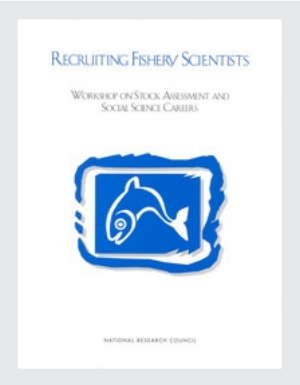

Recruiting Fishery Scientists: Workshop on Stock Assessment and Social Science Careers

DETAILS

36 pages | 8.5 x 11 | PAPERBACK

ISBN 978-0-309-07308-0 | DOI 10.17226/10000

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Recruiting Fishery Scientists: Workshop on Stock Assessment and Social Science Careers

Ocean Studies Board
Commission on Geosciences, Environment, and Resources
National Research Council

National Academy Press
Washington, D.C.

NATIONAL ACADEMY PRESS 2101 Constitution Ave., N.W. Washington, DC 20418

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance. This report was supported by a grant from the National Oceanic and Atmospheric Administration. The views expressed herein are those of the authors and do not necessarily reflect the views of the sponsor.

International Standard Book Number 0-309-07308-1
Additional copies of this report are available from:
National Academy Press
2101 Constitution Avenue, N.W.
Box 285
Washington, DC 20055
800-624-6242
202-334-3313 (in the Washington metropolitan area)
http://www.nap.edu

Printed in the United States of America

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ACKNOWLEDGMENTS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in their review of this report:

Lee Anderson, University of Delaware, Newark

Keith R. Criddle, Utah State University, Logan

Cynthia Jones, Old Dominion University, Norfolk, Virginia

Michael K. Orbach, Duke University, Beaufort, North Carolina

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Andrew Solow (Woods Hole Oceanographic Institution), appointed by the Commission on Geosciences, Environment, and Resources, who was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

CONTENTS

EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS) employs many fishery scientists with diverse skills. The agency finds that the supply of fishery biologists is adequate to meet most of its demand. However, increasing demands on the agency to understand fish populations and the social and economic conditions in fishing communities have created a need for additional experts in the fields of fisheries stock assessment and social sciences.

NMFS has developed plans for meeting its anticipated staff needs in stock assessment and social sciences and asked the National Research Council (NRC) to convene a workshop to discuss the plans and suggest other actions the agency might take to ensure an adequate supply of experts in these fields. Approximately 30 individuals gathered in Woods Hole, Massachusetts on July 17, 2000 under the auspices of the NRC's Ocean Studies Board to discuss NMFS' plans. This document summarizes the presentations and discussions at that one-day workshop. No attempt was made to reach consensus among the participants; thus, the suggestions recorded in this summary represent the personal views of workshop participants, as summarized by NRC staff.

Information was presented by NMFS at the workshop about their need to hire additional individuals in stock assessment and social sciences. NMFS proposed several actions to boost recruitment and retention of NMFS employees, including

- developing targeted recruitment programs and cooperative arrangements with universities,
- enhancing continuing education opportunities for NMFS employees,
- increasing recruitment of individuals from related fields,
- increasing diversity, and
- building capacity in minority-serving institutions.

A number of bottlenecks, differing by institution, constrain enrollment in graduate schools. At the most basic level, some universities do not receive enough applications from individuals with relevant skills who can meet their entry requirements. In some cases, universities cannot provide financial support at the beginning of a student's graduate education, even though such support could be forthcoming later when the student possesses greater skills that could be applied to his or her advisor's research projects. In other universities, both funding and qualified applicants are available, but either the number of faculty or the infrastructural support limit the expansion of fisheries education programs. Foreign students often bring financial support with them and can surmount the other bottlenecks, but are ineligible for employment by NMFS and other federal agencies after graduation until they become permanent residents or U.S. citizens.

The supply and demand situation differs for stock assessment and social scientists. For stock assessment scientists, NMFS is the primary employer and demand is already large relative to the total supply. NMFS' anticipated expansion in this area exceeds the present capacity of university programs. On the other hand, NMFS is a minor employer of social scientists; thus, even relatively large changes in NMFS hiring decisions would add only a few slots and have a relatively small effect on the overall pool of social scientists available. NMFS' anticipated expansion in this area could probably be accommodated with little difficulty. A caveat, however, is that relatively few social scientists focus on fisheries and thus would require some persuasion to enter the field and time to learn the nuances of fishery issues.

Some suggestions for reducing the total demand for qualified scientists (including those at the Ph.D., Master's, and Bachelor's levels) may include (1) decreasing the regulatory requirements for fisheries, (2) managing more cautiously (e.g., setting lower total allowable catches) so that less information and analyses are needed, (3) developing and implementing management methods that require less stock assessment and social science advice, or (4) increasing technological capabilities for performing analyses without increasing staff levels. Another way to reduce the demand for stock assessment and social scientists within NMFS—and possibly total demand—would be to contract out a greater percentage of stock assessment and social science analyses to universities or private consultants.

However, most of the workshop discussions focused on ways to increase the supply of stock assessment and social scientists in the event that NMFS receives funding for its plans. Workshop participants considered both traditional and more innovative approaches. Traditional approaches included increasing the availability of graduate and post-doctoral fellowships, funding faculty positions in universities, sponsoring programs to reach undergraduates, placing NMFS employees in academic institutions, and disseminating information about career and employment opportunities more broadly. NMFS already is using many of these approaches and has made progress in targeted graduate fellowships for stock assessment science and fisheries economics, and in offering NRC and other post-doctoral fellowships to bring new individuals into NMFS laboratories. Many participants felt that NMFS could make additional progress using these traditional approaches.

As suggested by some participants, the most obvious approach to attract more stock assessment and social scientists to NMFS would be to offer higher salaries for individuals with these specialties. This is a particular need for stock assessment scientists because their quantitative skills enable them to find work in other, more lucrative, professions. If salaries cannot be increased to competitive levels, non-monetary incentives could be offered to make up for the salary differences. Examples include travel to professional meetings, support for individual career development, funding and release time to conduct research, and exposure to national-level policy and projects.

