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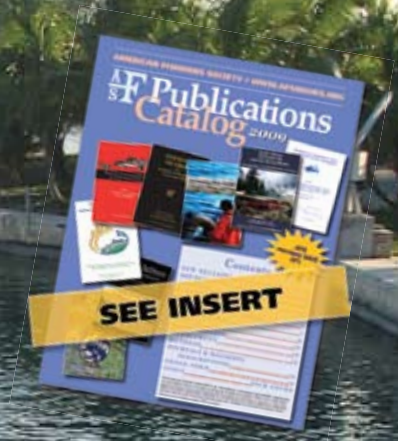

FISHERIES STOCK ASSESSMENT SCIENTISTS: Is There a Shortage? Addressing the Shortage through Undergraduate Workshops

COMMUNITY FISHERIES SUSTAINABILITY INDEX

LOCAL VS. BROAD INLAND FISHERIES MANAGEMENT

ESSAY:
EDUCATION

Is There a Shortage of Fisheries Stock Assessment Scientists?

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INTRODUCTION

Stock assessments are critical to the management of marine fish stocks and fisheries. Stock assessment scientists develop the tools used to evaluate the status of fish stocks and fisheries, estimate the likely effects of alternative management policies, and contribute in the design of monitoring and research programs that provide the input necessary for assessments. Quantitative skills are essential; implementation of legislation, including the Magnuson-Stevens Fishery Conservation and Management Act (hereafter referred to as the Magnuson-Stevens Act), Marine Mammal Protection Act, and Endangered Species Act, requires the continual involvement of individuals with such skills. Stock assessment scientists are employed by many organizations, including state, federal, and tribal agencies; resource users, such as commercial and recreational fishing groups; non-governmental organizations (NGOs); and environmental consulting firms.

For years, anecdotal accounts have circulated of organizations, including the National Marine Fisheries Service (NMFS), facing difficulties in recruiting a sufficient quantity and quality of stock assessment scientists. University professors have also expressed concern in attracting incoming graduate students to work on stock assessment research projects.

As a result of these concerns, NMFS asked the National Research Council (NRC) to convene a workshop in 2000 to review NMFS plans for meeting its anticipated staff needs in stock assessment and social sciences. The NRC panel concluded, "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." (NRC 2000). Over time, programs were designed and implemented to increase the number of stock assessment scientists (DOC and DOE 2008), but concerns about a shortage still persisted.

As a result, Congress, in its 2007 reauthorization of the Magnuson-Stevens Act (MSRA), directed that a study be conducted to determine if a shortage exists in the number of individuals with post-baccalaureate degrees who have the ability to conduct high quality scientific research in fishery stock assessment, fishery population dynamics, and related fields for government, non-profit, and private sector entities (P.L. 109-479, sec. 217). This essay is a synopsis of the studies that we conducted in response to the directive by Congress; the complete Congressional Report (DOC and DOE 2008) is available at the following website: www.st.nmfs.noaa.gov/report_congress/.

Based on the results of two studies, one investigating the anticipated demand and one estimating the current supply, the Congressional Report concludes that a shortage likely does exist. Numerical estimates of the shortage were calculated, albeit with a number of well-defined limitations and assumptions, as one would expect from broad-based surveys. In this essay, however, we take a slightly different approach in the hopes of eliciting further discussion as to whether a shortage exists, and if so, what the likely causes are and what the solutions may be. To do this, we draw evidence from the studies within the Congressional Report and pose the question, "Is the likelihood of a shortage sufficient to require the development

and implementation of a strategy to increase the supply? If so, what should be the strategy's components?"

For the purpose of this article, the term "stock assessment" will be used to represent "stock assessment, fishery population dynamics, and related fields." The term "stock assessment scientist" will be used to represent "individuals who have the ability to conduct high quality scientific research in stock assessment, fishery population dynamics, and related fields."

DEMAND

Over time, fisheries management has required increased involvement of stock assessment scientists. Further, legislation has given science, scientists, and stock assessment scientists a larger role in the management process. Increased data availability and computing power have allowed more complex questions to be addressed.

