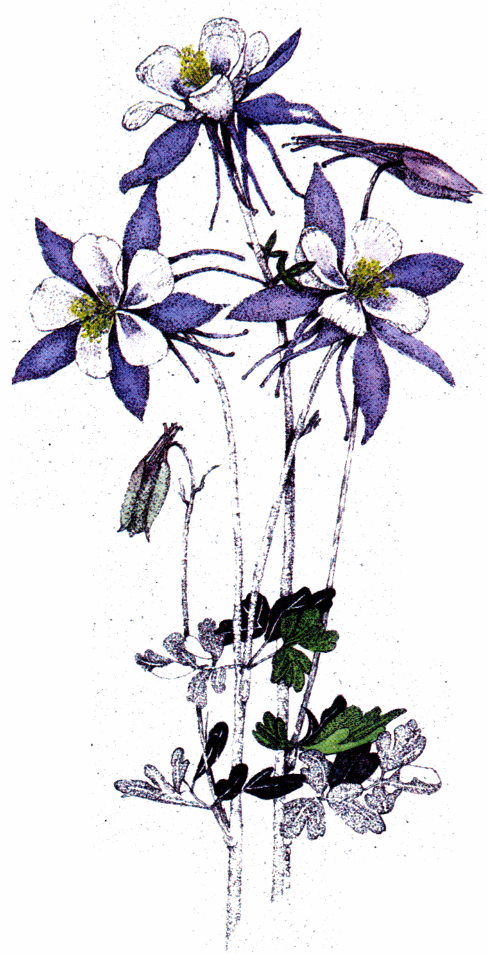
Rocky Mountain Biological Laboratory
Miscellaneous Publication No. 3
April 1995

A New Horizon for Biological Field Stations and Marine Laboratories



Rocky Mountain Biological Laboratory, P.O. Box 519, Crested Butte, CO 81224 **Phone (303) 349-7231**

A New Horizon
for
Biological Field Stations and Marine Laboratories

Report of a Workshop Held in Santa Fe, New Mexico, 9-12 March 1995
by the
Organization of Biological Field Stations
and the
National Association of Marine Laboratories

edited by S.A. Lohr, P.G. Connors, J.A. Stanford and J.S. Clegg

Sponsored by the Biological Research Resources Programof the
National Science Foundation
Grant No. BIR-9503675

Rocky Mountain Biological Laboratory, Miscellaneous Publication No. 3 **April 1995**

Executive Summary

Biological field stations and marine laboratories (FSMLs) have been at the forefront of biological research and education for more than a century. Many advances in biological theory have been made at these facilities, and most professional biologists have received field education and training at FSMLs.

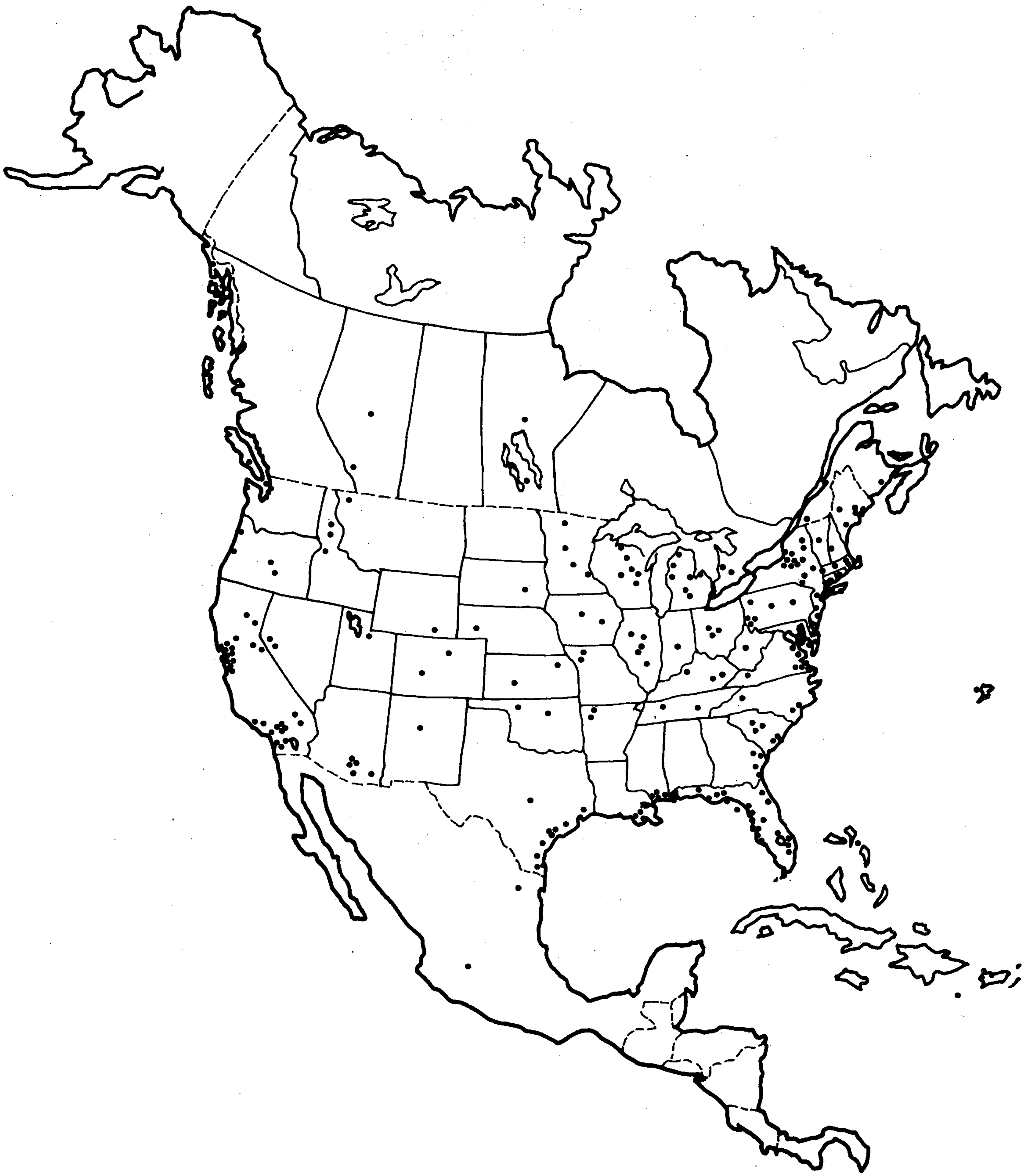
In our rapidly changing world, FSMLs are searching for mechanisms to meet the increasingly complex needs of scientists and students. This report suggests that one mechanism for meeting those needs is to formalize a network of field station and marine laboratory facilities. The editors make recommendations for the establishment of a formal network and estimate that the cost would be on the order of $50 million per year. A planning effort to initiate the network would cost about $500,000.

The importance of FSMLs to national research and educational agendas cannot be overestimated. The value of studying biology in the field is fundamental. In order to make the best and most productive use of national educational and scientific resources, more political, administrative, and financial support needs to be provided to FSMLs. Such support may come in the form of requiring that courses at FSMLs be taken as a graduation requirement, establishing cooperator programs with governmental agencies, or initiating a variety of grant competitions for federal and state funds.

This report is the result of a comprehensive assessment of the current state of research and education at FSMLs, and an analysis by 33 directors of FSML facilities as to how FSMLs can best organize themselves to meet the challenges of the future.

Table of Contents

Figure 1. Map of Field Stations and Marine Laboratories in North America



Preface

In October of 1994 the Organization of Biological Field Stations (OBFS) and the National Association of Marine Laboratories (NAML) jointly submitted a proposal to the National Science Foundation (NSF), titled "Request to Support an Appraisal of Field Station and Marine Laboratory Needs for the Next Decade". This request was funded in January of 1995.

The OBFS was founded in 1967 to provide a forum in which the directors of field stations could share common interests and concerns. OBFS holds an annual meeting each September hosted by a member institution. Currently there are 147 member stations from every region of the US, and a few from Canada, Latin America, Australia and Africa.

The NAML was founded in 1991. Its members represent an affiliation of three regional associations. These are 1) the Southern Association of Marine Laboratories (SAML), which includes member institutions from the East Coast (Maryland south), Bermuda and the Gulf Coast; 2) the Western Association of Marine Labs (WAML), which includes marine laboratories of the West Coast, Alaska, Hawaii and the Pacific US territories; and 3) the North East Association of Marine and Great Lakes Laboratories (NEAMGLL), which includes member institutions of the East Coast (north of Maryland) and the Great Lakes. Each of the regional associations host annual meetings at member institutions, and the national association meets every other year. NAML currently has 103 member laboratories, about 90% of the total marine laboratories nationwide. Sixteen facilities belong both to the OBFS and the NAML.

Once funding for the joint assessment effort was received, both organizations developed a survey (Appendix B) for distribution to member stations. Responses were received and tabulated, and a workshop was organized for early March 1995. Thirty-three directors of field stations and marine laboratories (Appendix A) assembled in Santa Fe, New Mexico for three days. The task set by the workshop co-chairs, Jack Stanford (Flathead Lake Biological Station) and James Clegg (Bodega Marine Laboratory), and the workshop facilitator Susan Lohr (Rocky Mountain Biological Laboratory) was to analyze the results of the survey effort and write a report addressing the status and needs of field stations and marine laboratories (FSMLs) for the next decade. This report is the product of that effort.

Acknowledgements

Support for this effort was provided by the National Science Foundation through the Biological Research Resources Division, Grant No. BIR-9503675.

The facility directors of the member stations of OBFS and NAML who answered the survey responded to a very short timeline and urgent need with unfailing cooperation and grace under pressure. The result is an archive of considerable value.

Those who attended the workshop participated enthusiastically in an intense effort of analysis and writing. They are to be commended for their endurance, camaraderie and thoughtfulness. They represented the community of FSMLs well.

And finally, this production would not have happened nearly as smoothly nor successfully without the assistance of Sonda Eastlack, who staffed the workshop with humor and skill.

Introduction

Field stations and marine laboratories (FSMLs) have been contributing to scientific research and education for more than a century. Although suffering chronic funding problems, scientists working at FSMLs have produced major contributions quietly and consistently. Their discoveries in many cases are huge, although the facilities where the work was done are in general small in size and impoverished instrumentationally. After reviewing examples of scientific discoveries that have taken place at FSMLs, one marine laboratory director remarked: "These facilities have already done an amazing amount for this nation and deserve much greater recognition and support".

In this report we document the importance of biological field stations and marine laboratories (FSMLs), their current success in accomplishing their mission, the needs they have in order to better fulfill that mission, and opportunities for financing those needs. We suggest an approach for the future that involves setting research priorities for FSMLs and accomplishing those priorities through a formalized network of FSMLs.

Thirty-three directors of FSMLs contributed directly to this document, and more than 100 colleagues provided indirect assistance by responding to our survey. Through this comprehensive effort we feel we have expressed both the complexity and diversity of our facilities. We hope that these recommendations provide guidance to those in a position to assist FSMLs, and that our words provide greater understanding about our facilities to everyone interested.

I. The Importance of Field Stations and Marine Laboratories

The general mission of FSMLs is to understand biological processes and responses on a wide range of scales, from molecules to ecosystems and milliseconds to eons. To accomplish this mission, FSMLs engage in the collection, analysis, and synthesis of information, integrating the expertise of a variety of disciplines. FSMLs represent an important resource for addressing questions concerning the relationship between human society and natural systems. The field setting of FSMLs is their most important attribute.

Many FSML programs focus on the interactions of creatures with their environment. These range from taxonomic-, genetic-, behavioral-, and population-level assessments of organisms, to large-scale evaluations of ecosystem and landscape patterns and processes. Biological work is often combined with detailed physical and chemical analyses, requiring complex instrumentation. Together this diversity of programs has made substantial contributions to a wide range of scientific fields, including physiology, cellular and molecular biology, animal behavior, population genetics, evolution, aquaculture, conservation biology, oceanography, climatology, biogeography, taxonomy, hydrology, limology, ecology and ecosystem studies.

Field stations and marine laboratories provide direct access to an incredible diversity of habitats. A major goal of FSMLs is to facilitate multi-disciplinary investigations of these habitats and provide accessible, long-term databases which permit the evaluation of environmental change. FSMLs can be called upon to provide information and guidance on the social and political implications of the data they collect. They are in a position to help develop, understand, and implement through educational programs, sustainable environmental practices for our nation's dwindling natural resources.