Some of the shortfall in qualified employees can be met by hiring individuals from related fields with similar skills, but these individuals often require additional training to acquaint them with problems specific to marine fisheries. As an alternative, intensive retraining of qualified staff might help reduce the current shortfall.

Other less obvious, but potentially productive, approaches to meeting NMFS staffing needs could include working through scientific societies to find individuals in the academic or consulting communities who could fulfill NMFS' analysis needs, employing foreign scientists as guest researchers, nurturing applied mathematical ecology and population dynamics programs in universities, and sponsoring programs to reach high school students in an effort to influence their college careers.

1

SUMMARY OF WORKSHOP PRESENTATIONS

INTRODUCTION

The National Marine Fisheries Service (NMFS) asked the National Research Council's Ocean Studies Board to convene a one-day workshop on educating and recruiting experts in the fields of fisheries stock assessment and the social sciences.[1] The board was asked to discuss possible approaches for ensuring an adequate future supply of stock assessment scientists, fishery economists, and fishery social scientists to meet government science and management needs, and to maintain university training capabilities.

The workshop was designed to yield a summary of discussions without reaching any consensus recommendations. At the workshop—held on July 17, 2000, in Woods Hole, Massachusetts—NMFS presented its plans for recruiting specialists in fisheries stock assessment and social sciences. Participants discussed those plans, a presentation on student career choice, and the results of a study on marine fisheries scientists (see agenda in Appendix A). The projected need for additional stock assessment and social scientists was not evaluated[2], nor was a number of important factors related to fisheries education and recruitment. Such factors are listed at the end of Chapter 2 as questions that NMFS could address to understand its recruitment needs.

Human Resource Needs

NMFS is the primary provider of scientific advice to guide the management of marine fisheries in the U.S. exclusive economic zone; as such, the agency must estimate how many fish exist and the optimum harvest levels. Regional fishery management councils (established under the Magnuson-Stevens Fishery Conservation and Management Act of 1976) and other management entities then set harvest levels and allocate harvests in ways that are economically

[1] Stock assessment science involves the development and use of mathematical models to combine statistically designed samples of fish populations, data from directed commercial and recreational fisheries, and supplemental biological data to estimate current fish population size (relative to previous years) and levels of catch that populations can sustain. Fisheries social sciences, as used in this report, primarily refers to economics and anthropology, although the specialties of sociology, cultural geography, demography, political science, and law are also important.

[2] NMFS did not provide quantitative evidence of an existing need for more personnel, such as a list of stock assessment and social science positions that are vacant because suitably qualified individuals cannot be attracted to vacancy announcements. Instead of being presented with such evidence, workshop participants were presented with a projection of a number of positions that NMFS hopes to be authorized to create. All of the report's conclusions are conditioned on that hope. NMFS did not present information regarding the probability that NMFS will receive an increase in funding to open new staff positions.

efficient and socially acceptable. Effective management thus depends on expertise contributed by fisheries stock assessment and social scientists. Another way to think of this issue is that an appropriate distribution is needed among employees who produce scientific data and information and those who use the information, as well as individuals who can bridge the gap between these two areas.

To support its scientific advisory role, NMFS employs individuals skilled in fisheries biology, stock assessment, and the social sciences. Regional fishery management councils, states, and interstate and international commissions based in the United States share responsibilities for fisheries management and also must have access to individuals trained in these same fields. In addition, industry groups and nonprofit environmental organizations employ fishery scientists to provide independent assessments and to participate in management. Fishery biologists are in relatively ready supply and NMFS does not anticipate any difficulty in recruiting such individuals. The demand for specialists in fisheries stock assessment and social sciences, however, is expected to increase in the near future. The problems related to fisheries management are critical and solution of these problems is hindered by the shortage of experts. Lawsuits against NMFS by the commercial fishing industry and the environmental community challenge fishery management plans and other regulatory actions on technical grounds primarily related to the statutory requirements of the Magnuson-Stevens Fishery Conservation and Management Act, Regulatory Flexibility Act, Endangered Species Act, Coastal Zone Management Act, and their associated regulations, requiring more effort for stock assessment and social science analyses.

The NMFS scientific workforce is spread among 5 regional science centers composed of 26 laboratories. Michael Sissenwine, director of NMFS' Northeast Fisheries Science Center, attended the workshop and presented information about the current status of NMFS staffing in the areas of stock assessment and social sciences. The scientific staffing at these facilities has decreased overall in the past several decades. However, a consistent level of employment in stock assessment and social sciences has been maintained to meet the added responsibilities resulting from the Sustainable Fisheries Act of 1996 and the 1996 amendments to the Regulatory Flexibility Act of 1980.

Stock assessment and fisheries social sciences differ significantly in the types of employees required, but both areas are characterized by relatively small pools of experts available to conduct research and train future practitioners. These individuals are spread among many institutions and different departments in these institutions. NMFS relies on universities to produce an adequate supply of employees with the expertise required. Currently, 2,670 persons are employed in more than 80 job categories. – Approximately 1,130 of these employees are technical experts and about 520 will have served with the federal government for at least 20 years in 2005. Similar to other federal agencies, NMFS anticipates regular retirement of 30 percent of its scientists within the next 5 years; an additional increment of as much as 20 percent will leave because of early retirement incentives.

Stock Assessment Science

Stock assessment requires individuals with strong mathematical training, excellent skills in statistics and population dynamics, and knowledge of fish biology, population biology, and fishing practices. Such individuals may hold undergraduate degrees in biology, statistics, or applied mathematics. No standard curriculum is available for preparation of stock assessment scientists, although the National Research Council's 1998 report *Improving Fish Stock Assessments* made recommendations with respect to desirable coursework and internships for students to work with NMFS scientists. Stock assessment skills are further developed after hiring. The demand for quantitatively trained individuals is also high in other fields, such as computer programming, industrial operations research, and investment analysis. Thus, fishery management organizations compete with industry for individuals with mathematical skills and training.[3]

NMFS estimates that 583 of its employees collect, process, and use data for stock assessments. Of these, approximately 95 individuals actually conduct assessments, do research on stock assessment methods, and conduct policy analysis and follow-up related to stock assessments; approximately 20 of these individuals are women, and a few are Asian Americans. Other ethnic or racial minorities are not presently represented.