The MSRA increased the responsibilities of stock assessment scientists by requiring the establishment of annual catch limits and associated accountability measures on all stocks addressed in fishery management plans (Section 104 (a) (15)). Addressing this critical new requirement, along with additional requirements in other parts of the MSRA, created substantial new responsibilities for stock assessment scientists.

For the Congressional Report, we asked NMFS science centers about their current number of stock assessment scientists and their anticipated future needs (DOC and DOE 2008). They reported the following:

- NMFS currently employs about 90 stock assessment scientists.
- Approximately 40–44 retirements are anticipated over the next 10 years.
- To meet its growing responsibilities, NMFS would need to create 95-102 new stock assessment scientist positions within the next 10 years.
- Combining the number of retiring stock assessment scientist positions to be replaced with the number of new positions required summed to a total of 135-146 new hires within the next 10 years.
- The minimum number of new hires within the next 10 years amounts to 150% of the current number employed.
- Approximately one-half of the new hires are needed within the next 5 years.

The numbers above do not account for state marine fisheries agencies, regional fishery management councils, or interstate commissions, all of which are included in the Congressional Report. Neither the numbers above nor the Congressional Report account for tribal fishery management agencies, nongovernmental organizations, environmental consulting firms, state and federal freshwater fisheries agencies, or the many other organizations that rely on individuals with the skills required of stock assessment scientists. Given the increasing role of stock assessment scientists in fisheries management, demand is likely to grow in all of these professional sectors.

SUPPLY

While the demand for stock assessment scientists has been increasing, the supply has not kept pace. As part of the Congressional Report addressing the supply of stock assessment scientists, we surveyed college and university department heads with fisheries-related programs (DOC and DOE 2008). Several of the survey components indicated a trend towards academia supplying insufficient numbers of graduates with training that would allow them to enter into a stock assessment position with a skill set advocated by NMFS. In particular, faculty expertise, graduate education, and quantitative training of undergraduates were viewed as major concerns in the supply issue.

Faculty Expertise

Faculty are at the center of the supply issue, as faculty teach courses and supervise research and training of students entering the discipline and job market. Department heads provided the following responses concerning faculty:

- Retiring population dynamics faculty will be replaced at a lower rate than fisheries faculty in general (77% vs. 91%).
- Assuming new faculty positions were available, only 12% of the hires would be in the field of population dynamics.
- Nearly one-third of fisheries programs reported that they do not have the resources necessary to train students to conduct research in population dynamics.

Graduate Education

As part of the supply survey, we created a list of graduate-level courses potentially available to fisheries students at most institutions with fisheries-related programs (DOC and DOE 2008). From that list, the NMFS science centers were polled to devise an "essential curriculum" that would prepare graduates for employment as stock assessment scientists for the federal government. Nine of the 32 courses identified were deemed essential by the NMFS science centers: *population dynamics*, *fish ecology*, *multivariate statistics*, *sampling theory*, *fisheries or natural resources modeling*, *Bayesian statistics*, *stock assessment*, *risk and decision analysis*, and *fisheries or natural resources computer programming*. Department heads were asked whether or not their universities offered each course and, if so, the percentage of their fisheries students who took each course. Results indicated that:

- Only 7% of the universities offered all 9 essential courses, while more than one-half of the universities offered 4 or fewer.
- Less than 12% of graduate students took a stock assessment course.
- A relatively small percentage of fisheries graduate students took courses in fisheries or natural resource modeling (18%), Bayesian statistics (13%), risk and decision analysis (6.2%), and fisheries or natural resources computer programming (3.5%).

Quantitative Undergraduate Education

Problems on the supply side are not limited to faculty expertise and graduate education. The lack of undergraduate students with strong quantitative skills translates into a lack

of adequately-trained incoming graduate students. Based on our survey:

- Department heads ranked the strength of recent first semester M.S. students in 12 skill areas in the following order: verbal communication, fishery biology, fishery ecology, critical thinking, information synthesis, fishery management, fishery science, written communication, mathematics, statistics, population dynamics, and modeling.
- They were also asked to compare these strengths for recent incoming M.S. students to students in the past decade. Not only were mathematics and population dynamics the two lowest ranking skill areas overall, but population dynamics was the only skill area where recent students were perceived to be weaker than students a decade ago.
- Department heads were less successful at recruiting M.S. students capable of conducting population dynamics research than M.S. students in general.

