capability of obtaining water samples from towed sampling systems. Therefore, the stern A-frame should be capable of towing tethered sampling systems.

The acquisition of clean atmospheric samples will require a bow tower structure that is located at the leading portion of the ship. The placement of the bow tower will aid in minimizing atmospheric sample contamination. Samples obtained from the bow tower should be provided with an easy path to the wet and dry laboratories, where appropriate in-line analyses can be performed. The ship should be instrumented with state-of-the-art meteorological instrumentation so that parameters such as wind speed, wind direction, temperature, and humidity can be "ground-truthed" in real-time with satellite estimates.

Laboratories

Climate-controlled laboratories should be amply provided to take into account the increase that is expected in the numbers of analyses that can be performed in near real-time. Dry laboratory space will be provided for analytical instrumentation such as gas chromatographs, atomic absorption spectrophotometers, automatic titrators, and radionuclide detectors. Uninterrupted power supplies are essential to minimize spurious signals to sensitive analytical equipment. Fume hoods are required for proper ventilation of noxious gas mixtures resulting from analytical procedures.

Wet laboratories will have direct communication with the sample bottle (Niskin, Gerard) room. This will be necessary so that water samples can be drawn into appropriate sampling containers from the wet laboratory. The sample-bottle room should be capable of easy manipulation of large-volume water sampling devices.

With the advent of specialized analytical technology, chemical oceanographers will increasingly use containerized "laboratories" that can be hoisted from the dock and placed directly onto the deck or into the hold of the ship. Deck space on Class I-type vessels should be ample enough to hold four standardized 8 ft by 20 ft containers that can be used for laboratory or berthing space.

Numbers of Vessels Required

Using present-day size descriptions, and considering the numbers of global measurements that will need to be made to satisfy our global ocean programs, it is estimated that at least six Class I-type vessels be obtained to satisfy NOAA's global change research program. These vessels should have an endurance of at least 60 days at sea.

Significant growth in the numbers of measurements in shelf and coastal ocean environments require that NOAA obtain approximately ten Class II vessels to handle this requirement. Smaller vessels will be required for estuarine studies.

NOAA Fleet Improvement for Fisheries Research

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INTRODUCTION

Forecasting: The Ultimate Goal of the NOAA Fisheries Program

The ultimate goal of any stock assessment program is forecasting so as to provide managers with sufficient information about the state of the stock to make informed decisions as to the appropriate action to be taken for the conservation and management of selected species. Over the past decades, population assessment of commercially and recreationally important species has been provided through traditional trawling methods. The catch is processed on board the vessel and statistics as to the characteristics of that population are acquired, usually species, sizes, weights, etc. Such routine population characterization is taken in all regions of the U.S. and provides an abundance of data to try to obtain a snapshot of the biomass at various times.

Identification of Present Limitations to Accurate Forecasting and Envisioned Midcourse Corrections to Overcome These Limitations

It has become increasingly obvious over the past decade or so that this effort, although a tremendous one, falls short in providing the managers with the type of data that they need for the proper management of the species. First, it is now no longer sufficient to give a picture of the distributions of the individual species. It is now necessary to look at the "why" of the observed distributions. We must attempt to answer the question, "What are the reasons that this species is distributed in the way it is?"

To answer the "why" question, it is essential to look at all of the other factors which affect the distribution of the catch. These factors include environmental factors such as density structure and currents which may ultimately control the distribution of the organism through vertical and horizontal water mass movements; salinity, temperature, DO ,pH,and light which trigger migratory and growth responses of the organism; food abundance and nutritional content of the food source which dictate the growth factors as well as the success of the year classes; and predation and toxics which ultimately have an impact on the survival of entire populations. This, in effect, comprises a "process oriented approach." Without such information on the regulating factors which modify the populations, it is impossible to make any intelligible estimates as to the future of the species. In order to implement these estimates of the dynamics of the population, *it is essential that environmental measurements be taken in conjunction with the population assessment sampling.*

It is also necessary in tandem to improve the resolution of the sampling program so as to decrease the variance and bias of the present catch data. At the moment, the temporal and spatial sampling scheme is not adequate to adequately describe the status of the populations with any reasonable error. This error stems from the fact that the limitations of the present sampling methodology. Either one must increase significantly the number of vessels surveying the area *and* increase the number of days of surveying *or* modify our way of doing the surveys. At present, the NOAA fleet (and funding) is stretched to the limit in terms of the number of days allocated to the assessments. This is also corroborated by the number of chartered vessels that are needed to do just the routine trawls. Increased number of ship days does not appear to be feasible. It is also not likely that there will be significantly more platforms available in the future from which to do the work. Therefore, the reasonable alternative is *revise the way we perform the surveys.* This can essentially be done *through the incorporation of new prototype instrumentation to provide better temporal as well as spatial coverage* and *to modify the strategic design of the individual sampling scheme to make better use of remote technology.*

If the management of the stock is the primary goal of the program, there is another factor which is also must be implemented simultaneously, that is *infrastructure of data handling.* This actually has to be modified at three basic levels, based on decision-making requirements of: 1) the chief scientist, 2) the regional manager, and 3) the national needs.

1. To fulfill the first need so that the chief scientist is capable of making the best possible decision with regard to sampling strategy, it is essential that the sampling vessel have the *capability of onboard processing and analysis and display of all of the collected data from one cruise so that midcourse corrections in the sampling schemes can be implemented during the cruise.*

2. To provide the regional manager with the timely information so as to be able to make rapid responses concerning permits, catch limitations and so forth, it is essential that *all processed cruise data be transmitted from the vessel either at certain time intervals or at the*

end of a cruise to a regional integrating center where multicruise analysis or trends analysis is done.

3. To provide the Assistant Administrators with information concerning trends in the national stock necessary for forecasting and thus for the continuous refinement of the national plan it is essential that there be *a central networking and analysis of all of the regional trends data.* Only when the above tasks have been accomplished will the forecasting be accurate and timely.

SAMPLING REFINEMENTS

The major goal of an alteration to the sampling program is to improve the RESOLUTION and decrease the BIAS through the modification of instrumentation as well as the strategic design. Refinement of the instrumentation will essentially be focused on the improvement of the spatial resolution, while the sampling scheme modification will aim at the proper utilization of these instruments so as to give the best spatial as well as temporal coverage.

Instrumentation

1. Catch Assessment Instruments. There are a number of reasons why we want to replace or supplement our net hauls with other methods aimed at assessing the stock. Net hauls give data on numbers of species, sizes, and gut contents of specimens over a spatial extent. Because the towing of trawls must be done at a low speed, the aerial coverage is poor. In addition, another factor not normally recognized that may eventually lead away from the net hauls is that of the environmental waste of the tons of fish enumerated at sea. There are available today new technologies for the noninvasive assessment of the stock. Ultimately, the concept which we would like to explore is the feasibility of *substituting acoustic or optical nets for the traditional fiber nets.* "Smart samplers," which embrace both acoustic and optical technology, are in the prototype today. Many research teams have spent the past several years testing and modifying their instruments to produce a state–of–the–science field instrument (i.e., Ortner, Jaffe, Pieper, Holliday, Weibe). In addition, many of these devices can potentially be moored or operated off of remote vehicles to give an added dimension to the ship sampling.

2. Environmental Data Instruments. One of the most influential technologies to affect the way in which we sample the environment has been the satellite. Sensors which detect surface parameters of the ocean are now providing the chief scientist with the temporal and spatial information of an oceanographic feature so as to be able to actually modify the sampling program in real time. Aircraft–borne sensors also are playing a major role in the monitoring of surface features of the ocean such as laser stimulatable fluorescence from chlorophyll. Vertical profilers now are capable of simultaneously logging C, T, D, S, O, flu, I, current speed and direction. Any processes–oriented approach must include these parameters for correct interpretation of the environment.

Strategic Design

To incorporate the above improvements in stock and environmental assessment so as to reduce sampling bias and increase the temporal and spatial resolution of the data acquisition phase, there must be a revision in the temporal and spatial sampling schemes. Such refinements must include the greatest usage of remote technologies and vehicles to supplement between station and between cruise information. The actual criteria for establishing the optimum sampling strategy should be dictated by the resolution needed to unravel the processes operating in a specific environment. For example, the spatial coverage needed to adequately sample an ocean population may be on the order of 10,000 km^2, whereas that required to survey an estuarine species may be an order of magnitude or more less. Thus, the dynamic range of the species will dictate the T/S sampling scheme. If the temporal resolution needed for assessment in a region requires more than the number of ship days available then it is necessary for the program to go to remote means of assessment (i.e., moorings). By the same token, if the spatial variability of the population exceeds the size of the sampling grid, then it would benefit the program to improve its detection methods either by changing the grid size or by improving the instrumentation. It quickly becomes apparent that the incorporation of remote and higher resolution instrumentation dictates a midcourse correction in the sampling strategies. This makes more efficient use of the mother ship (high–tech vessel) by incorporating other ancillary platforms such as submersibles, moorings, and airborne vehicles.

CONCLUSIONS

Generic Fleet Improvements Required to Accommodate the Refinements in Sampling Strategy and Instrumentation

It has become apparent that the vessels which we are now operating are unable to accommodate the new conceptual as well as technological advances needed to properly assess our national fisheries. Fleet modification is needed in the following areas:

- STRATEGIC SAMPLING: positioning, speed, navigation
- INSTRUMENTATION: power, vibration, deployment/recovery hardware
- DATA PROCESSING: power, hardware linkages, communications
- REGIONAL: Ice, shallow/deep water

Fleet Requirements for Fisheries Research

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Introduction

This position paper is devoted principally to the application of advances in mapping and charting methodology and technology to fisheries research and management. Also discussed are those areas where mapping and charting technology overlaps with the technology used in fisheries research, and finally, some discussion of vessel support equipment is included.

Charting Technology and Methodology

1. Marine Positioning. The satellite-based Global Positioning System (GPS) will likely be the standard for marine positioning for the next 20 to 30 years. The system is incomplete now, but should be fully operational within 5 years. The use of GPS receivers on fisheries research vessels will allow very accurate positioning for all navigational and scientific purposes.

GPS will operate in two modes, standard positioning service (SPS) for civil use and precise positioning service (PPS) for the military and other selected users. SPS will provide continuous positions accurate to within 100 meters. This is accurate enough for vessel navigation, but may not be accurate enough for scientific research work. PPS will provide continuous positions accurate to within 20 meters. This probably would be accurate enough for research purposes, but PPS will require classified special access keys which are unlikely to be provided to fisheries vessels except, perhaps, some Federal research vessels.

The accuracy of SPS can be improved to equal or better than PPS by the use of differential positioning techniques. In this scheme, signals received on the vessel are compared to the signals from a receiver at a known position ashore and corrected accordingly. Differential positioning requires a nearly continuous radio link with the shore station, but this should not be an insurmountable problem, especially within the U.S. EEZ. A network of continuously operating shore stations has been proposed by Coast Guard.

GPS technology could also be used for remote, shore-based tracking of any fishing vessel equipped with a receiver and a communications satellite uplink. Such a system could be installed in a self-contained mounted topside on the vessel to be tracked, saving time and effort related to monitoring of jurisdictional and closure boundary infringements.

2. Integrated Data Acquisition Systems. Hydrographic and bathymetric surveying technology depends heavily on integrated data acquisition systems to record, correlate, and process position and sounding data. Systems such as these have applicability to all types of data acquisition at sea. Integrated systems are capable of recording digital data from positioning sensors (GPS), acoustic sensors (echo sounders, sonars), oceanographic sensors (CTD, doppler profiler, etc.) and correlating those data with fisheries data. Optical disks and other high-density media have proven adaptable to at-sea data acquisition and storage systems. Positioning data and other selected data can be processed in real time and output to plotters or graphics display terminals for on-line interpretation by investigators or ship control personnel.

On a ship with suitable propulsion systems, the integrated data acquisition system can automate dynamic vessel positioning. The integrated system can compute ship's position continuously, compare computed position with desired position, and send the necessary commands to the propulsion and steering system in order to regain or maintain station.

Fisheries research vessels will probably continue to have an occasional ancillary requirement to conduct a limited bathymetric survey, either for navigational purposes in remote areas such as the Pacific Islands, or for gear deployment in other areas. Integrated data acquisition systems will allow ship's personnel to conduct this type of survey accurately and efficiently, and easily provide the data to a centralized digital bathymetric data base such as that maintained by NOAA's National Geophysical Data Center.

3. Acoustic Sensors. Both mapping/charting and fisheries research have well-established acoustic technology. This technology has recently been developing rapidly and can be expected to become even more sophisticated during the next 10 to 30 years. Advances in both hardware and in digital signal processing are anticipated.

In the mapping and charting field, multibeam hull-mounted sounders are providing 100% bottom coverage and 10-meter-or-better depth resolution for deep water bathymetry. In water less than 150 meters deep, the efficiency of these systems diminishes because the smaller swath of coverage requires much closer vessel sounding lines. Newer hull-mounted systems offer the prospect of extending efficient coverage into somewhat shallower water, and interferometric sidescan sonar may allow efficient 100% coverage into water as shallow as 10 meters.

Digital echo sounders and sidescan sonars are providing much more information about bottom characteristics than earlier analog systems. Modern sounders operate on two or more frequencies simultaneously, greatly increasing the quality of data available for interpretation of bottom and mid-water echoes. The digital data received from these sonars can be processed and analyzed on the basis of pattern matching and echo signal strength to provide valuable information on bottom hardness and roughness. With some advance knowledge and ground truth data, multifrequency echo sounders could likely provide continuous real time bottom character analysis.

It seems reasonable to assume that like mapping sonars, fisheries sonar sensitivity and resolution as well as signal processing capabilities will improve continually over the next 30 years. Based on these improvements, acoustic methods for monitoring net deployment and, more importantly, for directly assessing fisheries resources should become more efficient and more valid.

4. Remotely Operated Vehicles (ROV's). ROV's or towed vehicles offer increasing opportunity for deployment of acoustic or video sensors. Low-light video cameras may provide continuous monitoring of net conditions, or may allow assessment of bottom-dwelling species without the need for nets. Very short- and ultra-short baseline acoustic positioning systems coupled with integrated data acquisition systems can provide continuous and accurate tow body or ROV coordinates.

5. Large Scale Map Products. The advances in positioning and echo sounding systems described in preceding paragraphs have made possible the preparation of very accurate and very detailed map products. With time and ships to carry out the necessary surveys, the mapping and charting program can produce large scale (1:100,000 and, if needed, 1:50,000) bathymetric maps of the continental shelf and slope. These high-resolution maps can provide very accurate depths and bottom hardness delineation in areas of rugged bottom or smooth bottom. Accurate seafloor maps can aid in locating specific habitat types and potential areas of nutrient-rich upwelling, and also in guiding the deployment of sampling gear or acoustic sensors.

6. Remote Sensing Products. Shallow water habitat classification using photogrammetric techniques has been demonstrated recently in two projects. Very accurate maps were compiled of coral reef habitat in the Looe Key Marine Sanctuary, Florida, and of submerged aquatic vegetation (seagrass) in Core Sound, North Carolina. Improving digital photogrammetric processing capabilities will increase the opportunity to provide such products in the next 10 to 20 years. It is also likely that a data base of metric quality digital photography will be initiated easing access to such data. These photogrammetric products can provide highly detailed information as baseline data to supplement the broad coverage of nearshore habitat which may be available from satellite imagery.

Vessel Characteristics

1. Endurance, Stability, and Seakeeping. Adequate design in this category is an obvious requirement. Because of the large number of sea days assigned to each NOAA vessel, extended endurance is highly desirable. Longer cruise legs are more efficient, and three weeks should be the minimum endurance for any vessel intending to operate offshore. It is critical that the vessel maintain good stability even after three weeks of fuel have been consumed.

Seakeeping ability is not necessarily controlled by vessel size. Regardless of the size of the vessel, it must provide an acceptable platform for conducting assigned research.

2. Electronics Support. Over the next 10 to 30 years, fisheries research will require increasingly sophisticated electronics aboard ship. The sensors and data acquisition and processing systems must be supported by abundant and clean electrical power, and will undoubtedly require good climate control. To eliminate the need for large deck-mounted vans, well-designed plot rooms or computer rooms will be necessary. These spaces should be arranged in a modular fashion to allow rapid and simple change out of electronics equipment from one project configuration to another.

3. Diver Support. All NOAA vessels should be equipped to support diver operations. This would include, as a minimum, facilities for entering and leaving the water, a dive locker for equipment, and an approved air compressor. Larger ships should be capable of accommodating a recompression chamber. Shipboard staffing procedures should recognize the need for divers among the ship's crew.

Ancillary Ship Use

Fishery Management Conservation Act has resulted in loss of a significant number of research days at sea previously supplied by foreign vessels. If acoustic assessment becomes more of a practical reality, other vessels equipped with such gear, for example Coast Guard cutters on patrol, might supplement data acquired by the NOAA fleet of dedicated fisheries vessels.

NOAA Oceanographic Fleet Needs Into the Next Century

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Direction of Fisheries Research

Consumptive Resources and Stock Assessment. The direction of fisheries research for the Southwest Fisheries Center (SWC) can be divided into near term (<10 years) and longer term (20–30 years). In the near term, the SWC will require significantly expanded sea days. In recent years, pressures to respond to marine mammal concerns have made the SWC fall behind in coastal and groundfish data collection at sea to the point where we are unable to keep up with management needs. At the same time, responsibilities for west coast groundfish research have expanded. Because fishing effort for groundfish has greatly increased during the last decade, stock assessments are much more critical than before. Unfortunately, we cannot adequately assess the condition of west coast groundfish stocks without a significant increase in the fishery survey capabilities of NOAA. The trend will continue as some presently lightly fished stocks become fully exploited and the fishery moves into different areas, such as deeper water. Additional attention will also be required with respect to tuna and billfish resources. A strong research involvement by the SWC will be required as a basis for treaty negotiations, international management efforts, and continuation of U.S. fishing throughout the Pacific and conceivably in the Indian Ocean. Combined, these activities will require greater vessel time for SWC resource surveys in at least the coming two decades.

Over the longer term, we may see a decreasing reliance on the use of dedicated research vessel surveys for fishery independent stock assessment, particularly for well–known coastal and shelf/slope stocks; exceptions occur for species exhibiting schooling behavior or for developing new fisheries. It is conceivable that mandated catch–and–effort data combined with increasing application of limited access systems and observer programs will improve analysis of fishery–dependent data. For better known fisheries under stable conditions, increased use of charter vessels (some possibly in exchange for quota allocations) could decrease research vessel requirements. This decreasing need will be tempered, however, by management or legislative requirements; fishery closures caused by stocks falling below threshold levels or by excessive interaction with marine mammals will likely require periodic assessment cruises on NOAA research vessels; this could include measurement of stock recovery, as in west coast wetfish stocks.

Beginning in the short term and continuing to the longer term will be an increasing need for dedicated vessel time for pre–recruit surveys. For many fisheries resources, new techniques and understanding of the ecology of pre–exploitation life stages will allow development of indices of population change for anticipatory management efforts. In the next decade, these surveys will be vessel–intensive but will decrease as the understanding, and thereby accuracy, of the surveys improve; advancing optical and acoustic technology will provide new sampling methods for these surveys. These data will also be important for ground truth on the performance of ecosystem /environmental recruitment models; dramatic improvement of these models combined with improved remote sensing data could reduce certain needs for vessel time, but this will be even longer into the future than 30 years.

Habitat and Ecosystem. An increasing environmental awareness by the general public combined with increasing degradation of habitat due to industrial, agricultural, and urban development will require greater efforts by NMFS to conserve habitats and ecosystems. Habitat conservation, as presently elaborated in the NOAA Coastal Ocean Program, is principally concerned with coastal ecosystems, particularly the "no net loss" policy for benthic habitat. A similar sentiment now exists for open ocean systems, as is evident in the present concerns about marine debris, driftnetting, and marine mammals in general. Public concern will lead to legislation requiring research efforts outside the Exclusive Economic Zone (EEZ); the 1987 Driftnet Act is an example. Current needs for research vessel–based population assessment and monitoring of marine mammals may continue over the next decade, but should decrease thereafter; improved capabilities in remote sensing and increased observer coverage (where fishery interactions occur) will decrease research vessel requirements. Federal management of marine mammal populations after recovery will require some research vessel time, but to the extent possible, it will be coordinated with multipurpose ecosystem research cruises.

International agreements and conventions will make further demands on NMFS/SWC expertise, such as in the Antarctic Ecosystem Research Program. All these concerns will require increased environmental and ecosystem monitoring and consequently a large commitment of research vessel time. Studies of ecosystem balance or quality will require new sampling methodologies for components of the ecosystem previously little studied by NMFS; important in this area will be studies of negative impacts of fisheries, such as by–catch and habitat destruction. Improved physical data collection and the development or maintenance of selected time series (such as CalCOFI) will be bolstered by such funding initiatives as Global Climate Change.

Anticipated Rate of Growth

While the responsibilities for fisheries management advice and the traditional needs of NMFS remain, new research areas identified above will demand new expertise and new funding. Over the near term, budgets will lag behind responsibilities with the consequent result that existing expertise will be spread thinner and thinner; the same holds for research vessels (although for the SWC, demand for sea days exceeded supply several years ago). New initiatives and legislative mandates will divert research vessels from planned activities. With the changes noted above (including increased tuna/billfish research, groundfish assessment research, and possibly reduced sea days for marine mammal observations), we anticipate that the SWC will require a doubling of sea days over the coming 5–7 years.

There will also be significant growth in the complexity and diversity of equipment used in fisheries and oceanographic research. With improved vessel capabilities, increasingly specialized instrumentation costing large amounts of money will be deployed over the side, demanding higher levels of seamanship to prevent unacceptable losses. Working with such equipment will require a highly trained and experienced crew and officers with extensive, firsthand experience with the gear and the vessel. This will require longer assignments of officers aboard vessels to ensure familiarity with equipment and vessel handling characteristics. Options such as the presence of one non–NOAA corps officer as a mate should be considered to provide needed continuity and corporate memory on each vessel.

Growth of technology will continue and the design of NOAA vessels should be such that technology (e.g., computing equipment) can be incorporated and upgraded without major disruptions to vessel service. These upgrades and the increased technology will expertise should be supplied aboard the research vessels to facilitate use by different groups.

Shipboard Observations versus Remote Sensing

There is little doubt that data from remote sensing instrumentation will increase in utility for fisheries research problems in the coming decades as the range of functions and the data quality from remote sensing improves. The sources of such information may include satellites, moored arrays, and, conceivably, automated vehicles akin to Stommel's "Slocums."

In the near term, however, this will not decrease the need for vessel days because the remotely sensed data provided by satellites and buoys by themselves contribute relatively little to practical solutions to fishery and habitat problems. For this reason, we should not assume that improved remote sensing will decrease our need for research vessels. Instead, in both the near and long term, a vast task awaits to establish practical biological correlates of the remotely sensed information that will hold over the long term. Examples include forecasting recruitment, migrations (and spatial distribution), toxic blooms, or monitoring marine mammals. Developing these calibrations will require extensive ship time well into the 21st century and may be one of the most important NOAA programs.

Short–Term Studies versus Long–Term Monitoring

Long–term monitoring will be the area most directly aided by remote sensing efforts, but the principal contributions will be in physical data collection. Shipboard activities in long–term monitoring of biological features will represent an increasing share of vessel days for fisheries research. Measurement of population trends, analysis of species balances in selected ecosystems, and monitoring of predicted changes in the face of global climate change will all require research vessel time.

Geographic Areas of Interest; Seasonal Constraints

Typically, habitats and ecosystems of coastal fisheries resources have been better studied than those in oceanic areas, but the great complexity of the coastal regions will require continued study. Man's impacts are greater nearshore than offshore and in many instances are increasing. In oceanic ecosystems, more remains to be learned about resource ecology, species interactions, and basic ecosystem function, requiring increased fisheries research vessel time; in the near term, research on shorter term studies will continue although long–term studies will expand with time.

For the SWC, the principal geographic areas of interest are coastal waters of California, Oregon, Washington, Hawaii, and the U.S. flag states of the Pacific. Farther reaching programs include those for tunas throughout the Pacific and Indian Oceans; the North and South Pacific transition zones (for albacore resources); the tropical Pacific; and the tropical Indian Ocean. Our programs will continue in the Antarctic, where our research program represents a major U.S. contribution to the Commission for Conservation of Antarctic Marine Living Resources. With the exception of the Antarctic program (vessel time in the Austral summer), no seasonal constraints require special consideration; it should be noted, however, that weather constraints in several activities require larger, more seaworthy vessels to minimize the time spent unable to work due to weather.

Changes in Real-Time Data Analysis

The transmission of data to and from research vessels in real time will increase for a variety of reasons. The most important aspects of real-time data analysis that will change in the future involve mainly those which will alter the subsequent collection of data at sea. For example, real time analysis of currents (from acoustic doppler current profiler data processed at sea) or frontal zones (from remotely sensed information) may be used to allocate biological sampling to meet certain objectives. In any case, improved data transmission and satellite downlink capabilities will be desirable on any new fisheries research vessels. These needs will be particularly acute for coordinated, multi-vessel surveys. Improved processing of remote sensing data will require work-station-level computing capability.

International Collaboration

The SWC research programs are characterized by significant international collaboration. Collaborative research on coastal ecosystems exists with Mexico and several South Pacific island nations including the Compact States (formerly the Trust Territories of the Pacific Islands). Open ocean ecosystem studies as well as research in support of international management of highly migratory species will require multivessel synoptic surveys and will be enhanced by international collaboration. Collaborative efforts for SWC programs exist or are envisioned in the eastern Pacific (with Latin American coastal states), in the central and western Pacific (island nations and major fishing nations), in the North Pacific (Japan, Taiwan, and Korea), and in the Indian Ocean (coastal states and major fishing nations). Regional cooperative research programs are likely to emerge from existing or new (e.g., PICES) international bodies. These programs will require advance commitment of research vessel time by the U.S. as well as by other parties.

Specific Requirements Needed on Ships

Anticipated Vessels Required. Future research needs of the SWC, as outlined above, will require both coastal and oceanic research vessels. As a general idea of our requirements, we provide vessel needs identified for the near term under current conditions of work required. Although the vessels described below will have the necessary configurations, additional vessel time would be required for new programs that may be funded under the Coastal Ocean or Climate Change Initiatives, particularly those with major university or non-NOAA involvement. Our needs are four dedicated vessels and the principal use of another. Two dedicated coastal vessels of the 30–40 m class will be required, one for west coast research programs and one for insular studies in the central and western Pacific. Two dedicated, large vessels of the 70–75 m class will also be required. One will principally work in the central and western Pacific and Indian Oceans, while the other will work on the west coast and eastern and North Pacific. A third vessel will be required for approximately 180 sea days annually for the Antarctic Ecosystem Research Program; this vessel should be the large oceanic class with polar (i.e., ice strengthening) capabilities and capability for trawling. Requirements above and beyond those provided by this set of five NOAA vessels will depend upon funding under new initiatives and will be supplied primarily through charter of special commercial fishing or research vessels to match particular needs. Total additional requirements for chartered vessels are expected to range between 200–400 days at sea per year over the long term. Longer range estimates of SWC sea day requirements are shown in Figure 1.

The characteristics required of vessels listed below are principally for the oceanic vessels, although many of the characteristics are generic and desirable for the coastal vessel as well. Detailed specifications are not provided but generally concur with those provided in the Fisheries Working Group report. The coastal vessel has been described in an earlier report from the SWC (memo from Barrett to Angelovic of 23 May 1986) and will not be described in detail here. Generally, however, it should be 30–40 m long, able to cruise at 14 kn with an endurance of 30 days and a scientific complement of 8 (although temporary, short-term berthing of up to 14 may be necessary for island field camp deployments). It should be multipurpose, with both fishing and oceanographic capabilities, station holding abilities, and wet and dry labs.

Hull and Vessel Technical Characteristics.

Size: 70–75 m with draft suitable for stability in weather; twin screws, steerage at speeds as low as 1 kn

Speed: 18 kn cruising to minimize run time between stations

Endurance: 45 days at sea

Power plants: Suitable for speed and trawling power equivalent to a large commercial fishing vessel

Bow thrusters: Independently powered; sufficient for moderate speeds and station holding capability

Ice strengthening: Required for vessel deployed in Antarctic program

Special Layout Considerations.

Berthing requirements: 18–20 scientists

Laboratory space: · Wet lab (fish processing, plankton processing, flexibility for live animal research); walk-in constant temperature room
· Chemical lab (biochemistry, ultracold freezer, centrifuge)
· Hydro lab (water sampling, salinity, nutrient analysis, chlorophyll, etc.)
· Electronics lab (deck units for instrumentation, computer interfaces, output devices, monitors, computer terminals)

Deck space: Large fantail area for work/sampling; flexibility and deck space for van/module placement, with power and computer linkup capability

Dark room for photographic processing

Recreation/common areas (exercise, library, lounge)

Office/conference room space with PC's, supplies

Gear/sample storage: On deck bin-type storage for large sampling gear (trawls, doors, traps); Chemical/toxics storage for preservatives, etc. Secure dry storage for equipment and biological samples; Blast freezer, and specimen storage

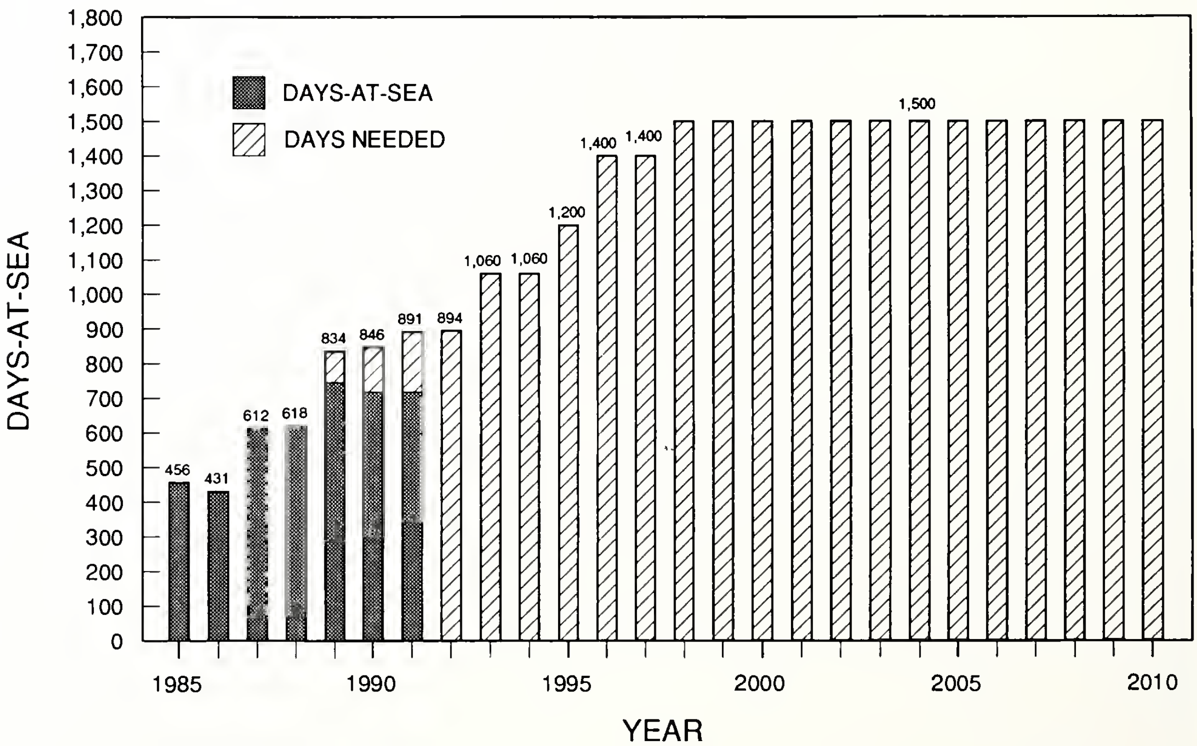

Figure 1. Historical and Projected Vessel Requirements, Southwest Fisheries Center, 1985–2010.

freezer. Drying area for gear, etc.
Workshop/tool bin for gear repair/fabrication
Helicopter deployment capabilities
Flying bridge observation deck with visibility to 180° forward

Deck Equipment.

A–frame requirements: Midships for small to moderate sized plankton and trawl gear; stern for large, fixed–mouth midwater trawls
Winches (all to include wire out, strain gauge instrumentation): · Commercial trawl style winches for double warp trawling to 1,800 m; capability for third wire gear mensuration equipment; bridge ability to monitor fishing deck · Oceanographic winch (conducting cable), 5,000 m wire capacity, strength for plankton and moderate sized midwater trawling gear, coring · Hydro winch, 5,000 m conducting cable capacity.
Net reels: Double, suitable for holding two trawls and capacity to switch trawls at sea; flexibility for gillnet and longline deployment
Trawl ramp for stern trawling configuration
Cranes: Stern telescoping boom crane for gear deployment, including ROV's, midships for multipurpose uses; cranes must extend minimum of 8 m beyond vessel
Small boat needs: Rapid deployment for two 6 m launches; large vessel with ability to deploy 10 m workboat
Hydraulics: Flexibility for special winch/gear installations
Below deck storage with capacity to double as circular bait well/holding tanks
Waste disposal system including incineration /compacting/storage space

Instrumentation.