FSMLs and National Policies

A dramatic example of the role of FSMLs in developing natural resource management practices and policies comes from the Pacific Northwest. The "President's Plan for Management of Federal Lands in the Pacific Northwest" was derived from consideration of terrestrial, aquatic, estuarine and marine research on the ecosystem processes and interrelatedness of these systems, largely studied at FSMLs. The basic concepts behind "ecosystem management", the current operational philosophy of federal land management agencies, were developed at field stations such as the Andrews Experimental Forest and the Hatfield Marine Science Center.

The development of broadly based environmental programs (e.g., Long-Term Ecological Research, Land-Margin Ecosystem Research, National Estuarine Research Reserves, etc.) is facilitated by FSMLs. They also foster technology transfer, collaborative research and shared curricula among different field sites, and with associated universities. The network of FSMLs can guide the development of priorities for research, and can disseminate basic knowledge to a wide range of researchers, policy makers and the general public. Each FSML serves as a node for the evaluation of biosphere vitality. These contributions are enhanced by the function of FSMLs as honest arbiters of environmental issues for government agencies and community concerns.

Field stations and marine laboratories are being established around the world at an increasing rate. We envision a global organization of these sites in the near future, providing novel and exciting opportunities for research worldwide. For example, pollutant levels in food webs can be systematically measured and analyzed around the world by a network of FSMLs, to underscore the development and evaluation of pollution control strategies. The United States should be positioned to play an important leadership role in this expected global organization of FSMLs.

Activities at FSMLs have led to substantial advancements in many areas of scientific inquiry. Below we list a few prominent examples.

Ecological Theories and Processes: FSMLs are critical resources for successful research endeavors in ecological theory and processes. Seminal insights into general problems in ecology have occurred at these facilities. For example, Paul Ehrlich's work at Jasper Ridge Biological Reserve led to the emergence of coevolution as a field of study. Sustained ecological research on the flux of water and chemicals from precipitation through forests and associated aquatic ecosystems within the Hubbard Brook Experimental Forest has provided major insights about ecological systems. It was here that acid rain was discovered in North America. The population dynamics of white-tailed deer in northern forest ecosystems were described at the Adirondack Ecological Center. At the Southwestern Research Station Jerram Brown applied cost/benefit analysis to problems of behavioral ecology, resulting in the synthesis of territorial behavior in population regulation known as "Brown's Levels". Major models of ocean-atmosphere coupling were developed at the Nova Southeastern University Oceanographic Center.

Long-Term Environmental Change: FSMLs have contributed to the understanding of global change in several ways. Many FSMLs have compiled substantial long-term records that are used to develop predictions based on global climate scenarios. Long-term records are also used to generate fundamental understanding of the interactions between climatic factors and ecosystem patterns and processes. The experimental capabilities at FSMLs are being used to develop programs to test directly the effects of elevated carbon dioxide levels, as illustrated by current research programs at Jasper Ridge Biological Reserve and the Rocky Mountain Biological Laboratory. Long-term studies at Flathead Lake and Lake Tahoe, two of our nation's largest and most pristine lakes, show that chronic deterioration of water quality (defined by increasing growth of algae) is directly related to increasing human activities within their watersheds.

Whole-Ecosystem Manipulation Projects: Programs at several FSMLs have contributed substantially to the understanding of fundamental ecosystem processes through the use of large-scale experimental manipulations. Examples include investigations of the role of instream processing by aquatic invertebrates at the Coweeta Hydrologic Laboratories, assessments of the importance of the effects of coarse woody debris on stream processes at the Andrews Experimental Forest, and a test of iron limitation of oceanic primary production at the Moss Landing Marine Laboratory. At the Rocky Mountain Biological Laboratory a multi-year project simulates global warming by heating a subalpine meadow surface 3 degrees C. year-round. The resulting impacts on soil gas exchange, plant composition and phenology, and other biological processes are being analyzed.

Echolocation by Bats

Donald Griffin was a resident biologist at the E.N. Huyck Preserve in 1938. He was interested in the natural history of bats and was collecting various species and observing their behavior. He observed that bats were able to manuever to avoid obstacles and catch flying insects even on the darkest night. He conducted an experiment wherein he placed small opaque cups on the eyes of individuals, temporarily blinding them, and released them in a room equipped with a maze of wires hanging from the ceiling. He discovered the bats could negotiate the maze even though blind.

Griffin then contacted some physicists and engineers. Together they were able to record the ultrasonic pulses used by the bats to navigate and catch food. Griffin's work subsequently was useful in the full development of sonar and radar technology used during WWII. This is but one example of how curiousity-driven observation and experimentation at field stations results in significant technological innovation.

Environmental Toxicology: Research at several FSMLs has contributed to the development of environmental assessments of toxic substances. For example, researchers at Bodega Marine Laboratory were the first to demonstrate that DDT was responsible for egg-shell thinning of seabirds. Studies at Trout Lake Station demonstrated how laboratory bioassays were of limited utility in predicting the effects of acidification at the scale of a whole lake. Results from waterfowl studies at Forbes Biological Station were instrumental in convincing federal agencies to outlaw the use of lead shot.

Biomedical Research and Biotechnology Development: There is a rich history, including the award of several Nobel Prizes, of the use of marine organisms as premier models in biomedical research. Marine molluscs have been especially important in neuroscience. Use of the squid giant axon played a major role in elucidation of the universal mechanism of the nerve impulse, and has provided essential clues about how axons repair themselves. The sea slug *Aplysia* has been a powerful model for learning and memory research at the molecular level. Elasmobranch fishes (sharks, rays, skates) are especially resistant to carcinogens and have been used in key studies of immune systems and disease resistance. Pharmacologically active substances from marine invertebrates have proven effective in clinical trials on cancer, and molecular techniques are being used to produce transgenic fishes and molluscs with superior traits for aquaculture.

Exotic Species Assessments: Major disruptions of ecological systems occur with the introduction of exotic species. The development of long-term records from a wide range of systems at FSMLs has been critical in discovering, documenting and evaluating the effects of the invasions of species. Researchers at the Lake Michigan Biological Station have studied the spread of exotic species such as zebra mussels and round gobies through the Laurentian Great Lakes. A long-term monitoring program developed at the Hancock Biological Station has documented the effects of the exotic *Daphnia lumholtz* on zooplankton populations and of the invading zebra mussel on mollusk populations. Researchers at Flathead Lake Biological Station discovered a food web cascade that resulted from the introduction of *Mysis* shrimp to the lake.

Basic Experimental Biology: FSMLs have provided facilities and opportunities for investigation of a full spectrum of research questions in basic biology. For example, marine organisms have for many decades provided suitable and unique systems for studying a wide variety of biological processes, from the molecular to the ecosystem level. Much of what we know about early embryonic development, cell division, and fertilization was first described in oocytes, fertilized eggs and embryos of marine invertebrates, notably echinoderms and molluscs. There are many similar examples (*Dexter et al. 1988*).

Conservation Biology of Endangered Species: Many FSMLs conduct basic research in conservation biology of specific endangered plant and animal populations, often in conjunction with state and federal agencies. For example, researchers at the University of California Bodega Marine Laboratory are developing innovative methods of population genetics-based breeding and culture of the endangered winter-run chinook salmon (*Oncorhynchus tshawytscha*), and are conducting basic studies of population genetics of the endangered dune plant, Menzies' wallflower (*Erysimum menziesii*) and of the biology of the presumed extinct but recently rediscovered showy Indian clover (*Trifolium amoenum*).

FSMLs make substantial contributions in ways additional to their research and educational efforts. Activities at FSMLs have often fostered significant economic advances in the regions they serve. They have advocated the development of sustainable uses of natural resources. FSMLs can themselves be substantial components of local economies, returning federal dollars to local areas, providing jobs, and attracting visitors. Finally, FSMLs are "watchdogs" at the local level, keeping track of potential threats to the environment. Their activities translate to a national level of awareness and alertness.

An Example of the Importance of Basic Science to Environmental Management (Uman 1993)

Basic research conducted by marine laboratories on primary production and nutrients in the Chesapeake Bay during the 1960s, 1970s, and 1980s provided both the information base and motivation for the formulation, implementation, and continuation of a regional nutrient control strategy to reduce nutrient (P and N) loadings to the Bay by 40% by the year 2000. The goal was articulated in the 1984 Chesapeake Bay agreement signed by the governors of Delaware, Maryland, Pennsylvania, and Virginia and the mayor of the District of Columbia. This was followed by the 1987 and 1992 Chesapeake Bay agreements that not only assured continued political support, but presented a tributary-specific strategy for achieving the goal on the regional scale of the entire Chesapeake Bay watershed, based on the results of empirical research and modeling.

There are several important aspects of this interplay between research and management:

(1) A quantifiable goal was set and remains in place due to the availability of information derived from basic research on the structure and function of an ecosystem;

(2) The management plan was formulated and implemented based on ecological boundaries rather that political (state) boundaries;

(3) Most of the plan is being implemented through mutual agreement rather than through regulation and enforcement;

(4) The goal and the efficacy of management decisions for the control of point and diffuse nutrient inputs are re-evaluated and modified based on new scientific information on a tributary-by-tributary basis;

(5) Ecological indicators of the success or failure of management actions have been agreed on in advance.

II. Education at Field Stations and Marine Laboratories

A critical feature of FSMLs is their ability to foster the synergistic interaction of research and education. Research and education at FSMLs are inextricably linked. Research is facilitated by work conducted by graduate and undergraduate students who, in turn, gain vital educational experience through their participation in FSML programs. In addition, many undergraduate students receive significant motivation for scientific careers at FSMLs. Overall, FSMLs contribute substantially to the development of human resources for environmental work.

> ***Educational Use of FSMLs (from 77 survey respondents):***
>
> - *45 FSML respondents conduct courses for undergraduates.*
> - *Annually an average of 870 courses are taught to a variety of audiences.*
> - *32 FSML respondents provide scientific education for the general public.*
> - *28 of FSMLs that replied to the survey conduct programs for K-12 students. This means a minimum of 25,000 K-12 students annually received an educational program at a FSML site.*
> - *Other public education activities include docent programs and teacher education.*
> - *50 FSML respondents are involved in educating the general public; annually over 340,000 people visit FSMLs for tours, lectures or to participate in workshops.*

Educational activities at FSMLs extend far beyond traditional undergraduate and graduate level programs. Many FSMLs provide support for K-12, teacher development, and continuing education programs. In many cases FSML facilities provide the only reasonable access to natural systems for a great number of residents and visitors. FSMLs are truly a nationwide resource for our citizenry.

Approximately 80% of FSMLs have specifically articulated educational missions. These educational activities occur at many different levels for a broad range of groups, which include graduate students, undergraduate students, docents, teachers, K-12 students, and the general public.

Field stations and marine laboratories provide valuable opportunities for integrating education and research. Access to facilities, equipment, and study sites are often shared by both students and scientists. Students get direct exposure in studies that assess and measure biodiversity, ecosystem services, and restoration issues, to name only a few examples of current research endeavors. Research is the vehicle through which students experience sound science. At the same time, students often become a valuable resource for research efforts.

Educational use of FSMLs is growing rapidly (*Fig. 2*). The average annual rate of increase in the number of students FSMLs have served over the past five years is 15.6%. The types of educational interactions that occur at FSMLs include training for future research scientists, hands-on experience about the scientific process, increased scientific literacy, developing an appreciation for the value of basic research, experiencing the joy that accompanies new discoveries, interdisciplinary and integrative learning opportunities, and small student/teacher ratios.

There is no obvious comparable experience for the educational activities taking place at FSMLs. Some of the most effective programs for increasing the scientific literacy of students and the general public are closely tied to FSML activities. Many of our country's most prominent scientists were initially inspired to pursue research careers as a result of experiences at FSMLs. When asked recently by a photojournalist why an undergraduate student might find a field station experience important, Dr. Janis Antonovics of Duke University replied:

> *"What's fun is to go out with a professor, see that they understand the animals, the organisms, they have ideas, they curse, they get excited. I think this is what a field station is about. And for an undergraduate it's just a superb experience. I always say to my own undergraduates don't stay in the university, go out into the field, learn about biology, meet with professors. I think that's absolutely critical."*

The educational opportunities at FSMLs can often be more flexible and more personal than those at large universities. Many students are attracted to field courses because of the smaller student/instructor ratio and the opportunity to learn outdoors. This flexible nature of FSML programs has made it possible to encourage a diversity of students to consider biological studies. Many FSMLs report that participation by woman students is significantly greater than in biology courses located on campus. Additionally, there is an increasing emphasis on attracting minority students from backgrounds currently under-represented in biology to FSML facilities for research and study.