DISCUSSION

The discipline of stock assessment is neither the first nor the only discipline to notice a decline in the quality of quantitative education in U.S. institutions of higher learning. There has been an ongoing multidisciplinary call to improve undergraduate science, technology, engineering, and mathematics (STEM) education nationally (NRC 1996; NSF 1996). Stock assessment is only one of many disciplines feeling the effects of decreased performance from incoming graduate students in quantitative fields.

Demand for stock assessment scientists is increasing at a time when faculty are not being added or replaced in the same proportion as currently employed. As a result, limited graduate course offerings are likely to be further reduced, and quantitative skills of incoming graduate students will likely continue to decline.

As the leading employer of stock assessment scientists, the burden of reducing the shortage of stock assessment scientists, if one truly exists, largely lies with NMFS. Producing additional stock assessment scientists requires time: time to find promising students and time to train them adequately. The new mandates under the MSRA do not allow for delays, which means that efforts to increase the supply need to begin immediately. Such efforts would need to incorporate mechanisms to increase faculty with expertise in stock assessment, graduate course offerings, and the number of incoming graduate students with strong quantitative backgrounds. NMFS has created and implemented programs aimed at accomplishing each of these goals, but their current scale is likely to be insufficient to solve this potential shortage (DOC and DOE 2008).

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FEATURE:
EDUCATION

Addressing the Shortage of Stock Assessment Scientists through Undergraduate Workshops

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ABSTRACT: A recent Congressional report identified a shortage of scientists entering the discipline of stock assessment. The Southeast Fisheries Science Center of NOAA's National Marine Fisheries Service and Virginia Tech created the Population Dynamics Recruiting Program (PDRP) to improve the quality of graduate students interested in entering the field. An annual week-long workshop identifies top students nationally with the potential to excel in population dynamics and educates them about the discipline. Program evaluation indicates that between 25% and 33% of workshop participants have subsequently entered graduate school in the field. Sixty-nine percent of those students knew little about the field before the workshop, and 85% reported wanting to pursue population dynamics because of their workshop experience. Continuing and strengthening the PDRP is an important component of a strategy to reduce the shortage of qualified stock assessment scientists.

Estudio sobre la escasez de evaluadores pesqueros a través de talleres estudiantiles

RESUMEN: En el reporte de un congreso reciente, se identifica una escasez de científicos dedicados a la disciplina de la evaluación pesquera. Como respuesta, El Centro de Estudios Pesqueros del Sureste, dependiente del Servicio de Pesquerías Marinas de la oficina de Administración Nacional Oceánica y Atmosférica, en conjunto con el Tecnológico de Virginia, crearon un Programa de Reclutamiento en Dinámica de Poblaciones (PRDP) para mejorar la calidad de los estudiantes graduados que estuvieran interesados en el área. En un taller anual con duración de una semana, se identificaron los mejores estudiantes a nivel nacional con el potencial de destacar en dinámica de poblaciones y se les instruye sobre el tema. La evaluación indica que entre 25% y 33% de los participantes del taller han ingresado subsecuentemente a escuelas relacionadas al área. Sesenta y nueve por ciento de los estudiantes conocían muy poco acerca del tema antes de que comenzara el taller y una vez concluido, 85% reportaron tener deseos de continuar con el estudio de la dinámica de poblaciones. Continuar y fortalecer el PRDP es un componente importante de una estrategia para reducir la escasez de evaluadores pesqueros calificados.

INTRODUCTION

Stock assessment scientists are critical to fisheries management because they develop and apply the tools used to evaluate the status of fish stocks and fisheries and to estimate likely effects of alternative management policies. Over time, stock assessment scientists have played an increasingly important role in resource conservation, guiding the design of monitoring and research programs and providing critical information needed for science-based management.