Communication: State–of–the–art satellite links for voice and data transfer; capacity to communicate with moored instruments or remotely deployed drogues/sensors
Navigation: State–of–the–art satellite positioning
Remote sensing capabilities: At–sea receiving and processing for thermal and ocean color data and meteorological data
Oceanographic instrumentation: CTD's with oxygen sensor and rosette; thermosalinograph; acoustic doppler current profiler as standard on all NOAA vessels; link to computing system
Computer support: Central computing system with input from vessel sensors and scientific equipment; workstations for data processing; budget and flexibility for periodic (5 year) upgrading of system
Radar: Standard navigational plus weather/bird radar
Hydroacoustics: Multifrequency, hull–mounted transducers for biomass estimation; flexibility to install new acoustical equipment as it becomes available; modern fishing acoustics with viewing terminals both on bridge and in area convenient to fishing deck; flexibility for towed transducers; bottom mapping sonar.
Maintenance: All instrumentation should have budgeted maintenance, upkeep, and replacement plans under contingency situations

Specialization of Officers/Crew. As noted above, the officers and crew will require more specialized training with the increasing technology. Survey technicians will be required to specialize in certain tasks and technical support for instrumentation will be needed.

Shoreside Support. Docking, office space, storage areas, loading equipment, repair and maintenance facilities, and general cruise preparation areas should be carefully planned to facilitate cooperation by different elements of NOAA and to co–locate certain activities of the users and operators of the vessel.

ROV's. Increasing use of ROV's will require that most NOAA vessels have the capability of handling such vehicles, and NOAA should have systems available for deployment on different vessels as needed. The vessel designs should take into account use of these vehicles. Ultimately fiber optics cable will be commonly used for real–time video monitoring, and special handling considerations will be necessary. An integrated navigation system will be necessary to allow input of ROV navigation information and simultaneous tracking of vessel and ROV. Depth capability should be to 2,500 m.

NOAA Ship Requirements for Fisheries Oceanography

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Introduction

This document describes my perspective as an ecologically oriented coastal physical oceanographer on the subject of research vessel usage for the next decade or two. Most of basic points I'll make are generally applicable to oceanographic research vessels, but some will be biased towards coastal ecological or fisheries objectives. This first page serves as a general summary and overview. Many of the more specific considerations are treated in detail in the UNOLS document titled "Scientific Research Requirements for Oceanographic Research Vessels."

I bring to this forum considerable experience as a field-oriented oceanographer and a modest amount of ship design and usage information I acquired as a scientific representative on the UNOLS Fleet Replacement Committee (for two years as a research faculty member at University of Southern California). I don't know all that much about specific vessel requirements associated with fisheries oceanography other than the fact that substantial net handling systems are usually desirable.

I view oceanographic research vessels first as data gathering platforms, then as a means of getting to where you want to be, and finally as a place to stay while you are working at sea. If you aren't getting good data, then one is wasting time and energy in transit and occupying stations, etc. In short, I feel strongly that we should focus most of our effort in this exercise on plans to upgrade NOAA's shipborne data acquisition capabilities. This involves capable and appropriate vessels and reasonably well-matched data acquisition technologies and vessel design.

The accelerated evolution of measurement technologies has revolutionized the way we observe the ocean. Appropriate application of acoustic and optical sensing technologies has dramatically increased data rates and volumes as well as the breadth of topics that might be addressed as part of a single oceanographic expedition. More precise navigation and ship motion specification combined with the above technologies has lead to some remarkable advances in the way oceanography is done at sea. In short, there is more potential these days for getting exceptional data sets using more modest vessels (if they are well-equipped) or for abusing the potential opportunities afforded by larger, better-equipped vessels, if critical components are "down" or inoperable during a particular cruise leg. The bottom line is bigger doesn't necessarily mean more capable with respect to data acquisition.

How will these vessels be used? What speed, endurance, and crew carrying characteristics are most desirable? What will the vessel of the 90's look like? Will each region of the U.S. have access to a range of vessel types? Is there a prototypical one-size-does-it-all vessel? I think we have to address all these questions in one form or another as part of this activity.

Here are some quick, general answers to the above questions that are difficult to refute. We need faster vessels (on average) to get from one data gathering point to another in less time, so we can gather essential data a greater percentage of the time (versus transit time). Vessels should be more efficient (in terms of fuel consumption) and require less crew to operate so that a greater percentage of the total ship operation expenditure can go towards data gathering. Endurance and crew-payload carrying capacity are paramount considerations for open ocean, trans-basin type vessels, but may be less important than speed or data acquisition capability for coastal vessels. There is no prototypical one-size-does-it-all-on-a-cost-effective-basis vessel, period! Each region will have to have access to a range of vessel types. Hopefully, all vessel types will be well-equipped in terms of data acquisition instrumentation.

Vessel Types

Vessel types usually break down by size (large, 200+ ft; medium, 130-200 ft; small, 70-130 ft), but there is considerable overlap in data acquisition capability as a function of size. There days a 100-ft vessel can acquire the same type and amount of data per unit time as a 300-ft vessel in many variable fields assuming comparable instrumentation. That is, the relationship between vessel size and data acquisition capability is changing with the advent of microprocessor-based, down-sized instrumentation systems.

With today's improved data acquisition equipment there is a greater need for precision navigation, tracking and station-keeping capabilities. This translates to modernized low speed propulsion units (Omnithrusters or Z-drives) and positioning systems which employ the best possible navigation electronics and control technology.

It is obvious that a small vessel must operate in coastal waters or at least within easy transit of a port which might be located in oceanic waters. No one would suggest that this vessel class should be used for pelagic work; just that they can be very cost-effective, capable platforms for coastal research efforts. SWATH (or catamaran) designs could be especially appropriate in this niche. Much of NOAA's currently planned research is sited in coastal waters as a result of the fact that most of man's activity and impact on the oceans is concentrated within 200 km of the coast. Even small "work boats" can play a significant role in this research context.

NOAA can probably count on the need for operating a minimum of one large vessel per ocean basin. These vessels should have an endurance of two months, accommodations for a scientific crew of 24 (minimum), cruising speed of 15 kts, range or 10,000 miles, and excellent low speed maneuverability and station-keeping capability. They should be equipped with the best possible navigation and data acquisition instrumentation which will probably require (for effective use) a permanent onboard instrumentation support team. These vessels typically cost 10K$/day (or more) to operate.

NOAA can probably count on the need for operating a minimum of two small vessels per coastal region. These vessels should have an endurance of at least two weeks, accommodations for a scientific crew of 10 (minimum), cruising speed of 15 kts, range of 3,000 miles, and excellent low-speed maneuverability and station-keeping capability. They should be equipped with the best possible navigation and data acquisition instrumentation which will probably require (for effective use) a permanent onboard instrumentation person. These vessels typically cost 4K$/day (or more) to operate.

Intermediate size vessels fall between these two categories and play an important role in benign oceanic regimes or more rigorous coastal regimes. In the former they can play a large ship role; in the latter, they are a necessary consistently perform successful coastal missions. Their operating cost is closer to that of a large ship. Small SWATH (or catamaran) vessels can overlap significantly with intermediate size vessels in many operational categories.

I favor a vessel with a more flexible, open-deck-type design that can effectively accommodate additional van storage or portable labs. Generally speaking, vessels seem to gravitate towards the other end of the design continuum with more permanent lab space at the expense of open fantail and versatility. In my opinion, that defeats some of the possible utility of large- and intermediate-size vessels. This is especially true of vessels for fisheries work in that plenty of open deck space is required for net handling and associated gear. Three characteristics seem to be part of designs which try to mold intermediate-size or large ships into do-it-all vessels. They tend to be beamy (to get more space per length) and thus are slow or inefficient, and ironically are less versatile than one might expect because of the emphasis put on permanent lab space (which is often just used for storage anyway). The former characteristics disallow the possibility of faster, longer-range, higher-endurance designs with open deck configurations (e.g., similar to modern-day tuna-fishing vessels).

How Will These Vessels Be Used?

I am presuming that these vessels will be primarily used for the purposes of oceanographic research) including fisheries oceanography). One needs to get on station efficiently, get the essential data with supporting environmental data, and get back to port. Hopefully this can be achieved with high odds of success, with adequate living quarters, and with moderate ship and scientific operational costs in that order. Too often operational costs are minimized first and foremost.

First, basically well-suited vessels and sound data acquisition systems must be selected and meticulously maintained and operated. These criteria sound straightforward, but are surprisingly difficult to achieve in a multiple-use environment with rigorous scheduling constraints and ever-present economic restrictions. Some of the data acquisition gear can come aboard with the scientific party, but many systems must be attached to the ship for effective shared use. Special purpose design requirements can make one group's well-suited vessël another group's working nightmare. Fisheries research vessels can suffer from this syndrome in that special features needed for efficient net handling may be incompatible with other research vessel requirements. This applies particularly to fantail design. It is my understanding that there are very few vessels in the U.S. research fleet that are appropriately rigged and configured for fisheries research activities. This is probably an indication of the fact that fisheries research vessels have a number of special design features that the rest of the research community has difficulty with.

What are these features and how might they be accommodated in innovative vessel designs? I'll appeal to my colleagues who work specifically in fisheries oceanography to address this question, but it is one that this working group needs to tackle.

Two special-purpose designs that can play an important role in many coastal environments are the small SWATH (or catamaran) vessels and the "work boat." Fully instrumented versions of either type of craft can acquire a tremendous amount of data per dollar and offer a high degree of versatility. The performance of such activities as NOAA's Coastal Ocean Program would be significantly enhanced by upgrading this vessel class in NOAA's fleet.

What Types of Sampling and Data Acquisition Systems Are Required for Fisheries Oceanography Research Vessels?

Research vessels should be very well suited for obtaining significant oceanographic data with the highest possible likelihood of success. This implies that appropriate data acquisition systems are an integral part of ship's equipment and are also given high priority for maintenance and periodic updates. Traditionally, most data acquisition systems have been brought aboard by scientific parties, installed and troubleshot on a real-time basis. This mode of operation often leads to a significant drop in efficiency if it is gauged in terms of critical data words acquired per ship day. There is a growing consensus in the research community that many of today's critical oceanographic research problems are interdisciplinary in character and demand thoughtful, well-balanced programs of study to further understanding in these areas. In contrast to disciplinary approaches, these interdisciplinary efforts require broader data bases and unique mixtures of variable fields. On a very basic level (dictated by fundamental sampling theorems) it is important to cosample diverse fields so that data grids are collocated in space and simultaneously in time. Otherwise it is impossible to establish covariability relationships. Shipboard data acquisition systems are one of a few technological approaches which currently allow such sampling schemes to be implemented on a practical basis. But doing it well on a demand basis requires careful planning and coordination of effort.

Successful interdisciplinary sampling schemes can be promoted by shipboard data acquisition systems that can operate in parallel at comparable data rates. Historically, this goal has been frustrated by low data rate systems which demand dedicated "wire time" and are deployed and retrieved intermittently. In the absence of parallel winch configurations on winch-independent data acquisition systems, this class of technology disallows collocated, simultaneous sampling of complementary environmental data fields. We must advance beyond such technologies where possible and exploit designs which allow practical joint operations of parallel winch and A-frame configurations.

I envision ships as data acquisition platforms similar in many ways to satellites, but more practically adaptive and controllable. The ocean sciences community has fallen far short of the data acquisition benchmarks established by the atmospheric sciences and space research communities. It is up to us to "pick up the pace" and implement reasonable and consistent advances in the observational end of our science. A prime component of our resource base for this activity involves using ships as observational platforms.

Where can improvements be made? In my view, the big short-coming or blind spot is the implicit assumption that ships can be used efficiently as scientific tools regardless of how well instrumented they are. That is, give a scientific team ship time and they'll come back with lots of good data. It doesn't work that way, everyone knows it, and we're not doing much to improve our plight.

NOAA should commit to making the following shipboard measurements as a matter of routine:

1) Underway pumping system which measures near-surface temperature (T), salinity (S), optical properties (OP's), nutrients (NUTS), biological properties (BP's)
2) Profiling system which measures all the above
3) Dual frequency Acoustic Doppler Current Profiler (150 & 600 khz) to measure currents underway and on station as well as estimating profiles of "acoustic biomass" (backscatter intensity)
4) Meteorological variables (wind speed, direction, humidity, irradiance) at two standard heights
5) Precise navigation data (x, y coordinates and time)
6) Ship motion data (speed, heading, pitch, heave, roll)
7) Satellite remote-sensing data for the operating region should be available through data links in near real-time
8) Buoy data for the operating region should be available through data links in near real-time

All data should be archived using a single computing network (e.g., a local area network of PC's or a minicomputer cluster) at full data rate (~1 hz) to optical disk. Preprocessed average data (1 minute averages) should be available in real-time in both tabular and graphic formats. Daily preprocessed archives and summaries should also be available in near real-time. All data should reside on a PC interactive system hosted by a central data storage and processing node (which might also be a glorified PC or minicomputer).
One can envision modular integrated systems which would do most of the above (minus a few vessel mounted sensors and transponders). These units would

be of modest size and weight (and thus easily shipped). They would employ a standardized architecture (easily serviced or recalibrated at a central facility) and utilize "off-the-shelf" component elements (little prototype development).

Oceanographers spend a great deal of time and effort trying to acquire the above data fields aboard ship and are seldom able to realize this goal. If this data were available as a routinely acquired baseline set, we all could start concentrating upon more specific measurement objectives. This in itself would be a dramatic improvement in the scientific utilization of research vessels. The price would be a modest increment (perhaps 10%) in the future overall ship acquisition and operation budget. The scientific return, in terms of data acquired per ship day, would be dramatic (perhaps a 10-100-fold increase). The increased data return per extra dollar spent would be truly spectacular! We could do this now. Why wait to get this underway? Let's let our ideas and insight limit our understanding of this component of our environment, not a grossly inadequate observational data base.

What are the more specific measurement objectives associated with fisheries oceanography research? Evaluation of fish stocks is an important activity. Larval and juvenile survival studies are also significant components of this research area. Are there other distinct categories that can be named? The first category seems to be the one which requires specialized vessel and equipment configurations that may be at odds with more general usage requirements. How generic are these needs as a function of fishery type and oceanic environment? Will acoustic methods soon (within the next decade or so) supersede or partially replace more traditional methods of sock assessment?

The Great Lakes Environmental Research Laboratory does not have responsibility for research on exploited Living Marine Resources in the Great Lakes, but it does conduct ecosystem-oriented studies of nutrient and contaminant flux impacts on lower trophic levels including forage fish. Scientists at GLERL are currently conducting programs titled Coordinated Ecosystem Research, Pollutant Effects, Exotic Species, and Large Lake Climate and Global Change, in addition to other research activities. These programs all treat aspects of food web dynamics in relation to environmental variability and have substantial field components that must be supported by research vessels. In order to successfully reach our research goals in these areas, we require 150-300 ship days per year on a range of coastal and estuarine vessels. Approximately one half of this time must be supported by a larger coastal vessel (70-100 ft) with greater crew carrying capacity and seakindliness characteristics. The remainder of the ship days can be supported by smaller, higher-speed "work boats." Both vessel types should be fully instrumented with the best possible suites of oceanographic instruments, and should be relatively high speed (15 kts or greater). A premium should also be placed on minimizing operating and maintenance costs associated with these vessels.

We have planned studies of physical-biological interactions and ecosystem variability that require colocated and simultaneous measurements of a broad range of physical, chemical, biological and optical variables guided by near-real-time satellite imagery and meteorological data. It is the concerted opinion of the scientific staff at GLERL that we are severely constrained by the operational characteristics of our research vessels and shipboard measurement capabilities. The success of our planned research efforts for the 1990's hinges upon revitalization of these infrastructural components.

Operating conditions vary significantly with season in the Great Lakes. Practically speaking, ship operations are not feasible (with our current vessels) in winter months due to severe weather conditions and ice cover. The remainder of the year tends to be fully scheduled and coincident, multi-lake ship operations are common in our laboratory research agenda. At present, we employ a second "work boat" with split crew to cover such requirements. The scientists in the Great Lakes community would welcome a modernized, more-capable research fleet.

Conclusions

In summary, my responses to specific questions posed in letter requesting input on this topic are:

1. *Direction of Physical Oceanography in Coastal Ecosystem Research.* NOAA can play a big role in longer-term ecosystem studies over the next few decades. No one entity will be able to shoulder all the responsibility for such studies, but NOAA is in a position to play an expanded leadership role with NSF, DOE, EPA, and MMS each contributing as their mandates dictate. It is my understanding that NOAA will play a central role in that its mandate includes the longer-term observation and stewardship of shelf/slope regions, estuaries and Great Lakes. Longer-term observations are required before the community can improve their understanding of the entire annual cycle, physically, biologically and geochemically, in various geographical regions. If we can't fully understand or predict "simple" fields like mass and heat, we will never

be able to tackle the tougher vector fields (momentum) or biologically active fields (nutrients, plankton biomass, etc.). After we get the annual cycle under control (in numerous fields and geographical settings), then we are prepared to understand more subtle, gradual rectification of the more energetic annual cycle. These activities will all require longer–term interdisciplinary data sets. Let's note here that the phase "longer–term" is relative and for coastal ecosytems one independent episode or time step may take several years. In this context, our "longer–term measurement efforts" are really equivalent to "flash in the pan" experiments.

2. *Anticipated Rate of Growth.* Technologically and scientifically faster than we've ever experienced. Future shock! But I don't think we will see funding and "activity" keep pace with the technology and ideas generated by new observations and insights. One already has that sense at the close of the 80's. I think our science will progress at an unprecedented rate. Unfortunately, the ratio of what–we–could–do to what–we–are–doing will also grow at a high (and frustrating) rate. Right now we are putting a serious drain on the working community just planning what we hope to do. If these plans get funded at even a modest level, there won't be enough horsepower to get the work done effectively, especially if we take a brute–force approach (i.e., use old technology, labor–intensive methodology, untrained personnel, etc.).

3. *Changes in Mixes of Technology.* Traditional shipboard observations will gradually be replaced by advanced shipboard technologies (including acoustic remote–sensing techniques). We all have some homework to do first so we can establish and come to a consensus on what can or can't be done with technologies or various sorts. I don't think ships are going to be replaced by satellites any time soon, especially in interdisciplinary studies. I do think that shipboard data acquisition could easily become more "robotic" in character. I grimace every time I recall scenes from past cruises...senior scientists (500$/day each after overhead and benefits) on the fantail of a 10K$/day ship patching up some ancient piece of sampling gear while other senior scientists, engineers, technicians, etc. await their turn to occupy the fantail.

4. *Monitoring.* I think short–term versus long–term is a matter of perspective. A sixty year time sequence is statistically equivalent to a one–hour laboratory study if the processes of interest have time scales of one year and one minute respectively. It will take us another 50–100 years (if we start today with a serious effort) to sort out some of these interannual and climate variability issues. After we leave this exploratory, pilot–study phase, the intellectual progeny of our grandstudents can worry about whether or not it will be worthwhile "monitoring" such processes.

5. *Regional Needs.* The coastal regions of the U.S. can be split up into 14–20 relatively distinct regimes (viewed from a physical perspective). They all have their own set of characteristics, interesting phenomena, and problems. I don't think we can discount any of them in terms of ecosystem studies. The same goes for the major ocean basins.

6. *Anticipated Changes in Real–time Data Analysis and Integration of Data from Other Sources in Near Real–time.* Members of the community are already doing this integration. It pays off scientifically and economically so we need to do it better (more appropriate technology, and better prepared scientists, engineers and technicians) and more consistently (do the stuff we can do now, on a pilot basis, all the time) while continuously upgrading our capabilities.

Vessel Needs for the Northwest Fisheries Science Center

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Introduction

The research for the next thirty years envisioned by the Northwest Fisheries Center (NWFC) covers three basic vessel capabilities: 1) estuarine, 2) coastal, and 3) offshore. The estuarine habitat includes the protected bays, sounds, and estuaries of the region (Puget Sound, Lower Columbia River and estuary, and the tidal estuaries of Grays Harbor, Willapa Bay, Yaquina Bay, and Coos Bay). The coastal habitat includes the Strait of Juan de Fuca and the waters near the Washington and Oregon coasts. The offshore habitat involves the deeper waters stretching across the Continental Shelf and, possibly, down the Continental Slope for certain benthic resources, which require deepwater fishing techniques.

The Northwest Fisheries Center does not currently have the full range of vessel requirements typical of the other four NMFS centers. This is an anomaly resulting from decisions made in 1988 when the former Northwest and Alaska Fisheries Center was divided into two centers, and the Alaska Fisheries Center (AKFC) retained responsibility for conducting at-sea surveys of fishery resources in both the Northwest (Washington and Oregon) region and the Alaska region. Because of the likelihood that the NWFC will be assigned resource survey responsibilities for the Northwest region at a future time, our long-term projection of vessel requirements is based on a scenario wherein: the AKFC conducts fishery resource surveys within the Northwest region until January 1995, and, thereafter, all NMFS at-sea fishery research within the Northwest region will be the responsibility of the NWFC, with the exception of cooperative cruises with the AKFC and Southwest Fisheries Science Center (SWFC).

Near-Term (1990–95) Ship Requirements

Looking at research activities anticipated for the next five years, the estuarine efforts will continue to be met with center-operated, under-65-foot-long research vessels (i.e., HAROLD W. STREETER, SEA OTTER, EGRET, NERKA, COLUMBIA). While these vessels will need to be modernized, replaced, or expanded to meet NOAA and cooperative state-federal efforts, they will probably continue to be managed by the NWFC. They will be engaged in resource surveys (trawling, purse and beach seining, pots, dredging) and environmental studies (trawling, bottom sampling, diving) in shallow, protected waters, usually as day-boat operations.

In the nearshore habitat somewhat larger NOAA fleet vessels are needed which can provide more endurance, seakeeping ability, habitability, and can carry heavier sampling/scientific equipment. For the next five years we have assumed that our field needs will be met with existing NOAA platforms; Table 1 sets forth our anticipated needs.

The NWFC has been using the NOAA Ship McARTHUR (S-330) on the west coast and the NOAA Ship FERREL (R-492) on the east coast for the National Benthic Surveillance Project of NOAA's National Status and Trends Program (NS&T) in the coastal areas. While much of the NS&T sampling occurs in protected habitats, the overall magnitude of the field operations (multi-boat operations and frequent open-water transits) requires a Class III or IV general-purpose vessel. For example, on the McARTHUR (and the NOAA Ships FAIRWEATHER and DAVIDSON for similarly-implemented damage assessment surveys) we conduct multi-boat operations with the vessel at anchor or alongside a pier while two to seven launches (19–29 feet length) are deployed up to 25 miles away conducting fish and sampling operations.

Working in close cooperation with the Pacific Marine Center, we have developed a very practical means of benthic sampling using a 25-foot Otter trawl and various bottom sediment samplers (i.e., box corers, VanVeen and Smith-McIntyre grabs) from converted 29-foot Jensen hydrographic survey launches. A hydraulic A-frame was attached to the aft deck and a commercially-available fisheries winch (600-foot capacity) and a windless were mounted on a platform in the cockpit. When a Jensen launch is dedicated to research uses, the hydrographic survey instrumentation is removed providing additional inside cabin space for scientific activities. Using quick-disconnect hydraulic lines, we have also successfully modified these survey launches with a salmon gill-net reel and with halibut long-line pulling gear without modifying existing hydrographic survey capability. These launches have a complete suite of navigation equipment (LORAN, radar, fathometers, sextants, radios) for safely working away from the mothership; fish are frequently transported rapidly from the field in live boxes using 19-foot outboard launches. A Class III vessel carries two Jensens (or equivalent) and one 19-foot outboard for routine field operations, and a Class II can carry four Jensens and three outboards.

Offshore research efforts have not yet required direct at-sea operation of NOAA deep-sea vessels by the NWFC since near-term resource assessments are being conducted by the AKFC and SWFC using the NOAA Ships MILLER FREEMAN (R-223) and DAVID STARR JORDAN (R-444).

Other regions in which the NWFC conducts research also have specific habitat-driven vessel characteristics around which we have successfully designed our research operations. Work in Alaska on the National Status and Trends Program has required high-endurance platforms, such as the MILLER FREEMAN, for sampling in the Chukchi and Bering Seas and the open Gulf of Alaska. We have used and plan to continue to use from time to time specialty vessels, such as the NOAA Launch 1273 in the Beaufort Sea and the multi-boat operations of the NOAA Ships FAIRWEATHER (S-220) and DAVIDSON (S-331), in the ongoing EXXON VALDEZ natural-resources damage assessment program.

On the east coast, the National Status and Trends Program uses the NOAA Ship FERREL which is well-suited, due to its shallow draft (6 feet), to work in many shallow bays and estuaries. Because vessel configurations are different, our mode of field operations on the two coasts is also different. On the east coast we usually employ single-boat trawl operations directly from the FERREL, except in very shallow embayments (<10 feet). We do not believe that it is necessary to standardize hulls between the two coasts since the habitats in which they operate are significantly different; however, we feel strongly that we should have comparable sampling equipment, gear, and laboratories on whatever platform we use.

Future Vessel Considerations

Trying to look ahead thirty years leads to one very important consideration -- the need for the NOAA fleet to remain flexible. We need flexibility of the individual platforms to accommodate changing research needs and flexibility of Office of NOAA Corps Operations (ONCO) policies to shift platforms to locations and projects where they can be best used. While mistakes have made in the past trying to design platforms that attempted to be all things to all people, basic utilitarian designs are desirable, especially when looking ahead to

Table 1. Northwest Fisheries Science Center Vessel Requirements.

TIME	CAPABILITY	PLATFORM	DAS	LOCATION	PURPOSE
NEAR-TERM 1990-1995	COASTAL	• McARTHUR	50	West Coast	NS&T
		• FERREL	70	East Coast	NS&T
		• FAIRWEATHER/ DAVIDSON	80	Alaska Coastal	Special Studies
		• Charter	30	East & Gulf Coasts	NS&T, Special Studies
	OFFSHORE	• MILLER FREEMAN		Wash/Oregon	Stock Surveys (AKFC)
		• DAVID STARR JORDON		Wash/Oregon	Stock Surveys (SWFC)
		• Charter			
OUTYEARS 1995-2020	COASTAL	Class III & IV	120 60 60	West & East Coasts	Environmental Studies Coastal Ocean Studies
		Class III	100	Wash/Oregon	Stock Surveys
	OFFSHORE	Class II	60	Wash/Oregon	Stock Surveys

the uncertainty of the next thirty years. One of the strengths of the NOAA fleet has been its ability to adapt a well-balanced mix of vessel sizes and capabilities to a number of new initiatives over the past two decades; the mix of sizes and designs should be maintained in order to meet the challenges of NOAA's future oceanic missions.

Beyond 1995, we foresee needing vessel capabilities equivalent to existing general-purpose Class III (McARTHUR/DAVIDSON) and Class IV (FERREL) platforms for NWFC coastal, environmental, and special studies (Table 1). A general-purpose Class III oceanographic research platform should support classical physical, chemical, and geological sampling programs as well as more limited biological oceanographic/fisheries research which would not require a dedicated fisheries research vessel (i.e., marine mammal surveys, plankton sampling, National Status and Trends Programs, Coastal Ocean Program, offshore krill studies) within several hundreds of miles of shore.

We will need access to a research vessel capable of carrying 8–12 scientists for 14–25 days, modern and comfortable working and living spaces, and provisions for collecting a wide variety of marine samples and data. The eventual replacement of existing Class III/IV vessels would provide an excellent opportunity to design a truly multipurpose platform containing a core of support facilities (hull; power plants and utilities; quarters and messing for crew and scientists; office, storage, and medical spaces; navigation, communication, and computer systems) to which are added modular deck-sampling equipment (winches, cranes, live tanks, launches) and modular scientific vans specific to the project(s) embarked. If these universal modular units are designed to insert into specific receptacles onboard, they become a part of an integrated system. Being portable, these vans can also be used on different platforms and as an adjunct labs at their home institution. Like the modular deck vans, which are becoming more specialized, the deck sampling units can be exchanged between platforms instead of being hauled around on the vessel as dead weight. If possible, provision should be made for construction with a convertible stern ramp (removable deck boards and stern rail) and with a centerboard, should current electronics modifications on the MILLER FREEMAN prove successful.

Design consideration should be directed to automation and safety to reduce crew size while maintaining operational capabilities. For instance, the wheelhouse should have as close to 360° visibility as possible with an unobstructed view of the stern area, engine controls on the bridge wings, remote controls for the trawling equipment, and remote readouts in engineers' staterooms which might help reduce crew size. However, as crews are reduced and ship schedules increased, provisions are necessary to allow proper and timely maintenance of ship's systems while in port by the ONCO marine centers.

Future fishery stock surveys off the Washington and Oregon coast require a size and type of platform not currently available to the NWFC. A new Class IV platform could serve as a multipurpose fishing and oceanographic research vessel built on a proven hull design using state-of-the-art automation and safety features. The NWFC needs access to a medium-endurance fishing vessel (8–12 days at sea) having moderate draft (12–15 feet; deep enough for open-water stability but shallow enough to cross coastal river-mouth bars), and medium-size (130–150 feet overall). It could be used for short cruises from small coastal ports carrying 6–8 scientists and a crew of 8–10 with sufficient seakeeping ability to ride out marginal weather but able to run for port in heavy weather. Such a vessel should have protection of a large open working deck aft and a sufficiently low freeboard aft to safely allow for over-the-side pot or trap, long-line, purse-seine, and gill-net operations. It should be built on a stock hull and equipped with commercial fishing gear (stern-ramp, deepwater trawl system, and cranes) as well as an oceanographic winch in order to duplicate fishing industry techniques where appropriate. Design considerations need to be given to versatility of use and to proven fishboat characteristics.

For this vessel size the ability to add modular scientific vans may be severely restricted so that laboratory spaces must be readily converted to various types of operations. However, it should still be feasible to have modular-mounted winches and cranes which would allow a certain amount of exchange of sampling gear between cruises (i.e., heavy trawl winches, CTD winches, oceanographic and plankton winches, hydroacoustic and faired-conductor cable specialty winches, pot and long-line pullers, gill-net reels). For a vessel dedicated to west coast fisheries research, the design features and uses should influence the crewing needs. The programmatic use of such a vessel would reflect seasonal climatic conditions where field operations offshore would probably take place between late spring and early fall while inshore research/maintenance would occupy the stormier winter months.

The NWFC needs the deepwater fishing capability of a Class II stern-ramp trawler for roughly 60 days a year for offshore stock surveys in areas inaccessible to the smaller Class IV fisheries research vessel.

General Suggestions For Future NOAA Fleet Needs

Existing Hulls with FRAM. Since the bulk of the NOAA fleet was built and commissioned in the 1960's, most hulls are reaching the limits of their service lives. However, due to the generally high degree of maintenance exercised by the ship's crews and by the farsightedness of the ONCO marine centers, the vessels are in a higher state of readiness than comparable Navy, Coast Guard, or UNOLS units. Therefore, at least several of the units are susceptible to extensive FRAM (Fleet Renovation and Modernization) which could extend many of the mid-1960 hulls for another two decades of faithful service. For example, it may be feasible to take a Class III vessel, such as the DAVIDSON or McARTHUR, and insert a 30-40 foot-long midsection thereby increasing berthing, messing, and scientific spaces while increasing the seakindliness of the design. If you add re-engining of the mains and auxiliaries, upgrade water and electrical service, and hydraulic services for modular oceanographic equipment (winches and cranes) and vans, the result would be an entirely modern research platform on an existing well-designed and serviceable hull.

Experimental Platforms. A new type of hull form starting to receive more attention is the SWATH (small-waterplane-area-twin-hull) design which combines extraordinary seakindliness with an unusual ability to sustain speed in degrading seaways. This improves the window of operations, decreasing transit times and reducing seasickness, thereby increasing personnel productivity. A SWATH vessel uses two cylindrical hulls which run submerged under the water's surface, aided by inwardly facing gyro-stabilized trim fins. The combination of lift from the buoyant pontoons, the clearance between the design waterline and the bottom of the main (or wet) deck, and the automatic fin-control system means that such a vessel escapes collision with most waves.

For instance, the 67-foot-long FREDRICK G. CREED, recently built by SWATH Oceans Systems of California, is being evaluated by NOAA and the Canadian Department of Fisheries and Oceans for oceanographic research and hydrographic surveys. The 80-ton full load displacement design permits transit speeds of 20 knots and service speeds to 26 knots with the equivalent loading of 125 passengers. While transiting at 13.5 knots in sea state 7 conditions (50-knot winds and 25-foot beam seas) off New York, the maximum occasional heel was only 10°. A larger vessel on the planning boards would be 116 feet long; maximum beam of 45 feet; trimmed running draft of 9.7 feet; maximum draft (loading) 11.5 feet; full load displacement of 170 tons; 4000 square feet of space for labs, offices, galley, and berthing; 30-knot service speed at 4500-5500 bph; $5 million (bare hull and machinery); and 9-12 month construction time.