Social Sciences

The demand for fishery economists and other social scientists is somewhat lower than for stock assessment scientists, and few individuals are being trained in this area. Social scientists perform crucial functions for fisheries management, including

- Description of the current and historic social and economic characteristics of fishers and fishing communities
- Characterization of the probable local, regional, and national social and economic consequences of alternative management actions
- Determination of what fishers and members of fishing communities know about biological, economic, and social aspects of fisheries and associated management processes
- Dissemination of information about the social and economic characteristics of the fisheries and how the fishery management process works
- Study of the outcomes stakeholders seek and what management institutions and policy instruments they prefer
- Design and nurture of data collection programs for the previous purposes
- Design of management alternatives for fishery management plans

Multidisciplinary teams composed of stock assessment scientists, fishery biologists, economists, anthropologists, lawyers, and others are important for developing and reviewing fishery management plans. It appears that NMFS and the regional fishery management councils

[3] The demand for quantitatively trained individuals is also strong in other areas of ocean sciences, such as physical oceanography, creating the same kind of competition for graduates.

employ too few social scientists, particularly anthropologists and economists, thereby limiting the rigor of policy analysis and constraining participation by social scientists.

NMFS presently employs 37 persons in the social sciences (34 economists and 3 anthropologists). Of the anthropologists, 2 are females and 1 is male. Of the economists, 29 are males and 5 are females (4 are minorities). This level of staffing is quite low in light of the need to collect social science data and analyze them rigorously and to provide input to policy recommendations. NMFS has proposed two major initiatives (described below) that would require hiring a significant number of new employees.

NMFS ACTIVITIES AND PLANS

Stock Assessment Improvement Plan

A *Stock Assessment Improvement Plan* has been drafted by NMFS to describe systematically how staff think stock assessments could be improved and how many additional staff would be needed to achieve different levels of improvement. This plan is

> a blueprint for improving NOAA's capacity to provide best available scientific advice conforming to new national stock assessment standards of data quality, assessment frequency, and analyses.

The plan was stimulated in part by recommendations in the 1998 National Research Council report *Improving Fish Stock Assessments.* For example, that report (NRC, 1998, p. 117) states that

> NMFS and other bodies that conduct fish stock assessments should ensure a steady supply of well-trained stock assessment scientists to conduct actual assessments and to carry out associated research. NMFS should encourage partnerships among universities, government laboratories, and industry for their mutual benefit. This can be accomplished by exchanging personnel and ideas and by providing funding for continuing education at the graduate, postdoctoral, and professional levels, including elements such as cooperative research projects and specialized courses, workshops, and symposia.

The *Stock Assessment Improvement Plan* was created by the NMFS National Task Force for Improving Fish Stock Assessments and describes NMFS's vision of desirable future levels of stock assessment activities in terms of three tiers of activities that encompass five levels of stock assessment analysis (see Appendix C). The tiers are

Tier 1—Improve assessments using existing data

Tier 2—Elevate all assessments to a nationally acceptable level

Tier 3—Next generation assessments

NMFS seeks to elevate all assessments to a nationally acceptable level (Tier 2) And according to its analyses, such a shift would require adding 358 full-time equivalent stock assessment and data collection personnel to the existing 95 individuals (estimated to add about $50 million annually for salaries and benefits).

Social Science Research Program

Complementary to NMFS' plans to enhance its stock assessments, the agency is developing plans for a Social Science Research Program. The program's mission is to "establish a coordinated social science capability that can contribute to the science-based conservation and management of living marine resources." The objective of the program is to "enable NMFS to implement policy alternatives that achieve resource stewardship goals while providing the greatest benefit to, or imposing the least cost on, society." This will entail recruitment and retention of more analytical economists and anthropologists. NMFS estimates that development of such a capability would require $18.2 million per year to fund additional salaries and benefits, as well as research expenses. This plan would involve phasing in 96 new social scientists over a period of five to seven years. About three-fourths of the new employees would be economists and one-fourth would be sociologists and anthropologists.

Recruitment Plans

NMFS is pursuing a five-element plan for recruiting and training stock assessment and social scientists, including

1. targeted recruitment programs
2. cooperative arrangements with universities
3. continuing education
4. increased recruitment from related fields
5. increased diversity and capacity building

Several of these elements have already been implemented. The prime example of targeted recruitment programs is the new Joint Graduate Fellowship Programs in Population Dynamics and Marine Resource Economics, sponsored by the National Sea Grant College Program and NMFS.[4] Four Ph.D.-level students, funded starting in 2000, are expected to work on "thesis problems of public interest and relevance and to have summer internships under the guidance of a NMFS mentor at participating NMFS Science Centers, Laboratories, or Regional Offices." Two additional students will be supported by each program in each subsequent year, up to a maximum of six students per program at any given time. The population dynamics program will provide up to three years of support and the resource economics program will provide up to 2 years of support. At the time of the workshop, the first four students had been selected, and one attended the workshop. Although the fellowship program is a good concept for increasing the number of students in the employment pipeline, as presently configured the program is too small to significantly address the proposed increase in staff.

[4] http://www.nsgo.seagrant.org/research/rfp/fellowship_fy2000.html , accessed 10/28/00.

The National Oceanic and Atmospheric Administration (NOAA) has established a number of cooperative and joint institutes with academic institutions to work on research and education matters. NMFS already participates in several of these institutes (Box 1.1), which often focus on issues of high priority within their regions. Such participation has the added benefit of allowing students to familiarize themselves with NMFS scientists and activities.