A recent report to Congress identified a shortage of individuals with post-baccalaureate degrees who have the ability to conduct high quality scientific research in fishery stock assessment, fish population dynamics and related fields (DOC and DOE 2008). Three main causes of this shortage include (DOC and DOE 2008):

1. There are not enough university faculty to teach undergraduate and graduate students about the discipline and to supervise related research;
2. There are not enough graduate courses available that are essential to prepare graduates for employment as stock assessment scientists; and
3. The quantitative skills of graduate students presently entering fisheries programs are not sufficient for these students to enter the pipeline to stock assessment positions.

Eliminating this shortage will require solving all three problems.

As the largest U.S. employer of stock assessment scientists, the National Marine Fisheries Service (NMFS) carries much of the burden of reducing this shortage (DOC and DOE 2008). NMFS has established several programs designed to reduce it (DOC and DOE 2008). In order to increase faculty numbers, NMFS has long provided research support to university faculty, and also has encouraged NMFS stock assessment scientists to teach at universities and supervise graduate students. NMFS also has been working for years to increase the number of graduate students in the discipline by supporting graduate student assistantships and fellowships. The President's 2009 budget includes an additional $1 million for this successful graduate population dynamics fellowship program (DOC and DOE 2008). NMFS also has many programs aimed at recruiting and educating undergraduate students, but historically, none has been directed specifically at the discipline of stock assessment, or designed to attract undergraduate students with better quantitative skills.

NMFS and Virginia Tech created the Population Dynamics Recruiting Program (PDRP) in 2003 to improve the quality of graduate students entering the field of population dynamics. Stock assessment focuses on exploited living marine resources and is a subdiscipline of population dynamics, which focuses on both exploited and non-exploited species, including legally protected species. NMFS hires population dynamics scientists to work in stock assessment and in related fields, and the same skills are required whether a population is exploited or not. Because of this, and because "population dynamics" is a broader and better understood term than "stock assessment" on college and university campuses, the program was named the Population Dynamics Recruiting Program. Here, the term "marine resources population dynamics" will be synonymous with the term "stock assessment."

To improve the quantity and quality of graduate students entering fisheries degree programs to study population dynamics, the PDRP uses two main strategies:

1. Identifying top students with potential to excel in population dynamics and bringing them into the PDRP, and
2. Educating and motivating them so that they will potentially enter the discipline.

This article presents and evaluates the week-long undergraduate workshop of the PDRP.

WORKSHOP METHODS

Identifying Students

The PDRP looks for undergraduates with strong quantitative skills and interests, and a basic understanding of ecology. Such students typically are scattered at colleges and universities across the country, in a variety of majors such as ecology, environmental science, biology, fisheries science, wildlife science, natural resources management, conservation biology, and marine biology. Finding these students is not easy. Each year the PDRP contacts faculty members and other academic advisors across the country who are likely to know students who fit our profile. Over 400 individuals have been contacted annually by e-mail, mail and, to the extent possible, telephone to encourage their best students to apply.

Encouraging Students to Apply

The next challenge is encouraging the students identified to apply to the workshop. Many do not yet know about population dynamics, because the topic is not covered on all campuses or within all programs. Because of this, merely asking students to attend a population dynamics workshop would not draw as many qualified students as desired.

To heighten students' interest, we offer a week-long workshop in the Florida Keys. The workshop's timing in early January puts it before most students return to classes. All costs are covered for the students, which ensures that any qualified student can apply without financial concern.

Students are selected on the basis of grade point average (GPA); standardized test scores (verbal and quantitative); number of college-level math and statistics courses taken; number of college-level ecology-related courses taken; grades in math, statistics, and ecology courses; quality of thought, organization, and writing in their answers to essay questions on the application; internships, research experiences, and other out-of-classroom experiences; and the responses of their references to specific questions. In the first year (2004), 16 students were selected. In each of the following years (2005–2008), 15 students were selected.

The Workshop

Throughout the workshop, a case study approach (Herreid 1994, 2005) is applied to demonstrate the roles that population dynamics scientists play in the complex world of marine resources management. One case study presented each year focuses on sustainable harvest of a fish stock, such as swordfish (*Xiphias gladius*). Because many undergraduate students are interested in protected species, rather than or in addition to harvested ones, a second case study each year focuses on a protected resource, such as threatened loggerhead sea turtle (*Caretta caretta*). This combination also dem-

onstrates the diversity of projects researched by NMFS population dynamics scientists.