In addition to the higher transit speeds and increased stability over a monohull, the SWATH design allows for a center well with winches and cranes located outboard over (or inside) the twin hulls. Such a design could be advantageously used in coastal areas of northern California, Oregon, Washington, Southeastern Alaska, and the Gulf of Alaska for short-duration cruises (3-5 days) where a fast, stable, smaller-sized platform can operate in marginal weather and seek shelter (<12-foot draft) from severe weather.

The higher speeds attainable with a hull design (as well as with a true catamaran or a more-expensive hydrofoil) provide greater range for the same time, although at a higher fuel consumption. In some cases, this range/time parameter could be important, such as providing ground truth for satellite monitoring which will undoubtedly increase with global monitoring programs. Likewise the servicing of ocean buoys may require fast vessels; the use of large seagoing research platforms dedicated to funded oceanographic research for routine buoy servicing may not be cost-effective. A limiting factor to building larger SWATH designs is the hull shape which can reduce maneuverability.

Small Boat Utilization. For many environmental monitoring and damage assessment programs in nearshore waters, the use of multiple small boats (i.e., Jensen hydrographic launches) has been unique to NOAA research. The modification of these launches to conduct fisheries and oceanographic sampling has greatly expanded our ability to survey numerous shallow-water habitats unapproachable by the large research vessels. In some cases, due to the experience and competence of the NOAA teams, fishery surveys have been conducted from survey launches without losing any installed survey capability. This points up the desirability of maintaining a collection of modern ship-deployed, multipurpose launches. In some cases, it might be possible to expand the versatility of some ships (i.e., Class II) by carrying various combinations of launches and vans (in the launch davit spaces) depending on specific program needs. These launches need to be kept up to date on state-of-the-art hydrographic and navigation equipment in support of the various programs.

Fisheries Oceanography

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Direction of Fisheries Oceanography Research

Research in fisheries oceanography will expand into the foreseeable future. The rate of expansion is dependent on results of research presently underway or expected to be initiated during the next two to five years. If the result of these investigations identify the relationships between the ocean environment and fisheries productivity, and suggest that predictive capability of stock abundance can be improved then research in this discipline will greatly increase. On the other hand if findings do not improve understanding of the underlying mechanisms controlling abundance, the direction and level of effort in fisheries oceanography will differ significantly.

At present there are two somewhat different areas of investigation in fisheries oceanography. The area currently receiving attention focuses on identifying the mechanisms controlling abundance and species composition both on the short–term (interannual) and the long–term (interdecadal). The second topic under investigation is understanding how fish distribution is affected or influenced by physical features of the ocean. Obviously, these are not mutually exclusive areas of research; however, at present, the former deals primarily with early life history stages, the latter with adults. Whereas research on distribution will, because of its implications to harvesting, probably continue in the future, research on mechanisms controlling abundance will continue and expand only if results demonstrate the need. Thus, the next 10 years are critical in determining the direction of the discipline.

Assuming the current program proves worthwhile, five major elements consisting of seven large–scale, multidiscipline investigations will be underway during the next ten years. These will consist of studies that integrate physical oceanography and climatology with biological oceanography, ecology, and fisheries biology. The number of investigations will decline to about four in 15 years, but a larger number of smaller–scale investigations will be initiated. These will focus on particular forcing functions for different species or communities. All investigations will include intra–NOAA and interagency cooperation as well as major contributions from the academic community. Leading the way in this area of research will be NOAA's Coastal Ocean Program and the National Science Foundation's GLOBEC program if the process–oriented efforts are not pursued, then most research will be pursued within NOAA with some activity from academia and the fishing industry (recreational and commercial).

Anticipated Rate of Growth

As stated, the rate of increase is dependent on the incoming data. In my opinion, growth will increase during the next five years at a rate of $2 million a year. Once the ramp–up period is completed the level of support should remain constant except for additions needed to keep up with inflation. The research and associated monitoring that will eventually be necessary should continue well into the 21st century.

If the past 10 years can serve as a baseline for the rate of technological advances, then the changes that will be forthcoming are difficult to imagine. During the next decade and beyond more and more information will be automatically processed. Net and other cast–type sampling techniques will be replaced increasingly by smart samplers that will provide data in real–time. Advances in acoustics, laser technology, and video equipment integrated with autonomous vehicles will provide enormous data sets that will require very high speed computers onboard. Such equipment will be large to begin with but should be reduced in size in out years. Prototypes of these types of equipment are current being developed. The rate at which they are developed and made operational is dependent of funds rather than ideas.

Changes in Mix Between Traditional and Advanced Observation Technology

Although one can anticipate major changes in technology needed to pursue fisheries oceanography, few of the advances preclude the use of ships in favor of pure remote sensing such as satellites or buoys. As the discipline advances and technology becomes available, there may come a time when preprogrammed autonomous powered buoys and submersibles could be used for monitoring purposes. Such hardware would be analogous to weather satellites. Unlike weather satellites, a network will be needed to link the unattended equipment to shore–based forecasters. There will be a continuous need for ships from which experimental data–gathering devices can be deployed. This will necessitate ships with multiple winches and large areas for servicing and storing sophisticated electrical equipment.

Mix Between Short-Term Studies and Long-Term Monitoring

Initially (5-10 years) the vast majority of the fisheries oceanography effort will concentrate on short-term process studies. Monitoring efforts will gradually increase as we are able to identify forcing functions that control abundance. There will also be a need to continue some of the more important time series presently being maintained by NMFS. These form the basis for long-term studies on the effect of climate on fish community structure and abundance.

Geographic Areas of Interest and Time Constraints

Fisheries oceanography research in NOAA will be pursued in the Gulf of Alaska, Bering Sea, California Current, northwest Gulf of Mexico, South Atlantic Bight, Gulf of Maine/Georges Bank, Lake Michigan, and the various portions of the Gulf Stream and adjacent coastal waters and estuaries. The exact location(s) within these areas will be quite limited. For example, the Gulf of Alaska study area is centered in area of the Chilikoff Strait. Areas were selected because they represent the major ocean systems identified in the NOAA Recruitment Fisheries Oceanography Program Development Plan.

Unlike many fisheries investigations that are associated with adult fish, fisheries oceanography research, in general, is constrained by time. Most of the research deals with early life-history stages, eggs-to-juvenile stages (year 1). As such virtually all sampling must be conducted and concentrated within relatively narrow timeframes dictated by the spawning season. The time for sampling is dependent on the species or species complex under investigation. For example, the Southeast Atlantic Bight Recruitment Experiment (SABRE) will concentrate sampling in the late winter, the time of menhaden spawning. Similarly, FOCI field work is pursued in April and May when pollack-spawning concentrations occur. The field season, although relatively short, requires vessels to be on-station continuously for three to five months, depending on the organisms under investigation.

Data Analysis

As sampling gear becomes more efficient and dependency on net samples diminishes, the closer we will come to real-time analyses. To accommodate rapid analysis, computer capability must be shipborne. One of the major improvements that is necessary for fisheries oceanography research is the ability to change sampling in response to the dynamics of the organisms. If following a larval patch is important, it is critical to know that the patch is moving and to adjust sampling. This cannot be done very well at this time. The development of new sampling equipment will reduce present manpower requirements not only shipboard but also on land.

Ship Requirements

Fisheries oceanography being a hybrid of fisheries and biological and physical oceanography requires vessels that can accommodate the needs of each of these disciplines. If technology advances as anticipated, requirements will change from the traditional fisheries survey to a "typical" oceanographic survey vessel. The singlemost important technical advance that dictates vessel design is the ability to identify species and quantify fish abundance without the use of nets or traps. If such a technological breakthrough does not take place, the design of fishery research vessels cannot change substantially from what now exists.

Assuming that technology does move in the "right" direction, there will be no need to have vessels uniquely designed for fisheries oceanography.

Future Research and Associated Vessel Requirements of the Northeast Fisheries Science Center

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Introduction

The primary goal of the Northeast Fisheries Science Center (NEFC) research programs is to understand the structure and dynamics of the Northeast Continental Shelf ecosystem, and to assess the effects of natural and anthropogenic factors on fish and shellfish populations within this system. In order to achieve this goal, the Center has developed a long-term research program consisting of a combination of three major types of activities requiring vessel support: 1) specific process-oriented studies of relatively short duration (weeks/months); 2) directed studies requiring continued effort for multiyear periods; 3) monitoring on an annual/seasonal basis.

Monitoring and process-oriented/directed studies are complementary, and all need to be conducted concurrently in a carefully integrated long-term program. Identifying causal linkages among components cannot be accomplished without directed research programs designed to test hypotheses. Conversely, the broader context afforded by monitoring and long-term directed programs is essential for corroboration and interpretation of process-oriented studies.

For example, testing specific hypotheses about the relative importance of physical and biological mechanisms of natural mortality in the first year of life will require a series of intensive small-scale (weeks, months) recruitment experiments of the process-oriented category. Each successive experiment builds on the results of the previous studies, narrowing down the range of possibilities, and contributing to a definitive test of a set of hypotheses about the mechanisms controlling first-year mortality. In addition, complementary directed studies on a somewhat broader scale (multiyear) will be required to determine density-dependent effects on critical population parameters such as growth, maturity, fecundity and predator-prey functional relationships, over a range of population levels. These data are essential as inputs for multispecies models of long-term effects of various harvest strategies.

The core NEFC monitoring program measures changes in relative abundance and species composition of fish and shellfish communities and basic demographic characteristics (growth, mortality, reproductive output, recruitment) of exploited populations over time. In order to maintain comparability of abundance indices within a time series, standardized or intercalibrated vessel/trawl and dredge-gear combinations are essential for resource surveys. The monitoring program also provides information on other relevant biotic information (e.g., distribution/abundance/composition of the total fish community, as well as phytoplankton, zooplankton and ichthyoplankton communities, fish food web, marine mammals, etc.) and physical/chemical factors. Monitoring provides an empirical quantitative description of long-term (years, decades) and large-scale changes in the ecosystem. This is a necessary context within which to interpret results of and evaluate hypotheses about causal linkages and mechanisms controlling recruitment and yield potential.

In view of the broad scope of the NEFC research program, vessels are needed which have the capability for sampling a wide array of marine fauna. Of critical importance are the space and operational capability for large specialized gear (commercial-size trawls and dredges with associated deck space, ramps, gantries, net reels, large wet labs, etc., not generally found on oceanographic vessels) for capture and onboard processing of large catches of fish and shellfish. Other capabilities needed for sampling the physical environment (water column, sediments) and other biota (plankton, benthos) are similar to those of modern oceanographic vessels with modern winches, articulated cranes, lab spaces, etc., although the specific placement and arrangement might differ due to the trawling requirements.

The major kinds of sampling projected by NEFC for the future are listed below with associated types of scientific gear for the different categories of research. Approximate design specifications for the vessel and equipment needed to handle the scientific gear and operations are given in the summary tables of Chapter III of generic scientific mission requirements for offshore and inshore research vessels needed by NEFC.

Monitoring Phase

Traditional Methods. For the foreseeable future, it will be necessary to continue broad-scale assessment of distribution/abundance/composition of selected marine populations (fish, shellfish, and planktonic communities) using capture gear such as nets, dredges and traps. In order to maintain comparability of abundance indices within a time series, standardized or intercalibrated vessel/trawl and dredge gear combinations are essential for such monitoring surveys. Similar considerations apply to sampling plankton with nets. The key criterion here is comparability even though the abundance indices may only be relative as opposed to absolute. The emphasis in the NEFC monitoring (MARMAP) surveys is on multispecies coverage of the fish and plankton communities. These surveys provide an invaluable index of long-term changes in these ecosystem components at the same time that they generate information on resource stock status necessary for ongoing assessments and near-term management decisions.

Zooplankton monitoring provides information on a key component in marine ecosystems that includes the youngest life stages of fish and the herbivorous zooplankton which represent their food. The NEFC zoo- and ichthyoplankton monitoring with bongo and CPR nets provides a baseline for use in time series analysis and models to characterize variation in the plankton community on a seasonal and interannual scale. These data are necessary for evaluating anomalies or long-term trends for indications of changes in the structure of the ecosystem. A large deviation from the expected biomass of a dominant component could be an indication that new factors (e.g., overfishing, pollution, climate change) are altering the structural relationships measured by the time-series model. In addition, these data are necessary as a context for extrapolating results of process-oriented studies on predator-prey interactions which are vital to survival of young fish, where composition as well as biomass of prey populations may be critical.

CPR surveys provide regular monthly coverage of established SOOP routes across the Gulf of Maine (28-year time series) and the Mid-Atlantic Bight (12-year time series) with zoo- and phytoplankton sampling and associated physical parameters. This program supplements the broad-scale MARMAP surveys on dedicated fishery vessels with monthly data on the plankton populations in the southern and northern extremes of the Northeast Shelf ecosystem.

Physical environmental parameters (primarily Temperature and Salinity profiles with state-of-the-art CTD instruments, XBT's, etc.) are routinely collected concurrently on monitoring surveys for correlation with biological data, as well as for building up a time series of basic physical data on shelf water properties. However, other approaches (arrays of moored buoys together with satellite imagery) are proposed for synoptic and high frequency monitoring of physical and biological (phytoplankton) oceanographic properties. These, together with shipboard coverage, will provide better definition of interannual variations which will improve our ability to correlate environmental changes with changes in fish stocks and their food supply.

Another type of monitoring proposed for the Northeast Shelf ecosystem is contaminant loading in several commercial species of bivalve mollusks. Bivalves accumulate both metals and organic compounds in their tissues, and contaminant loadings may be expected to increase over the long term due to seaward transport of contaminants from estuarine and nearshore areas. It would be possible to construct meaningful "benchmarks" at selected shelf locations for assessing trends or catastrophic pollution events. Collection of specimens would be with traditional shellfish or benthic gear from fishery research vessels.

Additional monitoring in the Northeast Shelf ecosystem, which must be expanded and continued into the future, is for apex predators, especially marine mammals, birds, and large pelagics (sharks). Marine mammal and bird sightings should be systematically recorded on line transects during routine fish surveys; these observations will add useful information to the data base on distribution/abundance of these species which consume a significant fraction of fish production. However, additional surveys on research vessels will be necessary to provide a more precise estimate of marine mammal abundance to comply with statutory requirements for marine mammal/fishery interactions. Also, special inshore surveys will be required to address related questions for harbor porpoise and harbor seals.

The large pelagic fishes (large sharks, tunas, billfish) are another important group of apex predators for which assessment is severely hampered by lack of a fishery-independent monitoring program. These large pelagic predators also play an important role in the ecosystem, but quantitative evaluation of this role has been difficult due to lack of good abundance data. Standardized line trawl surveys of the Northeast Shelf and adjacent shore and Gulf Stream waters at regular intervals (every second or third year, if not annually) would be needed to provide abundance data; these would require significant amounts of shiptime (45-50 days per survey).

"New" Methods. Additional methods of monitoring ecosystem properties of importance to fishery research include such approaches as moored instrument arrays, hydroacoustic methods, various towed instrument packages, and remote sensing. Although further technological advances are still needed, many operational instruments are commercially available and being applied to marine research, and, in that sense, they are not "new." However, NEFC has not had the resources to fully utilize these technologies. They have a clear role in ecosystem monitoring with important implications for fishery research, and will require sampling aboard research vessels for sea- truth calibration as well as monitoring/assessment of variables heretofore not feasible with traditional methods.

For example, dual-beam hydroacoustic techniques now available can be used to provide continuous real-time data on abundance and size distribution of ensonified populations ranging in size from large zooplankton to fish. These methods are needed, in particular, to help assess distribution and abundance of pelagic fish stocks. In addition, micronekton (late larval and juvenile fish, mysids, euphausiids) which are difficult to sample quantitatively with nets can be detected readily with higher frequency sounders. Still higher frequencies can detect larger copepod species of the zooplankton community. These components should be included in the suite of measurements taken on pelagic and demersal fish-monitoring surveys. Although the total days at sea for such monitoring wouldn't necessarily increase, the instrumentation requirements and scientific complement to run them would be increased.

Still another method involves towed body samplers which provide for continuous underway sampling of various biological and physical parameters. One application proposed for the Northeast Shelf region is to purchase and deploy the Undulating Oceanographic Recorder (UOR) for use on the SOOP runs. The UOR contains a CTD and a chlorophyll a sensor in addition to the continuous plankton recorder, and covers a programmable depth range collecting physical data and biological samples throughout that range. Deployment of the UOR on routine monitoring surveys by fishery research vessels would enhance the information on vertical distribution of zooplankton; again sea days would remain the same, but scientific complement and space requirements would be greater. Addition of image analysis technology to towed body samplers eventually may augment our capability for monitoring plankton populations by detecting small-scale distribution patterns (aggregations) in real time, thereby allowing for more efficient sampling strategies along standard transects, as well as possibly reducing the manpower requirements for sorting and identifying zooplankton samples.

Still another "new" approach is a moored monitoring system for the Northeast Shelf region. For many aspects of the physical and biological environment of this region the seasonal and short-term variability are much greater than interannual changes. Consequently, precise determination of interannual variability and of longer-term climatic change will require nearly continuous measurements to allow averaging and comparisons on appropriate time scales. The temporal resolution necessary for these measurements could not be obtained from shipboard sampling. However, such measurements can be made by a system of moored instruments at a few locations, since interannual variations in shelf water properties are coherent over large areas within the Northeast Shelf ecosystem. Properties which could be measured easily at various depths would include temperature, salinity, oxygen, and chlorophyll. These measurements relayed to shore stations by telemetry via satellite would provide valuable real time information on stratification and occurrences of unusually heavy blooms of algae which are relevant to problems associated with anoxic events or biotoxins in the environment and seafoods. These moorings would not reduce the core shipboard monitoring program, but they would enhance the usefulness of the broader-scale data collected on the ships. Furthermore, they could increase the efficiency of vessel operations, for example, by early warning and location of hypoxic conditions which could lead to a need for a contingency cruise to document anoxic shellfish mortality.

In addition to moored instrument arrays, there is a need to plan for a program of monitoring chlorophyll biomass as well as temperature at the sea surface via satellite. Phytoplankton standing crop and annual production are ultimately linked to fish production. We need to begin to develop an understanding of this coupling via empirical monitoring as well as experimental and modeling studies, in order to help evaluate long-term effects of habitat degradation or climate change on fish production. A satellite surface-pigment-measurement program could also identify red/brown tide extent and help evaluate the long-term effects of coastal eutrophication on phytoplankton populations which can have serious impacts on shellfish and finfish stocks and fisheries in coastal and, even, shelf waters.

The moored instrument arrays would quantify the high frequency temporal changes in chlorophyll, and the shipboard cross-shelf transects (included in the proposed standard monitoring protocol) would measure the major cross–shelf gradients and vertical profiles of chlorophyll as well as species/size composition and periodic ^{14}C pp measures, thereby providing the sea truth necessary for calibration and interpretation of the remote–sensing data on phytoplankton pigments. Each type of sampling by itself has significant limitations, but when integrated into a pooled data base, linkages can be established between the various temporal and spatial scales. The integrated data can then provide a significant new basis for measuring change in phytoplankton production and its linkage to LMR production.

Process–Oriented/Other "Directed" Studies of Limited Duration

As noted earlier, high–intensity studies over small temporal and spatial scales, and other directed studies of limited temporal scope, are a part of the long–term fishery research strategy of NMFS. These studies are designed to quantify the functional processes and types of coupling between different ecosystem components that support the living marine resources. Without them, it will be impossible to investigate the relationships of ecosystem structure to ecosystem function.

An example of an important category of process–oriented studies are high resolution site specific experiments on predator–prey interactions involving o–group fish to elucidate factors controlling natural mortality in this critical pre–recruit life stage. Another important category of directed study involves periodic documentation of changes in demographic properties of selected fish populations with changes in population density in relation to changes in exploitation, environment, or habitat. This category includes studies which go beyond the scope of monitoring to determine stock identification (tagging, etc.) or changes in spawning patterns and reproductive output that occur over time.

It is difficult to accurately project the scope and duration of such studies that will be needed for the next 30 years. However, it is certain that there will be a continuing requirement for a significant commitment of ship time dedicated to these types of studies in support of the NMFS mission. The studies will employ all of the shipboard sampling capabilities needed for monitoring as well as many other specialized "high–tech" instruments needed for high–frequency precision measurements and operations. Specific NEFC studies proposed for the next 5 to 10 years and associated vessel/gear requirements are described briefly below. These illustrate the type of fishery research vessel capabilities that will be required into the next century.

Eutrophication of Coastal Waters. Evidence is accumulating for excessive nutrient loading of nearshore water of the Northeast Shelf ecosystem, and a seaward advance of eutrophication resulting in an apparent increase in the frequency and extent of phytoplankton blooms. These are associated with an apparent reduction in the mean–size fraction of phytoplankton species, oxygen depletion, and losses of shellfish resources due to anoxic mortality and elevated tissue levels of biotoxins (PSP). An anoxic event in the Mid–Atlantic Bight in 1976 resulted in mortalities of surf clams, scallops, lobsters, and finfish amounting to a loss of over $200 million. Studies are proposed to test hypotheses about the linkage between coastal eutrophication and toxic blooms and their effects including: poisoning of marine resources, impairing food webs involving larval fish, and causing anoxic conditions. In addition, a cooperative Northeast Fisheries Science Center/Woods Hole Oceanographic Institute study is proposed to investigate the recent occurrence of PSP outbreaks on Georges Bank which threatens the $100 million scallop industry on the Bank.

Research vessels are needed for benthic sampling of Georges Bank sediments for occurrence of *A. tamarensis* cysts. Vessel time will also be needed for process–oriented field studies on effects of shifts in phytoplankton population structure on larval food webs.

Recruitment Studies. Better understanding of the recruitment process in fish and shellfish is perhaps the singlemost important fishery research objective in NMFS, since it is critical to modeling long–term effects of various harvest strategies, climate change, and habitat degradation on fishery yield potentials. Recruitment of any one species is a complex process involving multiple interacting biological and physical factors, including many life stages and other species as well as the size/structure of the spawning population. The complexity will require clarification of mechanisms affecting interannual variability as well as average levels of recruitment. Consequently, it represents a long–term problem and it will require a significant amount of ship time for process–oriented field studies.

For example, NEFC has proposed several recruitment studies in the current round of research planning. One study focuses on Georges Bank cod recruitment and comparative studies with five other distinct cod stocks in the North Atlantic in collaboration with other countries (ICES) and academic research institutions in the U.S. (e.g., GLOBEC). Initial work will be on the effects of small–scale turbulence on the development and survival of cod eggs and larvae, and pelagic juveniles. Another phase will examine the effects of variability in the strength of the Georges Bank gyre on retention of cod eggs and larvae on the Bank. Field studies would include work on density distributions of cod eggs and o–group stages in relation to their predators and prey (zooplankton), and would require a suite of state–of–the–art instrumented samplers (e.g., MOCNESS), towed instrument packages, hydroacoustics, image analyzers, etc. Another study will focus on the influence of predation on o–group gadids by high biomass species including mackerel, herring, and elasmobranchs. Experiments on any one question may involve several high–intensity studies each year for a period of 3–5 years.

Still another proposed investigation involves mapping the inshore "pupping" and nursery grounds of major shark species along the U.S. Atlantic coast which are now under heavy exploitation. Little is known about these areas or the factors controlling survival of juvenile sharks; also attempts will be made to develop recruitment indices needed for management purposes. Ship time is needed to sample the juveniles using gill nets.

Recruitment experiments are also proposed for the surf clam to test hypotheses about the role of predators and density–dependence in controlling recruitment success. Field studies would utilize tray–settlement and predator–exclusion experiments as well as direct observations with an ROV to identify the predator field, quantify predation rates, and vulnerability of various size clams to different predators. The density of experimental clam beds will be manipulated to test for density effects of spawning and setting. Results will have significant management implications for surf clams and possibly other bivalve mollusks. Significant ship time will be required for each year over a period of 2–3 years; an inshore research vessel probably would be adequate. Additional experiments on surf clams probably will be desirable in the future as well as studies on other bivalves. The long–term payoff from better management of these valuable shellfish resources could be very large.

Marine Mammal Studies. The continental shelf edge from Cape Hatteras north and east toward Georges Bank is an important habitat in winter months for cetaceans, large pelagic fishes (tunas, billfish), and sharks. These apex predators all depend on schooling concentrations of pelagic fishes such as squid, myctophids, mackerel, and herring, which, in turn, are the object of commercial fisheries with by–catch of cetaceans. A 3–year study is planned to clarify predator–prey interactions among these species and map their distribution patterns in relation to the shelf, shelf slope, and Gulf Stream water masses. Offshore research vessel time will be required utilizing satellite telemetry, hydroacoustic sampling, bottom and midwater trawls, longlines, visual cetacean sighting surveys, and oceanographic sampling. Additional field studies will very likely be necessary in another 3–5 years to refine estimates of predator–prey interactions and abundance levels.

Ecology of Fishes in Perturbed Environments. Winter flounder and many other coastal fish populations in the northeastern United States have declined over the last decade. As yet, it has not been possible to sort out the relative importance of natural environmental factors and anthropogenic factors including habitat loss, fishing, and pollution. Although much experimental work has already been done on contaminant effects, further studies (both lab and mesocosm, and field) are needed to partition the various sources of mortality and examine their cumulative effects on population levels. Fecundity, egg size and quality, and larval survival will be intensively studied in the field for several stocks of winter flounder representing a range of environmental pollution gradients. Complementary studies will be done in controlled laboratory and mesocosm experiments. Inshore research vessel time will be needed for collecting and sampling winter flounder larvae, juveniles, and adults. Gear requirements include bottom trawls, dredges, and adequate lab space and deck space for live tanks.

Effects of Slope Water Intrusions in the Gulf of Maine. It is proposed to test the hypothesis that slope water intrusions through the Northeast Channel into the Gulf of Maine influence the circulation of the Gulf of Maine, increase primary and secondary production, and result in improved Atlantic herring recruitment. Slope water incursions will be monitored with a series of moored buoys outfitted with current meters, fluorometers, and CTD's. Extensive sampling will be conducted from ships to describe the distribution and abundance of zooplankton and herring larvae for comparison with the phytoplankton standing stock data from the moored–buoy arrays; traditional bongo–net sampling will be augmented with high frequency acoustic measurements of larvae and zooplankton. Satellite data on sea surface temperature and color would be integrated into the data base.

Directed Surveys/Assessments of Limited Duration. Special purpose fishery surveys or assessments focused on selected species or regions are required more–or–less regularly to meet specific problems often related to management issues. For example, stock ID questions about Northwest Atlantic herring in the 1960's led to an extensive international program by ICNAF focused on the Georges Bank area. Some of those questions still remain and are being studied jointly by U.S./Canadian fishery scientists since Georges Bank herring represent a "transboundary" stock. With recovery of the Georges Bank stock, a larger joint research program of tagging, genetic studies, etc. may be necessary. Other examples include special surveys to describe distribution of pre-recruits as an aid to establish closed areas for reducing pre-recruit mortality, or to obtain demographic data (e.g., fecundity) which cannot be obtained on monitoring surveys due to timing. These are just a few examples of the kinds of special surveys needed to supplement the core monitoring for assessment and other research purposes. Another type of need is for unscheduled contingencies (oil spills, fish kills, etc.). The principal need here is for sufficient flexibility in research vessel schedules to allow for such contingencies.

Another type of need is for gear studies including development of new gear for special purposes, or new gear for monitoring surveys as is sometimes required. In the latter case, significant time must be available on the standard survey vessel(s) to develop vessel/gear calibration coefficients so that comparability is maintained in the time series.

Anticipated Growth/Technological Advances

Projecting ahead to the year 2000, it is anticipated that NEFC research vessel requirements can be met with about four vessel-years of ship support, partitioned into two full ship-years on offshore vessels, and about one ship-year each on coastal and estuarine vessels. Both the offshore and coastal vessels will require a full range of fishery resource assessment capabilities, as well as sufficient space/equipment/instrumentation for the wide range of fishery oceanography and environmental studies discussed in this report. Space (decks, labs, scientific berthing) and gear handling equipment and capability are not adequate on existing East coast vessels (including DELAWARE II and ALBATROSS IV) for the full range of NEFC fishery assessment research now in progress. These same general deficiencies must be corrected in order to carry out proposed new multidisciplinary studies under the Coastal Ocean Program and Climate and Global Change Program initiatives. In addition, modern instrumentation will be essential in order to take advantage of new technology (as it exists and as it develops) for making physical/chemical/biological measurements in the sea.

For example, principal off-the-shelf technological advances in the near-term should include:

1. Hydroacoustic packages for shipboard use to aid in the assessment of pelagic species, and process-oriented studies of micronekton

2. ROV's and AUV's with launch/recovery capabilities and necessary electronic support personnel for direct observation as well as augmenting traditional sampling methods. For example, video surveys could be combined with dredge surveys for scallops and surf clams

3. Various sensor packages for use on traditional gear (bottom and midwater trawls, micronekton gear, plankton nets) and linked via conductor core cables for real-time gear performance monitoring

4. Data loggers linked with microcomputers for real-time quality control and preliminary shipboard data analysis

5. Direct accessing and use of satellite data on board ship

Traditional Shipboard Observations vs. Remote Sensing

In considering possible future changes in the mix between traditional shipboard observations and remote sensing with advanced technology, it seems clear that utilization of remote sensing will certainly increase in fishery research but probably not as a replacement for vessels. The ships themselves will become more efficient at sampling/census of marine animals through the use of new technology (hydroacoustics, flow-through samplers with automatic counters and image analyzers, tethered ROV's, access to satellite imagery in real time, etc.), but the need for vessels will increase because more traditional as well as new kinds of sampling will need to be done to meet fishery research requirements. For example, hydroacoustic methods need to be expanded especially for assessing pelagic fish stocks in the Northeast, but this will require new survey activity since specialized pelagic fish surveys are not now being done. Similarly, hydroacoustics will certainly be a valuable tool for process-oriented studies of micronekton, but they will not preclude the need for traditional net sampling for species identification, size frequency calibration, etc. Rather, the hydroacoustics will enhance the potential gain from a process- oriented study and, thus, justify, as well as require, a more comprehensive study which will use more, not less, ship time.

Moored research "stations" with advanced sensors including hydroacoustics, image processors, real time data telemetry, etc. could provide valuable new insight to temporal/spatial scales of dynamics of marine biota (e.g., micronekton and zooplankton) monitored over significant periods. However, here again they would not supplant the need for shipboard sampling in the foreseeable future because of the need for extensive calibration and testing over a range of areas, environmental conditions, planktonic communities, species mixes, etc.

Short-Term vs. Long-term Studies

As indicated earlier, a successful strategy for assessing the effects of natural ecological factors and anthropogenic impacts on living marine resources will require a long-term research program consisting of both monitoring and short-term studies. Broad-scale monitoring with research vessels will be needed indefinitely (although efficiencies of methods may increase) to document changes in the structure of the fishery resources and the other ecosystem components and properties which affect them. Similarly, short-term studies on research vessels will be needed long into the future in order to clarify the functional forms of ecological relationships controlling fish production. The long- term need for process-oriented studies exists because these processes are very complex and because the ecosystems will be changing in response to environmental change and anthropogenic impacts, thereby altering the functional form of the controlling relationships.

The ideal mix between process-oriented studies and monitoring or other directed studies will depend on the nature and priorities of the questions being asked and may vary among regions. However, a properly balanced fishery research program will have a significant amount of ship time available for all three categories. The total amount of ship time needed probably will increase over current needs for a number of reasons. Increasing demand for fishery products will expand fisheries onto under- utilized species and create the need for more assessments; also, the general level of exploitation will increase on all stocks reducing the margin for error and requiring more accurate assessments to meet management objectives.

Geographic Areas/Seasonal Constraints/Trends

In the Northeast, there will be greater focus on joint habitat- fishery studies emphasizing recreational species in inshore waters. The demand for recreational fishing is steadily increasing at the same time that the coastal environments are being degraded. This will require more emphasis on coastal and estuarine habitats and species by NMFS, with more collaboration with states, universities, and other components of NOAA and federal agencies such as EPA, FDA. Consequently, this will enhance the need for NOAA coastal research vessels; these will be smaller than offshore ships, but probably larger than most Northeast states or other relevant agencies could operate and maintain.

Another change in the Northeast is the projected growth in NMFS studies on marine mammals and large pelagics. This will necessitate additional research vessel operations in continental shelf waters and beyond to encompass the wintering range of these highly migratory species. Thus, fishery research vessels in the Northeast will require greater endurance than heretofore available. Greater endurance may also be needed to allow joint U.S./Canada or NAFO-sponsored studies of transboundary stocks in areas well beyond the U.S. EEZ, e.g., flounder stocks in the Grand Banks region.