Continuing education has long been a priority within NOAA and NMFS. Since 1993, the agency policy has been to dedicate 1.5 percent of personnel costs to training and professional development. Professional development courses are offered through the NOAA Office of Human Resources Management and through arrangements with outside institutions by NMFS regional offices and science centers. In addition, NMFS employees are encouraged to use the National Conservation Training Center run by the U.S. Fish and Wildlife Service, in Shepherdstown, West Virginia, which offers courses in related biological sciences, mathematics and statistics, and education and outreach.

NMFS sometimes recruits from such related fields as applied statistics, non-fisheries population dynamics, and non-fisheries resource economics and plans to continue to do so. The agency recognizes that hiring from outside the fisheries field results in a longer time to train new employees in the nuances of fisheries, so there is a definite benefit to hiring individuals who focused on fisheries issues for their graduate work.

As part of its overall recruitment efforts, NMFS is committed to expanding the racial and ethnic diversity of its workforce and to building the capacity of minority-serving institutions. These goals have been communicated through active outreach efforts to such institutions, including cooperative agreements with 21 minority-serving institutions. An example is the agreement between the Woods Hole NMFS laboratory and Jackson State University to develop a fisheries curriculum.

SURVEY OF FISHERY SCIENTISTS

At the workshop, Bonnie McCay presented preliminary results from a survey of fishery scientists that is part of a larger study of science and policy in fisheries management.[5] The more than 350 fishery scientists surveyed included individuals from NMFS, state management agencies, academia, and non-governmental organizations. The results of the survey provide insight into the work of fishery scientists and their attitudes about fisheries management, although fishery scientists may not be the best judge of what is lacking or most important in fisheries science and management. A survey of fishery managers or fishers might yield different conclusions. According to McCay, the preliminary analysis shows a high level of consensus among fishery scientists about the importance of additional investment in both stock assessment and social sciences.

[5] The survey was intended to include individuals with training in the natural science dimensions of fisheries and those whose jobs included significant responsibility for fisheries science. Few of the respondents were social scientists. Analysis of data from the study is still in progress.

BOX 1.1 NMFS SCIENCE CENTER COOPERATION WITH UNIVERSITIES AND PARTICIPATION IN COOPERATIVE AND JOINT INSTITUTES

Southwest Fisheries Science Center (La Jolla, California)

- Scripps Institution of Oceanography (Joint Institute for Marine Observations)
- University of Hawaii (Joint Institute for Marine and Atmospheric Research)
- University of Washington (Joint Institute for the Study of the Atmosphere and Ocean)

Alaska Fisheries Science Center (Seattle, Washington)

- University of Alaska (Cooperative Institute for Arctic Research)
- University of Washington (Joint Institute for the Study of the Atmosphere and Ocean)

Northeast Fisheries Science Center (Woods Hole, Massachusetts)
(Cooperative Marine Education and Research Program)

- Rutgers University
- Southampton College of the Long Island University
- University of Massachusetts
- University of Rhode Island
- Woods Hole Oceanographic Institution
- Virginia Institute of Marine Sciences/Hampton University (minority-serving institution)

Southeast Fisheries Science Center (Miami, Florida)

- University of Miami (Cooperative Institute for Marine and Atmospheric Studies)
- Florida State University
- University of Florida
- Duke University/University of North Carolina (Cooperative Institute for Fisheries Oceanography)

Northwest Fisheries Science Center (Seattle, Washington)

- University of Washington (Joint Institute for the Study of the Atmosphere and Ocean)

Survey questions addressed work activities, time pressures, expertise, and issues in training new fishery scientists. These results revealed that fishery scientists in different employment sectors have somewhat different job requirements. One workshop participant suggested that differences in job requirements may indicate that academic programs in fisheries science could be more useful if students were offered career tracks with different types of training or internships and on-the-job training.

A high value is placed on opportunities to conduct scientific research, and basic research is an important component of the job in all sectors except the non-governmental organizations. All but the non-governmental scientists surveyed stated that they probably would be willing to forego career advancement to do more research. Scientists at NMFS were more likely to agree that the most important changes in work activities in the past three years were reduced funding

and fewer personnel. Academic and non-governmental scientists indicated very heavy or overwhelming time pressures in their jobs. Fishery scientists in all sectors indicated that time pressure had increased over the past three years.

Regardless of sector, fishery scientists agreed on the areas of expertise that are the most important for training fishery scientists today: quantitative stock assessment, data collection, mathematics, statistics, computer science, and habitat and aquatic ecosystem science, followed closely by socioeconomics, law, policy, administration, and conservation biology. Respondents from the fisheries science sector believe that training is neglected in many of these areas. Areas that were less often cited as important include fish behavior, genetics, taxonomy, physiology, and fish culture. NMFS scientists, in particular, indicated that fisheries social sciences and mathematics were the most neglected topics.

Fishery scientists indicated that the most useful work being done today is in the areas of quantitative stock assessment and habitat or aquatic ecosystems. Most responses to the question "where do you believe the most intellectually exciting work is being done by fisheries scientists today?", were "stock assessment and population dynamics, aquatic ecology and fish habitat, genetics, and ecosystem management."

Overall, the results of the survey indicate that basic attitudes toward fisheries management are similar among U.S. fishery scientists from different employment sectors. Although some differences depend on where a scientist works, these differences are small. State scientists differed from scientists working in other sectors in their responses to questions about working with industry, use of ecosystem-level management, and the use of predefined requirements for overfishing and stock rebuilding. State scientists were more likely than NMFS scientists to favor collaboration with commercial and recreational fishers, although the differences were small (but statistically significant).

In summary, reduced funding and fewer personnel may be putting more time pressures on fishery scientists at NMFS and other agencies. Although some differences were noted in the beliefs of fishery scientists from the different sectors, the importance of stock assessment, quantitative skills, and understanding of fish habitats were broadly apparent. Many scientists also indicated socioeconomics, law, policy, and administration as important areas in fisheries training. McCay pointed out that the survey results support NMFS' need to train and/or hire fisheries stock assessment and social scientists.