The workshop offers a wide range of activities, including field trips, lectures, discussions, computer exercises, student research, and student presentations, to keep students interested throughout the week. Half the instructors are NMFS scientists; the other half are Virginia Tech faculty. Instructors are selected for interest in workshop goals, subject expertise, effective teaching, and enthusiasm.

Workshop students typically get to know the instructors and teaching assistants much better than in an ordinary classroom setting. Students and instructors eat together, attend fieldtrips together, and share recreational activities during breaks. A popular event each year is an evening dedicated to answering questions about graduate schools and career opportunities. The strong relationships built at the workshop have provided opportunities for longer-term mentoring, benefiting both the agency and the students' career development.

Many students consider careers in environmental science because they want to work towards conservation and sustainability. Throughout the workshop, instructors stress that individuals working in marine resource population dynamics help meet those goals by providing critical scientific guidance to policymakers.

The workshop occupies a NMFS stock assessment scientist and a Virginia Tech project coordinator for about four months each year, as well as six to eight additional instructors for about three weeks each. Non-personnel costs are about $50,000 per workshop.

EVALUATION METHODS

We evaluated the PDRP workshop program to answer three main questions:

1. Does the program attract the right students?
2. Have past workshop students entered graduate school in marine resources population dynamics? and
3. Were those students influenced to enter graduate school in the discipline by the workshop?

We also investigated the workshop's influence on all past students, including those who have not entered graduate school in the discipline. The evaluation took place under the auspices of Virginia Tech's Institutional Review Board policies pertaining to research on human subjects (approval #06-229).

Evaluation of Finding and Attracting Students

To evaluate our effectiveness at attracting qualified students, the following information was compiled about each student accepted into the program from his or her application materials:

College or university attended,
State in which college or university is located,
Undergraduate major,
Year in school,
Grade point average (GPA), and
Standardized test scores (SAT, ACT, GRE).

Basic statistics (mean, standard deviation, minimum, and maximum) were calculated for GPAs and standardized test scores. Using tables from the national testing services, percentiles were assigned to mean values of standardized test scores.

EVALUATING IMPACTS OF THE WORKSHOPS

Questionnaire

To evaluate effectiveness of the PDRP workshops, participants from 2004–2007 were asked to complete a questionnaire in the spring of 2008 (N = 61). Participants from the 2008 workshop were not included because it was too soon after their workshop to query the longer term effects being investigated. The questionnaire was designed using the software package SurveyPro 4.0 (Apian Software, Inc.) and distributed online. Each past participant was contacted one week prior to the questionnaire's opening with a letter explaining its goals and methods (Dillman 2000). Once the questionnaire was open, each past participant was sent unique login information. The questionnaire was closed after two weeks, and the results were compiled using SurveyPro 4.0 Net Collect software (Apian Software, Inc.).

Students were asked the following:

What schooling and jobs have been undertaken since the workshop?

We wanted to know how many were working on marine resources or population dynamics, how many were in graduate school, and how many were working with NMFS in some context (internships, jobs, graduate school funding). Most importantly, we wanted to know how many had entered graduate school to focus on marine resources population dynamics.

Did the workshop increase interest in our three main subject areas (marine resources, population dynamics, and potential employment with a marine resources agency)?

We asked whether interest in those areas increased (or not) as a result of the workshop, or if the respondent had been very interested even before the workshop.

What benefits were received?

We asked respondents to select zero or more possible benefits from a list of 17 (see results section).

Students who did not respond to the questionnaire during the two-week response period were sent a final e-mail with the following abbreviated list of questions:

1. What professional interest are you pursuing right now (graduate school, working, etc.)? On what kinds of projects are you working?
2. Did you find the workshop beneficial? How?
3. Did the workshop help you decide whether or not you wanted to work with population dynamics? Marine resources? NMFS?