Real Time Data Needs

The need for real time data transmission and analysis is expected to increase in proportion to the amount of process-oriented research, where real time data on fine-scale distribution of organisms and associated environmental properties are critical to efficient sampling designs and interpretation of results. Another type of need for real time data will involve studies of phenomena associated with gradients of sea surface temperature and color (phytoplankton pigment) such as distribution of marine mammals and pelagic fish, WCR's and shelf ichthyoplankton communities, and shelf-wide phytoplankton patterns. Still another need for real time data will be in multiship operations studying fast-changing events such as predation effects on micro-nekton communities by a rapidly migrating population of predators (e.g., mackerel). In such a study it would be necessary to monitor the location and vertical movements of the leading edge of the migrating population with hydroacoustics, and, at the same time, conduct sampling of the predators for stomach analysis as well as the micronekton prey field in three dimensions. Hydro-acoustic data acquisition, processing, analysis and plotting would have to be done in real time and faxed to all the ships involved so that they could target their sampling in the most efficient manner.

Scientific Vessel Requirements for Offshore Fishery Research Vessels

General. The ship is to serve as a medium-sized (approx. 200') vessel capable of extended offshore cruising and conducting research in a wide variety of disciplines. This requires a vessel with a significant amount of space for scientific operations in terms of laboratory arrangement, deck space, winches (type and location), and deck equipment.

The vessel will support science and engineering operations at sea in terms of equipment handling, laboratory space, and a generally clean, quiet, and vibration-free environment for precise data collection. The vessel must provide stable and clean 120/240 VAC power in all science spaces and labs. All areas of the vessel must be air-conditioned and heated to maintain a 72°F temperature and a 50% relative humidity. All spaces must fall within OSHA safety guidelines for ambient noise levels.

In general, the vessel should tow all instruments from one side of the vessel and have all discharges, engine, bilge, and scientific from the other side.

Endurance. Thirty days, with full staff for a 24 hour/day operation of all equipment. A 10,000-mile range at cruising speed is minimum and she should be built to ABS Class lC ratings to be able to transit very loose pack ice.

Accommodation. 16-20 scientists, berthed in two-man staterooms. A single one-man stateroom for the chief scientist. A scientific library/lounge with conference capabilities as well as a dedicated science office.

Speed. 12-14 knot cruising speed through a sea state 4. Speed control ±0.1 knot in the 0-5 knot range.

Stationkeeping. Should be able to maintain station and work in sea states at least through 5, and with some limited capacity in sea state 6. Must be able maintain dynamic position in sea state 5, with a 3-knot current and a 35-knot wind speed.

Must be able to maintain a precise trackline (at speeds as low as 1 knot) within a 300' maximum width corridor.

Deck Area. Spacious and clear fantail area of at least 2000 ft^2. Deck tie-downs on 2 ft centers provide deck loading of up to 1200 lb/ft^2, and a total deck load of 90 tons.

Bulwarks should be removable along at least 20' of rail on each side of the ship.

The deck should be a dry working deck with no more than 8' or less than 6' of freeboard. The entire working deck must be accessible by the cranes or booms and have 120 and 240 VAC, fresh and salt running water, compressed air, and voice communications to all points on the vessel.

Cranes. A suite of cranes, booms and A-frames must be able to reach all working deck areas to load and off-load vans and heavy equipment of up to 15,000 lbs. At least one should have a 20' outboard reach at 10,000 lbs.

At least two A-frames or J-frames installed on the same side of the vessel. These frames must extend 8' outboard and 3' inboard, withstand a working/towing load of 4000 lbs, and have at least a 15' vertical clearance. If these are A-frames, then a width of 6' up to 12' is required; J-frames require a 1 m J at their top. A heros platform must be provided for each of these locations.

A fantail mounted hydraulic gantry or A-frame is required over the trawlway. This must be capable of reaching outboard or inboard 15' with a lifting capacity of 20 tons.

Trawlway. The vessel is to be configured as a stern trawler with a ramp of at least 12' wide. This ramp should be fitted with a hydraulic tailgate and have a slope no greater than 45°.

Winches. All winches must be hollow cored for use with conducting core cables. All winches will be equipped with adjustable levelwinding gear and be placed to minimize fair-leading. Winch control stations must be located for maximum visibility of the deck area impacted by that winch, and have direct communications to the deck, laboratories, and bridge.

At a minimum the following winches are required:

1) A pair of main trawl winches, metered to include wire out, rate, and tension, clutched and capable of handling 5000' of 1" trawl warp. Freespooling is desirable.

2) A pair of oceanographic winches for the instrument and the plankton A-frames/J-frames. These should have constant tension ability, readouts of wire out, speed, and tension. They should have a 2500-4000 m capacity of .322 wire, and have a maximum of 4000 lbs torque at an average wrap. The winches must operate at speeds of at least 50 meters a minute both in an out, and be capable of freespooling.

3) Several additional small deck winches and capstans are required for gear handling on deck.

4) A pair of removable net reels should be placed forward of the trawl ramp for use with mid-water

nets, gill nets, long line gear, as well as the storage of spare trawls.

Towing. The vessel must be capable of towing/deploying a large array of scientific gear from net systems to bottom grabs. Mid-water trawls ($250m^2$ opening) that are towed in excess of 4 knots are the design maximum for the vessel (estimated 60,000 lbs pull on bollards).

Laboratories. The vessel should have a single, large, hose-down wet laboratory with direct main deck access. This may be through a trawlway hatch to receive the catch if the lab is below deck or through double doors if the lab is on the trawldeck. An open flexible floorplan if required to allow for multidisciplinary cruises. Sinks, running salt and fresh water, counters, clean and stable 120 and 240 VAC power and a working powered conveyor belt/gurry scupper are required.

Smaller, specialized labs should be located near the wet lab. A plankton lab and an instrument room should be located near the A- frame/J-frame area for plankton sample work and care of the oceanographic instruments deployed at the instrument platform.

A bio-chem laboratory should be adjacent to the instrument room for access to the water samples.

An electronics laboratory (scientific as opposed to ship) for computerized systems is also required. This room should have a bank of 19" racks for electronic equipment storage. The room must be adequately climate controlled and have clean stable power. A nonstatic floor covering and good ship-wide communications are required.

A separate environmental room of approximately 100 ft^2 should have programmable temperature and light regime settings and have running sea and fresh water. Deck drains for spillage removal are also needed. This area will be used for hatching experiments, live animal storage, and primary production work.

Scientific freezer and refrigeration equipment is required. A large single walk-in freezer of at least 100 ft^2, with racks or shelves and tie downs, and with direct access to an overhead hatch or outside door for unloading. Refrigerator spaces may be broken up and spread around the vessels labs for greater utility with a total capacity of approximately 75 ft^3.

No lab should serve as a general passageway, and access between laboratories should be convenient.

Labs should be constructed of environmentally stable and clean materials such as stainless steel, with all furnishings planned for maximum lab cleanliness and ease of cleaning.

Each lab must have good positive ventilation and the plankton and chemistry labs should have fume hoods with no less than 400 ft^3/min air handlers.

All labs should have tie-downs across the floor and along all walls and counters. The HVAC supplied to the labs should maintain a temperature of 72°F; a relative humidity of 50% and 10 air changes per hour. Labs should be furnished with 120 and 240 VAC with a total lab demand of 75 KVA. Clean running seawater, and fresh water, deck drains and compressed air should be supplied.

A scientific ready room should be located near the laboratories for the storage of foul weather gear, boots, and equipment.

Storage. A total of 1000 ft^2 of scientific storage area is required. This must have access to laboratories and hatches. Part of the area should have shelves and part of it should be open with tie-downs located liberally throughout both areas. This area includes space for spare nets, field equipment as well as laboratory supplies.

Vans. The vessel should be able to carry at least one 8'X20' portable van on deck without compromising the normal trawling and other scientific activities. Hook-ups for power, HVAC, water, and communication must be supplied. The ship should be able to load and off-load such vans with her own cranes and booms.

Acoustic Systems. The ship should be as acoustically quiet as possible, with acoustic noise generation taken into consideration in all equipment selection and mounting location.

The vessel should have a retractable transducer head within a transducer well in the center of the ship. This allows for the maintenance and installation of transducers and transponders at sea.

Communications-Internal. Tthere must be good quality voice communication throughout all spaces and labs, this includes phones in every stateroom and office. Additionally, there must be good quality voice, hands-free communication from all working deck spaces to the bridge.

A shipboard computer and datalogger system must be installed, with repeater locations located in every laboratory and office. Monitors for all ship control, environmental parameters, science, and overside equipment performance should also be available in all science areas.

External. Reliable voice channels for communication to shore facilities, other ships and aircraft are required. This includes satellite, VHF, and UHF.

Facsimile communication to transmit high resolution graphics on a regular basis is needed.

High speed data communication (56K Baud) links to shore stations and other ships is required.

The vessel should carry transponding and receiving equipment to interrogate and receive satellite readouts of environmental remote sensing data.

Ship Control. The chief requirement is safety in all aspects of shipboard gear handling operations. This requires maximum visibility of deck work areas during launching and recovery operations. This describes a pilot house/bridge with an unobstructed 360° view.

The functions, communications, and layout of the ship control station should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, and positioning will often be integrated with scientific operations requiring control to be exercised from a laboratory space.

Requirements for General Purpose Inshore NOAA Research Vessel

General. Vessel of 80'–100' (single hull), about 500 gross tons, to operate at least in waters as shallow as 15' but with sufficient sea worthiness to operate as far as 15 miles off the coast or out to the 60 meter contour in winter conditions. Must be capable of deploying demersal trawl and dredge gear, hydro-graphic, hydroacoustic and plankton-sampling gear and other types of specialized capture gear (e.g., gill nets, traps) commonly used in inshore areas. Also, must have adequate winch/boom capabilities for various sediment and benthic grab sampling, and laboratory facilities for collecting/preserving samples for contaminant analysis. Deck space must be adequate to accommodate one or more vans for special-purpose studies including diving SCUBA operations, and also live tanks for holding and transport of live specimens. Finally, the vessel should be large enough to accommodate 8–10 scientists (at least for working space) to facilitate collaboration among scientists from NOAA, states, universities, etc. Crew size should be adequate to allow 24-hour operations for limited periods.

Endurance. 14–21 days with full complement of scientists and crew.

Accommodation. At least 10 scientists.

Speed. 10 knot cruising speed. Faster is better but not at expense of adequate space for personnel, labs and deck area, and power and equipment for towing and handling gear efficiently. Maximum loading would be for MW trawl (perhaps 60 m^2 mouth opening) at 4–5 knots. Should have fine speed control at low speed, i.e., 1 knot + 0.1 knots.

Station Keeping. Should be able to maintain station and perform all work in sea states up through four, with moderate capacity in sea state 5. Must be able to maintain position in sea state 4 with 3 knots current and 25 knots wind. Must be able to maintain trackline (at speeds as low as 1 knot) within 300' maximum width corridor.

Deck Area. 700–900 ft^2 open deck space aft for trawling/dredge operations, winches, vans and an articulated crane. Also space/provision for up to four (4x4) live tanks with sea water hookups for transport of live specimens.

Seaworthiness. Sufficient stability up through Beaufort Scale 5 (lower end sea state 5) to continue most over-the-side and laboratory operations with reasonable comfort and safety. Freeboard not less than 4'.

Cranes/Trawlway/Winches. Similar layout as described for offshore vessel except reduced commensurate with smaller size (about 2/3). Trawling and dredging capability to at least 100 m.

Towing. Maximum fishing gear size suggested is 3/4 Yankee bottom trawl, 8'–10' scallop dredge, and 60 m^2 mouth opening MW trawl at 5K. Would require 800–1000 HP.

Laboratory Areas. 1000 ft^2. of lab space including 400 ft^3 storage. At least three separate laboratories including wet lab (largest), chemistry lab and dry lab. The chemical lab should be outfitted similarly to that for the offshore vessel.

Storage. 800 ft^3 of storage below deck for scientific gear, supplies, etc. but with ready access to labs/deck above.

Vans. Adequate deck space for one large (8'x20') portable van or several small vans, with appropriate tie–downs, and water, power, communication hookups.

Acoustic system. Conventional acoustic gear for depth/fish finding and provision for additional transducers as required via transducer wells with at–sea access for installation and servicing.

Communication. Analogous to systems aboard offshore vessel.

Fisheries Research Vessel Needs Into the Next Century

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Introduction

The Southeast Fisheries Center is directly responsible for research and assessment on marine resources within an area of approximately 400,000 square nautical miles (not counting oceanic pelagic resources in the entire Atlantic). At present, approximately 380 sea days are provided by NOAA ships, 80 sea days by contract, and 100 sea days through cooperative state-federal agreements. This equates to approximately one sea day per 700 square nautical miles per year. The level of NOAA vessel support is less than one sea day per 1,000 square nautical miles per year. Obviously, this level of vessel availability can best be described as minimal.

The Southeast Fisheries Center collects data and provides analyses for development of management plans by three separate Fishery Management Councils (five councils for swordfish, billfish, and sharks). The number of fishery management plans implemented or under preparation has increased substantially in recent years. Likewise, the number of other resource issues such as sea turtles, by-catch, red tides, habitat deterioration, and resources shared with neighboring countries has also increased. NOAA's recent rediscovery of the ecosystem has placed increased emphasis on the collection of environmental data and on defining the impact of both short- and long-term perturbations (natural and man-induced) on estuarine, coastal, and oceanic resources. The ultimate goal of developing a predictive capability for resource abundance is entirely dependent on our ability to conduct at-sea baseline and process-oriented studies with sufficient intensity and detail to adequately describe and understand the marine resources and their environment, and adequately model interactions within large marine ecosystems.

These circumstances have substantially increased the need for vessel support for both baseline and process-oriented studies in the southeast, while such support has actually declined due to the allocation of NOAA Ships OREGON II and CHAPMAN sea days to the Northeast Fisheries Center in recent years. A cooperative state/federal program for the collection of fishery-independent fisheries data, SEAMAP (Southeast Area Monitoring and Assessment Program) has been successful in providing smaller state vessels for coordinated estuarine and coastal sampling activities, but cannot be expanded without additional funding. Large vessel needs of the southeastern U.S. coastline (North Carolina-Florida) are only partially being met through a grant to the state of South Carolina for fishery-independent survey activities from Cape Hatteras to Cape Canaveral. In almost all cases, the available vessel days are being used for resource surveys to provide basic descriptions of living marine resource stocks and trends in their abundance to improve regional Fishery Management Plans. The process-oriented studies necessary for understanding the dynamic of resources and their changing environment are currently receiving very little vessel support in waters of the southeastern United States. Not only is the current level of vessel support inadequate for southeastern fisheries needs for routine assessment activities, but neither vessel time nor adequate gear and instrumentation is available for the ecological studies vital to the completion of NOAA's mission in the southeast.

General Description - Southeast Area and Fishery Resources

The Southeast Fisheries Center's area of responsibility extends from Cape Hatteras, North Carolina to the U.S.-Mexico border at 25 degrees N. latitude. The area is marked by high levels of river outflow, with extensive coastal mixing areas and wide (up to 10 nm) continental shelves off of the southeastern states and in the Gulf of Mexico.

The South Atlantic Bight is a partially closed large marine system bordered on the east by the meandering Gulf Stream and on the west by extensive highly productive estuaries, protected by low barrier islands and beaches. Cape Canaveral to the south and Cape Hatteras to the north mark breaks in faunal distribution and composition. A large percentage of the area's resources are estuarine dependent, with offshore spawning, inshore larval transport, estuarine juvenile nursery areas, offshore movement during the first or second year, and subjected to estuarine/coastal fisheries. Both summer and winter shrimp fisheries occur, and coastal sciaenid stocks are fished extensively by small-scale local fisheries and sports fishermen. Coastal migratory fisheries such as king and Spanish mackerels are fished extensively by recreational and commercial fishermen, as are reef fish over much of the southeast shelf area. Most resources are overexploited and subject to strict state and/or Federal regulation.

Information to optimize use of these resources is lacking, as is information on the factors which influence the distribution and productivity of the resources.

The Gulf of Mexico, "the Nation's Sea" according to the EPA's Gulf Initiative, is characterized by the inflow, in the north, or river systems draining most of the mid-United States. Caribbean and Central Atlantic waters flow in through the Yucatan Straits, forming the Loop Current, which, along with the Mississippi River plume, are the dominant and most dynamic oceanographic features of the Gulf. Menhaden, the nation's largest volume fishery, and shrimp the nation's largest value fishery, are maintained by large estuarine nursery areas across the northern Gulf. Coastal sciaenid and mackerel recreational and commercial fisheries occur throughout the coastal shelf area as do reef fisheries. Major fisheries for oceanic pelagic resources such as yellowfin tuna and swordfish occur along the edge of the Gulf continental shelf. Subsidence is occurring in the northern Gulf, along with increased inflow of sediments, contaminants, and nutrients, bringing about a rapid aging or eutrophication. Most northern Gulf resources are overfished, and increased knowledge of those resources and processes which affect fisheries productivity is critical to the effective management and allocation of Gulf of Mexico (GOM) living marine resources.

NOAA's area of direct fisheries responsibility in the Caribbean is limited to the 200-mile Fisheries Conservation Zone (FCZ) around Puerto Rico and the U.S. Virgin Islands, although cooperative studies with other countries on recruitment processes could well expand activities to a majority of Caribbean waters. Except for longline fisheries for tuna and swordfish pursued by many nations, most of the fisheries, at least in the eastern Caribbean, are small-scale artisanal fisheries for limited resources on constricted shelf areas around the islands. These resources are overfished, and substantial information is required for effective resource conservation.

Current Southeast Fisheries Science Center Vessel Usage

Predominant usage of NOAA vessels, at the current time, is for studies on the distribution and abundance of benthic and midwater resources to quantify stock status and to develop indices of abundance to determine annual trends (see Tables 1 and 2 for current and projected NOAA vessel requirements for the Southeast Fisheries Science Center). Major efforts are being expended in the Gulf of Mexico, in cooperation with all five Gulf states to conduct shrimp and groundfish cruises to collect data annual evaluation of the effectiveness of management plans and for providing real-time data used by the states and GOM Fishery Management Council to open and/or close specific areas to shrimping. Real-time data are being transmitted via satellite link from both the OREGON II and state vessels for development of weekly mail-outs to participating organizations and interested parties during summer SEAMAP cooperative state/federal cruises.

Real-time data are also being provided for latent resource cruises conducted in the GOM with large demersal and pelagic trawls by the NOAA Ship CHAPMAN. Substantial sea time is currently being expended on these cruises as initial seasonal assessment are being conducted, and as adequate sampling gear for midwater fishes is being developed and tested (Table 1). Acoustic surveys with the NOAA Ship CHAPMAN are an integral part of the latent resources assessment activities.

A special ichtyoplankton cruise is conducted in the GOM for development of an annual index of bluefin tuna spawning stock size to support U.S. participation in the International Commission for Conservation of Atlantic Tunas. The Southeast Fisheries Center has the responsibility for providing data and analyses necessary for development of the U.S. position on management of Atlantic oceanic pelagic resources. Ichthyoplankton cruises are also conducted to determine spawning location and develop indices of spawning stock biomass for Gulf Spanish and king mackerels and red drum. Ichthyoplankton cruises are being conducted jointly with Mexico to define spawning season and intensity throughout the GOM, with mackerel spawning activities in Mexican waters being targeted.

Process-oriented studies or specific experiments are being conducted off of North Carolina to evaluate the impact of upwelling areas on larval survival, in the vicinity of the Mississippi River plume to study larval concentration/ feeding/survival mechanisms, and off the northeastern Yucatan peninsula to study upwelling in relation to mackerel spawning activities. In some cruises, near-real-time (same day) satellite thermal imagery is being transmitted to the NOAA Ship OREGON II to aid in sampling specific locations related to thermal fronts or upwelling areas.

Reef fish survey activities are extremely limited with one annual assessment methodology cruise in the GOM and on the shelf area around Puerto Rico and the U.S. Virgin Islands. Reef fish assessment methodology and abundance index studies in the South Atlantic Bight are being conducted with the R/V PALMETTO through a grant to the State of South Carolina.

Table 1. Current (FY 90) Southeast Fisheries Science Center (SEFC) Vessel Usage and Projected Requirements in 2001.

ACTIVITY	VESSEL DAYS (CURRENT)			PROJECTED
	NOAA	STATE	CHARTER	
Assessment Surveys				
• Benthic Trawl (Shrimp & Groundfish)	69	80	5	280
• Benthic Sampling (Reef Fish)	24	--	45	240
• Fish Trawls (Latent Resources)	90	--	--	90
• Ichthyoplankton (Special Surveys)	126	20	--	180
Process Studies (Ecosystem)	30	--	--	130
Gear Development (Including Submersibles)	30	--	30	30
TOTAL	379	100	80	950

As part of area efforts to improve communication and assessment capabilities of the research activities using NOAA vessels in recent years, NMFS has provided the following communication systems and instrumentation for the NOAA Ship OREGON II (1–6) and the NOAA Ship CHAPMAN (7–15).

1) Biospherical CTD, used to measure temperature, depth, conductivity, salinity, dissolved oxygen, transmissivity, and light levels for depth intervals of surface to 600 meters, unit also contains rosette samplers

2) IBM personal computer model 50 used to control the CTD and record the data

3) Continuous flow-through thermosalinograph, used to measure temperature, conductivity, salinity and fluorescence of near surface water

4) IBM personal computer model 60 used to control the thermosalinograph and record the data; also used for recording and analyzing biological data

5) INMARSAT satellite communication system used for transmission of digital data and voice communications

6) Petroleum cellular telephone used for nearshore communications of both voice and digital data

7) FURUNO chromoscope echo sounder 50 and 300 KHZ

8) SIMRAD sweep sonar 30 KHZ

9) SIMRAD FS 3300 trawl survey system

10) IBM personal computer (AT) for control and data recording of the STD

11) Bell South cellular telephone (shared ownership with NOS)

12) BioSonics digital echo integration system

13) Deep Ocean remote underwater operating vehicle

14) Stainless davits used to launch and retrieve the hydroacoustic transducer array

15) Dole plate freezer used to quick freeze bio samples

Table 2. Projected Total Southeast Fisheries Science Center (SEFC) Vessel Requirements (Sea Days) in 2001 by Activity and Area. (Of the total, requirements for NOAA fisheries research vessels are shown in parenthesis.)

ACTIVITY	GULF OF MEXICO	S. ATLANTIC BIGHT	CARIBBEAN
Assessment Surveys			
• Benthic Trawl (Shrimp & Groundfish)	160 (80)	120 (80)	--
• Benthic Sampling (Reef Fish)	120 (120)	80 (40)	40 (40)
• Fish Trawls (Latent Resources)	60 (60)	30 (30)	--
• Ichthyoplankton (Special Surveys)	120 (90)	30 (30)	30 (30)
Process Studies (Ecosystem)	60 (60)	40 (40)	30 (30)
Gear Development (Including Submersibles)	30 (30)	--	--
TOTAL	550 (440)	300 (220)	100 (100)

Projected Fisheries Research Vessel Needs

Needs for fishery research vessels are being rapidly driven along two basic lines of activities. Increasing numbers of fishery management plans and needs for improvement in the basic biological data in existing plans are generating enormous pressures for additional routine assessment surveys for stock abundance and information on trends. Catch-per-unit effort data from surveys are being used to improve the accuracy of assessments (particularly for the most recent years) that are the basis of council management plans. In some cases, additional studies are required on gear effectiveness and on methods to conduct basic assessments.

The other line of required research is in the nature of individual experiments designed to provide information on the ecology and processes that affect the productivity and well-being of southeastern resources. A knowledge of the impacts of man-induced and natural changes in the coastal ocean on living marine resources is vital if those resources are to be managed for maximum benefit to the nation, while insuring long-term viability of those renewable assets.

Over the next ten years, this information can only be obtained if adequate support is made available to conduct these surveys and studies. The number of sea days required is approximately 76% greater than is currently available (Table 2). The number of NOAA vessel days required (760) is approximately twice the 379 sea days provided in FY 90. The areas of expansion are:

Resource Surveys. Increased vessel time is required to expand shrimp and groundfish surveys from twice yearly to quarterly in the Gulf of Mexico and to initiate such surveys in the South Atlantic Bight. A substantial portion of the required vessel time can be provided by the Gulf and South Atlantic states through existing cooperative state/federal programs for the collection of fishery-independent data.

Reef fish assessment surveys, required to support fishery management plans for all three southeastern Fishery Management Councils are conducted well offshore, requiring larger NOAA vessels. Quarterly surveys are required, at least initially, to define seasonal abundance and distribution of reef resources in the Gulf of Mexico and South Atlantic Bight. Annual surveys for shallow and deep reef resources will be required around Puerto Rico and the U.S. Virgin Islands. Joint cruises with Mexico are being planned to determine the extent to which reef resources are shared between the two countries. It is anticipated that some assessment cruise support will continue to be provided through contract with the South Carolina MARMAP program. Additional methodology work is required to develop appropriate assessment techniques for many of the coastal reef fish species, requiring 20–30 days annually of ROV or shallow-water (less than 2,000 ft.) submersible support.

Coastal herrings (latent resources) cruises are required during the summer (inshore distribution) are winter (offshore distribution along the shelf break) seasons in the Gulf of Mexico. NOAA vessels with stern ramps will be required to tow the large demersal and midwater trawls used in these surveys. One annual survey is required for the South Atlantic Bight. Advanced hydroacoustic systems will be required on ships conducting either directing trawling surveys or rapid, broad-scale echo-integration studies.

Ichthyoplankton cruises will be conducted annually in the Gulf of Mexico for bluefin tuna, mackerels, and red drum. Periodic seasonal cruises should also be conducted to better define the total complex of spawners in both the Gulf and South Atlantic Bight. At least one cruise annually will be conducted in the Caribbean as part of a long-term study to define seasonality and reef resource throughout the Caribbean. In addition to routine ichthyoplankton cruises to provide indices of spawning stock biomass, ichthyoplankton sampling will be piggybacked on shrimp and groundfish and other coastal resource surveys.

Ecological or Process-Oriented Studies. Although large number of vessel days are not currently devoted to these types of studies, that is only because of the demand for resource survey data and because of commitments for cooperative state/federal research programs. Ecological studies and *in situ* experiments will become increasingly important as basic information on resource abundance, status, and variability is obtained and efforts are expanded to determine the physical and biological causes of fluctuations and trends in abundance and resources status.

Fishery oceanographic studies most needed in the southeast are those that describe the correspondence between physical conditions and various life history stages of fish. This requires the capability to monitor both physical structure and dynamics and the ability to locate and capture all life stages from eggs to adults. We expect a rapid growth in research aimed at melding an understanding of physical processesthat operate on recruitment a= mesoscales (eddies, plumes, fronts, etc.). Biological processes of major interest are spawning, growth and survival of larvae, of juveniles in nursery zones, as well as distribution and aggregation of all life stages.

The physical conditions and processes in the South Atlantic Bight of most importance are those associated with the Gulf Stream, e.g., upwelling, meanders, eddy formation and other influences on thermal structure of shelf waters. The major physical processes of importance in the Gulf of Mexico include the loop current, the Mississippi river plume, which has a significant impact on the distribution of spawning and survival of larvae of most of the Gulf's Coastal and estuarine-dependent species, and upwelling areas. Periodic hypoxic areas and subeddy systems, off of the loop current, also need extensive study to evaluate their impact on GOM resources. General objectives for the process-oriented studies are to determine the:

1. Role of abiotic environmental variation (intra- and inter-annual) on survival of eggs, larvae and juveniles

2. Role of physical factors on transport of eggs and larvae to juvenile habitats

3. Physical and chemical health and variability of juvenile and adult habitats

4. Role of physical and chemical processes in community structure shifts

5. Impact of toxic materials on survival at various life stage

6. Role of physical processes in the concentration or dispersal of contaminants and nutrients that impact survival and growth of individuals

Because process-oriented studies frequently require extensive stationkeeping and collection of biological and substantial environmental data, state of contracted vessels are generally inadequate, and larger NOAA vessels will be required. Three 20-day cruises are required annually in the GOM to evaluate seasonal patterns of resource abundance and survival in relation to the Mississippi River plume and upwelling areas (Table 2). Two 20-day cruises are required annually in the South Atlantic Bight to conduct process-oriented studies. Initial emphasis will be placed on larval concentration and larval survival processes associated with upwelling in the Charleston bump area. One annual cruise is required in the Caribbean to study Pan-Caribbean transport processes and their importance in recruitment to fish stocks of the continental United States from Caribbean spawning populations. Additional process-oriented sea time will be obtained through special studies piggybacked on required ichtyoplankton surveys. For example, segments of the bluefin larval index cruise can be used to conduct MOCNESS tows for vertical distribution of larvae at thermal fronts for comparison with zooplankton distribution and abundance, chlorophyll concentration, light penetration, convergence (downwelling), etc.).

Anticipated New Programs. In addition to the expanded assessment and ecosystem activities identified in this paper, enhanced research programs are expected through large-scale cooperative studies in the GOM, South Atlantic Bight, and the Caribbean.

Efforts will be made to coordinate and integrate research activities by over 20 agencies and facilities in the northern Gulf that are addressing factors influencing the productivity of that area. Attempts will be made to build on the extensive planning process related physical and biological studies already underway through the EPA Gulf of Mexico Initiative to integrate studies on factors affecting fisheries productivity in the northern Gulf. Multidisciplinary teams conducting process-oriented research at the same time and location will develop a more rapid understanding of the impact of those processes than separate, disjunct studies in physical, biological, and chemical oceanography that then have to be merged and extrapolated.

Expanded research on larval transport in the Caribbean would hopefully involve several countries and organizations with the capability to conduct fisheries research. An expansion of the MEXUS-GULFO program to determine the extent to which reef fish and mackerels resources are shared between the two countries is under consideration. Hopefully, vessels provided by other agencies in the northern GOM and South Atlantic Bight, and by Mexico and some of the Caribbean nations will reduce the vessel burden placed on NMFS and NOAA. At the least, it is anticipated that participation by other organizations will allow comprehensive studies to be undertaken, maximizing the effectiveness of NOAA vessels through joint assessment surveys and process-oriented studies. It is also anticipated that support from the NOAA Climate Change and Coastal Ocean Programs will be provided to accelerate studies on resources and their environment that are of major importance to the commercial and recreational well-being of citizens of the United States.

Future Requirements for Equipment and Operations.

The following requirements are grouped by those needed for resource surveys and those needed for process-oriented studies:

1. Resource Surveys. Much of the resource survey activities involve routine trawling, plankton collections, and standard oceanographic sampling at preselected or random stations. However, even these surveys involve real-time satellite imagery. In addition, the development of appropriate methodologies for surveying midwater fishes requires sophisticated hydroacoustic systems. Enhanced environmental sampling systems for the collection of data that provides baseline information for the expansion of process-oriented studies is also required. Needs for any vessels operating in the southeast, and specifically for the two NOAA ships currently providing support, the FRS OREGON II (a-k) and the FRS CHAPMAN (1-x) are as follow:

a) State-of-the-art data logger system

b) Replacement Conductivity-Temperature Device (CTD)

c) Geographic Positioning System and Loran positioning system

d) Doppler current profiler system

e) Automated wire angle measurement system

f) Highly regulated, conditioned, uninterruptible power for the instrumentation room

g) Back up self-contained conductivity-temperature device

h) Dual frequency echo sounder

i) Dissolved oxygen and PH transducers for flow-through instrumentation system

j) SIMRAD trawl system

k) Third wire winch for netsonde unit

l) Back up transducer for trawl survey system

m) Replacement for the third wire winch

n) Hydraulic telescoping crane

o) Highly regulated, conditioned, uninterruptible power for the dry laboratory

p) Conductivity-Temperature Device System

q) Data logger system

r) Doppler current profiler system

s) INMARSAT satellite communication system

t) Continuous flow-through instrumentation system for measuring near-surface temperature, salinity, fluorescence and dissolved oxygen

u) Personal computer for control and data recording of flow-through system

v) Automated wire angle measurement system

w) Underwater tracking system and forward sonar for the remote underwater operating vehicle

2. Process-Oriented Studies. In addition to the equipment and systems defined above, ecological studies would be greatly enhanced by the application of "high-tech" sensing and analytical equipment such as:

a) Nutrient and toxic chemical sampling systems and autoanalyzers

b) Automated equipment for primary productivity and oxygen production-respiration measurements

c) Automatic Doppler Current Profiler for mapping 3-D ocean current fields

d) Spectroradiometer and transmissometer for underwater bio-optical fields

e) Onboard technology for reception, display and analysis of satellite-measured sea surface temperature, color and derived products; includes a satellite and/or digital HF or VHF radio communications systems

Traditional methods of studying many of the important problems in fishery oceanography are so expensive that substantial progress can be attained only through use of new and innovative technology. In order to document spawning areas we need: 1) efficient particle counters which can measure the abundance of specific (egg size) particles as the counters are towed or remotely navigated through specific water masses, and 2) high resolution sonic or optical sensors which can effectively scan wide areas in search of spawning aggregations. In order to evaluate larval growth, survival, and transport, we need: 1) remotely operated opening and closing nets which sense environmental conditions such as temperature, salinity, light, particle concentration and size spectrum and chlorophyll concentration; and 2) drogues or other devices which will allow sampling of the same water mass over time. Studies on juveniles in oceanic nursery zones will require utilization of remotely sensing systems attached to opening and closing nets, and hull-mounted (or towed) sonic and optical sensors to identify appropriate targets in specific oceanographic features. Documentation of the distribution and aggregation of all life stages will utilize real-time oceanographic surface data remotely sensed from satellites; environmental sensors (moored, towed, or suspended) at appropriate depths, optical or visual observation from remotely operated vehicles, as well as appropriate nets for biological sampling.