STUDENT CAREER CHOICE

Although employment opportunities at academic research institutions are decreasing in many scientific fields, the demand for scientists in government, industry, and teaching is outpacing the availability of qualified individuals in some fields (NRC, 2000). At the workshop, Arnold Spokane of Lehigh University's Department of Education described some of the factors that influence student career choice, selection of science careers, and interventions for increasing interest in science careers. His comments are summarized here.

Models of Career Development

Career choice is influenced by interacting factors. The use of models to describe the process of career development helps to isolate factors that may influence career choice and therefore may be affected by specific interventions to increase the number of students entering science careers. Educators recognize three general models of career development: the differential model, the developmental model, and the social systems model. Each model describes a different set of factors related to career development, but actual career choice decisions may result from a complex combination of the factors.

The *differential model* recognizes that individuals choose careers based on inherent personal traits, probably with a genetic component, that may be affected only partially by external influences. An individual's perception of his or her personal traits leads to selection of occupations consistent with the perceived traits. Interventions in career choice based on this model may seek to describe and clarify an individual's personal traits and facilitate exploration of consistent occupations.

The *developmental model* of career development suggests that career choices progress through stages, building on previous experiences. Decisions about careers are responses to such practical considerations as academic performance, available opportunities, and perceived state of employability. Career choice interventions based on the developmental model may seek to improve the quality of decisions about careers through counseling.

The *social systems model* of career development focuses on the influence of external factors in the choice of careers. Economics, parental education level, parental encouragement, and peer opinions are examples of such social factors. Career choice within the social environment is based on observation of others in a similar environment and emulation based on these observations. Interventions are designed to alter or enhance the social environment in ways that might affect career choice.

Choice of Science Careers

Large numbers of students with an interest in science depart from this career path at all levels of education, and most do not return. In addition, it is considered very difficult for students to enter science from other fields if they do not have a strong background in mathematics and basic sciences. Consequently, the number of students completing advanced science training is a small fraction of the number of students who express an interest in science in high school. One estimate (Massey, 1989) suggests that the number of Ph.D. degrees awarded in science and engineering is 1.7 percent of the number of high school seniors showing interest in science and engineering.

Some workshop participants asserted that students may avoid careers in fisheries because of the mistaken view that fisheries science focuses solely on harvest of fishery resources to the exclusion of harvest, conservation, management, and scientific understanding of marine

ecosystems. The existence of such associations has led many academic fishery departments to change their names to emphasize conservation. Examples cited by the workshop participants often integrated the word "environment" into the name, even when it seemed redundant. Some participants stated that students may be increasingly attracted by the environmental aspects of fisheries science. The field might be more attractive to students if it emphasized the fundamental issues of population dynamics and biological regulation, the role of fish stocks in structuring marine communities, and other topics related to interactions among the environment, marine ecosystems, and fish populations.

Influencing Career Choice

Research on career choice has shown that short-term increases in science career interest can be achieved. Hearing scientists talk about their personal career development and career satisfaction, successfully completing mathematical activities, and observing a science-related task performed successfully can increase an individual's confidence in making career choices (Luzzo et al., 1999). These kinds of interventions have not been effective, however, in producing large or long-term changes in attitudes toward science, perhaps because they do not create any necessary changes in an individual's self-perception. Interventions late in the process of career development may be ineffective. Early intervention or intervention at a critical time (perhaps the middle-school years) may be necessary to both develop the necessary skills and career interest in science.

The JASON Project provides insights into the opportunities and difficulties associated with initiating interventions for stimulating interest in science careers. A program of undersea exploration, the JASON Project combines a specially developed curriculum with live broadcasts from remote ocean sites to allow students to participate secondhand in scientific observation and discovery. In addition, some students participate in the actual cruises. The goal is to improve the attitudes of teachers and students in grades 4-12 toward science, and ocean science in particular, and to inspire students to pursue scientific careers. More than 250,000 students have participated in the live broadcasts. A small study was conducted at one site to assess the program's impact (Bazler et al., 1993). Participants completed surveys on attitudes toward science before and after the JASON Project telecasts. The results indicated that this type of intervention to enhance science attitudes may not have universal positive effects. According to Spokane, the most significant impacts of the JASON Project cruises appear to occur in students who participate in the cruises directly. The relationship between a student's grade in school and the effect of the JASON experience suggests that middle school may be the best time for interventions in science attitudes, or that science interest peaks during these years.

A broad array of intervention strategies at all educational levels (K-12, undergraduate, graduate) could be used to increase interest in fisheries science and the pool of individuals interested in pursuing a career in this field. Interventions (and possibly job analysis and redesign) are particularly important for increasing the participation of women and minorities. Support—financial, emotional, and social—is needed to retain women and minorities in the educational pipeline.

2

SUMMARY OF WORKSHOP DISCUSSIONS

Recruitment of appropriately trained stock assessment scientists to NMFS appeared to be more serious than the problem of recruiting fishery social scientists. In contrast to the case of stock assessment scientists, there is a relative abundance of social scientists who might be attracted to new NMFS positions or who might conduct research of interest to NMFS through grant and fellowship funding.

One workshop participant suggested that if NMFS creates additional positions, they should be concentrated in the regional fishery science centers so that a critical mass of expertise is present in the centers. New staff at the Ph.D. level should also have opportunities to engage in general scholarly research in addition to research focused on requirements in the Magnuson-Stevens Act and Regulatory Flexibility Act. However, simply creating staff positions for stock assessment scientists in NMFS laboratories is unlikely to address the shortfall in the short term, because there are not enough graduates possessing U.S. citizenship to fill such positions.

NMFS might be better able to help the regional fishery management councils manage fisheries sustainably, and be more likely to avoid lawsuits, if the agency were to achieve the tier goals listed in Appendix C . Achieving such goals will require increased employment of stock assessment and social scientists, although workshop participants did not attempt to assess the accuracy of NMFS' estimates of the number of additional scientists needed to meet such goals.

CONCEPTUALIZING THE HUMAN RESOURCE PROBLEM

The human resource problem is a supply-demand problem, and NMFS could approach its human resource problems by either decreasing demand or increasing supply. Workshop participants focused on NMFS and university needs, recognizing that other sectors (industry, state governments, and environmental groups) would also benefit from any improvement.