We hoped that the brevity and format of these questions would prompt a response from those who did not complete the online questionnaire.

RESULTS

Finding and Attracting Students

To date (2004–2008), 76 students representing 49 colleges and universities in 22 states have participated in five PDRP workshops (Table 1). Southeastern states sent the greatest number of participants, as did southeastern colleges and universities (Table 1).

Participants represented a wide range of undergraduate majors, including many subdisciplines of biology, ecology, and resource management. We also attracted one physics major and one psychology major. Over 25% of workshop participants (20) were enrolled in double majors. Of the 76 participants, 12 were sophomores (16%), 21 were juniors (28%), 41 were seniors (54%), and 2 had graduated but not yet entered graduate programs (3%).

Accepted students had high grade point averages (Mean = 3.72/4.00; Table 2). Regarding both quantitative and verbal exams, the mean SAT score was in the top 7% of students taking the exam nationally; mean ACT score, in the top 5%; and mean GRE score, in roughly the top 25% (Table 2). The medians of all distributions were above the means, indicating that more students received scores above the average than below it.

Questionnaire Response Rate

A total of 50 participants responded to the questionnaire during the 2-week time frame, for a response rate of 81.9%. Of the 11 who did not respond to the initial questionnaire, we were unsuccessful at contacting 3. Four of the remaining 8 responded to the abbreviated list of questions, and their responses were included where applicable.

Current Activities

Of the respondents, 88% (47 of 53) had completed undergraduate degrees by spring 2008. Of those, 74% (35) were either in graduate school or had completed a graduate degree.

With regard to the workshop topics, 18 of the graduate school attendees were focusing on population dynamics, 20 were focusing on marine resources, and 13 were focusing on both (Table 3). From this point forward, the 13 students whose graduate studies focus on marine resources population dynamics—the goal of our recruiting efforts—will be referred to as the "13 in-discipline graduate students." Depending on the method used to count them, between 25% and 37% of past workshop participants have become in-discipline graduate students (Table 3). These 13 were comparable academically to the overall population of workshop participants, based on their workshop application materials.

Using similar calculations, between 34% and 51% of workshop participants have entered graduate school to study population dynamics in general, whether terrestrial, marine, or other (Table 3). Since the workshop, 33% percent of participants had worked for or with NMFS in some capacity.

Changes to Interest Levels

A majority of all respondents (n = 50) reported increased interest in all three areas (population dynamics, marine resources, and potentially working for a marine resources agency) specifically

Table 1. List of colleges and universities sending students to the 2004–2008 workshops. Seventy-six students representing 49 colleges and universities in 22 states have participated. Numbers in parentheses indicated the number by state or college/university. If no number is present, one student participated.

Alabama	University of Alabama
California (3)	Scripps College University of California, Berkeley University of California, San Diego
Florida (8)	Florida Institute of Technology (2) Florida State University University of Florida (3) University of Miami University of West Florida
Georgia (6)	Berry College Emory University (3) University of Georgia (2)
Indiana	University of St. Francis
Kentucky	Centre College
Louisiana (3)	Nicholls State University Northwestern State University Tulane University
Maine (3)	Bowdoin College Colby College University of Maine at Orono
Massachusetts (3)	Boston University Smith College (2)
Michigan (2)	Michigan State University University of Michigan
New Jersey	Princeton University
New York (3)	Columbia University Cornell University (2)
North Carolina (5)	Duke University (3) North Carolina State University (2)
Ohio (2)	Bowling Green University Ohio Wesleyan University
Oregon (2)	Willamette University (2)
Pennsylvania	Dickinson College
South Carolina (10)	Clemson University (2) Coastal Carolina University (3) College of Charleston University of South Carolina (3) Winthrop University
Tennessee (2)	University of Tennessee (2)
Texas (2)	Texas A&M University (2)
Virginia (15)	College of William and Mary (4) Old Dominion University University of Richmond (2) University of Virginia (2) Virginia Polytechnic Institute and State University (6)
Washington	University of Washington
Wisconsin	University of Wisconsin, Stevens Point

Table 2. Scholastic background of students accepted into the workshop program as reported on their applications, 2004–2008 (*N* = 76).