In planning for future vessel needs a premium should be placed on speed so that the strategic positioning of vessels can logistically keep up with changes in the dynamic environment as viewed from space. Vessels capable of speed of 16 knots, or better, as opposed to the standard 10 knots, are needed. Increased vessel speed would also increase the number of stations occupied during broad-scale cruises, reducing the number of sea days required, and increasing the synopticity of coverage. Such high-speed hulls should be designed to be bubble- and cavitation-free so that vessel operation will not interfere with hull-mounted acoustic transpondence. These vessels should have good position-keeping abilities, e.g., twin screw and bow and stern thrusters. Vessels should have stern ramps.

Assessment of NOAA's Fleet Requirements: Fisheries Oceanography

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Introduction

The ultimate goal of fisheries research is to maximize the yield obtainable from commercial fisheries. Where possible prediction of variability in resource production would be highly desirable. Even where such prediction is impossible, fisheries research can still be very useful to management by partitioning variation in resource production into understandable components, e.g., variability caused by physical dynamics, biotic interactions or large-scale climatic fluctuations. The essence of fisheries oceanography, as distinct from traditional fisheries science, is the recognition that this objective implies an effort to better understand the fundamental linkages between population variability and the physical environment, which, in turn, implies utilization of the theoretical and technical advances being made within the wider oceanographic community. The logistic demands of fisheries oceanography are, therefore, essentially similar to those mandated by modern interdisciplinary process studies. However, since even larval and juvenile fish can be more patchily distributed and considerably more motile than typical planktonic organisms, ship speed and real-time environmental feedback are especially important.

Fisheries Oceanography

During the next ten to twenty years one of the foci in marine science will be in interdisciplinary science, specifically in bringing together the fields of physical oceanography, meteorology, population biology, and ecology in an effort to better understand the regulation of productivity in the sea and the variability in abundance of marine populations. This theme is the core of the Global Ocean Ecosystem Dynamics (GLOBEC) program and is as well a centerpiece of the Coastal Physical Oceanography (COPO) program. Within NOAA the initiatives that are explicitly complementary to these programs are contained with either the Global Change Program under the Ecosystem Dynamics theme or the Coastal Ocean Program under the Coastal Ecosystem Dynamics theme. Particularly the latter is seen as the programmatic umbrella for fisheries oceanography research in NOAA. The Global Change Program has rapidly grown in the past few years from less than $IOM to a current budget figure in excess of $50M and there are sanguine hopes for similar growth in the Coastal Ocean Program. One of the principal components in that program will without question be fisheries oceanography. This comingling of fisheries science, biological oceanography, physical oceanography and meteorology suggests that the present relatively sharp distinction between the capabilities of the fleet of fisheries vessels and research vessels will or should become blurred. Indeed there is no question that, within the multiplicity of inter-related aspects of ecosystems dynamics and variability, fisheries oceanography per se is one research area in which the NOAA effort continues to be the predominant one.

NOAA "Fisheries" Fleet Requirements

An assumption made in all that follows is that NOAA will not have sufficient resources to maintain a fleet of traditional fisheries vessels (essentially variants on commercial fishing vessels) as well as a modern research fleet. I personally believe that the need for the former will gradually diminish but will not disappear which implies that replacement "fisheries" vessels will necessarily represent a compromise.

1. *Laboratory Space*. Fisheries vessels will have to provide laboratory space similar to that currently provided on comparably sized UNOLS vessels since many of the same analyses and experiments will have to be made. In addition, space for utilizing portable laboratory vans will have to be provided just as it the current practice on research vessels.

2. *Over-the-side Equipment*. Fisheries vessels will have to provide both the basic deployment capabilities of oceanographic research vessels (Stern A-Frames, CTD winches, etc.) and, in addition, the capability of handling, at least intermittently, some commercial fishing gear. In the future, much greater use will have to be made of drifting or stationary buoys, and the capability of easily deploying and retrieving such instruments will be especially important.

3. *Continuous Sampling*. Any new fisheries vessels will have to be equipped with continuous underway sampling instrumentation identical to that on oceanographic research vessels. It will be particularly important to follow the developing standards being used

throughout the UNOLS fleet in regard to such systems since data exchange will be essential. NOAA cannot go it alone in this regard. A minimal list of potential parameters will have to include: water temperature; salinity; plant pigments;and,most likely, plant nutrients (from a dedicated pumping system with an inlet at the bow); irradiance and standard meteorological instruments and interfaces for more sophisticated user-provided instrumentations. Naturally such data collection requires fully integrated navigation logging, presumably in the near future, by the GPS.

4. *Acoustics*. Acoustic technology is emerging as a technique of particular promise for fisheries oceanography applications. Future vessels will have to be constructed with a view towards minimizing their "noisiness" so as to permit underway sampling with Acoustic Doppler Current Profilers and other hull-mounted transducers. Addtitionally, vessels should be routinely equipped with the best of the commercially available fish-finding systems used in the fishing fleet.

5. *Satellite Oceangraphy*. The study of dynamic systems virtually requires real-time guidance of sampling effort in light of the physical field. On mesoscale and larger systems this can only be accomplished via satellite remote sensing. Future vessels will either have to be themselves equipped to receive and process satellite information (ocean color, AVHRR, scatterometry, and altimetry) or have a sufficiently efficient link with a shore processing facility that timely mappings may be supplied the ship in the near real time. It is significant that, in general, the richest fisheries are in particularly dynamic sites (fronts or upwelling systems).

6. *Ship Size, Speed, and Endurance*. For most fisheries oceanography problems ship speed is especially desirable but size and endurance need be only moderate. Class I vessels would be excessive since most fisheries are located in the coastal environment or at coastal/pelagic fronts and not in central ocean basins. Since size and speed are correlated in pure displacement hulls, I believe alternative hull designs ought to be considered. This is already being done within the UNOLS and Navy community.

Future Research Vessel Needs for the Alaska Fisheries Science Center

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Direction

Our long-term forecast of vessel needs in fishery resource assessment and research is based on our recent vessel usage, rapid expansion of the domestic fisheries in Alaska, the new NOAA emphasis in ecosystem and process-oriented research, the rapid rate of technological advances, and the age of two NOAA vessels that have been dedicated to our research. The future direction of NMFS research by the Alaska Fisheries Science Center in the Alaska and Northwest Regions that requires research ship support can be addressed for the following six research arenas.

1. Assessment of Fishery Resources. We foresee a continuing demand for improved stock assessment research, not only for the fishery resources of Alaska but also for the resources off the coast of Washington, Oregon, and California. The fishery resource surveys for these two areas require in excess of 1,000 vessel-days per year just to complete the existing annual and triennial survey strategy conducted for the Alaska and Northwest Regions and their respective regional fishery management councils. Improvements in the precision and accuracy of the survey assessments are desired for many of the highly managed stocks. With the growth in the human population, the market demand for many of the existing fish resources is growing which, in turn, increases the pressures on management to harvest at rates near optimum levels. The number of issues of resource allocation among the various segments of the fishing industry will continue to increase. Both of these trends will add further pressure on the Fisheries Service to expand survey coverage and experimental research to improve precision and accuracy of the assessments of our groundfish and shellfish resources.

2. Assessment of Marine Mammal Population. The need is rapidly increasing for population assessments for the marine mammal species of the coastal regions and high seas of the north Pacific Ocean. Assessments in the past have focused on large cetaceans and northern fur seals and sea lions. As our domestic fisheries expand, the possible fishery impact on many of the marine mammals goes undocumented. NMFS must improve assessments and monitor marine mammal populations for trends in abundance and to determine the causes of fluctuations that may occur. This is particularly critical for populations such as the northern sea lions that have undergone major population changes.

3. Salmon Research in Southeast Alaska. A third area is salmon research being carried out in coastal and inland waterways of Southeast Alaska where 34% of the Alaska salmon harvest is taken. This research provides information for fisheries managers and U.S. negotiators working to rebuild depressed stocks and to minimize or eliminate interceptions of U.S. salmon by other nations. Enhancement research is conducted on severely depressed coastwide chinook salmon stocks to provide the technology transfer needed to rebuild stocks that must be allocated among U.S. and Canadian fishermen under terms of the U.S.-Canada Pacific Salmon Treaty. Research to determine country and region of origin for salmon taken in interception fisheries is supported to compile stock identification data bases. Additional research to meet the management and information needs for the Pacific Salmon Treaty is supported to monitor salmon escapements, forecast preseason run sizes in the transboundary rivers, and determine migratory behavior, marine distribution patterns and early ocean ecology of chinook salmon in Southeast Alaska waters. Currently, this research requires about 140 sea days per year aboard the MURRE II. This work, coordinated with the Alaska Department of Fish & Game and Canada under the U.S.-Canada Pacific Salmon Treaty, will continue into the future at about the existing level.

4. Recruitment and Ecosystem Research. The fourth area is fishery oceanography research. This includes expanded research on recruitment processes controlling the year class strength of important coastal groundfish and shellfish stocks (modeled after FOCI). This research area is targeted by NOAA's new Coastal Ecosystems component of the Coastal Oceans Program. We also foresee new investigations to develop marine ecosystems indicators of global climate change. We are developing such a proposal for the Bering Sea ecosystem. These research programs would be carried out in partnership with the Office of Oceanic and Atmospheric Research/Pacific Marine Environmental Laboratory and the major universities in the region.

5. Oceanic Salmon and Driftnet Impact Research. There is an increasing demand for understanding how the ocean environment affects the dynamics of salmonids and marine mammals in the pelagic North Pacific Ocean--particularly their vulnerability to driftnet fisheries. The demand has emerged from recent legislative and diplomatic initiatives that call for information leading to the mitigation of driftnet fishery impacts on salmonid and marine mammal stocks. Existing information on population abundances, stock dynamics, effects of ocean conditions on temporal and spatial distribution of species and prey resources, and the structure and interannual variability in the ocean environment is inadequate to meet requirements of impact assessments. This research has historically been enhanced by cooperative efforts with foreign national research agencies and university studies. The lack of sufficient NOAA vessel research capability in this area subjects U.S. research objectives to those of the driftnet nations and places continuation of future research programs at risk. As such, future research studies will require use of existing vessel platforms for biological and physical oceanographic work and an additional platform with longlining and gillnetting capability for fishery oceanographic work.

6. *Conservation Engineering*. Another area where we expect increased research activity is in conservation engineering for the purpose of designing fishing gear that has lower catch of high-value, by-catch species and for measuring gear selectivity biases of the standard stock assessment survey sampling gear. During the 1960's and 1970's, gear research was a major activity in NMFS. For the last 10 years, it has been given a very low priority in NOAA. As the issues of by-catch limits and incidental take of marine mammals intensify, the call for government-conducted research or government-sponsored research will increase as we are starting to see in Alaska and the west coast. Also, the demand for improved assessments will require innovative research into the sampling efficiencies of the survey sampling gear. This research will require vessel support, although we might expect that most of the ship time would be provided by contracted vessels from the fishing fleet. For the Alaska and Northwest Regions most of this work will be accomplished in full cooperation with the fishing industry.

Growth

In the early 1980's, the research projects of the Northwest and Alaska Fisheries Center used 2,800 to 3,000 vessel days per year (Table 1). Two thirds of the time was devoted to fishery resource assessment surveys. Nearly two thirds of the vessel time was supplied by foreign research vessels. Contract vessels on charter to NMFS were used about 325 to 550 days per year; NOAA ships provided about 600 days per year. About 900 vessel days from Japanese cooperating salmon gillnet vessels worked annually on high seas salmon research. The NOAA ship JOHN N. COBB, which was operated 166 days per year, was removed from base funding in early 1989 with only a couple months of warning and was lost to our fishery assessment research programs. In 1990, we expect about 436 sea days on charter vessels for fishery resource surveys off Alaska and the west coast and 372 NOAA ship days in support of groundfish research and Southeast Alaska logistics for salmon field research. The foreign vessel component decreased by approximately one third from 1980 to 1990, as did the grand total number of vessel days. This declining trend in vessel usage was due primarily to reduction in program funds for both NOAA and the cooperating foreign research agencies. The decline was not the result of fewer problems to research.

Given that the marine resource issues have grown and intensified, particularly in the past five years, we expect a relatively rapid growth in the early 1990's of research projects that require ship support. This growth should slow by the year 2000. Beginning in 1991, we anticipate new funding for a number of initiatives for fishery research for the Alaska and Northwest fish and marine mammal resources. Most of these budget initiatives will require vessel support above that which is currently available. The areas of research are high-seas driftnets, by-catch in the commercial fisheries, Bering Sea pollock, marine mammal assessment, and fishery resource assessment surveys. If these initiatives are approved and our proposals for Global Climate Change and Coastal Ocean research are accepted, then our future vessel needs will expand to our 3,200-sea-day projection (Table 2). The foreign vessel component will not grow from the 1987-89 level for the research areas inside the U.S. EEZ, although we may see new interest in the areas outside the EEZ, especially for the high seas driftnet research, the assessment of pollock in the international zone of the Bering Sea, and fishery oceanography research related to global climate change.

To meet these needs, we foresee continuing the mix of charter, foreign, and NOAA ships. The chartered fishing vessels provide functional and cost effective means of conducting our summer multi-vessel surveys for the fishery resources and marine mammal populations. The NOAA ship MILLER FREEMAN is a necessary survey platform for the winter period and is particularly needed for winter acoustic surveys of spawning pollock and high seas ecology-oceanography projects. The logistic capabilities of the MURRE II are essential in support of the Southeast Alaska salmon research conducted by Auke Bay Fisheries Laboratory, but it is the oldest active vessel in the NOAA fleet by

Table 1. NMFS Research Vessel Day Summary for Areas Within Alaska and Northwest Responsibility Excluding Government Vessels Less Than 65 Feet. (Compiled by G. Stauffer 2/22/90.)

	Charter Vessels		NOAA Vessels		Foreign Vessels		Total	
	Groundfish Surveys	Total[a]	Resource Surveys[b]	Total[c]	Groundfish Surveys	Total[d]	Groundfish Surveys	Grand Total
1980	~325	~325	~460	~600	930	1,910	1,715	2,835
1981	~325	~325	~460	~600	1,110	1,850	1,895	2,775
1982	~325	~464	~460	~600	1,050	1,940	1,835	3,004
1983	324	409	496	635	872	1,789	1,692	2,833
1984	317	437	528	662	804	1,822	1,649	2,921
1985	471	553	287	419	743	1,709	1,501	2,681
1986	424	504	323	510	538	1,628	1,285	2,642
1987	508[e]	591	304	487	458	893	1,270	1,971
1988	369[e]	369	337	565	405[g]	815	1,111	1,749
1989	464[e]	509[f]	294	434[f]	360[g]	940	1,118	1,883
1990[h]	436[e]	?	232	372	300	540[i]	968	?

[a] Includes Auke Bay salmon and marine mammal research.
[b] Includes marine mammal surveys.
[c] Includes *Murre II* and status/trend vessel days.
[d] Includes high seas salmon and marine mammals research.
[e] Includes 65–75 days of no-cost charter for longline vessel.
[f] Does not include vessel days for Exxon oil spill research.
[g] Includes 120 days of Bering Sea "donut hole" research.
[h] Data incomplete.
[i] Does not include the usual Japanese high seas salmon vessels.

Table 2. NMFS Annual Research Vessel Projected Use for 1990–2020 for Alaska Region and 1990–1995 for the West Coast in Days At Sea. (C – Contract Vessels, F – Foreign Ships, N – NOAA Ships)

Program	Alaska and West Coast 1989			Alaska 1990–2000			Alaska 2001–2020			West Coast 1990–1995		
	C	F	N	C	F	N	C	F	N	C	F	N
Groundfish Assessment												
a. Triennial	180	0	38	370	0	0	370	0	0	200[a]	0	50[a]
b. Annual	284	360	145	400	360	190	400	120	190	50	0	0
Marine Mammal Assessment	0	120	0	100	120	30	100	120	30	25	0	0
S.E. Alaska Salmon	45	0	140	100	0	140	150	0	140	–	–	–
Oceanic Salmon and Driftnet	0	460	42	100	580	120	150	240	120	–	–	–
Fishery Recruitment	0	0	31	100	240	140	100	240	140	0	0	50
Conservation Engineering	0	0	0	50	0	0	50	0	0	0	0	0
Total	509	940	396	1220	1300	620	1320	720	620	275	0	100

[a] Triennial survey days for 1992, 1995, 1998, etc.

two decades. Therefore, we anticipate the eventual replacement of the MURRE II with a Class IV NOAA ship or a contract vessel. Trawl and longline capabilities on the replacement vessel would allow it also to support groundfish research. The fishing capabilities of the JOHN N. COBB and the TOWNSEND CROMWELL have been valuable in the salmon and groundfish research conducted out of Auke Bay. Future plans should include a replacement for the sea days on these vessels. In addition to the MILLER FREEMAN and the MURRE II, we foresee the need for another NOAA vessel to replace the JOHN N. COBB and with fishery oceanography capability. Since the active vessels in the NOAA fleet are fully scheduled, our near–term vessel needs will have to be met by contract or foreign research vessels.

Remote Sensing

Remote–sensing technology of the marine environment will continue to expand and will impact research vessel usage in at least three ways. As the technology for real–time transmission of satellite information on sea–surface conditions becomes readily available, scientists will likely develop cruise operation plans that are adjusted during the course of the cruise depending on the information from satellite transmissions. Also, we can expect that the percentage of the cruise time dedicated to developing ground–truth data to calibrate the satellite data will increase. Second, we can expect increases in shipboard acoustic systems for monitoring detailed bottom topography, ocean currents, sampling gear performance, plankton, and fish abundance. In the last five years, a number of new acoustic systems have become available. We should expect that the trend will continue and that the existing systems will be improved. To accommodate the transducers for this equipment, a special acoustic trunk should be built into each government research vessel. The trunk should be designed to allow easy access to the array of transducers without drydocking. This would facilitate calibration, maintenance, and replacement of transducers. Routine calibration of acoustic systems is critical to obtaining accurate data and the plans to accommodate calibrations should be incorporated into vessel maintenance plans. The third area of remote sensing is in the deployment and retrieval of oceanographic buoys, moorings, and drifters. We can expect the percentage of vessel time tracking, communicating, and tending these instruments will greatly increase, particularly for fishery oceanographic research. Vessel designs of the future should be to facilitate the use of all three aspects of remote sensing. Growth in remote sensing technology in conjunction with dedicated or shipboard computers will greatly improve the utilization of ship time and the efficiency of data collection. This gain in efficiency will not reduce our need for vessel days, but will allow for the collection of more data on finer time and space scales and will increase the time spent collecting data using traditional technology to calibrate the remote systems. These technological advances will greatly increase the need for expanded electronic laboratories and technicians aboard ship.

Long–Term Monitoring

The major portion of the vessel time currently utilized by NMFS scientists is for the continuation of time series on the distribution and abundance of important marine resources for which NMFS has management responsibility. Long–term monitoring of the abiotic as well as the biotic components of the ecosystem will be a major activity of NMFS research and that potentially sponsored by NOAA's Global Climate Change and Coastal Ocean Programs. Short–term event studies will generally require dedicated research cruises but will complement the long–term assessment and ecosystem research and will probably utilize less than 20% of the overall vessel time.

Regions and Seasons

The Alaska Fisheries Science Center has resource assessment responsibilities for oceans of the U.S. EEZ off Alaska, Washington, Oregon, and California. The west coast responsibilities are coordinated with scientists of the Southwest Fisheries Science Center and support the fishery management needs of the Northwest and Southwest Regions. For the purposes of the report, vessel requirements in support of resource assessment for the west coast under the Northwest Region after 1994 are reported by the Northwest Fisheries Science Center.

Groundfish assessment surveys are conducted on an annual and triennial basis. The triennial surveys rotate each year between the eastern Bering Sea shelf, Gulf of Alaska, and the west coast. The triennial survey usually requires three ships for 80 to 100 days each starting on June 1. The west coast groundfish triennial survey requires about 250 sea days and is scheduled for 1992, 1995, 1998, etc. For these years the triennial sea–day requirements for the Alaska Region would be zero. If the 1991 budget initiative is funded, then the triennial survey will be expanded to include the Aleutian Islands, which was dropped after 1986 following the withdrawal of the Japanese Fishery Agency. These surveys have historically been scheduled to assess the fish and shellfish stocks during their summer feeding season when their seasonal movements are at a lull and the weather is good. Our pollock surveys are often scheduled to coincide with the spawning period when the fish are concentrated into large spawning schools that are easily detected and enumerated by echo-integration acoustic methods. The FOCI research is timed to coincide with the timing of the early life-history stages of pollock. The salmon and marine mammal research is frequently scheduled to coincide with specific life-cycle events such as a spawning migration or breeding season. The vast majority of our vessel time is utilized during the spring and summer months. Of the 1,880 sea days in 1989, less than 200 occurred in the months of October, November, December, January, and February. However, as ground-truthing and deployment of remote sensors become more important, the need for Class II vessel time in the misery months will increase.

Specific Requirements

New or refurbished fishery or oceanography ships must be designed with capabilities for deepwater trawling (without exception), longlining, and gillnetting to support both inshore and offshore research. Vessels should have 360 degree visibility from the bridge. A stabilizing retractable center board that can serve as an acoustic transducer mount, like on the MILLER FREEMAN, is a valuable feature that should be incorporated into all research vessels. In addition, we recommend the following specific requirements:

1. Trawl to 700 fathoms, to answer depth and distribution questions. The trawl system should be paired programmable hydraulic winches with ˜ 1,200 fathoms of 1" trawl cable.

   Line speed of 300 ft/min and line pull of 22,000 lbs. Net reels should be split-reel type with capacity to hold large rope trawls and hauling capacity in the range of 8,000–10,000 lbs. Ramp haul-in winches with maximum pulls of 30,000 lbs.

   Provide adequate sheltered wet lab space to work up large catches – 2,200 lbs. All counter tops and work surfaces should be corrosive resistant, e.g., stainless steel, plastic, etc. The MILLER FREEMAN's fish lab is a good but not perfect example.

2. Interior lab spaces for vessels over 200' with the following approximate square footage: fish processing lab, 380 sq ft; wet oceanography lab, 350 sq ft; dry chemistry lab, 250 sq ft; data plot, computer and science information room, 200 sq ft; controlled light and temperature/incubation lab, 100 sq ft. A small class of vessels 150–185 ft should include all these spaces with a total area of ˜ 900 sq ft.

   Free deck space for a 200'+ vessel should equal that of the MILLER FREEMAN. A vessel of 150–185' should have approximately the same free deck space as the DAVID STARR JORDAN.

3. Setting and retrieving up to 30 km of 120 mm stretched mesh monofilament gillnet, 10 m corkline to leadline depth. Vessel should be configured to deploy gillnet from stern, retrieve gillnet off port side forward of pilothouse, and store net in stern well. Deck machinery should include net pullers and cylindrical tube for transporting net from forward deck to stern.

4. Deploy CTDO's to 3,000 m, the winch dedicated to this task should be capable of variable speed operation and equipped with UNOL's standard .322 multiconductor cable. This winch should be multipurpose to allow for the oblique deployment and retrieval of ichthyoplankton samplers such as bongo nets, MOCNESS nets, and Tucker trawls. This winch should be hydraulic with a line speed of 350 ft/min, line pull of 3,000 lbs, minimum capacity 5,000 m .322" UNOLS multiconductor cable and slip ring assembly.

   A backup winch with the same capabilities as described above, or a hydrographic winch using 3/16" or 1/4" 6x19 construction cable. This cable is a better choice if one is clamping collecting gear to cable.

5. Fish processing lab should be large enough to allow retention, movement, and disposal of large catches. Decks should be nonskid and equipped with seawater wash down, working surfaces fabricated of noncorrosive materials. Oceanographic wet lab should be large enough to store 24 Niskin-type sea water samplers. This could be accomplished with a motorized, oblong rosette. This lab should be adjacent to the CTD or hydro platform. In many respects, a hydro-bucket is superior to a hero platform when performing oceanographic operations.

   Wet and dry lab spaces should approximate those of the MILLER FREEMAN or DAVID STARR JORDAN. These labs could be below deck, if dumbwaiters were built into the ship to aid in the movement of fragile samples from one level to another. Minimal lab spaces would allow for the following:

a. Salinity determination.
b. Oxygen titration.
c. Chlorophyll extraction.
d. Nutrient analysis.

All these analytical tasks could be conducted simultaneously on a 24-hour basis.

6. The offshore fisheries vessel should have two propulsion systems. Come home capability is a must when working in remote regions, the Bering Sea, the Antarctic Sea, etc. Hull shapes must be designed for this and the propellers should be fitted with nozzles to maximize thrust when trawling. Station keeping and wire angle maintenance are essential to any oceanographic or ichthyoplankton survey; therefore, the vessels should also be fitted with bow thrusters. These thrusters should be state-of-the-art and situated so that noise, vibration, etc. are minimal and have little impact on quarters or other habitable spaces.

7. Labs should be plumbed for hot and cold fresh water. Uncontaminated ambient seawater must be available at all lab sinks. Heat should also be a primary consideration, as these vessels will operate during the winter months in high latitudes.

8. Scientific quarters should allow for at least 12 persons to be berthed at no more than 2 per room and at least one head/shower for each two rooms.

9. Fresh water should be readily available from watermakers. System requirements: 8,000 gallons in storage, 2,400 gallons daily production. Distilled water suitable for analytical chemistry should also be available.

10. XBT/SEAS system should be in place and linked to satellite data transmission system.

11. Satellite links should be in place for telecommunications, rapifax, weatherfax, sea surface temperature/color, etc.

12. All chemical and biological lab spaces should be adequately ventilated to allow for routine usage of formalin and other types of chemical preservatives/fixatives.

13. An uninterrupted stable voltage system with power loss protection should be installed for scientific instrumentation and computers.

14. An integrated network computer system on board to interface with the ADCP and other shipboard environmental and ship position data acquisition systems.

15. A thermosalinograph and ***in situ*** fluorometer for underway observation and collection of sea surface data. Remote readouts should be in the bridge and scientific instrumentation room.

16. CTDO/Niskin rosette/transmissiometer system with computer hardware and backup units for physical and chemical oceanography data collection. Data should be real-time and transmittable by satellite.

17. State-of-the-art analytical equipment for determining: salinity, oxygen concentration, and chlorophyll concentration of sea water samples.

18. Fish-finding and bottom-sounding equipment should include shallow and deepwater fish finders. 12 kHz PDR/UGR sounders and recorders. 12 kHz high resolution bottom pingers.

19. Net mensuration systems should utilize both third wire and acoustic link. Both systems should have an operational capability to 700 fathoms.

20. Positioning equipment: GPS, Loran. These should interface with a data recording device and the equipment in item 17 to catalog habitat data such as bottom depth and type, and off bottom signals.

21. Scientific echo sounder with signal processor to provide density estimates from midwater signals. "EK-500 type" with 3 cards for 38 kHz, 120 kHz, and 200 kHz transducers.

22. Two large capacity hydraulic cranes capable of deploying large towed transducers, buoys, etc., lift and extend 15' with a 20 ton load.

23. Hull and deck design should be suitable for hauling longline, pot gear, and gillnets. Line haulers for crab pots and sablefish longline gear. Net haulers for gillnets.

24. Two −80°C freezers for storage of histological grade tissue specimens.

25. Scientific blast freezers for specimens and bait equal to those presently on the MILLER FREEMAN.

26. Small boat capable of carrying five people safely on the high seas and adequate for transferring personnel between vessels.

Additional specifications for marine mammal research:

1. Helicopter pad, at least large enough for a small helicopter such as a Bell 206 or Hughes 500.

2. Observation area (the higher the better within constraints of vessel design) to include:

   - A wind break (deflection window)
   - Communication link from observation deck to the bridge
   - Radar and radio antennae higher than observers
   - Position readout on observation deck
   - No obstructions from 270 to 90 degrees
   - Writing platform
   - Seating that allows adequate viewing

3. Capability to launch and pick up Zodiac–type skiffs.

4. Communication links with Argos satellites to track transmitter–equipped marine mammals at sea.

5. Ice–reinforced vessel for research in high latitudes.

Ecosystem Research Needs and Fleet Requirements

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Fishery Research Mission

The mission of National Marine Fisheries Service is to achieve the continued optimum utilization of living marine resources (LMR) for the nation. A crucial objective of this mission is maintaining the biological productivity of these resources. That, ideally is accomplished through management of fishing and other human activities via an understanding of the living marine resources and their interactions, as well as the effects of climate, fishing, and pollution on these resources. NMFS pursues its mission under the umbrella of over 100 federal statutes; some of which are: the Magnuson Fishery Conservation and Management Act; the Endangered Species Act; the Marine Protection, Research and Sanctuaries Act; the Anadromous Fisheries Conservation Act; the Fish and Wildlife Coordination Act; the National Aquaculture Act; the National Ocean Pollution Planning Act; Superfund; Clean Water Act; Acid Precipitation Act; Agricultural Marketing Act; the Food, Drug, and Cosmetic Act; Coastal Zone Management Act; and the National Sea Grant Program Act. In summary then, the *GOAL* is full utilization of living marine resources without their depletion. This requires broad, yet detailed understanding of the living marine resources and the ecosystem within which they live.

An Ecosystem Approach Is Required

Living marine resources include the benthos (i.e., infauna and epifauna (flora) including certain shellfish), nekton (i.e., fish, squid, marine mammals and turtles including pelagic and demersal species), plankton (i.e., phtyo- and zooplankton including eggs and larvae of benthic and pelagic species), and neuston (i.e., those forms on the sea surface including certain eggs, larvae, snails, and jellyfish). As a consequence of the fact that these resources are found on the sea bed, in the water column, and on the surface of the ocean, all of these components must be sampled in order to capture, study, and understand the various life cycles and interactions affecting harvestable species of interest to humankind.

Living marine resources perform various roles in the overall functioning of the ecosystem. They are used as food for other living marine resources as well as for humans. They are valuable economically. They support the ecosystem by assisting in the balance between predator and prey, in the degradation of organic matter and contaminants, in the recycling of nutrients, and in the production of organic matter to sustain or provide a valuable fishery. In short, the living marine resources are valuable for sustaining a harvest of desirable, wholesome species. All of these functional roles and interactions must be studied; ergo appropriately sampled for the continued maintenance, restoration, or enhancement of these species.

NMFS also is concerned with the effects of pollution, fishing, and climate on living marine resources. Pollution effects can range from decreased fecundity and increased mortality to aesthetically displeasing resources and the hazardous ingestion of these resources. Pollution, therefore, affects the abundance and wholesomeness of living marine resources. Either set of effects can result in economic loss. Fishing pressure greater than a stock's ability to replace itself via recruitment ultimately will ruin the stock for economic or recreational harvest, and may lead to its replacement by other or less desirable species. However, fishing pressure which is too low may lead to underutilization of the stock and less economic return than could have been realized. Climate establishes the overall environmental bounds for a species. Whether or not an organism survives, thrives, or dies is the combined result of its internal makeup, ultimately genetics, and the external environment. As climate changes so does the distribution and abundance of species. This too affects socioeconomics and the harvest of species. As a consequence sampling to integrate the effects of pollution, fishing, and climate on living marine resources must be considered.

Additionally, the deep sediment layers are of paleoecological interest to help us understand the living marine resources of today and the future based on what happened in the past. Thus a capability for sampling these layers also must be considered.

While the primary emphasis of NOAA/NMFS is on harvestable fish and shellfish, and protected (endangered or threatened) species, it also must have the capability in the next 10 to 20 years to accomplish the collection of information necessary for understanding linkages between the various components listed above. To do this will require increased sampling in both time and space in shallow estuarine and coastal areas as well as over the continental shelf and in the deep ocean. The increased sampling comes about because as one begins to understand a system or resource, its apparent complexity increases, and the details that begin to show as exceptions need resolving in order to move to the next higher level of understanding for management. Questions of how the cumulative effects of coastal development are affecting fisheries are now being expressed. Questions concerning the decline in coastal stocks have been raised as to whether they were caused by degrading habitat, overfishing, or subtle climatic changes which have affected distribution and recruitment. The news media has expressed concern over the healthfulness of various food products, including fish, and relationship to human activity and socioeconomics. And now the question of global climate change and how it might affect our stocks and economy is being raised. For resolution of these questions long-term, detailed sampling in estuaries, over the continental shelf, and in the deep ocean will be required.