Minority Student Involvement at a Field Station

Increasing participation by minorities under-represented in biology is a goal at many FSMLs. At the Rocky Mountain Biological Laboratory (RMBL), support from the National Science Foundation's Research Experience for Undergraduates Program has led directly to training 22 minority students for research careers over the past five years. Of these students 14 are either in or planning to enter graduate programs. Their example has provided a number of role models, and in recent years minority students have applied to take classes, work as research assistants, and return as senior researchers to the RMBL. As one Hispanic woman recently wrote: "This is the experience of a lifetime."

III. The Changing Role of Field Stations and Marine Laboratories in the National Environmental Arena

The role of FSMLs has changed dramatically over the past two decades. Increasing pressures on many fronts have changed the scope of FSML activity. A greater appreciation of environmental issues on the part of scientists and the general public has led to increasing demands for FSML resources.

Over the past decade FSML needs have grown dramatically because of our better understanding of the integrative nature of problems faced by humankind. Both the public and scientists have come to recognize the finite limits of the global ecosystem and its vulnerability to perturbations. We also appreciate that human activities have the potential to alter climates for generations to come, and we recognize the interconnections and interdependency of terrestrial systems, oceans and the atmosphere. The primary force behind this recognition has been the increase in human population that has in many areas pushed the local environment beyond its ability to support that increase. Collectively, these trends make the research and educational functions of FSMLs increasingly important.

Rising demand for the use of FSML facilities (Fig. 2) has resulted in pressures for more laboratory and residential space. There is an increasing need to protect terrestrial, aquatic, estuarine, and marine areas around or near FSMLs to allow for future flexibility of sites for research. The National Science Foundation (NSF) and other federal, state and local agencies should be ready to work with FSMLs to support efforts to protect such areas.

In recent years technological advances in subjects such as molecular and cellular biology, that were once the domain of university campuses or a few large marine labs, have come to many FSMLs. It is clear that joint field and laboratory applications of such technologies will only increase, and support will be required to provide the necessary equipment.

Another area of dramatic change is our increased ability to transfer and process information, especially with the advent of Geographic Information Systems (GIS), which can manipulate and analyze large, spatially explicit data sets. The technology to merge data from remote sensing is rapidly evolving to meet the needs of scientists working over large spatial scales. The development of spatially explicit models is an exciting new area of research at FSMLs, showing no limits for creativity and applications. Clearly, FSMLs are uniquely suited as sites to validate data sets and models. The challenge is to create greatly enhanced research capabilities so FSMLs can reach their full potential.

Facility Needs for Research

To respond to these challenges, FSMLs must be able to acquire and maintain state-of-the-art facilities, equipment and personnel. What specifically is needed? The results of our survey provide some clear answers to this critical question.

Demand for use of FSMLs is increasing. Over the past five years, research users have increased at 54 out of 70 sites, and declined at only three (overall average increase of 14%). Student use has increased at 54 out of 71 sites and declined at only three (average increase of 15%). In contrast, total space available for research and education at FSMLs has not kept pace with demand. Space has increased at only 36 of 71 stations (average increase of 12%). This increase has been chiefly due to NSF facilities support (a total of $6.7 million was received by 30 responding FSMLs in the last five years). Also contributing to the modest increase are matching funds contributed by FSML parent institutions, by fund raising, and by tapping other sources.

Support budgets have also fallen behind the increasing use by researchers and students. Only 40 out of 69 FSMLs reported an increase in budgets over the past five years (average increase of 10%), while 10 decreased and the remainder stayed the same. Thus, FSMLs are experiencing increasing usage while facilities growth and budget support have lagged by comparison. Support from the NSF during the past five years has been largely responsible for not allowing this gap to be greater than it is, but there is clearly a need to enhance facilities and equipment to match the increased usage.

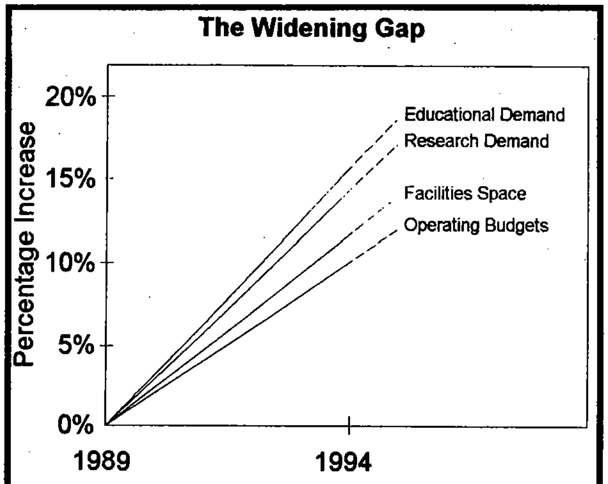


Figure 2. Research and educational use of FSMLs is growing rapidly, but growth in facilities and budgets to support this use is falling behind.

Computerization and information access have dramatically changed the way science has been conducted during the last five years. These developments have also supplied the *modus operandi* for "networking" among research teams that share data and ideas on a national and international scale. These communication links, as well as the hardware and software for computers, all require considerable capital investment. In addition, many technological developments have taken place in recent years that affect essentially all branches of modern science. One example is the rapidly expanding area of molecular biology, which requires expensive supplies and equipment. Methodological changes often require processing of samples at or near field sites. Thus, FSMLs are finding that researchers are requesting these capabilities at a rapidly increasing rate. Since many FSMLs now have larger resident faculties and staffs, this equipment is being used on a year-round basis.

Some essential needs have not changed. There is the continual need to replace worn out equipment, to purchase new equipment, to refurbish facilities, and to build new facilities. In a survey of 28 factors potentially limiting productivity at FSMLs, respondents identified "inadequate funding to support facilities and equipment" as the highest priority (Table 1). New or renovated facilities are a significant need for many FSMLs, as noted in Tables 2 and 3.

Table 1. Top 10 Limiting Factors at FSMLs (n=77)

1	Funding to support facilities
2	Funding for day-to-day operations
3	Technical support staff
4	Funding to support research
5	Research equipment
6	Laboratory space
7	Funding for administrative and operational staff
8	Residential space
9	Inadequate knowledge of resource base
10	Too few researchers

Table 2. Top 8 New Construction Needs (n=77)

1	Researcher or research assistant housing
2	Student housing
3	Individual laboratory space
4	Research offices
5	Shared laboratory space
6	Computer/data management space
7	Classrooms
8	Libraries

Table 3. Top 10 Facility Renovation Needs(n=77)

1	Individual laboratory space
2	Research offices
3	Student housing
4	Shared laboratory space
5	Classrooms
6	Libraries
7	Researcher or research assistant housing
8	Computer/data management space
9	Lecture/seminar space
10	Reference collection storage

Equipment needs vary widely among FSMLs, but several principal categories emerge as the most significant:

Data management and communications equipment constitute a critical need for the foreseeable future. In particular, major items for data analysis and storage are required in varying degrees by all FSMLs. Many FSMLs do not have local area networking (LAN) to facilitate database management, shared software and use of the Internet. This is an essential capability. We stress that the current NSF facilities competition for FSMLs is responsive to these needs. However, linking FSMLs to main campuses or fully networking the FSMLs for sharing of large databases (e.g., digitized images, PCR genetic analyses, weather and other long-time series environmental information from data loggers) and software (e.g., Geographic Information System, image analysis, mapping) requires a much greater investment. Many sites do not have connections to fiber optic trunks and also require top end PCUs (sparc stations), software (UNIX) and computer data managers to facilitate meaningful networking. Cost at a single site can exceed $50,000, not including trained computer data managers or system analysts to operate the system and to manage and archive the data. There are models to follow from programs such as LTER and LMR (*Gorentz, 1992)*. Most of these efforts are developing into national and international programs and need the type of coordination and data compatibility that computers and communication networks can provide.

In the coming decade, keeping pace with changes in communication technology will be a major task for FSMLs. Scientists and the general public have an increased awareness of the need to transfer data and information rapidly to address current environmental problems. An example of this is the recent exercise in the Pacific Northwest to develop scientifically based ecosystem management plans and policies that are acceptable to the public. Success was based on the ability to merge data, conduct analyses of alternative management, and convey the results to the public, all at a rapid pace.

Identified Costs of Equipment and Facility Needs at FSMLs:	
New Construction:	*$206.1 million*
Renovations:	*66.0*
Utilities	*28.7*
Equipment	*76.0*
Total	*$376.8 million*

Results from the FSML survey suggest a need of at least $2 million for computer equipment and $2 million for electronic communication equipment. Since respondents represent only about 30% of FSMLs; we estimate that a minimum of $13 million dollars are needed for computational and communication equipment at FSMLs nationwide.

Seawater and freshwater systems are an integral part of approximately 83% of marine laboratories and about 10% of field stations. These facilities are used for research, education, and public outreach by residents and visitors, in order to study organisms from all types of aquatic environments. Aquatic systems at FSMLs represent a capability that is rarely, if ever, found at university campuses. Among the 103 NAML members, a striking need is for infrastructure support for seawater and freshwater systems. Of particular concern at seawater facilities is the rate of deterioration of buildings, pumps, pipes, tanks and associated equipment, especially compared with standard dry laboratory equipment. Also needed are equipment and facilities for the care and culture of organisms.

Research analytical equipment will continue to be essential to research efforts at FSMLs. Many expensive items (e.g., CHN analyzers, mass spectrometers, CTDs and other computer-driven dta loggers) are now essential components of laboratories at most FSMLs.

Specialized equipment for assisting data collection is also indispensable at FSMLs. This equipment will vary in nature, but includes such items as small, usually trailerable, boats for collection and diving in protected and nearshore habitats, and 4-wheel drive vehicles for safe access to remote terrestrial or estuarine habitats. Some marine laboratories expressed a need for coastal vessels for regional research.

Human resources support is of critical importance to all FSMLs. The recent survey indicates clearly that there is a need for a mechanism to fund key personnel to operate central systems and equipment that are absolutely essential to FSMLs. Certain types of complicated equipment or systems, often funded at FSMLs by NSF, require trained technical personnel as core staff to assemble, maintain and operate them. Such a large capital investment deserves a commitment for personnel to be trained in efficient and safe operations, in much the same way as equipment or system maintenance contracts are authorized. Large-scale seawater systems, electron or confocal microscope facilities, and extensive data management systems are representative examples.

The survey also revealed that these needs for key operational and, in some cases, administrative personnel are considered major limiting factors in achieving the mission of FSMLs. We urge NSF to consider this problem. We believe there are cases where such personnel can be well justified, and should be eligible for NSF funding on a restricted basis. There is precedent for this within NSF, as in reseach programs where salaries of key personnel are covered when their main task is to maintain animal colonies or other special collections. We believe this is completely

Pressing Needs at FSMLs

<u>Facility Space</u>: Laboratory, office and housing space for researchers and students, data management and computer space, human resources, and libraries and lecture classroom space.

<u>Equipment and System Needs</u>: Research and analytical equipment, computer/data management/monitoring systems, electronic communication systems, and laboratory-seawater systems.

<u>Human Resources</u> Staffing for administration, operations and maintenance

appropriate at FSMLs which serve national needs (i.e., sites which serve the needs of many visitors other than those from parent institutions, or which have no parent institution).

Facility Needs for Education

Support from NSF for research facilities at FSMLs has generated significant research productivity and provided a great benefit to a diverse community of scientists. An important additional, but previously undocumented, consequence of this support is the enhancement of educational programs at FSMLs. NSF derives considerable educational benefits from FSML research support even though it has not invested in funding educational resources at FSMLs. While the FSML facilities competition remains focused on research, support is also needed for educational facilities and equipment. The importance of the educational mission of FSMLs should be recognized by the NSF Directorate of Education and Human Resources, which should be approached with a rationale for directing funding to support enhanced educational functions at FSMLs. With an estimated $96 million in educational facilities at FSMLs, we estimate that approximately $3.1 million is needed in annual replacement costs alone to maintain the existing infrastructure of educational facilities.