	GPA	Math SAT	Math ACT	Quantitative GRE	Critical reading SAT	English ACT	Verbal GRE
N	76	49	17	8	49	17	8
Maximum score possible	4.00	800	36	800	800	36	800
Accepted students mean	3.72	691	29.8	704	677	30.2	571
Percentile	N/A	93%[1]	95%[2]	73%[3]	93%[1]	94%[2]	79%[3]
Maximum score and (*N*) of accepted students	4.00 (6)	800 (5)	35 (1)	800 (2)	800 (4)	36 (1)	740 (1)
Minimum score and (*N*) of accepted students	3.18 (1)	470 (1)	19 (1)	650 (2)	470 (1)	24 (1)	450 (1)
Standard deviation	0.21	75.2	4.35	63.5	80.7	3.07	100

[1] from SAT Percentile Ranks; Critical Reading, Mathematics, and Writing; www.collegeboard.com/prod_downloads/highered/ra/sat/SAT_percentile_ranks.pdf
[2] from National Distributions of Cumulative Percents for ACT Test Scores; ACT-Tested High School Graduates from 2005, 2006, and 2007; http://www.actstudent.org/pdf/norms.pdf
[3] from Graduate Record Examinations, Guide to the Use of Scores 2007-08; Table 1A: Verbal and Quantitative Interpretive Data Used on Score Reports (Based on the performance of all examinees who tested between 1 July 2004, and 30 June 2006); http://www.ets.org/Media/Tests/GRE/pdf/994994.pdf.

Table 3. Number of workshop students now in relevant areas of graduate study, and corresponding percentages calculated on three bases.

	Area of graduate study		
	Population dynamics (18 students)	**Marine resources (20 students)**	**Marine resources population dynamics (13 students)**
As a percentage of all respondents who have entered any graduate program by spring 2008 (*N* = 35)	51%	57%	37%
As a percentage of all respondents who had earned a bachelor's degree by spring 2008 (*N* = 47)	38%	43%	28%
As a percentage of all workshop students expected to have earned a bachelor's degree by spring 2008 (*N* = 53)	34%*	38%*	25%*

*** Note that this is a minimum estimate as it assumes all non-respondents expected to graduate did graduate and are not studying or have not studied these topics in graduate school.**

because of the workshop (Table 4). Only 2 of the 50 respondents (4%) said their interest had not increased in any of the three areas.

A greater proportion of the 13 in-discipline graduate students entered the workshop already interested in each of the 3 topics as compared to all respondents (Table 4). This was particularly true with regards to marine resources, where 62% of the 13 in-discipline graduate students reported that they had been very interested in the subject already, compared to 26% of all respondents (Table 4). Fifty-eight percent of all responding past participants reported their interest in working for a marine resources agency increased as a result of the workshop (Table 4).

Workshop Benefits

A majority of respondents reported that this was a field they knew little about before the workshop, including 69% of the 13 in-discipline graduate students (Table 5). All 13 in-discipline graduate students reported that as a result of the workshop they wanted to learn more about this field, and 85% reported that because of participation in the workshop they learned this was a field they wanted to pursue (Table 5). These specific benefits were not limited to the in-discipline graduate students, as 80% of all respondents and all 13 of the in-discipline graduate students reported that the workshop influenced their career paths (Table 5) by teaching them about possible career opportunities and helping them better define their professional interests (Table 5). Similarly, 86% of all respondents and 85% of the 13 in-discipline graduate students reported that the workshop influenced their educational paths (Table 5), both in deciding what to study in graduate school and in deciding where to go to graduate school (Table 5).

All respondents reported receiving many benefits from the workshop (Table 5). More than 90% reported learning more about population dynamics, marine resources, and NMFS, indicating that a primary objective of the workshop was met (Table 5). Participants also appreciated the opportunities to establish contact with other top students and professionals in the field (Table 5).