Decreasing Demand

The first approach NMFS could use to deal with its human resource requirements would be to attempt to reduce demand within the agency for fishery stock assessment and social scientists. Suggestions for reducing total demand for stock assessment scientists included (1) decreasing the regulatory requirements for fisheries, (2) managing more cautiously (e.g., setting lower total allowable catches) so that less information and analyses are needed, (3) developing and implementing management methods that require less stock assessment and social science

advice, or (4) increasing technological capabilities to perform analyses without increasing staff numbers. Options 1 and 2 for decreasing demand for stock assessment and social scientists are included to reflect workshop discussions, but would probably not be feasible or desirable. One workshop participant believed that option 3 deserves particular attention and that new management paradigms should be sought because some elements of the Magnuson-Stevens Act may be virtually impossible to implement with a high degree of accuracy and precision, even with additional funds and personnel.

Agreement among managers, commercial fishers, recreational anglers, and environmental advocates will be necessary for any of these options to be successful. Only option 3— developing and implementing new management techniques that reduce the need for stock assessment and social science advice—is likely to be practical in the immediate future. Even this option can only be implemented if (1) commercial fishers could be convinced that their livelihoods would not be endangered, (2) recreational anglers could be convinced that their recreational opportunities would not be diminished, and (3) environmental advocates could be convinced that the target species and marine ecosystems would not be at risk.

Another suggestion for reducing the demand for stock assessment and social scientists within NMFS—and possibly total demand—was to contract out a greater percentage of stock assessment and social science analyses. Rationales for and against such an approach were discussed at the workshop. On the positive side, contracting out the analyses would make more obvious the incremental costs of implementing new regulations. At present, such costs are relatively hidden because added duties are often absorbed by existing personnel allowing Congress to consider existing scientific resource as seemingly free and infinite. Contracting out could also allow access to foreign graduates of U.S. stock assessment and social science programs so that their training and skills are not lost to the U.S. effort. By offering potentially higher salaries, contracting out could also help retain individuals who otherwise would leave the field for more lucrative occupations. Social science projects contracted out by NMFS accounted for approximately $800,000 per year in fiscal years 1999 and 2000. Fewer stock assessments are contracted out because of the limited number of stock assessment scientists in the academic and consulting communities. Also, NMFS scientists are more likely to understand the nuances of a fishery and to have participated in the design and conduct of data collection and analysis.

Contracting to university scientists and their students could contribute to the NMFS' recruitment and training goals and could strengthen the academic stock assessment and social science sectors and draw them closer to NMFS. In addition, the flow of resources into fishery-related academic areas might increase the on-campus standing of those departments, thereby encouraging the universities to invest, or protect resources already invested, in those areas and encouraging collaborative ties with other departments. For example, committing resources to a fisheries stock assessment program might strengthen ties with applied mathematics and statistics programs by providing internships and research assistantships to graduate students in those programs, where most assistantships are currently linked to teaching.

Several arguments were made against contracting out analyses:

- Analyses could decrease in quality and comparability over time because of disruption of the continuum within NMFS from data collection through analysis.
- Contracting analyses to consulting firms can raise concerns about the impartiality of the analyses because many consulting firms have represented one or another interested party in various issues.
- Some stock assessment activities will not be considered fundamental research in university departments and will be discouraged or prohibited. The character of university research and the conflicting demands on faculty time often limit university interest in contributing to analyses required for fishery management plans. One participant suggested that fisheries stock assessment and social science activities directed to universities should only be those that include fundamental scientific questions that would lead to new knowledge or approaches.

Retention

Some emigration from NMFS is inevitable, as individuals leave the agency to pursue career options in other sectors. Such emigration can have a positive effect, as such individuals can help build good relationships between NMFS and other sectors. However, excessive emigration rates negate recruiting efforts.

Retention could be increased by improving employee job satisfaction—especially for employees who are often involved in controversy by virtue of their involvement in the regional and interstate fishery management meetings—and by providing incentives for employees to stay. (Participants noted that some government programs encourage early retirement, which could work against retention of employees with critical skills.) NMFS could retain a higher percentage of its employees by providing continuing education opportunities, including formal apprenticeship programs, sabbaticals in universities, and Internet-based courses and an open-university concept. Continuing education could help staff to maintain their skills and develop new ones, including advances in their fields.

NMFS could contract some of its continuing education activities to scientific societies such as the American Fisheries Society, the International Institute for Fisheries Economics and Trade, and the Society for Applied Anthropology. Other actions to increase retention of employees could include keeping salaries competitive and providing clear career paths.

Increasing Supply

Most of the workshop discussions focused on ways to increase the availability of stock assessment and social scientists to NMFS. The supply of such specialists available for hire by NMFS is related directly to the number of students produced in these and related areas. Important factors in supply include recruitment and retention of employees. Recruitment is affected by the number and productivity of individuals, usually located in universities, who train students in these fields. Individuals can also be recruited into stock assessment and social

science positions from related fields. Post-recruitment retention of employees reduces the demand for new recruits and thus the supply needed.

Recruitment

Participants identified some impediments to recruitment:

- Lack of financial support in a student's early graduate school years
- Inadequate numbers of teaching faculty or inadequate funding for faculty to focus on areas that support the training of fishery stock assessment and social scientists
- Stringent entry requirements of institutions
- Inadequate infrastructural support from universities, for example, laboratory space, computing resources, and research vessels.

Any NMFS program to increase recruitment might be more effective if it recognized which of these impediments applies to a particular university. A comprehensive nationwide analysis of recruitment bottlenecks might help NMFS develop strategies for apportioning funding to relieve these four bottlenecks.