Existing NSF programs that would be appropriate for FSML educational funding include the Academic Infrastructure and Modernization Program, the Faculty Enhancement and Curriculum Development Awards, the Instrumentation and Laboratory Improvement Program, and the Research Experiences for Undergraduates Program. However, most of these programs target the main university campus and we urge NSF to redirect funding to special competitions for the recognition of FSML educational needs. For example, there could be a "Research Experiences at FSMLs" program that allows participation by gifted secondary students, undergraduates, entering graduate students, high school teachers, teaching college instructors, or federal/state agency personnel in a variety of research efforts at FSMLs. We also recommend consideration of an "Educational Facility Enhancement Program" at FSMLs. Alternatively, one special competition could serve as an umbrella for funding educational facilities, research training, curriculum development, public education and other programs at FSMLs. This alternative is preferred by most FSML directors.

> *The Need for Modern Equipment*
>
> *The use of modern instrumentation in educational programs, such as a CTD or GPS, greatly enhances the learning experience. For example, the immediate visualization of environmental data from a CTD lowered off a ship at the upwelling front off Oregon enables students to gather data and an understanding of the distribution of organisms and other features with respect to the physical and chemical features of the water mass in situ. Real time learning is much more effective than the delayed process of examining data derived from analyses conducted days, weeks or months later.*

Permitting the use of educational matching funds for NSF research facilities and equipment proposals has proved to be a valuable means of assisting FSMLs. Even so, many FSMLs would benefit from the ability to apply directly for funds to support their educational activities. FSMLs that conduct research, but whose primary mission is education, should not be discounted. They need an opportunity to receive support from NSF. Increasingly, FSMLs must justify educational activities and programs to parent institutions. Explicit recognition of the value of these educational activities by NSF would greatly enhance the credibility of FSMLs within institutional infrastructure, and underscore the need for continued improvements and matching funds. Support for the educational role of FSMLs will also assist development of research activities. Clearly, research and education are synergistic activities in the FSML environment.

Survey responses indicate that facilities for education are a common need at FSMLs. Eighteen of 32 sites listed student housing as their top construction priority. Twelve of 28 respondents listed classrooms, and 12 of 25 listed lecture/seminar space. The priorities were similar for facility renovation needs. We anticipate that this level of renovation and construction will cost approximately $55 million, when extrapolated to all FSMLs. We believe that this is a modest investment for the substantial return provided.

Equipment needs for education were also listed as a priority. There is a basic incongruity between state-of-the-art research on the one hand, and education with out-of-date equipment and facilities on the other. FSMLs allow students to do science in a realistic setting, facing real world constraints using modern techniques. The recent FSML survey and workshop recognized the need for funds for modern equipment to allow students to experience realistic science. This need should be acknowledged by NSF to support the unique educational functions performed at FSMLs. Survey results suggest that the national community of FSMLs needs only about $1.3 million per year for educational equipment.

IV. Sources of Support for Field Stations and Marine Laboratories

Field stations and marine laboratories are not only nationally important research centers. They are also extremely valuable training sites for the next generation of biologically oriented scientists and educators. Despite the obvious value of FSMLs in that critical role, their financial support has not been adequate to do the job as well as possible. Traditionally, FSMLs have received a preponderance of their funding from the NSF via various programs for enhancing facilities, research and education. Several alternative opportunities exist to increase funding for FSMLs, including "crosscuts" among federal agencies and within NSF.

National Science Foundation

Through traditional research grants to individual investigators, NSF has contributed substantially if indirectly to FSMLs. Considering reports from just 79 facilities, over the past five years individual scientists have brought $48 million from NSF to FSMLs. From this information, we estimate about $160 million in NSF research funds have been distributed to the entire FSML network over this five-year period. These funds pay facility use fees, investigator salaries, and provide equipment and research assistance to scientists who use FSMLs as the site for their research efforts.

The existing Equipment and Facilities Competition for FSMLs at NSF has provided a total of approximately $7.5 million over the past five years. [Note that this is $7.5 million to facilitate $48 million worth of NSF sponsored research in the past five years.] Current rules for this competition only allow enhancement of research facilities. Given the huge educational value of FSMLs, it seems appropriate that funding also come from the NSF Directorate of Education and Human Resources. In addition to specific college-level educational efforts, many FSMLs have a broader educational mission of increasing the scientific literacy of our society. Recognizing this more general educational value of FSMLs, it would also seem possible for NSF to broker and integrate support from additional federal agencies that are education-oriented.

Other Governmental Agencies

Many federal agencies (NOAA, NASA, NBS, NIH, USFS, Agricultural Research Service, Sea Grant, etc.) benefit from FSML programs, but they provide little or no support for them. In fact, many field stations are on federal land and interact closely with the local federal offices. Given the value of FSMLs to these agencies, it would seem exceedingly appropriate that they supply funding opportunities to FSMLs. Relatively small contributions from federal agency budgets, on the order of $250,000 - $500,000 annually, would represent major contributions. Precedent for this sort of support has occurred within NSF's Long-Term Ecological Research (LTER) program. A memorandum of understanding between NSF and the Forest Service has provided a mechanism for annual support from the USFS to the LTER sites that are located on their federal property.

The Private Sector

We also recognize the value and practicalities of increasing funding to FSMLs from the private sector. Industry has its own reasons for enhancing research and development in areas such as aquaculture, biomedical sciences, environmental and chemical sciences, and even education. Industry partnerships can provide FSMLs with funding which can be used to match government grants.

Examples of productivity increases resulting from NSF's FSML facilities competition awards:

- *The Bodega Marine Lab was funded for on-site facilities for research diving in 1985; this has allowed the number of research dives per year to increase by 50%.*
- *The Huyck Preserve was funded for basic laboratory equipment in 1988. This research support has led to an increase in research use from six investigators in 1988 to 38 in 1994.*
- *The Chesapeake Bay Lab was funded to renovate seawater facilities in 1983; this grant acted as a seed stimulus for a major overhaul of the complete seawater facilities at this lab and has allowed faculty to compete successfully for experiment-based research on marine food chains.*
- *The Rocky Mountain Biological Laboratory was funded in 1982 and again in 1987 for construction of year-round research laboratory buildings. These facilities enabled a number of investigators, many of whom receive NSF research awards, to extend their research seasons, resulting in an increase in facility user days from 3500 per year to 10,000 per year.*

Possible Ways to Enhance Individual Investigator Initiated Research

One of the values and strengths of the total network of FSMLs is the wide diversity of programs and orientations. While many of the FSMLs support multi-investigator interdisciplinary research, nearly all of the sites support individual investigator initiated research. There are several ways to enhance opportunities for these types of studies.

A basic, fundamental need at most FSMLs is to improve data and information management and intra- and intersite communications. Any up-to-date FSML needs to have the ability to move information between and among sites with ease. It is not just fashionable, it is *critical* to many current and future projects.

Equally important is the quality of on-site data management, processing, and archiving. The value of increasing analytical capability is obvious, but data management efforts, including documentation and archiving, are less appreciated. These activities are frequently underfunded at FSMLs, but that is changing rapidly. Nowhere is this more apparent than with studies involving environmental change, biodiversity, and sustainability. Well documented data sets that permit analyses of change in these areas are rare. The network of FSMLs has the potential of being one of the nation's best ways to monitor changes over a wide variety of habitats and ecosystems. Additional support should be targeted in this area.

V. Research Priorities for Field Stations and Marine Laboratories: A Network Proposal

Field stations and marine laboratories constitute a network of research nodes across the country (Fig. 1) that collectively offer an integrated, multidiscipinary approach for solving environmental problems (Fig. 3) that threaten our national security and undermine our leadership role in conservation of the biosphere. The strategic importance of sustaining ecological systems and the goods and services they provide is a fundamental aspect of the research mission of FSMLs. To our knowledge, no other mechanism exists to fill this important need.

We identified six research priorities for FSML sites that complement the recommendations of the Sustainable Biosphere Initiative (*Lubchenco et al. 1991*), Research Priorities for Coastal Systems (*National Research Council 1994*), The Freshwater Imperative (*Naiman et al. 1995*) and other national research agendas. We suggest a network of FSMLs as research and monitoring nodes spread across the USA and its coastal and territorial oceans, in a manner that allows a systematic resolution of these research priorities at local, regional, continental and global scales.

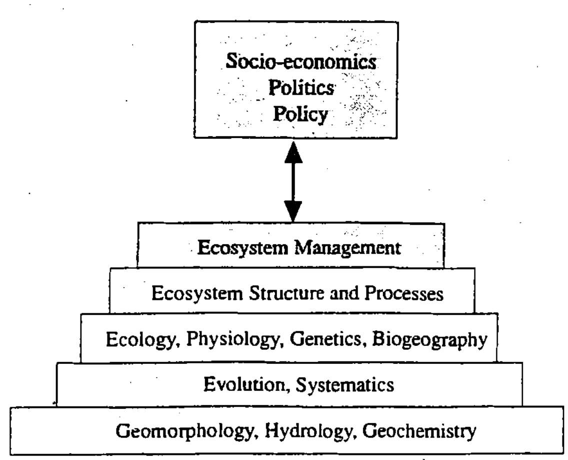
Priority #1: Fundamentals of Basic Biology and Ecology

For more than 100 years FSMLs have been contributing to the accumulating body of knowledge about basic biological processes. In fact, this is perhaps the most significant scientific role that FSMLs have played to date. Due to proximity to the natural environment, the study of biology at a FSML has a degree of validity difficult or impossible to achieve in a purely indoor laboratory setting. A continuing emphasis on basic biological research must be maintained. The proposed formalized network of FSMLs would facilitate the fertile exchange of information that is so critical to the furtherance of good basic science, which in turn is fundamental to all successful resource management efforts.

Priority #2: Assessing Environmental Change

Human activities add variation to natural trajectories of environmental change, often to the extent that delivery of ecological goods and services, essential to human well being, is impaired. Manifestations of impairments include massive alteration of hydrological flow patterns and pathways; deposition of toxic pollutants in the atmosphere, watersheds and coastal environments; fragmentation of landscapes and alteration of critical habitats for native biota through accelerated deforestation, desertification and eutrophication; and chronic loss of genetic variability and other measures of biodiversity. The proposed network of FSMLs provides an integrated and multi-scale sampling design for partitioning natural and human sources and consequences of environmental change. No other organized research or monitoring and evaluation effort of this magnitude has been attempted and it is only now possible due to the research infrastructure that has been established at FSMLs.

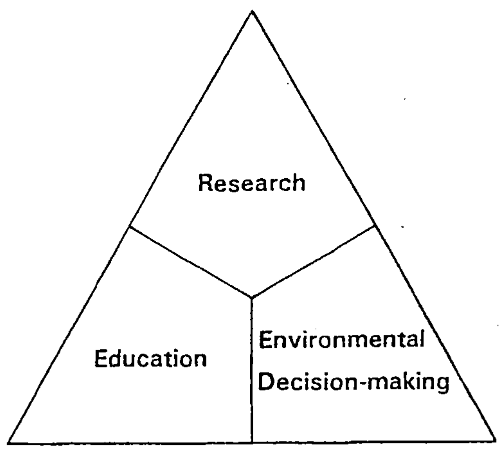
Figure 3. New Perspectives for Environmental Research and Management (Naiman et al. 1995)



Priority #3: Maintaining Biodiversity

FSMLs encompass sites that usually are not human dominated and retain natural biodiversity. Species distribution and abundance data, and natural- and human-mediated drivers of biodiversity, including the pervasive influences of non-native introductions, can be systematically evaluated in relation to various spatial and

Figure 4. The Utilization of Ecological Knowledge (Lubchenco et al. 1991)



temporal scales, and compared to adjacent sites where biodiversity is impaired. Moreover, by networking FSMLs, many of the uncertainties regarding effective biodiversity measures and sampling protocols can be evaluated and resolved.

Priority #4: Sustaining Ecological Systems

Ecosystem goods include timber, fisheries, minerals, natural pharmaceuticals, and other chemicals that are renewable and sustainable in naturally functioning ecosystems. Essential ecosystem services include healthful air and water quality, biological productivity, aesthetics and recreation. Implicit within this research priority is the inclusion of the role of human culture, values, and institutions that also contribute to the effective management of terrestrial, aquatic, and coastal ecosystems, all of which produce goods and services. FSMLs exist in alpine zones, forests, grasslands, marshes, riverine and lacustrine environments, and coastal areas and therefore allow comparative analyses of ecosystem function at multiple scales. Technology can be provided proactively to management agencies and policy makers. This directed information can then provide the basis for adaptive approaches to sustainability of vital ecological systems.