The approach to sampling then is to monitor stocks as well as improved understanding of the marine ecosystem such that ideally when one portion or species is impacted, the ramifications of that impact can be predicted and appropriate responses proposed in the a timely manner. In order to do this NMFS must be able to monitor (sample) stocks on appropriate temporal and spatial scales and make the linkages between these stocks and other parts of the ecosystem. In effect, we are talking about being able to collect the information necessary to build models; conceptual at first, later predictive. Such ecosystem models can be conceived as a series of boxes representing compartments of an ecosystem with lines connecting the boxes representing the flow of energy and materials between the boxes. NMFS needs to know the size of various boxes (i.e., abundance, concentration) and the magnitude and direction of flow along the lines between them--how much is coming in (i.e., recruitment, growth, productivity) and out (i.e., mortality, emigration, harvest) of each box, and where that energy or material came from or is going (i.e., which boxes are linked). To collect this information NOAA/NMFS requires broad sampling capabilities with a diversity of approaches, equipment and platforms, including surface ships, ROV's, buoys, aircraft, and satellites. While not all sampling will be accomplished by ships, ships will remain a primary sampling vehicle because of their versatility and the kind of support they provide other sampling platforms. As such, NOAA's fleet of the future must not only be able to collect samples required of an ecosystem approach, but also must be able to interface with each of the other sampling platforms. This particularly would include electronic communications and transfer of information between these platforms and land-based laboratories.

__Categories Requiring Vessel Support__

Basic categories of NMFS research requiring vessel support include the following:

- Resource Surveys to provide the resource information on which fishery management decisions are based.

- Fishery Ecology Studies to determine the effects of natural and human-induced habitat changes on living marine resources.

__Resource Surveys__. Sampling capability must include that required by fishery independent surveys of pre- and post-recruits for estimates of stock recruitment and assessments of abundance, distribution, and status of stocks of commercial (and recreational) interest. Such sampling would include use of plankton nets, trawls, dredges, and grabs. Gear development for commercial fishing may again come into vogue. Tests to check the efficiency of or the damage caused by certain gear may need to be accomplished. These commercial-sized gear are large and heavy, and may require special consideration regarding the capabilities of sampling platforms. Because other papers within this working group provide a much better analysis of the needs for resource surveys, I defer to them.

__Fishery Ecology Studies__. Sampling capability must include that required by the ecological studies. These are highly diverse in terms of platform endurance, number of scientists, equipment, deck and laboratory space, and specialized support (e.g., electrical voltage and amperage, fresh and salt water, contamination-free laboratories, vibration-free counter tops, reception of satellite imagery, etc.).

Platform endurance ranges from several days for vessels used in estuaries and nearshore coastal waters to three to four weeks for vessels used in outer-shelf and open-ocean studies. The number of scientists frequently will be 10 to 20 because of the diversity of studies being undertaken and the need for maintaining at least two shifts (watches).

Equipment will range from light and fragile to heavy and dangerous. Light meters, small water bottles, CSTD's, and plankton nets are among the lighter and more fragile pieces of equipment. Intermediate gear would include bottom grabs ranging from 200 to 700 pounds. Large water bottles (50 to 200 liters) and corers weighing almost one ton will require real skill in handling with minimal risk. Certain other kinds of gear are particularly large or awkward and require lots of deck space. These would include midwater and bottom trawls; certain dredges and other towed and vertical profiling samplers; and hose and tanks for vertical pump samples. Additional deck and storage space is often required for backup samplers and sample containers.

Laboratory space demands are often high because many of the experiments must be accomplished at sea. Under these conditions 500 to 700 sq ft of interior laboratory space may be required. Autoanalyzers, scintillation counters, and water baths for controlled temperature experiments may require 100 sq ft each. Temperature regulators and accessories for the water baths may require 150 amps of 110V AC. Certain equipment (e.g., ultraviolet lamps to break down organic matter) require 220V AC. Recorders require very stable voltage. Microscopes require stable, nonvibrating counter tops.

Nonfood refrigerator and freezer space (30 to 40 cu ft for each) for storage of chemicals and potentially contaminated water and sediment samples will be required. Provision for the storage and use of hazardous materials (e.g., acetone, alcohol, aldehyde, acids, and radioisotopes) must be planned. Such provision might include adequate ventilation and no recirculation of air through the vessel, fume hood, special noncorrosive counter tops, and flammables and hazardous materials lockers.

Additionally, the capability must exist to have many of the measurements entered directly into a computer. As such not only will a computer room be needed, but also linkages and ports will be needed in each laboratory, on the bridge, and perhaps on deck or near deck equipment. This would allow integration of station location, depth, sample time, variable(s), and measurement at sea. Finally, satellite reception is a must. It will materially improve cruise performance in sampling ocean fronts, plumes, upwelled water, and certain water masses.

Assessment of Future Remote-Sensing and Ship Instrumentation to Support Fisheries Research

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Introduction

The purpose of this paper is to assess the direction of fisheries remote-sensing (satellite, aircraft, and *in situ*) research and the supportive needs from the NOAA ships for research and resource management. I will focus on the remote-sensing systems capable of measuring and monitoring environmental conditions and processes affecting fisheries, and the shipboard instruments to support the research. Fish include the pelagics as well as groundfish which are influenced by surface-layer transport in their early life cycles.

Ingham (1979) states that "most of the research and monitoring endeavors of fishery oceanography are based on the axiom that environmental variation has significant effect on *abundance* and *distribution* of fisheries resources." It is well known that the operational fishing industry and fisheries research rely quite heavily on catch statistics and environmental data for fish exploitation and for management of the species. The fish abundance and distribution are affected by such ocean processes as current boundary movements, ocean currents, sea-surface-temperature gradients, thermocline structure, and ocean productivity. Fisheries research activities can make use of remotely-sensed data to measure these parameters with sufficient accuracy to correlate fish distribution and water parameters, providing input to fish recruitment assessment.

The value of environmental satellites for providing data and services is well recognized by satellite operating countries. Satellite remote-sensing instrumentation and data processing techniques for ocean research are rapidly maturing. Experience with the Nimbus-7 Coastal Zone Color Scanner (CZCS) launched in 1978 has demonstrated the feasibility of making useful ocean color measurements which have implication to phytoplankton productivity as well as global climate change. Ocean color measurements have been successfully used to map distribution of chlorophyll in the ocean (G.K. Clarke, et al., 1970; and J.C. Arvesen, et al., 1973) from which biological productivity affecting fish yield can be estimated (D.J. Collins, et al., 1986; and D. Kiefer, 1986). Studies (Gordon, et al, 1980; 1982) show that total phytoplankton pigment concentrations by CZCS measurements indicate accuracies of a factor of 2 over the range of 0.05-30 mg/m^3.

Sea surface temperatures (SST) have been produced operationally since 1972 and measurement algorithms and satellite instrumentation have improved (Warner, R. and W. Pichel, 1989). These measurements have been accepted by a wide spectrum of researchers. Sea surface temperatures can be determined by using NOAA AVHRR multichannel infrared radiometers and provide maps of surface temperatures with a resolution of one kilometer and accuracies of 0.5° (McClain, et al., 1983; and Strong and McClain, 1984). These data reveal oceanic fronts, eddies, convergence zones, temperature gradients, and upwellings important to fisheries research, management, and recruitment.

Laurs (1985), Laurs and Brucks (1985), and Clark, et al. (1985) review fisheries research applications of satellite oceanic remote sensing in the United States. Examples of uses of satellite data in U.S. fisheries in the eastern North Pacific are also given in Fiedler, et al. (1985). Yamanka (1982) describes the applications of satellite imagery to fishery studies in Japan. Montgomery (1981, 1986) describes the utilization of satellite-derived products to U.S. west coast commercial fishing operations.

Certainly there will be a steady increase of the applications of space technology in the next several decades for biological and physical oceanographic research. Already there are several oceanographic satellite systems in the planning and design phases which address areas such as surface wind speed and direction, significant wave height, ocean circulation, sea ice morphology, ice edge, and ocean productivity. A synopsis of these systems are shown in Table 1. They represent an international array of satellite systems and will require mutual sharing of data to support fisheries research.

The Ocean Color Instrument (OCI) scheduled for 1994 may become a key sensor to determine global productivity and a mainstay to determine carbon fixations in the oceans as part of CO_2 studies such as the Joint Global Ocean Flux Study (JGOFS). Further, ocean color measurements are essential to determining

Table 1. Oceanographic Satellite Synopsis.

SATELLITE	DEVELOPING ORGANIZATION	LAUNCH DATA	DESIGN LIFE	SENSORS	APPLICATIONS
ERS-1	ESA/European	Late 1990 w/Follow-ons	3 Years	AMI ATSR	Wind Speed/Direction; Wave Height; Ice Edge; Currents; Sea Surface Temperature
GEOSAT	Navy/USA	1985 with Follow-ons	3 Years	ALT	Surface Wind Speed; Significant Wave Height; Ice Edge
TOPEX	NASA/USA	1993	3 Years	ALT	Ocean Surface Topography; Currents
JERS-1	Japan	1993	3 Years	VNIR	Sea Surface Temperature
ADEOS	Japan /NASA SCAT	1993	3 Years	NSCAT OCTS	Wind Speed and Direction; Ocean Color; Temperature
RADARSAT	Canada	1994-95	3 Years	SAR	Sea Ice Topography
NOAA-11	NOAA/USA	1989 with Follow-ons	3 Years	AVHRR	Sea Surface Temperature; Circulation; Upwelling
DMSP	DOD/USA	1987 with Follow-ons	3 Years	SSM/I	Wind Speed; Sea Ice Morphology
SEAWIFS	NASA/USA	1991	3 Years	OCI	Ocean Color; Chlorophyll; Productivity
MOS	Japan	1986 with Follow-ons	3 Years	MESSR VTIR	Ocean Color; Sea Surface Temperature
EOS	NASA/USA	1998	5-10 Years	MODIS MODIS-T MERIS AMRIR SCATT ALT	Ocean Color; Biological Processes; Sea Surface Temperature; Wind Speed and Direction; Sea Ice; Circulation; Topography

pelagic fisheries habitat, distribution, and recruitment assessments.

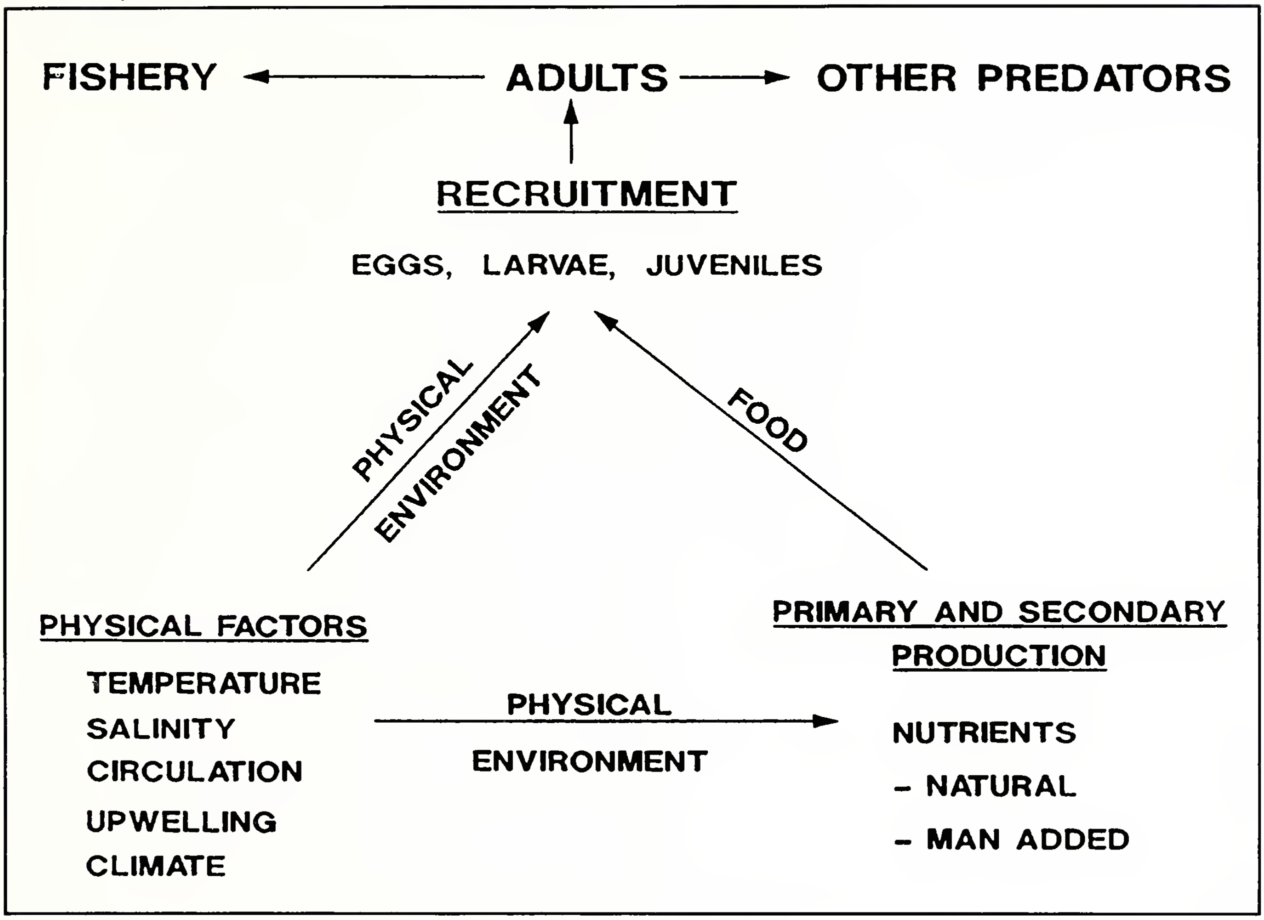
Parameters/variables important to fisheries oceanographers include: mixed layer depth and thermocline gradient, surface temperature, surface flow, subsurface flow, chlorophyll concentration in the photic zone, nutrients in the water column, cloud cover and fog, water color, suspended particulate matter, sea surface topography, sea state, solar radiation, dissolved oxygen, and other.

Some of these parameters can be measured from remote-sensing systems. The fisheries manager and the researcher require information on these variables and their interrelationships to estimate recruitment, population, age, etc. Figure 1 illustrates the influence the marine environment has on fisheries recruitment where remote-sensing technology can have a role.

Fisheries Applications – Pelagics: A Case for Remote Sensing

Conservation and management of species that travel through the jurisdiction of many nations require international cooperation in research and in access to international satellite data. In the tropical and subtropical Eastern Atlantic Ocean such species include shipjack, bluefin, albacore, bigeye, and yellow tuna; white and black marlin; Atlantic and plain bonito; Atlantic sailfish; swordfish; and West African Spanish mackerel. U.S. west coast includes the anchovy,

Figure 1. The Influence of the Physical Environment on Fishery Recruitment. (From NOAA's Coastal Ocean Program, October 1, 1988)



albacore tuna, billfishes, Pacific and jack mackerels, and Pacific salmons. These species are among the most commercially valuable species caught. Many feed on fish, squid, and crustaceans in the upper mixed layer of the ocean and, thus, are relatable to remote-sensing sea surface temperatures and the surface water mass they represent. Conservation and effective management of these fishery resources require scientific information on abundance, reproduction, and migration, as well as information on the number of each species caught and the time and location of the catch. This information, along with an understanding of the effects of the oceanic environment, can be used to determine how these populations can be harvested without jeopardizing the resource.

Programs Utilizing Remote Sensing

Remote sensing is advancing at a rapid rate and the potential for addressing this technology for fisheries research is great. Programs where this technology can be used for fisheries research include:

Ice Edge Ecosystems Study. Satellite imagery, AVHRR, and SAR should contribute to the understanding of biological productivity in the Arctic.

Fisheries Oceanography Coordinated Investigations. This activity could provide a test bed for remote sensing addressing shelf-slope water exchange. Satellite-tracked drifters coupled with SAR and doppler profile measurements can give insight to surface circulation patterns and eddies in the Aleutian Basin. Inputs of this information could be utilized for improved Lagrangian model development. All-weather remote-sensing capabilities (i.e., microwave) are necessary to accomplish the objectives.

International Collaborative Remote-Sensing Fisheries Research. This research is also important to our understanding of fish behavior, distribution, and abundance. NESDIS/ORA has proposed to NATO a workshop that will evaluate the scientific basis for the present and future role of spaceborne technology in the Eastern Central Atlantic Ocean. A key component will be the integration of remote-sensing technology into fisheries research. The tropical tuna will serve as a case study.

The Coastal Ocean Program. The Nutrient Enrichment and Enhanced Productivity project of the Coast Ocean Program lends itself to remote-sensing applications. Remote sensing from satellites and aircraft can provide wide area and temporal coverage of biological productivity and water quality conditions. Information gathered by the remote sensing systems can provide input to such problem areas as algal blooms, anoxia, eutrophication and increased turbidity, which affects the living marine resources.

Satellite Support to Fisheries Oceanography

Previous experiences with present satellite systems, as well as the potential of those programmed for the future almost guarantee an adequate availability of remotely-sensed data to support an integrated effort of our knowledge of surface and near-surface phenomena which can address fisheries research. The variations in ocean conditions control fluctuations of fish stock, their distribution, and harvesting. The evolving satellite instrumentation, and data processing technology combined with conventional shipboard data-collection techniques will become an increasingly useful tool.

In view of this, the following selected applications are summarized:

Sea Surface Temperature. Fisheries studies utilizing satellite sea-surface-temperature measurements rely on the Advanced Very High Resolution Radiometer aboard the NOAA polar-orbiting satellites. These satellites provide twice daily coverage and 1.1 kilometer spatial resolution and should meet the needs for fisheries research requiring sea-surface-temperature (SST) data. As an example, SST is an important variable to the studies of tuna stocks (Laurs, et al., 1984). The surface temperature influences the tuna behavior and provides an indication of processes in the ocean upper layer. According to Laurs (1973), horizontal and vertical temperature gradients are critical in the tuna forage areas, and are a determining factor in spawning and survival. Njoku, et al., 1985, discusses advances in satellite SST measurements and applications to fisheries.

Ocean Color. Ocean color measurements can be used in fisheries research to make quantitative measurements of chlorophyll-a within the phytoplankton crop; estimates of seston concentration, and to provide information on water masses, circulation patterns, and oceanic fronts. Kiefer (1986) is conducting work on the feasibility of using ocean color data to estimate the rate of primary production by marine phytoplankton.

Surface Layer Transport. The most critical survival period for many fisheries is during the time of egg and larval drift (Brucks, J., 1979). Finfish and shellfish which spawn offshore depend on surface currents to transport the eggs and larvae into estuarine areas (Fiedler, 1983; Laurs, et al., 1984; Herron, et al., 1989). Accurate estimates of wind-induced surface transport during spawning times could serve as input to predictive capabilities for fishery recruitment. Planned instruments (i.e., SAR, scatterometer) on future satellites can provide data on this need.

Salinity. The affects of salinity on fisheries in the surface layer is not well known. Laurs (1973) believes that salinity by itself does not have a great influence on the distribution and abundance of tunas. Stevenson (1974) states that strong salinity gradients in estuarine, coastal, and the open ocean many influence the distribution and patterns of some species.

At the present there are no salinity instruments in space, though advancing technology shows that this capability may be possible in the early part of this decade. Aircraft salinity instruments from low-cost aircraft are now being considered to address needs for estuarine oceanographers and fishery scientists. Studies will address physical and biological assessments and will be input to numerical hydrodynamic models. The technology will focus on a multifrequency microwave sensor to process and display salinity and temperature data near real-time. The system will provide measurements over the range of 0-35 parts per thousand.

Aircraft Support to Fisheries

Estuaries and their associated coastal waters are extremely fertile, producing large quantities of animal and plant material (i.e., total biomass) each year. They are sites of valuable inshore fisheries and the spawning/nursery ground of many species of pelagic finfish which range over the waters of the continental shelves.

Estuarine and near-coastal-ocean phenomena vary too rapidly in space and time for observation by conventional ship-based sampling techniques. Remote-sensing methods provide the capability of making the large-scale synoptic observations necessary for investigating these phenomena. As a result, satellites have been used successfully to observe various color and thermal features of the open ocean. However, estuaries and their associated coastal waters have more stringent spatial and temporal resolution requirements than the open ocean.

For instance, spatial resolution requirements for estuarine studies can be as small as 5–50 meters, as compared to 1–10 kilometers for the open ocean. Similarly, temporal coverage of every 0.5–6 hours may be required as compared to 1–7 days for the open ocean. As a result, in the coastal zone, satellites must be supplemented with aircraft sensors in order to obtain the spatial and temporal resolution needed to monitor estuarine dynamics to support fisheries research.

The need for an integrated, satellite/aircraft/ship approach was clearly emphasized at the Workshop on Remote Sensing of Estuaries (Klemas, Thomas, and Zaitzeff 1987) and at meetings of the Chesapeake Bay Remote Sensing Working Group. Table 2 shows present marine research ocean-color aircraft sensors which can be utilized to complement satellite and shipboard measurements. The Ocean Data Acquisition System (ODAS) is already being used routinely in Chesapeake Bay to monitor chlorophyll concentrations and will eventually be used for input into phytoplankton biomass measurements.

Recommended Shipboard Instrumentation to Support Fisheries Remote Sensing

Specific shipboard instrumentation to support remote sensing fisheries research are outlined in Table 3. Most of this technology is available for shipboard installation with minor modifications. The instruments should be integrated into turnkey or automated packages allowing for minimum trained technical support and simple downloading of data after the research cruise. It is possible existing fleet overside gear, laboratory space, and free deck space should be sufficient to accommodate this instrumentation.

Ship Features/Capabilities

The following define some needed vessel characteristics:

Table 2. Aircraft and Sensors.

INST.	TYPE	A/C	ALT	FOV	GSD
AMMS	6 CHANNEL	VARIOUS	> 500'	> 40 M	>0.1 M
AOL	LIDAR	P-3	500'	NADIR	1 M
MOCS	ELEC. SCANNER	P-3	500-23000	< 4 KM	15 M
ODAS	3 CHANNEL	VARIOUS	> 500'	NADIR	2 M
MARS	8 CHANNEL	VARIOUS	> 500'	NADIR	10 M
AVIRIS	128 CHANNEL	ER-2	65000'	25 KM	20 M
AOCI	8 CHANNEL	ER-2	65000'	33 KM	50 M
LASER	3 CHANNEL	VARIOUS	> 500'	NADIR	1 M

AMMS Airborne Multispectral Measurement System
AOL Airborne Oceanographic Lidar
MOCS Multichannel Ocean-Color Sensor
ODAS Ocean Data Acquisition System
MARS Multichannel Airborne Radiometer System
AVIRIS Aircraft Visible-IR Imaging Spectrometer
AOCI Airborne Ocean-Color Imager
LASER Light Amplification By Stimulated Emission of Radiation

Table 3. Recommended Shipboard Instrumentation Supporting Fisheries Remote-Sensing Research

(1) Personal computer/satellite APT and HRPT receiving and processing systems for near real-time sea surface temperature and ocean color data at shipboard. Capability will provide near real-time surface and near-surface processed images showing SST's, chlorophyll concentration, gradients, fronts, circulation patterns, upwelling, etc. Color enhancement of parameters will be required. Satellite to ship and shore to ship of processed data needs to be explored. Sophisticated satellite communication links as INMARSAT can be used, though it is expensive. Transmission of processed satellite data via single side band radios should be evaluated.

(2) Multichannel sunphotometer designed to provide accurate data for the calculation of integrated aerosol optical depth (atmospheric turbidity). Data bases used as input to models for providing corrected SST's and ocean color measurements.

(3) Lidar system (7 channel) for measurement of vertical layered profiles of atmospheric turbidity. This instrument complements the sunphotometer for specific atmospheric depth and validating SST retrievals at night.

(4) Acoustic doppler profiler to provide measurements of near and subsurface circulation structures. Provide insight into surface layer transport of early (larvae) fish stages. Provide correlation to surface transport which can be related to satellite observations.

(5) In water apparent optical (visible region) properties measurement instrument (spectrograph) to calibrate ocean color satellite and aircraft data. Capabilities require downwelling irradiance, upwelling irradiance, and radiance reflectance. Support ocean color (chlorophyll, seston, and dissolved organics) algorithm development. Measurements will be related to aircraft and satellite systems. Optimum capability is while vessel is underway, though technically not now feasible.

(6) Continuous underway system for measurement of phytoplankton levels via surface-water fluorescence values. Measurements should be tied to Loran-C or other high precision location instruments as the Global Position Systems. Data used as input to surface and near surface productivity levels and calibration of satellite systems.

(7) A long-track emitted thermal IR (5 channel). Used to corroborate NOAA AVHRR and EOS MODIS instrumentation for SST validation. Provide sea surface radiation skin temperature data.

(8) Expendable transmissometers for obtaining spatial distribution of suspended particle concentration. Instrument should also have a temperature sensor. System can be deployed and data recovered while vessel is underway. Flow through transmissometers also need to be incorporated.

(9) Measurement of UV-B radiation incident at the ocean surface and at ecologically significant depths. Data needed for estimating UV-B influence on phytoplankton primary productivity. Focus of measurement will be in Arctic and Antarctic regions.

(10) Spectroradiometer (252 channel) continuous along track measurements of water leaving radiance and downwelling irradiance will provide data for validating visible region satellite information and chlorophyll, seston, and dissolved organic algorithm development and verification.

(11) Underwater high sensitivity multi-spectral video camera for fish larvae distribution, identification, and population. Estuaries and near coastal areas will be focus for measurements. Use for groundfish larvae distribution such as pollock in Arctic should be explored.

(12) Dual-beam, high-frequency, bio-acoustic backscatter instrument for measurement of marine organism, i.e., krill. Measurement is density of organism/meter^3.

(13) Multifrequency oceanographer lidar for fluorescence-induced chlorophyll. Serve as ground-truth for satellite and aircraft chlorophyll and seston measurements.

(14) Laser for direct location, and identification of fish schools.

1) Ice-strengthened hull for polar regions research.

2) Hull design such as Catamaran type for shallow water estuarine environments; capability to include high-speed for high-density transects for *in-situ* data collection for correlating of satellite and aircraft overpasses.

3) Cabin and deck space for satellite receiving systems; space for the satellite reception and processing system including antennas.

4) High precision navigation which can be integrated into marine environmental data streams.

5) Hull should be designed to eliminate bubbles (this is important to acoustic doppler operations and inwater optical measurements).

6) Capability for deployment (starboard or port) of optical floating platforms for inwater measurements; platform will be tethered to ship.

7) Laboratory space (150 sq ft) for optical instrumentation calibration, testing, and storing.

General Summary

It is not possible to measure all parameters which affect fish behavior from remote-sensing techniques. This technology adds to our ability to better understand complex areas by (1) providing synoptic and detailed information on the surface and near surface field, and (2) directing research ships to maximize their sampling ability (Thomas, J., 1980). The remote-sensing systems (satellite, aircraft, and ship) discussed in this paper cover the basic needs for fisheries remote-sensing research for this decade and beyond. Depending upon a stable national ocean policy and funding commitment, there will be follow-on satellite systems to extend the lifetime of those systems in place or planned.

References

Arvesen, J.C., J.P. Millard, and Weaver, (1973), E.C. Astronaut, 1973. Acta 18.229.

Clark, D.K., H. W. Yates, and J.W. Sherman, 1985. Marine Applications for Satellite-Derived Ocean Color Imagery, *Sea Technology,* Nov. 1985.

Clarke, G.C., G.C. Ewing, and C.L. Lorenzen, 1970. Spectra of Backscattered Light from the Sea Obtained from Aircraft as a Measure of Chlorophyll Concentration, *Science,* 167:1119-1121.

Collins, D.J., et al., 1986. A Model for the Use of Satellite Remote Sensing for the Measurement of Primary Production in the Ocean, *Proceedings of SPIE-The International Society for Optical Engineering,* V. 637, *Ocean Optics VIII.*

Evans, R.H., 1976. *Remote Sensing: With Applications to Exploitation and Management of Atlantic Tuna Stocks,* Working document prepared for the SCRS Meeting of the International Commission for the Conservation of Atlantic Tuna, November 10-16, 1976, Madrid, Spain.

Fiedler, P.C., 1983. Satellite Remote SEnsing of the Habitat of Spawning Anchovy in the Southern California Bight, *CalCOFI Rep.* XXIV:202-209.

Fiedler, P.C., G.B. Smith, and R.M. Laurs, 1985. Fisheries Applications of Satellite Data in the Eastern North Pacific, *Mar. Fish. Rev. 46,* 1985, 1-13.

Gordon, R., D.K. Clark, J.C. Mueller, and W.A. Hovis, 1980. Phytoplankton Pigments Derived from the Nimbus-7 CZCS, *Science,* 210:63-66.

Gordon, W.S., D.K. Clark, J.W. Brown, O.B. Brown, and R.W. Evans, 1982. Satellite Measurements of the Phytoplankton Pigment Concentration in the Surface Waters of a Warm Core Gulf Stream Ring, *Journal Mar. Res.,* 40(2):491-502.

Herron, R. C., T.D. Leming, and J. Li, 1989. Satellite-detected fronts and butterfish aggregations in the northeastern Gulf of Mexico, *Cont. Shelf Res.* 9(6):569-588.

Ingham, M., 1979. Fisheries Oceanography, *Remote Sensing in the Coastal and Marine Environment, Marine Policy and Ocean Management Program.* WHOI-80-10, edited by J. Zaitzeff, P. Cornillan, and D. Aubrey.

Joseph, J. and M.R. Stevenson, 1976. *A Review of Some Possible Uses of Remote-Sensing Techniques in Fishery Research and Commercial Fisheries.* Proc. Symp. held in Constance, F.R.G., 23-25 May 1973, 75-100.

Kiefer, D.A., 1986. Consideration of Primary and Secondary Production in the Upper Ocean, *U.S.-Spain Workshop Report: Canary Islands Fisheries Oceanographic and Remote-Sensing Technique Development Utilizing Satellite-Based Data,* 75-100.

Laevastus, T. and H. Rosa, 1961. *Distribution of Tunas in Relation to Their Environment.* Paper submitted to World Scientific Meeting on the Biology of Tunas and Related Species, Information Paper No. 2, Honolulu, Hawaii.

Laurs, R.M., 1973. Requirements of Fishery Scientists for Processed Oceanographic Information. *Proceedings of the World Meteorological Conference,* Tokyo, Japan, October 2–7, 1972, 6(1):95–111.

Laurs, R.M., and J.T. Brucks, 1985. Living Marine Resource Applications, *Advances in Geophysics,* 27(1985):419–452.

Laurs, R.M., P.C. Fiedler, and D.R. Montgomery, 1984. Albacore Tuna Catch Distributions Relative to Environmental Features Observed from Satellites, *Deep-Sea Res.,* 31(9):1085–1099.

McClain, E.P., W.G. Pichel, C. C. Walton, Z. Ahmad, and J. Sutton, 1983. Multi-Channel Improvement to Satellite-Derived Global Sea Surface Temperatures, *Adv. Space Res.,* 2(6):43–47.

Montgomery, D.R., 1981. Commercial Applications of Satellite Oceanography, *Oceanus,* 24:56–65.

Montgomery, D.R., R.E. Wittenberg-Fay, and R.W. Austin, 1986. The Applications of Satellite-Derived Ocean-Color Products to Commercial Fishing Operations, *Marine Technology Society Journal,* June 1986, 72–86.

Njoku, E.G., T.P. Barnett, R.M. Laurs, and A.C. Vastano, 1985. Advances in Satellite Sea Surface Temperature Measurement and Oceanographic Applications, *Jour. Geophy. Res.,* 90(C6):11,573–11,586.

Smith, R.C. and K.S. Baker, 1989. Stratospheric Ozone, Middle Ultraviolet Radiation and Phytoplankton Productivity, *Oceanography,* November 1989, 2(2).

Stevenson, M.R. and F.R. Miller, 1974. Application of Satellite Data to Study Oceanic Fronts in the Eastern Pacific, *Final Rep. Grant #04-3-158-59,* p. 111.

Strong, A.E. and E.P. McClain, 1984. Improved Ocean Surface Temperatures from Space--Comparisons with Drifting Buoys, *Bul. Amer. Meteorol. Soc.,* 65(2):138–142.

Thomas, J.P. Assessment of Superflux Relative to Fisheries Research and Monitoring, *Chesapeake Bay Plume Study Superflux 1980.* NASA Conference Publication 2188, NOAA/NEMP ABCDFG 0042, Edited by J.W. Campbell and J.P. Thomas.

Warner, R.A. and W.G. Pichel, 1989. Past, Present, and Future of Data Processing and Utilization of Satellite Sensor Data for Ocean Color and Temperature Application, *"Marine Observation Satellite-1 International Symposium,"* March 2, 1989, Tokyo, Japan.

Yamanaka, I., 1982. Application of Satellite Remote Sensing to Fishery Studies in Japan, *NAFO Science Council Studies,* 4, 41–50.

__________. *Small Business Innovation Research for FY 1990.* DOC Program Solicitation.

Future Seafloor Mapping Requirements for the NOAA Fleet

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This informal position paper is contributed to the Charting and Applied Oceanographic Research committee assessing NOAA fleet requirements for the next century. The focus is on requirements and technologies for NOAA's seafloor research, with emphasis on geology and geophysics. Specific research areas are treated first, followed by specific suggestions of required capabilities.