Few institutions have what some workshop participants considered a critical mass of faculty members to constitute a program in stock assessment or fisheries social science. Examples of institutions that do have this critical mass include the University of Washington for stock assessment science and the University of Rhode Island for fisheries economics. One participant believed that having more institutions with a critical mass of faculty is important for the future of stock assessment and social sciences. At the moment, however, most universities with fisheries programs have only one or two faculty members in an area. Even so, these universities have been important in the supply of students in the past and some of today's most respected fishery scientists graduated from these small programs. One participant suggested that a combined approach of a few large programs and a diversity of smaller programs may be effective, with some investments in distance learning and other methods of sharing expenses and training. Recruitment from related fields and training recruited individuals in fisheries is another means to increase the supply of potential employees. In addition, some staffing needs in stock assessment and social sciences might be met by retraining qualified individuals already employed by the agency.

Workshop participants suggested a variety of actions that NMFS could take to increase the supply of fishery stock assessment and social scientists to the agency and the retention rate for employees. These actions include both traditional and innovative approaches to recruitment and retention.

- Offer graduate fellowships. The new Joint Graduate Fellowship Programs in Population Dynamics and Marine Resource Economics sponsored by the National Sea Grant College Program and NMFS are examples.
- Fund faculty positions.

- Offer postdoctoral positions in NMFS laboratories. This approach is already employed, through the National Research Council (NRC) postdoctoral fellowship program and other programs. NMFS is hosting 16 NRC postdoctoral fellows in fiscal year 2000. However, the number of fellowships has decreased in the past 5 years due to erosion of NMFS base funding.
- Sponsor programs to reach undergraduates. Through research grants to university scientists, NMFS and the National Sea Grant College Program help train students, primarily at the graduate level. This avenue could be expanded through undergraduate internships in NMFS laboratories and new activities by the NMFS cooperative and joint institutes. Stock assessment scientists usually enter the field through undergraduate majors in biology, statistics, and other areas of mathematics. NMFS could create special outreach activities to such departments to promote education in quantitative biology, providing opportunities for development of biological knowledge for individuals who major in statistics and mathematics, and development of mathematical skills for biology majors (Levin, 1992). It is more difficult to define the portals of entry for social scientists, because those who enter are so few.
- Place NMFS employees in academic institutions where they can help recruit students to NMFS. Such placements could be done through sabbaticals (e.g., through Intergovernmental Personnel Act assignments) lasting a few months to a year. NMFS scientists could conduct research, and perhaps teach, with their colleagues in universities. Such programs could reward NMFS scientists, increase creative thought, and provide them with a sense of intellectual renewal, which may increase retention. Although this action initially would effectively reduce the number of individuals available in NMFS laboratories to conduct stock assessment and social science analyses, interactions between NMFS scientists and university faculty and students might increase the effectiveness of the NMFS workforce and increase the numbers of students entering the fisheries stock assessment and social science fields in the longer term.
- Create opportunities for university faculty to take sabbatical leaves at NMFS research facilities. Most universities only offer partial support for sabbatical leave. If NMFS were prepared to cover the balance of faculty sabbatical salaries, it might be possible to induce university scientists to spend time in the NMFS research labs interacting with NMFS personnel, perhaps teaching continuing education classes or modules and collaborating on ongoing research projects.
- Advertise open positions and inform potential employees about job prospects.

Many of these approaches are currently being used by NMFS but could be more effective if they were expanded.

Other actions have not yet been tested or have not been considered viable in the past, but could help NMFS improve recruitment efforts. Participants suggested that NMFS could increase the supply of stock assessment and social scientists by the following approaches.

- Offer competitive salaries. The most obvious solution would be to offer salaries and benefits comparable to those paid by companies and organizations that

compete with NMFS for employees. Students with good quantitative skills are in high demand in fields such as pharmaceutical research, software design, consulting, and financial analysis and companies in these fields typically offer higher salaries than the government. If NMFS cannot pay salaries comparable to the private sector, it will be necessary to strengthen non-monetary incentives, such as continuing education, sabbaticals, and other opportunities to conduct research and interact with academic fishery scientists. McCay's research shows the value that NMFS scientists place on the opportunity to do research. Better communication of opportunities for scientific research therefore may help recruit talented scientists.

- Work through scientific societies to link academic scientists and new graduates with NMFS needs. The Environmental Protection Agency (EPA) enlists help from the Society for Applied Anthropology through a cooperative agreement to encourage interactions between the agency and the academic community. Approximately 50 projects, mostly community-based, have been carried out to date. The Ecological Society of America has implemented cooperative agreements and contracts with several federal agencies, including EPA and the National Park Service. NMFS could approach the Society for Applied Anthropology, International Institute for Fisheries Economics and Trade, and the American Fisheries Society to develop similar cooperative agreements.
- Employ foreign graduate students and foreign graduates of U.S. programs as guest workers. Another agency in the Department of Commerce, the National Institute of Standards and Technology (NIST), makes substantial use of this approach. NIST-sponsored foreign guest researchers can obtain J1 visas that allow them to stay in the United States for up to 3.5 years. Of the foreign guest workers at NIST, approximately 50 percent are sponsored by NIST and the other 50 percent are sponsored by their home governments or international organizations. Guest researchers range from graduate students to mid-career scientists on sabbatical leaves.
- Develop and nurture applied mathematical ecology and population dynamics in universities, particularly related to fishery problems.
- Sponsor outreach programs in high schools and middle schools near NMFS laboratories. (Many experts in career choice believe that undergraduate years are too late to reach many students.) NMFS should consider outreach to high schools located near NMFS laboratories to give students a first-hand view of potential careers in fisheries. Outreach could include sponsorship and personal involvement of NMFS scientists in school projects and science fairs and support of science teachers with curricular materials and training. A large number of students at all levels could be reached by developing information about fishery careers and including such information on the NMFS Web site.[1] NMFS could increase the visibility of fishery careers by describing such careers in college, graduate school, and career guides.

[1] http://www.nmfs.noaa.gov

BREADTH OF THE PROBLEM

The NMFS situation is a subset of a larger problem. Stock assessment and social scientists are employed by NMFS,, fishery management organizations (e.g., regional fishery management councils, interstate commissions, and international treaty organizations), the U.S. Fish and Wildlife Service and state fishery agencies, academia, industry, and nonprofit organizations. Several workshop participants noted that only a portion of their graduates who stay in fisheries science take jobs with NMFS. Strengthening the fields of fisheries stock assessment and social sciences could benefit both NMFS and also the academic, management, environmental, and industry sectors.