Priority #5: Predictive Management

The sustainability of ecological systems is compromised by an inability to predict future conditions that may result from human-mediated environmental change. Uncertainties in management actions are compounded by lack of a clear understanding of ecological theory, insufficient synthesis of existing data, and inability to react adaptively to new information. The result is a continuum of polemics that prevents the conservation of remaining sites of high natural integrity and the restoration of impaired systems. Due to their grassroots setting within local communities, many FSMLs are uniquely suited for technology transfer and interactive demonstrations of contemporary ecological science in principal and practice (Fig. 4). The validity of inferences from ecosystem modeling can be determined from the long-term environmental data routinely collected by these stations. These data have no limit to their shelf life, and in fact increase dramatically in value with age. FSMLs already have an outstanding track record in using results of basic research to solve local environmental problems. Greater emphasis on partnerships in ecological research and problem solving is needed between FSMLs, management agencies, government, industry and the public. Partnerships will result in adaptive solutions to today's problems, with a clear understanding of the consequences for tomorrow's environment.

Priority #6: Restoration and Rehabilitation

Emphasis in this area of research should be directed toward providing sound scientific information to guide the reversal of ecological impoverishment. The nation's most immediate needs for information center on an improved understanding of the way natural systems operate, from molecules to watersheds, in order to guide restoration and rehabilitation efforts effectively. Networked FSML sites include access to both relatively pristine areas and adjacent habitats varying in impairment. Their interdisciplinary, systems-science approach provides innovative hypotheses and mechanisms for comparative purposes. The broad distribution of these stations allows a continuum of data sets for intersite comparisons and intrasite experimental manipulation.

These research priorities underscore the fact that FSMLs have evolved from their original service mission supporting part-time visiting investigators and limited research capacity to full-time research centers. Many have well developed physical and intellectual infrastructures, and long legacies in the analysis and synthesis of environmental data derived from the unique ecological attributes of the site and the concurrent application of state-of-the-art techniques and methodologies. The NSF field and marine stations facilities competition is largely responsible for maturation of the science done at these sites.

The Network Proposal

Our network of FSMLs is poised to fill a vital role, not only in generating new science in response to research priorities listed above, but also in providing long term data for quantitative evaluation of national or global environmental conditions. The NSF LTER and LMER research program already implemented at some FSMLs clearly has demonstrated the crucial utility of field sites in documenting environmental baselines, and processes and responses produced by natural and human mediated environmental change. Moreover, most FSMLs already have a clear track record in the integration of ecological science and natural resource management at local to regional scales. This critically important grassroots function should be capitalized to a national and global scale to provide a more synthetic and scientific basis for policies and actions, in order that social-cultural systems may be sustained for future generations.

To accomplish our goal of networking FSMLs for focusing on these six research priorities, we recommend that NSF fund a series of workshops by OBFS/NAML through the national "Center for Ecological Analysis and Synthesis" to:

a) determine common, integrative measures of environmental change at FSMLs that will allow regional to global interpretations of present environmental conditions and strong inferences about future conditions;
b) derive and plan implementation of standardized monitoring and evaluation protocols for the FSMLs network; and,
c) provide budget estimates to NSF to achieve system integration within five years.

The cost of this planning effort is estimated to be $500,000. We expect that this series of workshops would present specific recommendations relating to standardization of policies and procedures for the proposed network. The practical aspects of a computer-based online network for FSMLs would be addressed, including specific recommendations relating to utilizing the network for research, educational and administrative efforts. We fully expect that great economies can be realized for individual facilities through participation in such a program, and that gathering information about opportunities at FSMLs can be immensely simplified for potential students and scientists.

Responses to minimize the negative influence of human-mediated environmental change are too often compromised by a lack of sound science and the inability of agencies such as the Environmental Protection Agency (EPA), Department of the Interior (DOI), and Department of Energy (DOE) to synthesize and evaluate environmental problems in a natural-cultural ecosystem context. Since FSMLs currently represent a network of natural-cultural research nodes throughout the country that provide basic biological science, we believe that this pervasive national problem could be resolved through systemic reform of agency funding to emphasize use of FSMLs data and expertise.

We will be pleased to assist NSF in developing additional funding opportunities for creation and administration of a new competition, separate from the current facilities program, that expands FSML-based ecological research in collaboration with local and regional scientists working for federal agencies within EPA, DOI, DOE, DOC and DOD. The current EPA-NSF watersheds competition is a suitable model for development of this program, except that the natural synergism of grassroots collaboration with agency scientists needs to be emphasized. This program can replace redundancy and inefficiency in efforts by the agencies to conduct their own research in the priority areas listed above. We suggest an initial budget for this function of $50 million/year based on the track record established by the NSF LTER program. Moreover, the LTER program can serve as a model for the quality of science that is intended from this new initiative.

Field Stations and Marine Laboratories Are Strategically Positioned As Environmental Early Warning and Reaction Systems

A unique feature of US field stations and marine laboratories is inherent in their broad distribution across environmental gradients. These facilities represent a finger on the pulse of the national environment. The institutions and staff scientists are often prepositioned to identify threats to security of the ecosystem and can perform as quick reaction teams to either counter the threat or alert responsible officials of the problem.

Certainly the national network of field stations and marine laboratories has alerted mankind to actual or potential threats of such broad-based events as global climate change, and specific events such as widespread damage to forests and acidification of lakes by the acid rain phenomenon. In the marine systems, far-flung laboratories and the worldwide movements of their research vessels have correlated important phenomena such as the relationships between El Nino and its climatic consequences.

The University of Hawaii and the Bermuda Biological Station for Research, Inc. are two long-term time series sites for measuring changes in open ocean ecosystems. Hydrostation S in Bermuda represents a 40-year data set as a background for measuring global warming and its relation to seawater temperatures.

There is presently a global increase in both toxic and other nuisance coastal algal blooms now being investigated by US and European marine laboratories which may be related to anthropogenic phenomena. One example is the persistent outbreak (now in its fourth year) of the "brown tide" organism in the Laguna Madre of Texas. This is an algal species, new to science, which has produced dense blooms that represent a shading threat to the benthic seagrass-based ecosystems and related fisheries in this unusual hypersaline lagoon. The phenomenon was discovered early on by researchers at The University of Texas Marine Science Institute. That laboratory had data in hand representing conditions prior to the outbreak; their routine sampling and monitoring programs caught and identified the initial outbreak; and on-going research continues to evaluate the impact of the phenomenon and its causes.

Scientists working out of the Louisiana Universities Marine Consortium (LUMCON) are following the spread of anoxic plumes that periodically wipe out benthic communities along the Gulf Coast of Louisiana and Texas. This phenomenon is related to the high nutrient loads and subsequent BOD introduced from the outflow of the Mississippi River. An organized networking of labs throughout the Mississippi and her major tributary watersheds provides valuable clues to marine scientists studying the downstream impact on coastal ecosystems.

Equally abundant examples exist for terrestrial and freshwater field stations and laboratories across the nation. One such example, which has had a significant impact both environmentally and socially, is the invasion of power plant and other cooling systems by the zebra mussel. Due to its location on the Illinois River since 1894, the Illinois Natural History Survey's Forbes Biological Station was able to document the initial expansion of this animal in 1991 from Lake Michigan into the Illinois River waterway, a major tributary of the Mississippi River system. This then forms a massive invasion pathway for the zebra mussel. The same laboratory, with its long-term data base, was instrumental in documenting the effects of the Great Flood of 1993 and has provided information valuable in the subsequent reexamination of flood plain management.

It is clear that marine labs and field stations from US territories on the Pacific Rim to the upper reaches of the nation's watersheds form a networked resource of immense value for environmental early warning.

Conclusion

The next decade is a time of great excitement for field stations and marine laboratories. The research and educational services they provide are most urgently needed by a nation concerned about husbanding its resources to sustain its citizens. There is a greater demand than ever before for FSML facilities and opportunities. A number of possibilities exist for providing the resources FSMLs will need to meet the challenge of the next decade. In cooperation with federal and state agencies, the National Science Foundation, their sponsoring institutions and their various concerned publics, FSMLs will undoubtedly find creative solutions to the problems they face, as indeed they have for more than a century.

References Cited:

Dexter, R.W. et al. 1988. History of American marine biology and marine biology institutions. American Zoologist 28:3-34.

Gorentz, J.B. 1992. Data Management at Biological Field Stations and Coastal Marine Laboratories: Report of an Invitational Workshop Held April 22-26, 1990 at W.K. Kellogg Biological Station. Prepared for NSF Division of Biotic Systems and Resources.

Lubchenco, J. et al. 1991. The sustainable biosphere initiative. Ecology 72(2):371-412.

Naiman, R.J., et al, eds. 1995 (in press). The Freshwater Imperative: A Research Agenda. Washington, DC: Island Press.

National Research Council. 1994. Priorities for Coastal Ecosystem Science. Washington, DC: National Academy Press.

Uman, M.F. (ed.) 1993. Keeping Pace with Science and Engineering. Washigaton, DC: National Academy Press.

Appendix A. List of Participants at the OBFS/NAML Workshop, 9-12 March 1995, Santa Fe NM

For the Organization of Biological Field Stations:

Dr. Nevin Aspinwall, Director, Reis Biological Station, St. Louis University, 3507 Laclede Ave., St. Louis, MO 63103, ph. (314)977-3902, FAX (314)977-3117, email "aspinwalln@sluvca.slu.edu"

Dr. Philippe Cohen, Director, Jasper Ridge Biological Preserve, Stanford University, Stanford, CA 94305-5020, ph. (415)723-1589, FAX (415)723-6132, email "hf.pcn@forsythe.stanford.edu"

Dr. Richard Coles (OBFS Secretary), Director, Tyson Research Center, Washington University, P.O. Box 258, Eureka, MO 63025, ph. (314)935-8430, FAX (314)935-8433

Dr. Peter Connors, Reserve Manager, Bodega Marine Laboratory and Reserve, Bodega Bay, CA 94923, ph. (707)875-2020, FAX (707)875-2089, email "pgconnors@ucdavis.edu"

Mr. Thomas Crandell, Associate Director, University of Michigan Biological Station, 1111 Natural Science Building, Ann Arbor, MI 48109, ph. (313)763-4461, FAX (313)747-1952, email "tfc@umich.edu"

Mr. Daniel Dawson, Manager, Valentine Eastern Sierra Reserve, Rt. 1, Box 198 Mt. Morrison Rd., Mammoth Lakes, CA 93546, ph. (619)935-4334, FAX (619)935-4867, email "dawson@crseo.ucsb.edu"

Ms. Sonda Eastlack (Workshop Staff), Assistant Director, Rocky Mountain Biological Laboratory, P.O. Box 519, Crested Butte, CO 81224, ph. and FAX (303)349-7481, email "rmbl_user@wsc.colorado.edu"

Dr. Thomas Frost, Associate Director for Trout Lake Station, Center for Limnology, University of Wisconsin - Madison, 10810 County Hwy. N, Boulder Junction, WI 54512, ph. (715)356-9494, FAX (715)356-6866, email "tfrost@facstaff.wisc.edu"

Dr. Robert Hastings, Director, Turtle Cove Environmental Research Station, Southeastern Louisiana University, Box 585, Hammond, LA 70402, ph. (504)549-2141, FAX (504)549-5092, email "fbio1519@selu.edu"

Dr. Steven Havera (OBFS President), Director, Forbes Biological Station, Illinois Natural History Survey, Box 590, Havana, IL 62644, ph. (309)543-3950, FAX (309)543-4999, email "sphavera@ux1.cso.uiuc.edu"

Ms. Susan Lohr (Workshop Facilitator), Director, Rocky Mountain Biological Laboratory, P.O. Box 519, Crested Butte, CO 81224, ph. and FAX (303)349-7231, email "rmbl_dir@wsc.colorado.edu"

Mr. Arthur McKee, Director, Andrews Experimental Forest, P.O. Box 300, Blue River, OR 97413, ph. (503)750-7350, FAX (503)750-7327, email "mckee@fsl.orst.edu"

Dr. Robert Nowak, Director, Whittell Forest and Wildlife Area, University of Nevada, Reno, NV 89557-0013, ph. (702)784-1656, FAX (702)784-1142, email "nowak@scs.unr.edu"

Dr. William Scharf, Director, Whitefish Point Bird Observatory, HC-48 Box 115, Paradise, MI 49768, ph. (906)492-3596