Director of NOAA's Seafloor Research Programs

There are currently two related areas of earth sciences research which will dominate oceanographic research for the next decade(s): Global Change and Ridge System Studies. NOAA, and the NOAA fleet, will play a significant role in both areas. Global change research requires a more synoptic view of the Earth's atmosphere/hydrosphere/geosphere, and in particular requires improved coverage of deep-ocean areas. The geospheric component of the system has been largely ignored, and the NOAA VENTS Program and National Science Foundation (NSF) RIDGE Initiative can do a great deal to further understanding of the dynamics of the global seafloor-spreading center system. Beyond these current initiatives, studies of continental margins and other deep-sea environments will become increasingly important for resource and environmental assessment. The tools required for the study of global change and ridge crest should apply directly to these other environments.

Anticipated Rates of Growth

Proposed funding in FY 90 for the Global Change Initiative is $200M, of which about $20M is slated for DOC/NOAA. This doubles FY 89 funding levels. The RIDGE Initiative estimates new ship-time needs increasing from 8 months in 1991 to 23 months in 1994. Most of this time would be taken from the academic fleet, but similar increases might be anticipated in the federal fleet. Although these growth rates can not be sustained over the long term, it seems evident that some increase in ship time for global seafloor studies will be required over the next several decades.

Changes in Mix

Remote-sensing techniques will become more important to future at-sea operations. This applies both to incorporating more advanced seafloor-imaging technologies into the shipboard capabilities, and integrating shipboard observations to satellite systems.

Long-Term Monitoring

Current research on global change and ridge-crest dynamics is beginning to undertake the long-term monitoring of seafloor activity. Such studies require both the installation of advanced instrumentation on the seafloor and regular access to study sites. These types of studies have been insignificant in the past compared to general surveying, however, the percentage of such activities will certainly increase in the future. Such operations require stationkeeping, maneuverability, wide-band conducting cable, heavy-lift capability, and access to the seafloor by ROV or manned submersible. If such monitoring sites are made real-time, cabling to land is required. The NOAA fleet may have an important role in such research, since long-term commitments can be made, while the academic fleet must respond to individual proposals from numerous investigators.

Geographic Areas of Interest

As the name implies, global-change studies will require access to the global ocean. Designated study areas, such as the Juan de Fuca Ridge, will continue to be the focus of more intense studies and technology development. Since the polar areas are a primary regulator of global climate, access to ice-covered areas may also be required.

Access to Satellite

Synoptic studies require the simultaneous analysis of data channels from widely spaced locations, requiring access to communications satellites.

Specific Requirements for Geology/Geophysics

1. *State-of-the-art swath sonars* will be a continuing requirement of the NOAA fleet. Such systems are rapidly evolving, providing wider and more accurate soundings. Often, upgrades are economical because they provide increased areal coverage.

2. *Digital sidescan sonars* allow detailed imaging of the seafloor. Such systems will probably not be

economical for direct operation by the fleet unless new requirements are identified. Leased systems provide an economic means of collecting detailed imaging when needed; however, the items identified in 3. through 6., below, must be available.

3. *Conducting/fiber-optic cable* is required to allow the use of towed or remotely-operated vehicles, such as sidescan sonar, camera systems, and heavy-lift ROV's. Such operations will be of increased importance as new seafloor monitoring observatories are deployed for studying global change. Recent advances in fiber-optic technology will likely make such cables standard by the year 2000. The high bandwidth and low-noise characteristics of fiber-optic cable allow more advanced packages to be operated at full-ocean depth.

4. *Cable handling* systems which compensate for ship motion and allow precise control of cable are critical to successful near-bottom work. Also, the winches must be properly designed to avoid unnecessary wear on expensive cables. Winches are currently one of our biggest problems on the Class I vessels.

5. *Launch and recovery* systems for deploying heavy equipment must be integrated into the ship design. Such systems allow work to continue in adverse sea states and provide a higher margin of safety for the deck crew.

6. *Ultra-short baseline navigation* systems allow a towed package to be positioned relative to the ship. For conducting broad-scale operations where moored acoustic beacons are impractical, the availability of such a system is critical.

7. *Stationkeeping/dynamic positioning* is required for conducting ROV operations and is desirable for all operations deploying packages near the bottom.

8. *Integrated navigation* systems collect all navigational sensors into a single recording medium.

9. *Integrated data acquisition* allows multiple sensors to be written to a single recording medium. Ideally, the system would be flexible for unusual requirements and integrated with the navigation sensors.

10. *Satellite data channels* to allow access to communications satellites are required for synoptic observations.

11. *Gravity/magnetics/seismic* systems should be available on survey platforms to allow integrated geophysical studies. The additional costs for operating these systems are minimal when compared to daily ship operating costs. Such capabilities improve the potential for collaborative studies with the USGS.

New Directions in Ocean Research and Future Ship Requirements

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This position paper only seeks to highlight an area of ocean research that should receive much more attention that it does now, and make a few suggestions as to the direction that survey and scientific techniques and logistics should be channeled in to make the maximum use of time and money.

Part 1 - Natural Gas Clathrates: Return to a New Direction

One of the primary geoenvironmental attributes that must be studied and understood in the 1990's and the 21st century is the field of gas hydrate or clathrate research. Clathrates will have a major impact upon energy resources and energy resource policy worldwide, especially when the oil begins to run out and probably before that when it becomes economically prohibitive to recover. Current estimates of the volume of methane in clathrates and trapped in shallow reservoirs beneath them are equal to, or greater than, the combined total of all other fossil fuels. Minimum estimates of methane clathrates are continually being revised upwards. It is also being recognized that polar and oceanic clathrates are intimately involved with atmospheric sciences because of their capacity for evolving vast quantities of methane, which is an important greenhouse gas. Atmospheric warming causes methane to evolve from clathrates into the atmosphere and this anomalous entry of methane, on a year-by-year basis, is capable of driving a positive heating or greenhouse effect. National and international issues are at stake.

Other scientific issues, such as fine resolution of acoustic structure, seismic interpretation, effect on sedimentation and sediment movement, role in generating slumping in oceans, interaction with biological and zoological ecosystems, acoustic propagation at moderate to low frequency, etc., also exist, but will not be dealt with here. Fine-scale bathymetry is also important because many of the gas traps and acoustic bright spots are mainly controlled by the shape of the bottom and its relationship to the geoid. Coring, using pressurized core recovery, will also be necessary, as will the new equipment necessary for handling the generally high pressure/low temperature materials. *In-situ* measurement of geophysical and other attributes will also probably be necessary, and this will also drive expansion of the ocean survey capabilities.

Clathrates occur in polar land regions associated with permafrost and subsea permafrost in continental shelves, but are mainly found in oceans below 400 meters water depth. Only ocean survey techniques, predominantly acoustic, are currently envisaged as being able to rapidly identify clathrate deposits in the ocean areas. Remote sensing from satellite or airplanes are not appropriate tools for resolving clathrates and their physical attributes except insofar as such tools might replace ships in deploying acoustic sources or receivers and possibly in receiving signals from distributed receivers such as hydrophone arrays. Thus, clathrate-oriented research should cause enlargement of the ocean survey effort that will be necessary to resolve volumetric and evolutionary issues that will have a major impact on national policy and international relations. Acoustic and other techniques, mainly operating from shipboard platforms, will be necessary to prove clathrate, its chemical composition, and depth/volume structure. Possibly one or more vessels may have to be configured mainly for clathrate-related work as the topic gains in recognition.

Arctic regions should be the first to be studied because it is likely that major clathrate deposits, and possibly large gas fields trapped below them, occur there. Clathrates identified elsewhere should provide the basis of new research that is currently being carried out by the Department of Energy (Morgantown office), the USGS, and the Naval Research Laboratory. Other research establishments such as universities and institutes, which began clathrate research in the 1960's, will also be involved.

Clathrate research should be a major research area attracting considerable funding in the not too distant future. I anticipate that funding and research should expand rapidly as will participation in international programs that will be necessary to supplement national programs because much of the clathrate occurs outside current EEZ's. There will obviously have to be a change in the mix of research equipment, and in the mix of research areas and scientists. Earth and marine sciences are going to have to interact much more intimately with other sciences, such as atmospheric and biological. Long-term monitoring will be necessary to identify changes in clathrate attributes. This will be necessary because modifications of the clathrate stability zone are slow thermodynamic modifications driven by gas production, heat flow, and ocean warming, which are in themselves long–term parameters. Geographic area for research is worldwide; we know that because clathrates have been identified in virtually every ocean basin and in a number of deep, large lakes. Ship design and sea operations will be affected by the need to carry out clathrate research.

Part 2 – Water Quality/Water Chemistry/ Environmental Impact

This is another area in which research will be considerably expanded. Because measuring attributes of the water column and bottom will be necessary, shipboard research will probably have to be considerably expanded. I would expect that this research will overlap with clathrate research and that mapping methane in the oceans, such as the Soviets are currently doing with seagoing rapid analysis wet labs on vessels such as the Aca. BORIS PETROV, will be one of the important aspects of this research. Rapid analysis of gases such as methane, oxygen, CO_2, etc., in the water column with an aim of taking *in situ* measurements at a variety of water depths at the same time while underway should be an aim of developing new techniques. Remote sensing of the water surface and lower atmosphere will be complementary to these studies, but cannot possibly replace shipboard operations, at least with current and envisaged techniques. Taking as research aim the three–dimensional mapping of the chemistry and structure of the water column for the Earth's oceans will obviously have an impact upon the nature of U.S. ocean research.

Bottom Morphology

Mapping of bottom morphology in the deep oceans will be important to the study of ocean acoustics and will provide a basis for biological and zoological research. It will also overlap with clathrate research because one of the major factors that affects the fine scale morphology of the sea bottom is pockmarking, which is mainly driven by gas bursting. Deep tow or fine resolution near surface mapping techniques of a multi–beam or sidescan character will probably be the main research tools.

Ship Design

For intensive use of ships as research platforms, it may be necessary to design special research vessels that allow for deck and/or hold space that will take modularized scientific containers in a formalization of the ship–of–opportunity concept. Two main concepts will drive research vessel design. The many issues, such as berthing arrangement, diving operations, placement of science labs, etc., can best be worked out by an individual on the committee who is tasked to deal with this specifically. This will preclude everyone from going over much of the same ground.

Because the primary means of studying the sea bottom and the water column may be primarily through the use of acoustics, either by developing current analytical or tomographic methods, ships should be optimized for acoustic performance. Machine and transient noise should be quietened, especially in those frequency ranges that research and survey equipment will be operating. Advanced hull designs may also provide gain to research equipment through providing for laminar water flow and diminished cavitation.

Ship Requirements

1. Large, self–contained research vessels that have a wide variety of research equipment for earth, water, zoological, and biological sciences, with on–board computers that are central to most, if not all, operations. A number of these vessels exist and are a result of the single platform concept that is designed to do everything. They are expensive and rarely do everything all the time, and thus have an inherent down–time for much of their capabilities. They are, however, usually very comfortable.

2. Smaller, modularized ships that provide a central core of research and computing facilities (such as multibeam systems that are built into the hull) and also provide adequate deck and hull space for containers holding integrated scientific/computing facilities which can be placed on any vessel of opportunity that can take them. Provision has to be made for analog or digital feed of core information, such as GPS to the scientific modules for integration. Data should be captured in a form that will allow for direct analysis; emergence of the Unix–based systems will probably allow this to happen.

3. ROV survey vehicles operating from a mother ship may provide one of the major new research techniques that will increase the logistical and research character of marine research. Semi–smart ROV's have an immense potential for working in difficult regions, such as under ice, and considerable development of these platforms has taken place. Other new technology issues comparable with this, which will have an impact on marine observation, such as undersea habitat, long–term site monitoring, robot–driven data collection, etc., are best left for discussion in a single document.

National Needs and Oceanographic Charting Requirements

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Direction of National Needs

Swath technology affords us the opportunity to obtain topographic information on the 60% of the Nation that is underwater with the same detail that we have on land. This information base should be a high priority for the entire Exclusive Economic Zone (EEZ). To amass this bathymetry data base will require at least a 20–30 year commitment. NOAA as the Nation's hydrographic agency has the mission requirements to produce this digital data base. Bathymetric information for the seafloor is essential for multiple uses including resource exploration, assessment, and recovery; communication; waste disposal; recreation; and geohazard prediction. This bathymetric information base is important to other Federal agencies, State agencies, and the private sector. The requests that NOAA is presently receiving for its EEZ digital bathymetric data is an example of the importance of these data to other agencies and the private sector.

Positional accuracy is important, and the efficiency of the mapping program should not be sacrificed. GPS should be available on all ships and until the constellation is complete for 24–hour coverage, Starfix should also be available. Radio shore–based navigation systems do not have sufficient range and are not cost–effective to set up. Efficient navigation systems should be used so that any part of the EEZ can be mapped in response to priorities determined by NOAA and the other ocean users.

NOAA traditionally has put out maps (paper products), but in the future digital data will be as important or a more important product. GIS–type systems using multidisciplinary data will require digital bathymetry data as a primary base data set. The form of NOAA's digital data (i.e., gridded vs. "raw" data) should be reviewed as "raw" data (highest resolution data) and may also be the preferred distribution form.

Transducers for multibeam bathymetry should be equipment on many of NOAA's ships. The deckside electronics could be shared by two or more ships much like NECOR facilities of UNOLS. Transducers on multiple ships would give flexibility to ship assignment to programs and maximize collecting bathymetry information in priority areas as priorities shift.

Besides the bluewater EEZ, the coastal portion of the EEZ will increase in focus and need. With over 50% of the U.S. population living within an hour's drive of the coast and a projected increase to 75% in the next century, the coastal ocean will experience great pressure. Just as bathymetry is necessary for deepwater, high–resolution digital bathymetry for the continental shelf is also necessary. The continental shelf has both living and nonliving resources and can be viewed as a resource for waste disposal, recreation, pipelines, communication, etc. NOAA, USGS, EPA, Corps of Engineers, NSF, and NASA all have programs targeting the coastal ocean. These programs have not developed to their full potential yet and even now there are not adequate platforms to support these programs. UNOLS also does not have coastal vessels that can handle the coastal program needs (1989 Federal Oceanographic Fleet Study for the Federal Oceanogrpahic Fleet Coordination Council, 1990). Just as bluewater studies are multidisciplinary so, too, are the coastal studies. Platforms capable of handling a variety of tools and teams of scientists will be necessary.

High–resolution bathymetry data adjacent to the coast and topography on the beach as part of the coastal system should be a priority. The most effective way to develop this data base would be using airborne techniques, remote sensing, and profiling laser technology. Detailed coastal topography and bathymetry is necessary to predict the coastal response to global change. In locations or at times where turbidity in the water may be a problem in determining bathymetry from the air, the tracking of the variability of the turbidity may lead to understanding the transport of pollutants in the coastal zone which are adsorbed to fine grain sediments. Adjacent to the coast net change studies will rely on high–resolution bathymetry and repetitive surveys.

Anticipated Rate of Growth

Emphasis on the nearshore coastal ocean will increase in the decade of the 1990's. Funding will be commensurate with the increased attention. The focus on the deepwater EEZ should remain level unless an energy crisis or other resource shortfall occurs.

Mix of Shipboard and Remote Sensing

New technology will need to be refined or developed to more efficiently study the topography and bathymetry of the coastal zone. Remote sensing will be the primary approach. NOAA, because of its hydrographic expertise and aerial photographic determination of sea level, should guide the development and implementation of this technology.

Satellite information of the Earth's surface will not replace shipboard information, but will increase the need for *in situ* observations.

Mix Between Short-Term Events and Long-Term Observation

The scale of phenomena in time and space will determine the sampling and observational scheme. Global change studies focusing on understanding and prediction require that baselines be established to determine what is natural variability and what is man-induced. A mix of both short-term events and long-term monitoring will continue to be necessary for the next decade. Flexibility to respond to catastrophic events should be considered (e.g., collect airborne photography of coast just before and right after a hurricane to determine storm effects).

Geographic Areas

As mentioned the coastal ocean (nearshore) will have increased attention. Polar regions may also have increased emphasis if new money results from the current OMB crosscut. Some mix of high-latitude- and low-latitude-capable vessels should be maintained.

Real-Time Data Analysis

Robust minicomputers are capable of operating at sea. A philosophical change in viewing data handling needs to occur. As much real-time data processing as possible needs to be done at sea while data collection is underway. Scientific personnel are available at sea and this expertise should be used. Real-time processing of multibeam data allows quality control to be exercised while a project is underway and any deficiencies to be corrected. Sufficient computer, plotter, and optical disc storage capacity should be planned for and available for use on ships.

Specific Ship Requirements

To minimize ship costs, manpower-efficient ships requiring small crews should be used. For ships to be versatile, scientific berthing should accommodate approximately 20 people. Ships should have free deck space to hold multiple winches to allow for deploying large instrument packages, and cranes to allow movement of instrument packages on deck as well as launch and recovery of instruments. Dynamic positioning will be critical. Navigation should include multiple systems all of which can be logged and integrated [GPS, Starfix (until GPS is operational), Loran-C, etc.]. Multibeam transducers should be included on as many ships as possible, as well as location of a sea chest to hold other acoustic systems so that they can be operated without interference (crosstalk between systems). Vessels should have 15-20 knot speed capability to cut down transit times, and endurance of 30 days to maximize surveying time. Data processing capability for multibeam data should be included. To cut expense, a plug-in computer facility that could be moved between ships should be considered.

A drastic ship design might be a modular ship where the hull and power plant are fixed but multiple containers (modules) could be put together depending on each cruise function. With the module concept labs could be completely set up with analytical equipment on the beach and only be at sea when in use. Modules would be an integral part of the ship not containers bolted on the deck. This modular concept would provide maximum ship versatility and minimize the need of duplicating large numbers of systems.

Acoustical Research and Technology Development for Mapping and Mapping Research

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Introduction

The material in this document is focused on acoustical technology development and research for charting, mapping and mapping research. Some areas in which non-acoustic measurement technology may be relevant or impact acoustic measurements and technology for charting purposes are also considered. Some implications of these considerations for NOAA fleet requirements are discussed.

Assumptions

I will assume that the greatest need and that the most severe requirements for acoustical measurement resolution will arise in the coastal ocean area with such need for resolution, accuracy, and precision generally increasing as one considers sea-bottom areas going from the outer edges of the EEZ to extremely shallow ports, rivers, estuaries and so on. I will assume that the most significant technological/electronic advances in acoustical systems will be made in the signal receiving and processing portions of said systems and that much less progress will be made in the actual acoustical signal generation portion of the system. By this I mean that the efficiencies and sizes of transducers and to an extent transducers arrays will not greatly change. On the other hand clever transmitted signal design or clever transducer geometry coupled with significant advances in signal processing could well reduce transmitter or signal power requirements.

I will further assume that a general design goal will be to convert received signal energy, as soon as practicable, in the receiving system, to a digital format thereby removing component ambiguities (e.g., gains) and permitting rapid transmission/processing of received signals.

Directions/Goals

A future goal, which is simply a continuance of a present goal, is to achieve as much surveyed area as cheaply as possible but as accurately as possible as well. One way in which this goal is currently being addressed is through mutlibeam sounding systems such as BATHYSCAN and SEABEAM. There does not appear to be a competitive alternative to acoustical systems for accomplishing this task, i.e., cost-efficient mapping in general, and certainly not for waters in excess of 100 meters (for example) in depth. One area of acoustical research associated with multibeam systems will be determination of measurement error as a function of steering or receiving angle of individual beams. This error will be more pronounced for the more horizontally steered beams; for certain near-horizontal steering directions, refractive effects must be considered.

Multiple goals arise as one considers shallower waters. One area of activity which is expected to grow significantly over the next 30 years is discharge of wastes and other material, e.g., dredge material, in the near-coast marine environment. What are the implications of these increased activities for the NOS charting and mapping mission? One implication which I draw is that in addition to simply providing a bottom depth estimate, something about the "nature" of the bottom for a given area should be specified (by NOS). Acoustical systems can reasonably be expected to be developed which can discriminate among coral reefs, kelp beds, faunal growth areas, oyster beds and other bottom types. Detailed maps of these areas and locations will be needed for discharge site considerations, offshore structure considerations and environmental impact considerations.

As new navigational and positioning systems are developed and become available (e.g., the GPS) both commercial ships and recreational boaters will have improved positioning information. Will the accuracy of the NOAA charts be compatible with the new accuracy in positioning which will be available in the next 30 years? Significant improvement in positioning will likely call for remapping of areas previously mapped.

Demand for improved charting and mapping accuracy will, of course, not be uniform over the coastal zone. High-precision charts useful for guiding large, heavily loaded vessels, traversing shipways, possibly near bottom types of environmental or economic concern, will be required. Mapping areas of environmental concern will be of use in planning responses to at-sea disasters such as oil spills. The existence of *sub-ocean-surface* components of spilled oil is poorly appreciated and understood by the oceanographic and environmental communities. Here possible areas of common interest with other Federal and State agencies should be explored. The Defense Mapping Agency, for example, is quite interested in high resolution maps for certain coastal areas.

It is not unreasonable to expect that in the future the ability to obtain high resolution, high accuracy (e.g., ±1 cm bottom depth measurements in shallow water; e.g., 100 m to 1/2 meter or so) rapidly will be achieved. Measurements of this accuracy will permit the study of the effect on bottom topography of short–term events such as a storm. Such measurement accuracy could, in turn, lead to a data set upon which a *predictive* mapping capability for NOAA will arise. By a predictive mapping capability I mean having a model for predicting both natural and man–induced topographical changes. The data sets needed for such a capability will involve both fixed (non–shipborne) and shipborne acoustical systems.

Advances in electronics should accelerate and expand the already present trend of transmitting data in real–time from ships or from fixed instruments. Of course in the coastal environment it is not absolutely necessary to use satellite transmission of data since other receiving/transmitting systems are available. A key research area will be the degree of processing carried out prior to transmission of data; this will be an area of intense and active research for some years.

Advances have been made in nonacoustical measurements of bottom topography yet none appear to be capable of providing the area coverage, resolution, and accuracy of acoustical measurements. For example, airplane–borne magnetic conduction devices developed by the Navy have given indications that bottom depths may be measurable to an adequate degree of accuracy along straight line tracks in water of not too great a depth. Synthetic aperture radar and optical systems have the ability to provide certain limited information regarding bottom topography in the coastal zone.

Some Fleet Implications

For shallower water measurements relatively small shallow draft, acoustically quiet boats will be needed. The crew will be small as a general rule. However, shallow–water *research* vessel design in addition to routine survey vessel design will need substantial consideration in the future. The shallow–water research vessels will be called upon to actually implant sensors, gather samples, and do significant shipboard data processing. For deeper waters toward the outer edges of the EEZ larger vessels will still be required.

Future Ship Requirements for Charting and Applied Oceanographic Research

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Scope

The Fleet Assessment work has been divided among three groups with titles of Oceanographic Research, Fishery Research, and Charting and Applied Oceanographic Research (CAOR). The CAOR group is, therefore, oriented toward the missions of providing for safe navigation and developing scientific and engineering knowledge of the conditions and processes at the seafloor. Measurements that are required and may need ship support include the depth of the water, state of the tide and current, and the general shape and composition of the seafloor.

Direction

Nautical Charting. NOAA has the statutory responsibility to produce nautical charts that can be used by mariners to safely navigate U.S. coastal waters. It is a serious mistake to believe that a uniform, current database exists for this area of responsibility. Many areas have nothing but sparse leadline soundings. Safe navigation requires basic hydrographic surveys when maritime activity begins to move to new areas, when the size of vessels using an area increases, or when there have been substantial natural or man-made changes to an area. Item investigations are required when there are reports of wrecks, debris or other obstructions to navigation. Incentives are economic (primarily transportation, fishing and offshore energy), national defense and recreation. The costs of neglect are stifling development and increasing risks to persons, property and the environment.

Over the next 10, 20 or 30 years, we can expect some shifts in transportation patterns. Pacific Rim trade is likely to grow and increase demand for surveys in Hawaii and the U.S.-affiliated Pacific territories. Shipping to and from Alaska is likely to increase, requiring improved charts of routes and harbors in Alaska. Demands for greater productivity are likely to mean that vessels operate with smaller draft margins in and out of many ports. Pressures will be to dredge deeper draft channels to high-volume ports and ensure that approach areas are clear to greater depths. Fishing and offshore energy exploration and production are likely to move to unexplored areas particularly off Alaska adding to demands there. Military activity may decrease but national defense will be maintained. Newly constructed submarines will have drafts equal to those of the largest commercial vessels. Naval exercises may move to poorly charted areas in the Aleutians. Recreational boating is likely to continue growth with increasing populations in coastal areas. High accuracy positioning information will be generally available at low cost through the Global Positioning System (GPS). A variety of GPS-based navigation aids (together with real-time tides and currents) will reduce incidents of mariners straying from their intended course. The precision of their knowledge of location will exceed that which was available for most of the pre-1969 hydrographic surveys.

Navigational requirements for measurement and prediction of tides and currents are driven by the same general considerations. In addition, nautical charts are part of the legal process of defining boundaries. There are likely to be increasing demands for re-examination of high and low water lines.

Coastal Processes. Demand to predict the character and course of seabed change is growing. Obviously these changes are important to navigators, but they are becoming even more important to coastal zone managers. The nation spends more than $500 million annually dredging U.S. ports and waterways. More and better hydrographic data was one of the chief recommendations of a recent Marine Board study (Marine Board, 1987) of dredging efforts. In addition to data on the shape of the bottom, information is needed on tides, waves, currents, and composition of the bottom. Through understanding of the patterns of sediment movement, dredging operations can be more effective and less disruptive to the environment. Undesired movement of contaminated sediment or other wastes can be minimized.

Offshore and coastal development must be done with consideration for sediment transport, erosion, deposition, and coastal flooding. Increasing coastal populations will intensify pressures and test the limits of building regulations. The "greenhouse effect" is predicted to cause a sea level rise of 0.5 to 2.0 meters by the year 2100. This would inundate most of the nation's wetlands and low-lying areas, including portions of major cities such as New York. The cost of shore protection measures has been estimated in the range of $100 billion (Smith and Tirpak, 1988). Areas around the Mississippi delta are already experiencing relative sea level rise of the predicted magnitude. Sallenger and Williams (1989) have shown the importance of analysis of shoreline and bathymetric changes, together with geophysical data, in devising appropriate mitigation measures. Continuation of that effort, together with similar work in other locations, is being proposed under the USGS Coastal Geology Program. NOAA, in cooperation with the USGS and in response to P.L. 100–220, has proposed the U.S. Great Lakes Shoreline Mapping Plan to gather and use multidimensional survey data to validate models and predict changes along the Great Lakes shoreline. NOAA's proposed Coastal Ocean Program also contains similar elements. Coastal erosion is listed as the highest science priority of the solid Earth processes addressed by the U.S. Global Change Research Program (Committee on Earth Sciences, 1989).

Deep Water. NOAA has been engaged in a program of high-resolution bathymetric mapping of the U.S. Exclusive Economic Zone (EEZ) since shortly after the Presidential proclamation in 1983. This is being done in cooperation with the USGS which is conducting GLORIA surveys of the EEZ. The objective is to determine the seafloor characteristics of the U.S. EEZ in order to advance the development of ocean resources and promote the protection of the marine environment. The EEZ area amounts to approximately 3.4 million square nautical miles and much of it is essentially unexplored.

Perspectives on the geologic framework in many areas of the EEZ have been altered by the images produced by GLORIA enormous erosional and depositional systems, large mass wasting events, massive lava flows, etc. High resolution bathymetry provides more detailed, quantitative data to interpret the images and to target exploration research efforts. These data are being used to produce bathymetric maps for fishermen, to aid in oil and gas exploration and development, to help delineate hard mineral resources, to model geologic and geophysical hazards, to select routes for cables and pipelines, and a myriad of other applications. Bathymetric data builds the foundation layer for a Marine Environmental Geographic Information System for the EEZ. Acquisition of other geophysical data (gravity, magnetic, and shallow seismic), as well as some oceanographic and atmospheric data, is compatible with bathymetric surveys. Determination of important seafloor characteristics requires that more advantage be taken of the opportunities for simultaneous data collection.

The RIDGE program (RIDGE, 1989) is a major component of the U.S. Global Change Research Program that includes similar surveys of the ridge system around the world. The primary goal of this initiative is to understand the geophysical, geochemical and geobiological causes and consequences of energy transfer within the global rift system through time. Material flux through this system contributes as much to the composition of sea water as does the total of river flows into the ocean. The program is envisioned as a decade long research effort during which reconnaissance scale mapping of the entire ridge system would be completed, as well as successively more detailed investigations of segments of the ridge system.

NOAA also has the responsibility to conduct a continuing program of research to support environmental assessment activities under the Deep Seabed Hard Mineral Resource Act. Included in the work are surveys of deep ocean mining areas and reference areas outside of the EEZ at a variety of scales.

Rate of Growth

Nautical charting activities have been shrinking since 1980. At the present, only one ship (RANIER) is devoted to hydrographic surveying with two others (RUDE and HECK) devoted to item investigation. No NOAA survey work is specifically oriented to coastal processes at the present time. EEZ surveying has grown since its beginning in 1984 to the equivalent of between 2.5 and 3 shipyears per year.

The coastal ocean and global change programs within NOAA are potential sources of additional support but present program plans do not contain surveying elements.

The Great Lakes Shoreline Mapping Program proposes support of NOAA hydrographic surveys at a level of $2.8M and USGS onshore and offshore geologic surveys at between $2–3M per year.

A FY 1991 legislative proposal would raise the harbor maintenance fee assessed on port use by vessels carrying waterborne commercial cargo and create a Marine Waterways Trust Fund to support nautical charting, tide and circulation programs and marine weather services. Of these monies, $19.7M would be available for charting survey ship support.

USGS GLORIA surveys of the U.S. EEZ are expected to be completed by 1993. At the present rate of progress, high-resolution bathymetric coverage will be completed for between 10–15% of the EEZ by the year 2000. The rate of progress may be accelerated through cooperation with academic institutions operating swath sonar equipped vessels once the Global Positioning

System (GPS) constellation is completed and providing accurate positioning around the clock. Funding sources, however, have not been identified for such an arrangement.

The RIDGE program envisions nearly two years of ship time per year for the duration of the program, which is likely to extend beyond the year 2000. The major portion of this work would be accomplished using U.S. and foreign academic vessels, although NOAA's research programs will be involved and expected to help provide resources.

Survey work related to the Deep Seabed Hard Mineral Resources Act is being carried out in cooperation with industry and academia. It is expected that this work will continue beyond the year 2000 ranging upward from the present level of 1–2 ship–months per year depending on the economics of the resources.

Changes in Mix between Shipboard and Non–Shipboard Measurements

Several techniques for shallow water surveying from aircraft are under development. It is reasonable to expect that, over the next decade, some combination of these, probably using lasers or lasers in combination with multispectral scanners, will mature into an operational tool. Once fully developed, the rapid response and cost–effectiveness of airborne techniques will likely make them the method of choice to water depths of about 30 meters with normal clarity. This development could mean a substantial reduction in ship requirements. Airborne missions could be combined with tide–coordinated aerial photography that is normally used for shoreline mapping. Photobathymetry from aerial photography is in use now but requires clear water, shallow depths, and distinct features on the bottom. As a result, the technique is not widely used.

Satellite observations are not expected to play a primary role in meeting charting and applied oceanographic research requirements, but they will play a growing supplemental role. Rough depth estimates in shallow water can be made from satellite–borne multispectral scanners (MSS) or from synthetic aperture radar (SAR). MSS imagery (such as from LANDSAT) can show sediment plumes in near surface water aiding in analysis of coastal change processes. Satellite altimetry (such as from SEASAT, GEOSAT, or SPINSAT) provides data on the geoid and long–wavelength bathymetry (such as seamounts) are clear in these data. On the other hand, because of ambiguity between these signals, bathymetric data can provide ground–truth to improve the extraction of geoid information from altimeter data. Altimeters can also provide information on sea surface topography, ocean currents and waves.

The Global Positioning System (GPS) is expected to make a substantial effect on ship productivity by relieving the need for setting and tending shore–based positioning equipment and periodically calibrating it. Developing techniques may make it possible to determine a ship's attitude (roll, pitch, heading, heave, and, perhaps, even the state of the tide – all important to sonar and some geophysical measurements) through use of GPS signals.

Coastal and estuarine current measurement techniques have evolved from direct measurement with mechanical meters, to remote acoustical measurements with acoustic doppler current meters (either shipboard or bottom–mounted) coupled with modeling. Radar backscatter data can provide information on surface currents and measurement of voltages induced in submarine cables can provide information on mass flows. These combinations of techniques have reduced requirements for ship support of circulatory surveys.

Changes in Mix between Short– and Long–Term Studies

Traditionally, in most mapping, charting and associated research, nature is viewed as static or dynamically constant. However, a growing portion of work is now in response to changes––sudden traumatic events such as hurricanes, earthquakes and volcanic eruptions, or more subtle, natural or anthropogenic changes altering the static, stable situation. There is growing need to be able to model and predict those changes. This may require repeated area surveys for validation of models such as sediment dynamics, or it may require long–term point monitoring such as with a current profiler. Deep–seafloor observatories are being proposed to monitor geophysical processes at midocean ridges.