IMPLICATIONS OF CAREER DEVELOPMENT MODELS

Federal agencies are experiencing a shortage of well-trained professionals to address cross-cutting issues in natural resource management. The issue of how to increase student interest in science careers has received significant attention in recent years and a number of career choice theories have been developed (see Chapter 1). NMFS could apply knowledge of the career choice models by

- making it easier for high school, undergraduate, and graduate students to explore what is involved in fishery careers and what skills and interests are consistent with such careers;
- increasing research and internship opportunities for younger students ensuring that counselors and career guides have sufficient information about fishery careers to share with students; and
- developing its own career guide and distribute it widely, including on its Web site.

QUESTIONS TO CONSIDER

The following questions were formulated during the workshop; however, because of time constraints, participants were not able to expand on them. NMFS could address the questions as part of its effort to increase the supply of stock assessment and social scientists.

- What role can masters-level (and talented bachelor's-degree level) graduates play in meeting needs for additional stock assessment and social science expertise?
- What are the characteristics of stock assessment and social scientists employed by NMFS and academic institutions in terms of degree level, training, age, potential years to retirement, race, ethnicity, and gender?
- What factors lead employees to join and leave NMFS and what interventions could be developed to reduce attrition?
- How many recruits are needed each year (on average) in each specialty and how large does the pool of teaching faculty need to be to meet the demand?

- What curricula would be most appropriate for the students given the likely fishery issues of the next few decades?
- Can any lessons be learned by examining the training of some of the eminent fishery scientists of the past several decades who have contributed to the development of stock assessment methods? (Many were trained in mathematics, engineering, and physics.)
- What is the feasibility of reducing the total demand for stock assessment and social scientists?

By considering these questions and others, NMFS can begin to foster the work force it will need in the coming decades.

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APPENDIX A

WORKSHOP AGENDA

Education and Training Needs for Fisheries Science and Management: Stock Assessment Science, Fisheries Economics, and Fisheries Social Science

Carriage House, NAS Study Center, Woods Hole, Massachusetts

July 17, 2000

AGENDA	
7:30 a.m.	Breakfast in Main Building
8:30 a.m.	Introduction – Ed Houde
8:45 a.m.	NMFS Demographics and Plan for Increasing Supply of Experts – Mike Sissenwine
9:30 a.m.	Results of Human Resources Questionnaire – Bonnie McCay
10:00 a.m.	Break
10:15 a.m.	Increasing the Supply – Arnold Spokane How do students make their career decisions? What methods can be used to attract students to a field?
10:45 a.m.	STOCK ASSESSMENT SCIENCE – Moderated by Ray Hilborn Reactions to NMFS Plans Other Ideas
12:00 noon	Lunch in Main Building
1:00 p.m.	STOCK ASSESSMENT SCIENCE (continued)
2:00 p.m.	FISHERIES SOCIAL SCIENCES – Moderated by Bonnie McCay Reactions to NMFS Plans Other Ideas
3:00 p.m.	Break
3:15 p.m.	FISHERIES SOCIAL SCIENCES (continued) – Moderated by Dan Bromley
4:30 p.m.	GENERAL DISCUSSION AND SUMMARY – Ed Houde
5:00 p.m.	Discuss workshop report: draft outline, timeline, potential reviewers
5:30 p.m.	Adjourn Workshop

APPENDIX B

WORKSHOP PARTICIPANTS

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APPENDIX C

TIER GOALS AND ASSESSMENT LEVELS IN NMFS' STOCK ASSESSMENT IMPROVEMENT PLAN

The Stock Assessment Improvement Plan drafted by the NMFS National Task Force on Improving Fish Stock Assessments sets goals for improved stock assessments at three tiers above existing assessments.

Tier 1—Improve assessments using existing data

- Conduct more comprehensive assessments for core species
- Re-examine data for species of unknown status

Tier 2—Elevate all assessments to a nationally acceptable level

- Upgrade at least to Level 3 assessments for core species (see following descriptions of levels)
- Implement adequate baseline monitoring for all managed species

Tier 3—Next generation assessments

- Assess all managed species at a minimum level of 3
- Assess core species at a level of 4 or 5
- Explicitly incorporate ecosystem considerations, environmental effects, oceanography, and spatial analyses

STOCK ASSESSMENT LEVELS[1]

The complexity of assessment methods used for a given stock generally reflects the availability of data and the value or importance of the fishery. The assessment level codes have the following meanings:

- Level 0—Although some data may have been collected on this species, these data have not been examined beyond simple time series plots or tabulations of catch.
- Level 1—Either:

- a time series of a (potentially imprecise) abundance index calculated as raw or standardized CPUE in commercial, recreational, or survey vessel data, or
- a one-time estimation of absolute abundance made on the basis of tagging results, a depletion study, or some form of calibrated survey.

[1] From the *Stock Assessment Improvement Plan.*

- Level 2—Simple equilibrium models applied to life history information; for example, yield per recruit or spawner per recruit functions based on mortality, growth, and maturity schedules; catch curve analysis; survival analysis; or length cohort analysis.
- Level 3—Equilibrium and non-equilibrium production models aggregated both spatially and over age and size; for example, the Schaefer model and the Pella-Tomlinson model.
- Level 4—Size-, stage-, or age-structured models such as cohort analysis and untuned and tuned VPA analyses, age-structured production models, CAGEAN, stock synthesis, size or age-structured Bayesian models, modified DeLury methods, and size or age-based mark-recapture models.
- Level 5—Assessment models incorporating ecosystem considerations and spatial and seasonal analyses in addition to Levels 3 or 4. Ecosystem considerations include one or more of the following:

- one or more time-varying parameters, either estimated as constrained series, or driven by environmental variables,
- multiple target species as state variables in the model, or
- living components of the ecosystem other than the target species included as state variables in the model.