Dr. Jack Stanford (Workshop Co-Chair), Director, Flathead Lake Biological Station, University of Montana, 311 Bio Station Lane, Polson, MT 69860, ph. (406)982-3301, FAX (406)982-3201, email "jstanfrd@selway.umt.edu"

Dr. Mark Stromberg, Director, Hastings Natural History Reservation, 38601 E. Carmel Valley Blvd., Carmel Valley, CA 93924, ph. (408)659-2664, FAX (408)659-3649, email "stromberg@violet.berkeley.edu"

Dr. David White, Director, Hancock Biological Station, Murray State University, Murray, KY 42071, ph. (502)474-2272, FAX (502)474-0120, email "a23111F@msumusic.bitnet"

Dr. Richard Wyman, Director, E.N. Huyck Preserve and Biological Research Station, Rensselaerville, NY 12147, ph. and FAX (518)797-3440

For the National Association of Marine Laboratories:

Dr. Kenneth Able, Director, Institute for Marine and Coastal Science, Rutgers University Marine Field Station, 800 Great Bay Road, Tuckertown, NJ 08087, ph. (609)296-5260, FAX (609)296-1024, email "able@arctic.rutgers.edu"

Dr. Arthur Brooks, Center for Great Lakes Studies, University of Wisconsin-Milwaukee, 600 East Greenfield Avenue, Milwaukee, Wisconsin 53204, ph. (414)382-1704, FAX (414)382-1705, email "abrooks@csd.uwm.edu"

Dr. James Clegg (Workshop Co-Chair), Director, Bodega Marine Laboratory, P.O. Box 247, Bodega Bay, CA 94923, ph. (707)8752211, FAX (707)875-2089, email jsclegg@ucdavis.edu

Dr. Gary Greene, Director, Moss Landing Marine Laboratories, P.O. Box 450, Moss Landing, CA 95039-0450, ph. (408)755-8655, FAX (408)753-2826

Dr. Roger Hanlon, Chief, Division of Biology and Marine Resources, Marine Biomedical Institute, University of Texas Medical Branch, Galveston, TX 77555-0863, ph. (409)772-2133, FAX (409)772-6993, email "hanlon@mbian.utmb.edu"

Mr. Rick Herman, Director, Harbor Branch Oceanographic Institute, 5600 US 1 N., Ft. Pierce, FL 34946, ph. (407)465-2400 ext. 220, FAX (407)465-5415, email "herman@hboi.edu"

Dr. Janet Hodder, Academic Coordinator, Oregon Institute of Marine Biology, University of Oregon, Charleston, OR 97420, ph. (503)888-2581, FAX (503)888-3250, email "jhodder@oimb.uoregon.edu"

Dr. Robert Hueter, Director, Center for Shark Research, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, ph. (813)388-4441, ext. 323, FAX (813)388-4312, email "mmlrhueter@aol.com"

Dr. Robert Jones, Deputy Director, Bermuda Biological Station for Research, Ferry Reach, St. Georges, GE-01, Bermuda, ph. (809)297-1880, FAX (809)297-0860, email "bob@bbsr.edu"

Dr. Thomas Malone, Director, Horn Point Environmental Laboratory, University of Maryland - CEES, P.O. Box 775, Cambridge, MD 21613-0775, ph. (410)228-8200, FAX (410)476-5473, email "malone@hpel.umd.edu"

Dr. Dennis Taylor, Director, Virginia Institute of Marine Science, School of Marine Science, PO Box 1346, Gloucester Point VA 23062-1346, ph. (804)642-7103, FAX (804)642-7097, email "dtaylor@vims.edu"

Dr. Kenneth Tenore, Director, Chesapeake Biological Laboratory, University of Maryland - CEES, P.O. Box 38, Solomons, MD 20688-0038, ph. (410)326-7241, FAX (410)326-7302, email "tenore@cbl.umd.edu"

Dr. Lavern Weber, Director, Hatfield Marine Science Center, Oregon State University, 2030 S. Marine Science Dr., Newport, OR 97365, ph. (503)867-3011, FAX (503)867-0138, email "weberl@ccmail.orst.edu"

Dr. Herb Windom, Director, Skidaway Institute of Oceanography, University System of Georgia, 10 Ocean Science Center, Savannah, GA 31411, ph. (912)598-2490, FAX (912)598-2310, email "herb@skio.peachnet.edu"

Appendix B. OBFS/NAML Survey Questions

General Information

1. Name of facility:
2. Mailing address:
3. Phone:
4. FAX:
5. Electronic mail:
6. Name of facility director:
7. Person filling out this questionnaire (if different):
8. Year of establishment:
9. Affiliation (circle one): independent of any governing institution ___
   governed by a private institution ___
   governed by a public institution ___
   governed by a consortium ___
10. Emphasis of activities (circle all that apply):
    research   undergraduate education   general public education   land preservation
11. Is your activity seasonal? ___yes ___no
    If yes, circle the season of greatest intensity of use: winter spring summer fall
12. Staff paid by your facility (circle on the chart below for each applicable category): [Definitions: "administrative" means supervisory and clerical office staff, "operational" includes buildings and grounds, kitchen staff, library staff, etc., "teaching" includes educators and their assistants, "research" means scientists and assistants paid by the institution to conduct institutional research. Don't include visiting scientists or grad students who use your facility for their own research but aren't hired by you.]

type	#of people:			
administrative full-time year-round	1-4	5-10	11-20	>20
administrative full-time seasonal	1-4	5-10	11-20	>20
administrative part-time year-round	1-4	5-10	11-20	>20
administrative part-time seasonal	1-4	5-10	11-20	>20
operational full-time year-round	1-4	5-10	11-20	>20
operational full-time seasonal	1-4	5-10	11-20	>20
operational part-time year-round	1-4	5-10	11-20	>20
operational part-time seasonal	1-4	5-10	11-20	>20
teaching full-time year-round	1-4	5-10	11-20	>20
teaching part-time year-round	1-4	5-10	11-20	>20
teaching full-time seasonal	1-4	5-10	11-20	>20
teaching part-time seasonal	1-4	5-10	11-20	>20
research full-time year-round	1-4	5-10	11-20	>20
research part-time year-round	1-4	5-10	11-20	>20
research full-time seasonal	1-4	5-10	11-20	>20
research part-time seasonal	1-4	5-10	11-20	>20

13. Annual operating budget (circle range that most nearly applies. Don't include special project capital improvements or extramural research funding):
    <100k 100-300k 300-600k 600-1000k >1000k
14. Source of annual operating budget (supply general percentage for each that applies):
    user fees charged ____
    funds from sponsoring organization _____
    donations (non-federal grants, foundations, personal contributions) ____
    federal grants _____
    state grants _____
    endowment income _____
15. Capital improvement budget (circle range that most nearly applies to the average annual amount over the past five years): <10k 10-50k 50-200k >200k
16. Source of capital improvement budget (supply general percentage for each that applies):
    user fees charged ____
    funds from sponsoring organization _____

donations (non-federal grants, foundations, personal contributions) ____
federal grants _____
state grants _____
endowment income _____

17. Do you have an endowment for your facility? (Include endowed staff positions): ___yes ___no
If yes, circle the range that most nearly applies to the total body of the endowment:
<50k 51-200k 200-1000k >1000k
18. What is the total value of your facility's assets? Include land, buildings, and financial assets, and circle the range that most nearly applies:
<100k 100-500k 500-2000k 2000-20,000k >20,000k
Of this number, how much is just your facilities (buildings and equipment)?
19. This chart is designed to elicit the number of users of your facility during a year, by type of user. Please give general numbers if specifics are too difficult to come by. Don't include the personnel counted above in question #12.

type	**total annually**
A. Research Use:	
scientists (Ph.D. level) from sponsoring institution)	
scientists (Ph.D. level) from other educational institutions	
scientists from public agencies or industry	
scientists from other countries	
graduate students conducting their own research	
scientists (other)	
research assistants (graduate students)	
research assistants (undergraduate students)	
research assistants (other)	
undergraduate students conducting independent research	
B. Educational Use	
faculty and teaching assistants instructing courses	
undergraduate students taking courses	
graduate students taking courses	
K-12 students taking classes	
continuing or professional educational program participants	
natural histroy educational program participants	
C. Other Public Service Use	
public users of collections, libraries, other facilities	
public information activity participants (tours, workshops,lectures, etc.)	
D. Scientific Meeting Participants, Seminar Speakers, etc. (not listed above)	
E. Volunteers	

20. How much land does your facility (hectares): own?_____ manage but not hold title to?_____
lease for research or educational purposes?_____ have cooperative agreements to use?_____
have available informally for researchers and students to use? _____
21. For the facilities listed below, indicate the number you have of each, the size where applicable, and the total monetary value of each type of facility, as best as you can. State where facilities are shared.
    a. Administrative buildings (#____, total size _______, monetary value __________)
    b. Laboratory buildings (#____, total size _______, monetary value __________)
    c. Libraries (#____, total size _______, monetary value __________)
    d. Dining facilities (#____, total size _______, monetary value __________)
    e. Classroom facilities (#____, total size _______, monetary value __________)
    f. Museum or collections facilities (#____, total size _______, monetary value __________)
    g. Meeting room facilities (#____, total size _______, monetary value __________)
    h. Animal care facilities (#____, size ______, monetary value __________)
    i. Vehicles (#______, monetary value __________)
    j. Vessels (#______, monetary value __________)
    k. Computers (#______, monetary value __________)
    l. Institutional research equipment (#______, monetary value __________)
    m. Weather monitoring equipment (#______, monetary value __________)

Facility Needs

22. "Need" is a subjective concept, but nonetheless we wish to know what you feel your needs are. As a more objective measure, before addressing questions 23-28 we'd like you to characterize the following trends at your facility over the last five years. List actual rates of change if available. If you have instituted a cap on station use, indicate rates of change in demand for space, and state below what your cap is.

	no change (within 5%)	increase+ 5-15%	increase +15-30%	increase +>30%	decrease - 5-15%	decrease - 15-30%	decrease ->30%
# research users							
# students							
staff							
operating budget							
facilities (sq. ft.)							

23. What are your facility's needs in the way of utilities? Elaborate briefly and estimate cost.
    a. conventional electric:
    b. solar electric:
    c. gas:
    d. water supply:
    e. sewage disposal:
    f. hazardous waste disposal:
    Other(explain):
24. Do you need improvements in site features? Elaborate briefly and estimate cost.
    a. land acquisition for research or educational use:
    b. land acquisition for protection:
    c. roads:
    d. trails:
    e. fences:
    f. trespass prevention:
25. With regard to maintenance, buildings and systems are (please circle as appropriate, and elaborate if you wish):
    being improved on a regular plan   being improved with a plan, but as funds are available
    being improved haphazardly   declining in quality   not receiving maintenance
26. What needs exist for construction of new buildings for the purposes listed below? Estimate number of square feet needed, projected cost, and rate the degree of need using a scale of 1 to 5 (1 = most needed. You may have as many of each number as you wish.)
    a. administrative services:
    b. dining facilities:
    c. researcher/research assistant housing:
    d. student housing:
    e. individual laboratory space:
    f. shared laboratory space:
    g. reference collection storage:
    h. library:
    i. boat storage and docks:
    j. vehicle storage:
    k. carpentry shop:
    l. machine shop:
    m. classrooms:
    n. visitor center:
    o. retail space:
    p. darkroom/photography space:
    q. computer/data management space:
    r. lecture/seminar space:
    s. lounge/recreation space
    t. research offices
    u. other (please specify):
27. What needs exist for renovation of existing buildings for the purposes listed below? Estimate number of square feet needed, projected cost, and rate the degree of need using a scale of 1 to 5 (1 = most needed)
    a. administrative services:

b. dining facilities:
c. researcher/research assistant housing:
d. student housing:
e. individual laboratory space:
f. shared laboratory space:
g. reference collection storage:
h. library:
i. boat storage and docks:
j. vehicle storage:
k. carpentry shop:
l. machine shop:
m. classrooms:
n. visitor center:
o. retail space:
p. darkroom/photography space:
q. computer/data management space:
r. lecture/seminar space:
s. lounge/recreation space
t. research offices
u. other (please specify):

28. What needs exist for the following types of equipment? Give number and approximate costs, and indicate if (and cost of) new staff must be hired to operate the equipment.
    a. computer capabilities (hardware and software):
    b. analytical equipment:
    c. microscopes and optical equipment:
    d. photographic, video or sound recording equipment:
    e. data management systems:
    f. library acquisitions:
    g. reference collection acquisitions:
    h. climatological equipment:
    i. electronic communication systems:
    j. office equipment:
29. What needs do you have for additional administrative, research or educational staffing at you current level of operations?
30. What is the total value of NSF support your facility has received over the past five years for:
    a. facility improvements? __________
    b. institutional research programs? __________
    c. institutional educational programs? __________
    d. public programs? __________
    e. administrative support? __________
31. For the same categories, how much money have you been able to leverage from other sources as the required matching funds for the same NSF grants over the last five years?
    a. facility improvements? __________
    b. institutional research programs? __________
    c. institutional educational programs? __________
    d. public programs? __________
    e. administrative support? __________
32. Does your facility receive overhead or indirect cost income from grants to researchers using your institution? yes ___ no ___. If yes, what rate do you receive for: federal grants ________? private grants_________? If you are affiliated with an institution, is this an "on campus" rate or an "off-campus" rate (circle one)?