Geographical Areas of Interest and Seasonal Time Constraints

Off the east and Gulf coasts and in the Great Lakes, time constraints are minimal. Demand will continue for investigation of reported obstructions to navigation. A few harbor improvement projects might be expected with accompanying survey demands. Cooperative efforts with state and other federal agencies to understand coastal processes and devise mitigation strategies will be needed in areas with high rates of shoreline change and high demand for development or protection. Offshore, bathymetric surveys of most areas in the Gulf of Mexico are likely to be completed. Priority areas are likely to be potential oil and gas regions off the east coast, east coast canyons for scientific investigations, deep water fishing grounds, possible dump sites, and mineral prospects on the Blake Plateau. With new survey systems efficient surveys of large areas of the continental shelf will become possible. Priorities are likely to be driven by the search for high biological productivity; hard- or live-bottom areas; the search for sand, gravel, placer, phosphorite and other mineral deposits; and scientific studies of bottom and nearbottom processes.

The west coast, Alaska, Hawaii, and the associated U.S. territories will present the largest ship requirements. Some of these areas present considerable constraints to survey operations because of their remoteness, rough seas, and other harsh weather conditions. Vessels must be designed to maximize working time despite these conditions. To the north, ice prevents operations from normal surface ships during a large part of the year.

Anticipated Changes in Shipboard Data Analysis Requirements

NOAA's traditional procedures for mapping and charting are for the commanding officer of the vessel to be responsible for the quality and completeness of survey work. Processing procedures are developed to provide quality assurance tools aboard ship. The largest advantage of this is that errors are detected where there is the greatest opportunity for detection (all the surrounding information is available) and, if needed, reinvestigation is possible. Disadvantages are that the ship's productivity in terms of gathering data is sometimes reduced and that the ship is less flexible to handle other missions. Some field parties have experimented with sending data (via land line) to a central office for processing. It is possible, although costly at the present, to handle shipboard data in a similar way.

Specific Requirements Needed on Ships

Ship requirements can be grouped into several categories as listed below. A fundamental question, for all categories of vessels, is whether to design for a particular mission with hull mounted equipment and deck arrangements, or design for flexibility using towed equipment, associated handling gear and modular spaces. Directly related to this is the division of responsibility and resources between program areas and ship operating organizations.

Coastal Surveying/Non-Remote Areas. This type of vessel would serve the needs of nautical charting and coastal processes investigations in areas where day operations or short-duration (1-3 days) cruises were adequate to accomplish the work. It would be used when logistics or the amount of equipment involved prohibited use of small trailerable boats. Some missions requiring this type of vessel may switch to aircraft as airborne techniques develop. It would be designed for comfortable use in cold, but not ice-filled waters, as well as warm areas. Typical equipment and missions are:

Coastal Surveying --
- very wide swath echo-sounder (>8 x water depth) with imaging capability (interferometric, multibeam, or combination)
- digital control, acquisition and processing system capable of nearly automatic system operation, handling and exercising quality control over data rates up to 100 Mbytes per hour
- sub-bottom profiler and sediment classification system, differential GPS positioning
- crane, winch, and short baseline acoustic positioning system needed if towed (with attitude measurement in towfish; ship attitude measurement system needed if hull-mounted)
- acoustic doppler current meter
- reliable continuous communication to shore and other vessels including graphic facsimile

Item Investigation --
- multibeam side-scan sonar
- similar digital system as above with image processing for contact identification,
- crane, winch, and short baseline acoustic positioning system
- differential GPS positioning
- dynamic vessel positioning system (operating off GPS signal or taut wire)
- underwater visual inspection system (from ROV or semimaneuverable platform)
- diver support

Desirable ship characteristics include:
- high transit speed -- 20 knots
- stability in rough weather
- shallow draft
- efficient 10 knot surveying speed
- acoustically quiet for sonars and personnel space for plotting, supplies, spares, and repairs
- easy passage and communication between mission spaces, bridge and deck
- reliable continuous communication, with voice and graphic facsimile capability, to other vessels and to shore

Coastal Surveying/Remote Areas. This type of vessel would serve the needs of nautical charting and coastal processes investigations in shallow areas that are beyond the range of smaller vessels working independently. It would carry launches for survey data acquisition and serve as a base of operations and a data processing center. Some missions requiring this type of vessel may switch to aircraft as airborne techniques develop. It would be designed for use in cold, but not ice-filled waters, as well as warm areas. Endurance of up to 30 days is desirable. Ship flexibility for accommodation of other missions would be limited by the permanent installation of launches and davits. Typical equipment would include:

Shipboard --

* wide swath echo sounder (>3 x water depth) for intermediate water depths with imaging capability (interferometric, multibeam, or combination) mounted on hull
* gravimeter
* magnetometer
* subbottom profiler and sediment classification system
* differential and Precise Positioning Service (PPS) operation with GPS
* ship attitude measurement system (inertial or GPS-based)
* velocimeter (CTD with winch, expendable probes, retrievable velocity sensor, or acoustic echometer)
* acoustic doppler current meter
* digital control, acquisition and processing system capable of nearly automatic operation of systems (including sequencing of acoustics), handling and exercising quality control over data rates up to 20 Mbytes per hour

Launch --

* simple multibeam echosounder (3-5 beams)
* differential GPS and laser-based positioning
* capability to tow small sidescan/sub-bottom profiler system
* velocimeter
* vessel attitude measurement system
* rugged digital acquisition and processing system capable of largely automatic operation, capable of handling echo-sounder and sidescan data digitally at rates up to 40 Mbytes per hour, and exercising at least minimal quality control

Desirable ship characteristics include:

- transit speed of 15 knots or better
- stability in rough weather
- efficient 10-15 knot surveying speed
- acoustically quiet for sonars and personnel
- space for plotting (ship and launch data), supplies, spares, and repairs
- reliable continuous communication, with voice and graphic facsimile capability, between launches and ship as well as to other vessels and to shore

Deep Water Surveying. This type of vessel would serve the needs of the EEZ program, the Ridge program, and surveys related to the Deep Seabed Mining program. Endurance of more than 30 days is desirable. NOAA should have at least one ice-strengthened vessel capable of this work. Equipment would include:

* wide swath echo-sounder (>2 x water depth) for deep water depths with imaging capability (interferometric, multibeam, or combination) mounted on hull or towed (towed system would require large, dedicated, carefully-designed launch and retrieval system)
* gravimeter
* magnetometer
* sub-bottom profiler and sediment classification system (towed or hull-mounted)
* GPS differential and PPS positioning
* ship attitude measurement system (inertial or GPS-based)
* velocimeter (CTD with winch, expendable probes, retrievable velocity sensor, or acoustic echometer)
* acoustic doppler current meter
* digital control, acquisition and processing system capable of nearly automatic operation of systems (including sequencing of acoustics), handling and exercising quality control over data rates up to 20 Mbytes per hour

Desirable ship characteristics include:

- stability in rough weather would be very important
- transit speed of 15 knots or better
- acoustically quiet and free of bubble sweepdown in sonar areas
- space for data analysis, supplies, spares, and repairs
- easy passage and communication between mission spaces, bridge, and deck
- reliable continuous communication, with voice and facsimile capability to other vessels, and with capability for voice, graphic facsimile, and data segments to and from shore

These ship characteristics require considerable additional detail.

References

Andreasen, Christian and Donald E. Pryor, (1988). "Hydrographic and Bathymetric Systems for NOAA Programs," Marine Geodesy, 12:21-39.

Committee on Earth Sciences (1989). "Our Changing Planet: The FY 1990 Research Plan" (Office of Science and Technology Policy, Washington, D.C.).

Marine Board (1987). "Sedimentation Control to Reduce Maintenance Dredging Of Navigational Facilities in Estuaries" (National Academy Press, Washington, D.C.).

Naisbitt, John and Patricia Aburdene (1990). Megatrends 2000 (William Morrow, New York).

RIDGE (1988). "RIDGE, Mapping and Sampling Workshop Final Report" (School of Oceanography, University of Washington, Seattle, WA).

RIDGE (1989). "RIDGE, Initial Science Plan" (School of Oceanography, University of Washington, Seattle, WA).

Sallenger, Asbury H., Jr. and S. Jeffress Williams (1989). "U.S. Geological Survey Studies of Louisiana Barrier Island Erosion and Wetland Loss: An Interim Report of Status and Results," U.S.G.S. Open-File Report 89-372.

Smith, Joel B. and Dennis A. Tirpak (1988). "The Potential Effects of Global Climate Change on the United States," draft report to Congress (Environmental Protection Agency, Washington, D.C.).

USGS-NOAA Joint Office for Mapping and Research (1989). "U.S. Great Lakes Shoreline Mapping Program".

Satellite Technology As It Impacts Charting and Applied Oceanography Research

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Introduction

This position paper is the assessment of the author and is not the position of the National Environmental Satellite, Data, and Information Service (NESDIS). It is prepared in response to the request of the Office of Charting and Geodetic Services (C&GS) of the National Ocean Service (NOS) and the NOAA Office of the Chief Scientist.

This paper is organized as follows:

Part I addresses the general trends of Earth observation satellites over the next several decades

Part II is an assessment of those satellite and remote sensing techniques that offer potential support to NOAA ship-charting mission

Part III considers the role of satellites in assisting applied oceanography research

Part IV discusses the manner in which evolving satellite systems and techniques might influence the design of future NOAA ships

A concluding general summary focuses on the relationship of current remote sensing technology to forecast for the next 10 to 30 years

The scope of this position paper has been expanded to include all electromagnetic remote-sensing applications to charting, not just those techniques used from satellite altitudes. This is believed necessary because there are aircraft techniques available, or becoming available, that could provide major support to charting operations that are not amenable to satellite platforms.

This paper reviews only the opportunities provided by unclassified satellite systems. The application of Department of Defense and Central Intelligence Agency satellites should be done as a separate evaluation. However, it should be pointed out that the Defense Mapping Agency has used civilian systems to assist in their evaluation of satellite bathymetry techniques (Hammack, 1976).

This introduction recognizes the importance of the mapping function of the position of terrestrial features, especially using high-resolution sensors such as those found on Landsat and SPOT. The paper does not discuss this application because it is not typically a ship-charting function.

Part I: General Trends of Earth Observation Satellites

A more general overview of developing oceanic satellites and techniques is in the position paper prepared by Gary Lagerloef of NASA Headquarters for the Oceanographic Research Working Group. Because NASA is the key civilian agency for space research in general and satellite oceanology specifically, NOAA relies on NASA for all new satellite developments. However, other nations are starting to participate more vigorously in oceanic satellite development so that NOAA is now negotiating with other countries for acquisition of oceanic satellite data well beyond that which NOAA/NESDIS can provide on an operational basis.

For sake of clarification, operational satellite data is defined here (and by NESDIS) as that data for which there has been a long-term commitment to provide such data to users. Operational data requires more than just one sensor flying on one satellite--it involves an extended commitment in order that the oceanic community can justify the expenditure of capital for ground equipment to acquire and use the data. What is of importance is the multinational involvement in oceanic satellites. These new sensors coming on-line will be sequenced over time on many foreign and NASA satellites that will provide the equivalent to an operational oceanic satellite system. While the arrangement is not as convenient as if NOAA flew these sensors on its own satellites, the data can be regarded as operational even if the satellites are research and/or development systems.

This paper does not consider the ancillary data that might be useful to the day-to-day operations of a charting vessel. Weather conditions and warnings, satellite communications, and navigation will be improved as the satellite systems are improved and the NOAA ships are configured to use these systems.

Part II: Remote Sensing Support to NOAA's Ship Charting Mission

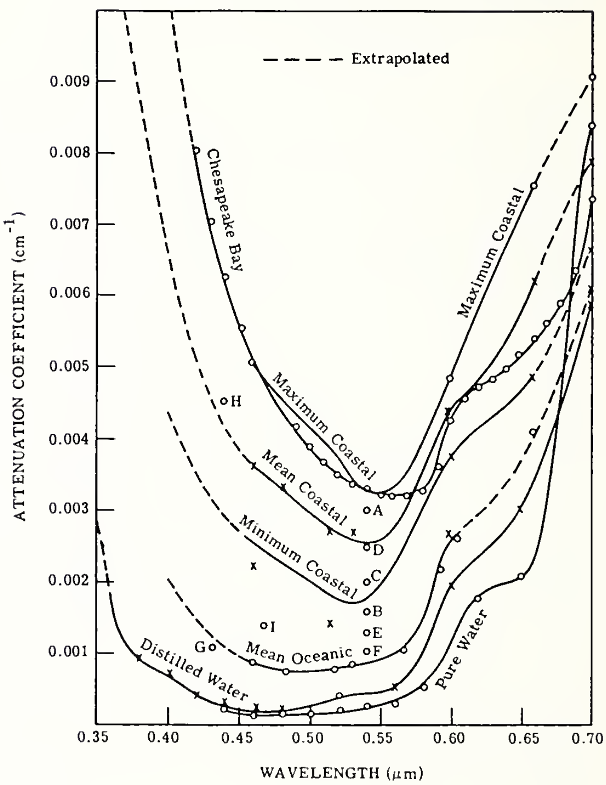
Criteria need to be established about safe depths for high-speed operation of survey ships if remote sensing is developed to improve charting (bathymetric) operations of ships. As example, it was previously held by the International Hydrographic Office that shoals were a hazard to shipping if they fell in the range from 0 to 17 m (≈55 ft). With the advent of supertankers this became obsolete. However, the specification of a minimum depth of safe operation for a charting vessel as a function of ship speed would be very helpful. As example, if depths were known to be greater than 15 m (≈49 ft) for safe operation at 20 knots (10 m/s) then satellite systems could probably define the 15-m (or less) depth region to an accuracy of about 10%.

This section is divided into two components; one for satellite techniques and the other for aircraft. It is assumed that the principal function of vessel charting is for bathymetric applications. The general optical characteristics of ocean water are sketched in Figure 1. Figure 2 illustrates that for bathymetric analyses in shallow water the bottom characteristics must also be known or determined. Early analyses of oceanic and atmospheric characteristics indicated that the use of a blue portion of the visible spectrum was necessary if useful marine applications were to be made using satellite observations (Sherman, 1970). The omission of the blue spectrum from the early Landsat satellites severely limited their near-surface oceanic capability. The Environmental Institute of Michigan (formerly the Willow Run Laboratories of the University of Michigan) has done the majority of bathymetric application studies of remote sensing (Brown, et al., 1971; Prewett, et al., 1973; Wezernak, et al., 1975; and Lyzenga, et al., 1976).

Satellite Support to Charting. There are two principal mechanisms by which satellite observations can support/improve ship-charting techniques. It is not presumed that either technique would replace the ship-charting approach. The first involves the use of the optical region with Landsat/SPOT optical characteristics (see Appendix IV of this paper) and the second uses wave refraction techniques.

The NASA/Cousteau ocean bathymetry experiment forms the basis for this discussion (Polcyn, 1976) and demonstrates the optical approach. Two ships and Landsats 1 and 2 were used in a series of observationsbetween August 21 and September 8, 1975, with the test sites in the Bahama Islands (Berry Islands) and near Hollywood, Florida. Supported only by measurements of average water transmission and bottom

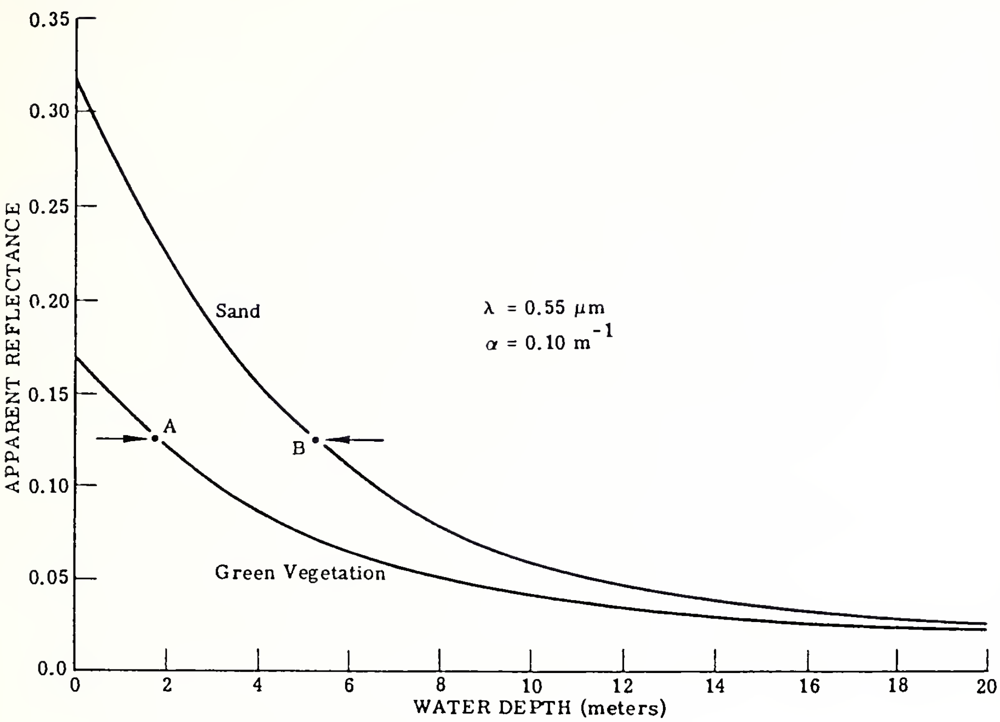
Figure 1. Attenuation Coefficient versus Wavelength for Pure and Oceanic Water.



reflection data, high-gain Landsat Bands 4 and 5 were used to construct bathymetry maps of test areas. Depths to 22 m were reliably verified at accuracies within 10% (rms) of measured values. Landsat data taken a month later in October over the same site successfully gave the same depths (within the same accuracies) as the earlier data. There are several specific types of information required for these measurements that include: knowledge of bottom type, optical transparency of water, and cloud-free scenes to avoid shadows. However, the concept can be made relatively powerful if known depths are used as "training sites" for the Landsat channels.

Water-depth measurements by wave refraction can involve either optical or radar measurement of ocean waves in shallow-water regions (Brown, et al., 1971) and was originated during World War II to determine water depths in denied-access areas. Although Brown used only optical measurements, the techniques can be adapted to high-resolution radar systems (Fu and Holt, 1982). Figure 3 is the physical basis for the shoaling

Figure 2. Apparent Reflectance of Sand and Green Ocean Bottom Vegetation.



been prepared by Gary Guenther (1985). This author defers to this reference as the principal source for evaluating aircraft support to the NOAA charting operation. This reference outlines the needed laser assessments that include the:

- optical properties of the water
- basic concepts and system design
- bathymetric field test
- surface reflection and volume backscatter characteristics
- bottom return signal and penetration
- depth measurement accuracy
- system design tradeoffs

effect of the bottom on ocean waves. From the wavelength ratio of shallow water to deep water (L/L_d), a corresponding relative depth can be extracted from the abscissa (d/L_d). The processing techniques for either optical or radar imagery is done using optical Fourier transform systems from the areas where the depth is to be estimated. For most practical applications the detection of a shoal area begins when the depth is about half the wavelength of the open-ocean swell. The advantage of this shoaling technique over the optical-penetration approach is that it is independent of the optical properties of the water, sunlight extinction, and atmospheric properties, etc. However, it does require finding the appropriate swell systems for the depth to be measured. The author could find no estimate of the overall accuracy of this technique.

Aircraft Support to Charting[1]. The optical or radar approaches can be used from aircraft as well as satellites. They were used from such platforms before being tried at orbital altitudes (Sellman, et al., 1975). This subsection focuses on a remote-sensing technique that appears primarily to be applicable to aircraft and not to satellite systems. Airborne laser systems began with Dan Hickman (Hickman and Hogg, 1969) in the late 1960's as a tool for bathymetric measurements. A very comprehensive assessment of the state-of-the-art applications of aircraft laser systems to bathymetry has

The error analysis provided in the discussion of accuracy indicates that each of several key sources of error run on the order of tens of cm. The root mean square of all errors should probably not exceed 1 m (this author's conclusion).

It is believed that the airborne laser approach is the most effective and efficient remote sensing tool that could be used to assist in vessel charting. This is one area in which there could be a change in the mix between traditional shipboard observations and remote sensing. Cost tradeoff will have to be made.

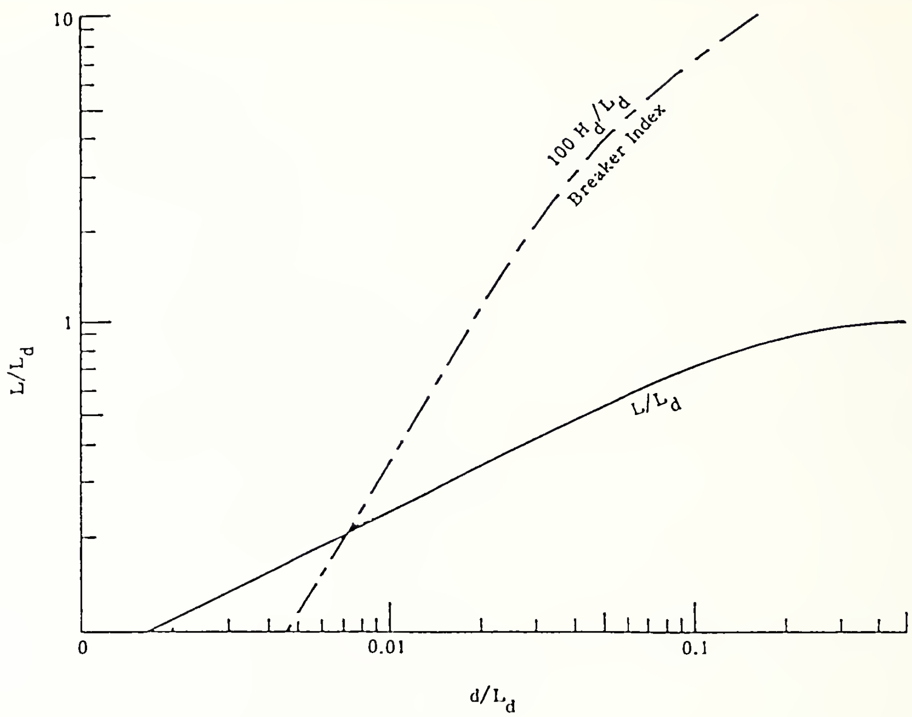
Part III: Role of Satellite for Assisting Oceanographic Research

The paper to be prepared by Gary Lagerloef should be used as a key supporting paper for this discussion. From the standpoint of satellites one of the most critical needs of NOAA is to establish its priorities not only for the charting activities, but as a collective agency position. DOD has established its priorities for environmental data from satellite shown in Table 1.

It has been demonstrated that these environmental parameters can be measured from satellite systems although many of them are not monitored on a continuing basis because of funding constraints within the United States. However, the picture becomes much brighter when the collective space agencies around the world are considered. Each of the marine parameters can support a broad spectrum of research activities and those requirements that enhance the safety of researchers working in the marine environment. A typical general listing is:

Life and safety at sea
Fisheries resource management
Climate and global change
Interdisciplinary studies
Search and rescue
Pollution and ocean dumping
Environmental quality
Coastal zone management
Mean sea-level
Ship and off-shore platform design
Oceanic engineering
Coastal ocean research

Figure 3. Change During Shoaling in Ocean Wavelength Ratio vs. Relative Depth.



The operational satellite systems of NOAA currently support, to one degree or another, these marine environmental activities. However, the point to emphasize is that the degree of support for one activity is much greater than for others. Case in point, life and safety at sea through early storm warnings from the GOES series of satellites and the search and rescue system utilizing SARSAT (an international program) provides a major safety net to the marine community. In contrast, pollution and ocean dumping, fisheries resource management, etc., will have little support until an operational ocean-color system is in place for systematic observations of the upper tens of meters of the ocean surface.

<u>Part IV: Impact on Future Ship Design by Satellite Requirements</u>

Shipboard instrumentation becomes a key consideration for ship support to satellite systems. However, it is believed that with few exceptions the same advanced instruments needed to conduct NOAA's non-remote-sensing oceanic research are the same as those needed to support satellite surface validation measurements. Coupled within this umbrella of requirements are good navigation systems which locate the ship absolutely to the given spatial resolution of the satellite sensors being validated. This can range from 10 m to about 50 km.

The exceptions to the instruments that are not normally configured on ships are the sensors required to measure the high-spectral resolution properties of both the ocean and the atmosphere. These optical measurements must be taken with care, including: solar angular effects, atmospheric transmissivity, clouds and cloud shadows, up- and downwelling light just above the ocean surface and with depth below the surface, wave action effects on the optical measurement, and the avoidance of ship shadows in making the observation (not a simple consideration). Such special applications will require deployment of optical buoys for periods of several hours up to a more permanent placement of several months to a year.

It is assumed that NOAA will continue to work on cooperative terms with the Navy. NESDIS has on several occasions used the high-speed (~36 kt) research vessel RV <u>ATHENA</u> (165-ft length; 23.5-ft beam; 245 ton) to follow the movement of the undertrack of specific satellite sensors from day-to-day. This special vessel, belonging to the David W. Taylor Naval Ship R & D Center, has the flexibility to move at high speed and is essential to the early performance and of validation space sensors. It is believed that accommodation of such special requirements should not be placed on the future NOAA fleet, but these requirements need to be recognized and supported by NOAA fleet management.

In general, the geographical areas of interest to NESDIS will be those under the major umbrella programs of NOAA such as Climate and Global Change, the Coastal Ocean Program, etc. However, under this umbrella there may be times when NESDIS scientists must be permitted to specify shiptracks on given days and/or conditions.

The current philosophy of using very limited onboard satellite processing by the NOAA operational satellites, and most likely those of other agencies, will probably continue over the next several decades. If the satellites did onboard processing it would limit the ability to develop new products and the retrospective processing of old data. Current growth in minicomputers will allow near real–time data to be processed aboard the ships to the degree necessary to optimize ship and personpower.

General Summary

This position paper has primarily focused on the next ten years of remote sensing from satellites and aircraft. The greatest payoff to the problem of charting is believed to be in the operational deployment of airborne scanning laser systems for shallow–water bathymetry. It is not believed to be short–sighted. Laser systems can operate effectively in ocean waters of 6–to–8 optical depths which, depending on the attenuation coefficient of the water, means waters from 5 to 150–plus meters. Such survey technique deployment would relieve charting ships of their most tedious and dangerous task and permit them to conduct deep ocean surveys.

If the reader asked why the longer–term forecast in the ten–to–thirty year period has not been discussed with creativity and imagination, the author will point out that in 1969 NASA determined that the fifth Earth Resources Survey Satellite (ERTS–E) would be an oceanic satellite. The research community worked toward that goal. ERTS became Landsat only after a new NASA program was developed called Seasat. And indeed, NASA management was so taken with calling the satellite after its intended purpose that it decided (momentarily) to call all its Earth–observation satellites by names related to its purpose. Seasat was launched in 1978 along with Nimbus–7 and TIROS–N. A virtual trilogy (Sherman, 1985) of oceanic satellites were launched within three months of each other in that year. Each satellite was a tremendous success.

However, the anticipated follow–ons were not forthcoming. The concept of the National Oceanic Satellite System (NOSS) as a tri–agency operational satellite was indefinitely deferred. The Navy–led Navy–Remote Oceanographic Sensing System (N–ROSS) was canceled in 1988 . Had the oceanic satellite capability followed the trend of the meteorological community, a U. S. operational oceanic satellite system would have been in place within two years after Seasat. If the oceanic community had followed the land–related satellite systems, then at least

Table 1. Department of Defense Priorities for Environmental Data from Satellites.

1. Clouds	15. Landlocked ice cover	29. Trapped particles
2. Vertical temperature profile	16. Solar radiation	30. Surface pressure
3. Absolute humidity	17. Land surface temperature	31. Ionospheric scintillation
4. Winds	18. Auroral emissions/airglow	32. Bathymetry
5. Electron density profile	19. Solar wind	33. Salinity
6. Precipitation	20. Geomagnetic field	34. Near shore currents
7. Sea ice	21. Sea surface topography	35. Ocean currents
8. Sea surface temperature	22. Ocean waves	36. Albedo
9. Visibility	23. Ocean vertical temperature profiles	37. Ocean color
10. Soil moisture	24. Precipitating electrons and ions	38. Bioluminescence
11. Pressure profile	25. Vegetation	39. Insolation
12. Neutral density	26. *In-situ* electric fields	40. Ocean tides
13. Liquid/solid water	27. Radiation backgrounds	41. Net heat flux
14. Snow cover	28. Solar proton emissions and galactic rays	42. Littoral sediment transport
		43. Turbidity

several operational satellites would have been flown in the 1980's. Instead only one oceanic remote-sensing system has flown in the last twelve years--the Navy's Geosat system (Geosat was terminated in January 1990 after a highly successful mission).

Thus, it is hard to be creative and let the imagination jump to periods thirty years hence. The forecast would be completely wrong, no matter what scenario was adopted.

Instead, the realism that there are many other opportunities for the United States to capture data from foreign oceanic satellites must become foremost. It is not anticipated that we will see any major advances beyond Seasat, Nimbus-7, and TIROS-N in terms of satellite oceanic applications. But it is anticipated that the data will become better and be available on a continuous basis. The United States oceanic community can then treat the satellite data coming online in the mid-1990's as operational data. If charting requires Landsat data and it is not available, there will always be SPOT. Some of the NASA research sensors planned for the Mission to Planet Earth (Earth Observation Satellite (Eos) will fly as the principal component of the NASA Polar Orbiting Platform) will be around for tens of years, so these sensor data sets can be treated as operational.

For the purpose of planning for the next thirty years, NOAA should model the program after what is planned for the next ten years. There will be a tremendous opportunity to explore the dynamics of the ocean surface and near surface with new NASA and international satellites. These opportunities will improve ocean forecasting, research, and commercial development.

References

Brown, W. L., Polcyn, F. C., Sellman, A. N., and Stewart, S. R., 1971: Water-Depth Measurement by Wave Refraction and Multispectral Techniques, Infrared and Optics Laboratories, Willow Run Laboratories, Institute of Science and Technology, The University of Michigan, NASA Manned Spacecraft Center Contract NAS 9-9784, Ann Arbor, MI, August.

Fu, L.-L., Holt, B., 1982: Seasat Views Oceans and Sea Ice with Synthetic-Aperture Radar, Jet Propulsion Laboratory, JPL Pub 81-120, Pasadena, CA, February 15.

Guenther, G., C., 1985: Airborne Laser Hydrography, System Design and Performance Factors, U. S. Dept. of Commerce, NOAA/NOS, Charting and Geodetic Services, Rockville, MD, March.

Hammack, J. C., ~1976: Landsat Goes to Sea, Internal Working Paper, Defense Mapping Agency, Hydrographic Center, Advanced Technology Division, Washington, DC.

Hickman, G. D., and Hogg, J. E., 1969: Application of an Airborne Pulsed Laser for Near-Shore Bathymetric Measurements, Remote Sensing of Environment, 1, 47-58.

The Joint Chiefs of Staff, 1986: Memorandum MJCS 154-86, Subject: Military Requirements for Defense Environmental Satellites, 1 August.

Lyzenga, D. R., Wezernak, C. T., and Polcyn, F. C., 1976: Spectral Band Positioning for Purposes of Bathymetry and Mapping Bottom Features from Satellite Altitudes, Environmental Research Institute of Michigan, Report No 115300-5-T, NOAA Grant No. 04-5-158-58, Ann Arbor, MI, January.

Polcyn, F. C., 1976: NASA/Cousteau Ocean Bathymetry Experiment, Remote Bathymetry Using High Gain Landsat Data, Final Report NASA CR-ERIM 118500-1-F, Environmental Research Institute of Michigan, GSFC Contract NAS5-22597, Ann Arbor, Michigan, July.

Prewett, O. E., Lyzenga, D. R., Polcyn, F. C., and Brown, W. L., 1973: Techniques for Measuring Light Absorption, Scattering, and Particle Concentrations in Water, Environmental Research Institute of Michigan, Report 190500-1-F, NAVOCEANO, Contract N62306-71-C-0108 for Spacecraft Oceanography Group, NOAA/NESS, Ann Arbor, MI, April.

Sellman, P. V., Weeks, W. F., Campbell, W. J., 1975: Use of Side-looking Airborne Radar to Determine Lake Depth on the Alaskan North Slope, U. S. Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 230, Hanover, NH, May.

Sherman, III, J. W., 1985: The 1978 Oceanic Trilogy: Seasat, Nimbus-7, and TIROS-N, Chapter 2, Advances in Geophysics, Vol. 27, Barry Saltzman, editor, Academic Press, New York.

Sherman, III, J. W., 1970: On the Use of a Single Blue Band in Oceanography, 3rd Annual Earth Resources Program Review, Manned Spacecraft Center, NASA, Houston, TX, 1–3 December.

Wezernak, C. T., Lyzenga, D., R., and Shuchman, R., A., 1975: Application of Passive Multispectral Scanner Techniques for the Analysis of Coastal Bottom Features, Environmental Research Institute of Michigan, Ann Arbor, MI, August.

Endnotes

1. This position paper does not consider the use of aircraft/helicopter towed acoustic array systems for bathymetric measurements. This is a demonstrated technology which could provide significant relief to ships for conducting hydrographic surveys.

Appendix B

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