Current and Future Role of Your Facility in Scientific Research and Education

33. What is special about your station with respect to current research efforts? For example, perhaps 85% of your researchers are women, or perhaps you have 100-year data sets that are being analyzed with respect to global change, or your habitats are unique in the US, etc.
34. What is special about your station with respect to undergraduate and graduate courses?
35. What is special about your station with respect to research training (e.g. providing opportunities for research experiences, both independent and as assistants, for undergraduate and graduate students)?

36. What is special about your station with respect to scientific education of the general public?
37. Name up to five major scientific advances that have occurred at your field station or marine laboratory. These examples may be extremely useful in establishing the contributions of field stations and marine labs for legislators and the general public. Please give this some thought.
38. Please attach a publications list from the previous five years, for work done at your facility. In addition, indicate general numbers for the types of research studies listed below, for the last five years (the purpose of this question is to emphasize the productivity of field facilities):
    a. Referreed articles:
    b. Ph.D. dissertations:
    c. Masters theses:
    d. Institutional reports:
    e. Undergraduate research papers:
39. What long-term data sets have been accumulated at your facility? Please fill in the chart for type, duration, whether quality controlled by your institution, whether accessible electronically. Add rows if necessary. Please include data that must be approached through individual researchers also.

type	duration in years	quality controlled? how?	electronic?

40. How many research projects are undertaken each year (average for last five years) at your facility by:
    a. faculty-level scientists?
    b. post-doctoral fellows?
    c. scientists from public agencies or industry?
    d. graduate students?
    e. international visiting scientists?
    f. undergraduate students conducting independent research?
41. How many courses are taught at your facility each year? Include all types of courses, of any duration greater than one day.
42. How many future scientific professionals receive research training at your facility each year? Add up the numbers of supervised research assistants, students in teaching laboratory or field courses, and supervised independent research students, as an annual average over the past five years.
43. Please give us an idea of your facility's financial impact on the local (county level) economy, either in narrative form (e.g. "our employees live nearby", etc.) or with dollar figures if you have ever determined this number.
44. What role does your facility play in cultural, civic or management issues at the local level? State level? National level? (This question is designed to assist in determining the public service importance of field stations and marine laboratories.)
45. What role would you like your facility to have in the future, in any or all of the following areas?
    a. education
    b. research
    c. research training
    d. public service in the local community
    e. government agencies
    f. visibility in the national scientific community
    g. visibility in the international scientific community
46. What factors limit the quality or productivity of research and/or educational efforts at your facility? To each of the factors below, assign a score of 1-5, with 1 representing highest importance as a limiting factor. It could be that you lack these facilities or services completely, or that what you have is inadequate to accomplish your goals.
    a. transportation (vehicles, boats, etc.) ___
    b. research equipment ___
    c. computers___
    d. technical and support staff ___

e. laboratory space ___
f. residential space ___
g. dining services ___
h. funding for day-to-day operations ___
i. too few (or no) researchers ___
j. too few (or no) students ___
k. inadequate communication with other field stations or marine labs___
l. inadequate communication with the research community ___
m. inadequate communication with the educational community ___
n. inadequate communication with the general public ___
o . problems with security, vandalism, feral animals, etc. ___
p. deficiencies in acquisition and curation of basic data ___
q. deficiencies in library resources ___
r. deficiences in reference collection resources ___
s. inadequate knowledge of the resource base and biota present ___
t. support services ___
u. conflicts among researchers ___
v. impacts of codes, rules, regulations, permits, etc, ___
w. high cost for space and services at field stations and marine labs ___
x. lack of funding to support research ___
y. lack of funding to support facilities ___
z. lack of funding for administrative or operational staff ___
aa. lack of public understanding of science ___
Others: (please identify)

47. If you could tell NSF anything about the importance of field stations and marine labs, what would it be?
48. If you are conducting long-term monitoring that is responsive to the Sustainable Biosphere Initiative or other national research agendas, please describe your efforts briefly and explain their potential significance.
49. Do you or your researchers or educators have any anecdotal statements about the importance of a field station or marine lab experience in your careers? We would appreciate any contributions, no matter how brief.
50. In so many words, how well do you think field stations or marine labs meet the needs today of their various roles in research and education, and how might it be possible to meet the needs of the future? Examples might be to enhance the nature of communication among facilities so as to avoid duplication of effort, to vastly increase public funding available to facilities, etc. Feel free to free associate!
51. Do you have a "wish list" or dreams for emphasizing the importance of field experiences in science professions? For example, one might be that university science departments require a field station or marine lab experience in order to complete an undergraduate degree in biology or ecology. What is (are) your dreams?

Additional Questions for Marine Laboratories:

52. Vessels
    a. Do you operate a UNOLS vessel? Name:
    b) # and lengths of oceanographic vessels (also list ROVs and other major equipment)
        List major capabilities and # of scientists that can be accommodated.
    c) #, lenghts and major capabilities (# scientists accommodated, winches, dry/wet labs, etc.) of nearshore vessels
53. Seawater systems
    a) none:
    b) mesocosm scale facility (y/n)
    c) experimental flumes/wave tanks:
    d) open seawater systems:
        none:
        total tank cpacity:
        # tanks:
        Largest and smallest size of tanks:
    e) closed seawater systems:
        none:
        total system capacity:

tanks:
Largest and smallest size of tanks:
f) is there a monitoring system or general data base for general paramters (temp, salin, pH, etc)?
g) how many persons are needed to run/maintain your seawater system?
persons:
FTEs (total):

54. Aquaculture/mariculture facilities
    a) none:
    b) scale of the facilities:
        pond/estuary:
        outdoor raceways:
        large indoor tanks:
        carvoys/test tubes:
        other:
    c) primary culture organisms:
        fishes:
        invertebrates (specify phylum and common name):
        macroalgae/seaweeds:
        phytoplankton
55. Divng capabilities
    a) none:
    b) dive officer at site?
    c) do you have a certification program?
    d) do you have AAUS affiliation (American Association of Underwater Scientists)?
    e) is equipment available
        for visitors (y/n):
        mixed gas capability: specify, eg. nitrox, rebreathers, etc.
    f) is a chamber available on site?
        if not, how far?
56. Oceanographic/coastal environmental monitoring systems
    a) none:
    b) do you have your own monitoriing system? (y/n)
    c) does a government agency have a monitoring system on your site or under your jurisdiction? Please name.
    d) remote sensing capability?
        none:
        imaging:
        receive capability (y/n):
        process capability (y/n):
        download processed images (y/n):
    non-imaged data:
        receive capability (y/n):
        process capability (y/n):
        download processed images (y/n):
57. List major reference collections (plants, animals, core taxa, etc.; specify taxa and uniqueness)
        none:
58. List major or unique analytical facilities (not already mentioned)
        none:
59. What are your emergency power capabilities?
        noen:
    What percent of your research facilities is covered?
60. Housing for visitors:
    none:
    if yes, how many beds available?
61. Libraries
    a) none:
    b) do you have a librarian?
    c) estimate FTEs for library staff

d) are you a member of IAMSLIC (International Association of Marine Libraries and Information Centers)?
e) are you online to your home campus library catalog?
f) do you have search capability for major marine-related journals?
g) do you share a library?
no:
shared building:
shared costs:
shared personnel

62. Communication
a) do you have email capability?
for faculty/staff?
for visitors?
b) do you have remote teaching capability at your lab? (e.g. interactive TV, or live one-way presentations)?
c) do you have satellite downlink capability (e.g. for the Jason Project or faculty enrichment, undergrad teaching, etc.)?
d) if not, do you anticipate a need for it in the next five years?
e) do you have GIS capabilities? (Geographic Information System)

63. Do you have a data management system?
a) do you have a person dedicated (part or full time) to this system?
b) estimate FTEs for data managers

64. What public education do you provide?
a) none:
b) established total number of public visitors each year:
c) aquarium/public displays:
specify:
d) gift shop (y/n)
e) tours:
f) Eldershotel:
g) TV/radio programs:
h) other:

65. Describe the single most unique interdisciplinary research program operated through your marine/aquatic laboratory (not to exceed 5 concise sentences)

66. In your opinion, how does your laboratory function as a "Window to theSea" (limit 5 sentences)?

Survey Summary:

The distribution of summarized surveys is: 42 from OBFS field stations, 10 from stations/labs that share membership jointly in OBFS and NAML, and 25 from NAML labs. Surveys that were returned too late to be included in this compilation will be added to a separate volume to appear later in 1995, complete with text for the narrative questions from all respondents.

Question 8: Age of facilities (n=73)

age in years	# of stations this age
1-5	4
6-10	4
11-15	7
16-20	3
21-25	9
26-30	13
31-35	6
36-40	6
45-50	2
55-60	4
61-65	5
66-70	3
71-75	3
85	1
96	1
97	1
101	1

Question 9: Affiliation (n=76)

independent of any governing institution	**8**
governed by a private institution	**21**
governed by a public institution	**41**
governed by a consortium	**6**

Question 10: Activity emphasis (n=74)

research	**68**
undergraduate education	**45**
general public education	**32**
land preservation	**15**

Question 11: Seasonality

Is your activity seasonal? yes **22** no **55**

Season of greatest intensity of use: winter **1** spring **8** summer **17** fall **5**

Question 12: Staffing (n=63)

type	#of people:							
administrative full-time year-round	1-4	**45**	5-10	**10**	11-20	**4**	>20	**2**
administrative full-time seasonal	1-4	**10**	5-10		11-20		>20	
administrative part-time year-round	1-4	**25**	5-10	**1**	11-20		>20	
administrative part-time seasonal	1-4	**4**	5-10		11-20	**1**	>20	
operational full-time year-round	1-4	**36**	5-10	**11**	11-20	**5**	>20	**4**
operational full-time seasonal	1-4	**13**	5-10	**3**	11-20	**1**	>20	
operational part-time year-round	1-4	**17**	5-10	**2**	11-20		>20	
operational part-time seasonal	1-4	**8**	5-10	**2**	11-20		>20	
teaching full-time year-round	1-4	**10**	5-10	**3**	11-20		>20	**2**
teaching part-time year-round	1-4	**11**	5-10	**2**	11-20	**1**	>20	
teaching full-time seasonal	1-4	**9**	5-10	**5**	11-20	**1**	>20	
teaching part-time seasonal	1-4	**11**	5-10	**2**	11-20	**4**	>20	
research full-time year-round	1-4	**15**	5-10	**9**	11-20	**8**	>20	**9**
research part-time year-round	1-4	**7**	5-10	**7**	11-20	**3**	>20	**3**
research full-time seasonal	1-4	**7**	5-10	**2**	11-20		>20	**1**
research part-time seasonal	1-4	**5**	5-10	**3**	11-20		>20	

Question 13: Operating budget (n=74)

100k	**18**
100-300k	**28**
300-600k	**10**
600-1000k	**4**
>1000k	**14**

Question 14: Source of operating funds

percentage range: (n=63)

source	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	total #
user fees	22	3	9	3	1	0	2	0	2	2	44
sponsoring organization	4	5	6	3	2	5	5	8	1	15	54
donations	14	5	6	3	2	5	5	8	1	15	29
federal grants	10	2	1	5	2	2	2	4	0	1	29
state grants	12	5	2	1	0	1	0	0	1	0	22
endowment income	13	2	3	1	1	1	0	1	0	0	22

Question 15: Capital improvement budget (n=71)

<10k	**30**
10-50k	**15**
50-200k	**10**
>200k	**16**

Question 16: Source of capital improvement funds (n=71)

percentage range:

source	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	total #
user fees	8	2	2	0	1	0	0	1	0	1	15
sponsoring organization	4	4	4	4	2	2	1	5	3	18	48
donations	6	0	2	0	5	1	1	3	1	7	26
federal grants	10	5	3	1	3	1	1	2	0	3	29
state grants	4	0	0	2	1	2	0	0	2	1	12
endowment income	6	1	2	0	1	0	0	0	0	1	11

Question 17: Endowments (n=70)

yes **28** no **45**

<50k	**5**
51-200k	**8**
200-1000k	**6**
>1000k	**6**

Question 18: Value of assets (n=69)

<100k	**2**
100-500k	**13**
500-2000k	**12**
2000-20,000k	**31**
>20,000k	**11**

Question 19: Facility Use

type	**total annually**
A. Research Use:	
scientists (Ph.D. level) from sponsoring institution)	**565 (n=56)**
scientists (Ph.D. level) from other educational institutions	**1,239 (n=54)**
scientists from public agencies or industry	**412 (n=39)**
scientists from other countries	**164 (n=41)**
graduate students conducting their own research	**910 (n=56)**
scientists (other)	**128 (n=23)**

research assistants (graduate students)	**404 (n=41)**
research assistants (undergraduate students)	**442 (n=46)**
research assistants (other)	**200 (n=22)**
undergraduate students conducting independent research	**246 (n+44)**
B. Educational Use	
faculty and teaching assistants instructing courses	**699 (n=45)**
undergraduate students taking courses	**7,486 (n=44)**
graduate students taking courses	**2,408 (n=33)**
K-12 students taking classes	**24,790 (n=28)**
continuing or professional educational program participants	**3,030 (n=29)**
natural history educational program participants	**54,191 (n=33)**
C. Other Public Service Use	
public users of collections, libraries, other facilities	**17,307 (n=39)**
public information activity participants (tours, workshops,lectures, etc.)	**337,122 (n=50)**
D. Scientific Meeting Participants, Seminar Speakers, etc. (not listed above)	**8,010 (n=49)**
E. Volunteers	**3,337 (n=40)**

Question 20. Land tenure:

owned	**27,103 ha (n=52)**
managed	**197,212 ha (n=16)**
leased	**2,989ha (n=15)**
cooperative agreements	**334,786 ha (n=15)**
informal arrangements	**2,680,674 ha (n=25)**

Question 21. Facilities:

a. Administrative buildings **#76**, total size **220,050 sq.ft**, monetary value **$18,912,669 (n=61)**
b. Laboratory buildings **#168**, total size **1,098,105 sq ft**, monetary value **$82,254,010 (n=68)**
c. Libraries **#47**, total size **75,297 sq ft**, monetary value **$8,866,000 (n=51)**
d. Dining facilities **#46**, total size **67,282**, monetary value **$5,550,700 (n=37)**
e. Classroom facilities **#76**, total size**81,709**, monetary value **$7,243,629 (n=45)**
f. Museum or collections facilities **#35**, total size **64,281**, monetary value **$5,031,500 (n=32)**
g. Meeting room facilities **#80**, total size **51,511**, monetary value **$4,513,000 (n=43)**
h. Animal care facilities **#34**, size **95,288**, monetary value **$4,049,076 (n=22)**
i. Vehicles **#360**, monetary value **$3,251,300 (n=65)**
j. Vessels **#361**, monetary value **$16,878,214 (n=53)**
k. Computers **#2336**, monetary value **$7,430,000 (n=67)**
l. Institutional research equipment **#5006***, monetary value **$35,893,000 (n=38)**
***note: some respondents didn't count pieces, but instead just stated a monetary value**
m. Weather monitoring equipment **#138**, monetary value **$695,750 (n=41)**

Question 22: Changes in demand/use over past five years

	no change (within 5%)	increase+5-15%	increase +15-30%	increase +>30%	decrease - 5-15%	decrease - 15-30%	decrease ->30%
# research users (n=70)	13	28	12	14	2	1	0
# students (n=71)	14	23	13	18	2	1	0
staff (n-71)	23	23	9	10	4	2	0
operating budget (n=69)	19	15	15	10	8	0	2
facilities (sq. ft.) (n=71)	33	12	7	17	0	2	0

Question 23: Utility needs for the future

a. conventional electric: **$1,900,400 for 19; 9 more said "yes" w/out giving $$$ amount**
b. solar electric: **$10,000 for 1; 3 more said "yes" w/out giving $$$ amount**
c. gas: **$547,200 for 13; 5 more said "yes" w/out giving $$$ amount**
d. water supply: **$729,450 for 18; 14 more said "yes" w/out giving $$$ amount**
e. sewage disposal: **$1,440,600 for 15; 10 more said "yes" w/out giving $$$ amount**
f. hazardous waste disposal: **$88,010 for 8; 7 more said "yes" w/out giving $$$ amount**
Other(explain): **$891,200 for 7; 2 more said "yes" w/out giving $$$ amount**

Quesiton 24: Site features improvements

a. land acquisition: **$7,526,000 for 7**
b. land acquisition for protection: **$9,550,000 for 3**
c. roads: **$1,916,000 for 6**
d. trails: **$81,000 for 7**
e. fences: **$83,000 for 8**
f. trespass prevention: **$58,000 for 9**

Question 25: Facility maintenance (n=77)

being improved on a regular plan	**3**
being improved with a plan, but as funds are available	**43**
being improved haphazardly	**19**
declining in quality	**14**
not receiving maintenance	**1**

Question 26: New construction needs

 # ranking (1 highest)

topic	1	2	3	4	5	n=#
a. administrative services:	7	6	0	1	6	20
b. dining facilities:	8	1	1	2	7	19
c. researcher/research assistant housing:	19	7	6	3	3	38
d. student housing:	18	7	1	0	6	32
e. individual laboratory space:	17	6	4	0	1	28
f. shared laboratory space:	15	7	2	2	4	30
g. reference collection storage:	7	7	4	0	2	20
h. library:	11	4	6	2	2	25
i. boat storage and docks:	8	6	2	3	4	23
j. vehicle storage:	6	2	4	3	7	22
k. carpentry shop:	1	1	5	3	7	17
l. machine shop:	1	2	3	2	8	16
m. classrooms:	12	4	5	2	5	28
n. visitor center:	2	5	4	3	3	17
o. retail space:	1	1	2	1	5	10
p. darkroom/photography space:	1	2	6	0	7	16
q. computer/data management space:	12	6	4	2	2	26
r. lecture/seminar space:	12	4	4	1	5	26
s. lounge/recreation space	4	5	4	5	7	25
t. research offices	12	12	4	0	1	29
u. other (please specify):	3	1	0	1	1	6

Question27: Facility renovation needs

 # ranking (1 highest)

topic	1	2	3	4	5	n=#
a. administrative services:	2	3	3	1	4	13
b. dining facilities:	1	4	2	3	5	15
c. researcher/research assistant housing:	5	5	1	0	1	12
d. student housing:	8	5	0	1	4	18
e. individual laboratory space:	10	6	5	1	1	23
f. shared laboratory space:	8	3	3	0	3	17
g. reference collection storage:	3	3	3	1	3	13
h. library:	8	2	1	0	2	13
i. boat storage and docks:	2	4	2	0	2	10
j. vehicle storage:	1	0	3	2	4	10
k. carpentry shop:	2	3	2	1	3	11
l. machine shop:	2	1	1	1	4	9

m. classrooms:	8	3	1	1	5	18
n. visitor center:	4	2	2	0	3	11
o. retail space:	1	2	0	0	3	6
p. darkroom/photography space:	1	2	4	1	2	10
q. computer/data management space:	5	3	3	0	2	13
r. lecture/seminar space:	6	2	0	1	5	14
s. lounge/recreation space	1	1	2	1	4	9
t. research offices	8	5	4	0	1	18
u. other (please specify):	1	2	1	0	0	4

Question 28: Equipment needs (items, cost, staff needed)

a. computer capabilities (hardware and software): **134, $2,054,000, 10 staff (n=44)**
b. analytical equipment: **68, $7,106,612, 6 staff (n=41)**
c. microscopes and optical equipment: **122, $1,718,000 (n=31)**
d. photographic, video or sound recording equipment: **22, $476,500 (n=19)**
e. data management systems: **17, $587,000, 5 staff (n=13)**
f. library acquisitions: **1,004 (includes multi-volumes), $828,400 (n=28)**
g. reference collection acquisitions: **$344,000, 2 staff (n=10)**
h. climatological equipment: **19, $507,000, 1 staff (n=23)**
i. electronic communication systems: **14, $2,019,000 (n=23)**
j. office equipment: **20, $661,700 (n=26)**

Question 30: Total value of NSF support for past five years

a. facility improvements? **$6,684,610 (n=30)**
b. institutional research programs? **$30,322,604 (n=27)**
c. institutional educational programs? **$1,442,874 (n=11)**
d. public programs? **$133,000 (n=1)**
e. administrative support? **$9,526,266 (n=3)**

Question 31: Money leveraged as NSF matching funds over past five years

a. facility improvements? **$20,306,400 (n=30)**
b. institutional research programs? **$35,928,235 (n=27)**
c. institutional educational programs? **$933,837 (n=11)**
d. public programs? **$267,500 (n=1)**
e. administrative support? **$370,210 (n=3)**

Qeustion 32: Indirect cost income (n=64)

Do you receive indirect cost income? yes **32** no **32**
If yes, what rate do you receive for: federal grants? **rates range from 4 to 87.97% (mean of 43.3%)**
private grants? **rates range from 4 to 72% (mean of 30%)**
"on campus" rate **19**
"off-campus" rate **4**

Question 38: Productivity measures, last five years

a. Referreed articles: **4875 (n=44)**
b. Ph.D. dissertations: **307 (n=36)**
c. Masters theses: **507 (n=36)**
d. Institutional reports: **1311 (=34)**
e. Undergraduate research papers: **1038 (n=27)**

Question 40: Research projects (total of averages for last five years)

a. faculty-level scientists? **1454 (n=59)**
b. post-doctoral fellows? **164 (n=35)**
c. scientists from public agencies or industry? **149 (n=30)**
d. graduate students? **534 (n=50)**
e. international visiting scientists? **112 (n=35)**
f. undergraduate students conducting independent research? **316 (n=50)**

Question 41: Total number of courses taught annually is 870 (n=55)

Question 42: Total number of future scientific professionals receiving research training is 5581 (n=69)

Question 43: Total economic impact figure is $83,170,000 (an underestimate because most respondents provided a narrative but not $$$ amount) (n=26)

Question 46: Limiting factors

 # ranking (1 highest)

item	1	2	3	4	5	n=#
a. transportation (vehicles, boats, etc.)	10	11	14	11	15	61
b. research equipment	20	15	16	6	9	66
c. computers	17	8	16	4	9	54
d. technical and support staff	21	25	9	4	7	66
e. laboratory space	24	16	8	8	0	56
f. residential space	23	8	13	7	13	64
g. dining services	7	7	6	6	28	54
h. funding for day-to-day operations	25	21	11	3	6	81
i. too few (or no) researchers	18	10	11	8	15	62
j. too few (or no) students	7	9	13	10	21	60
k. inadequate communication with other field stations or marine labs	4	12	13	13	17	59
l. inadequate communication with the research community	2	10	14	17	19	62
m. inadequate communication with the educational community	0	10	13	21	17	61
n. inadequate communication with the general public	1	10	14	17	18	60
o . problems with security, vandalism, feral animals, etc.	0	2	9	12	34	57
p. deficiencies in acquisition and curation of basic data	5	13	16	9	14	57
q. deficiencies in library resources	9	15	15	13	9	61
r. deficiences in reference collection resources	7	10	15	12	13	57
s. inadequate knowledge of the resource base and biota present	19	15	10	6	7	57
t. support services	9	17	16	10	10	62
u. conflicts among researchers	0	1	7	10	38	56
v. impacts of codes, rules, regulations, permits, etc,	2	4	10	15	25	56
w. high cost for space and services at field stations and marine labs	7	6	10	9	24	56
x. lack of funding to support research	29	12	9	6	4	60
y. lack of funding to support facilities	31	11	12	10	1	65
z. lack of funding for administrative or operational staff	17	25	7	7	2	58
aa. lack of public understanding of science	7	6	20	9	9	33
Others: (please identify)	4	2	0	0	0	6