DISCUSSION

Reaching the Goal

Colleges and universities are experiencing difficulty finding qualified graduate students to conduct population dynamics-related research. As part of the Congressional report (DOC and DOE 2008), department heads of university and college marine fisheries programs were surveyed. Results indicated that their success

Table 4. Reported increase in interest in focus areas (n = 50). Comparison of all respondents (denoted as All) to the 13 in-discipline graduate students (denoted as 13).

Looking back, perceived increase in interest in focus areas	Population dynamics		Marine resources		Working for a marine resources agency	
	All	13	All	13	All	13
Yes, my interest increased	80%	69%	60%	38%	58%	62%
I was already very interested	12%	31%	26%	62%	22%	38%
No, my interest did not increase	8%	0%	14%	0%	20%	0%

Table 5. Percentage of the 13 in-discipline graduate students and all respondents who either strongly agreed or agreed about specific workshop benefits.

Workshop benefits	Percentage of 13 in-discipline graduate students	Percentage of all responding past participants (n = 49)
I was introduced to a subject I knew little about.	69%	76%
I learned that this was a field I wanted to learn more about.	100%	88%
I learned that this was a field I wanted to pursue.	85%	45%
I learned more about possible career opportunities.	100%	90%
The workshop helped me define and/or narrow my professional interests.	92%	82%
The workshop helped influence my career path.	100%	80%
The workshop helped influence my educational path.	85%	86%
The workshop helped me decide what to study in graduate school.	77%	69%
The workshop helped me decide where to go to graduate school.	54%	27%
I learned more about NOAA/NMFS.	100%	100%
I learned more about marine resources.	100%	94%
I met and established good contact with professionals in the field.	92%	94%
I met new friends with similar interests.	85%	88%
I was able to apply what I had learned in school.	69%	76%
The workshop helped me decide whether or not to go to graduate school.	46%	55%
I learned that this was a field I did not want to pursue.	0%	12%

at recruiting graduate students to conduct population dynamics research was lower than at recruiting graduate students in general (DOC and DOE 2008). Department heads were also asked to rate the aptitude and ability of their recent first-semester fisheries graduate students in 12 skill areas related to graduate student success. Most felt students were "adequate," "strong," or "very strong" in all areas except modeling (DOC and DOE 2008). Population dynamics and statistics followed modeling as the next weakest skills (DOC and DOE 2008). Department heads reported that although most skills had improved in the past decade, skills in population dynamics and mathematics had remained stable or declined (DOC and DOE 2008).

The discipline of stock assessment is neither the first nor the only discipline to notice a decline in the quality of quantitative education in the United States. There has been an ongoing multidisciplinary call to improve undergraduate science, technology, engineering, and mathematics (STEM) education nationally (NRC 1996; NSF 1996). To reverse this trend, institutions of higher education must place a higher priority on the quantitative training of undergraduates.

Strengthening the quantitative training of all undergraduates would be one strategy to improve the quality of entering graduate students, but this is not within the capabilities of NMFS. Instead, NMFS is attempting to find and recruit students whose interests and abilities make them most likely to succeed as graduate students, and later as researchers, in marine resource population dynamics.

Undergraduates often know what subjects interest them, but not how those subjects can be applied. For example, many of our students knew they liked ecology, math, and computer sciences, but did not know how those subjects could be combined in a career. The PDRP showed them that population dynamics combines those subjects and that population dynamicists play important, fascinating roles in marine conservation. Use of real case studies was essential to this process. In addition, students were given more individual attention by instructors than is possible in the typical undergraduate classroom. Increasing interest and excitement about a specific career path, possibly for the first time in the students' academic experience, was part of the PDRP's strategy. Our evaluation indicates this strategy was successfully accomplished.

Finding Students

Finding the right students for this program has been time consuming but, over time, word of the program has spread, and recruiting has become easier. Our students have come from a wide range of colleges and universities and a diverse group of majors,

as expected. If we had limited recruiting efforts to undergraduate fisheries programs, we would have missed most of the students we selected. The intense effort involved in publicizing the program widely has proven worthwhile.

The PDRP is supported entirely by the Southeast Fisheries Science Center (SEFSC) of NMFS. The program's original goal was to recruit stock assessment scientists to the southeastern United States. Because of that, advertising in the first two years focused on southeastern colleges and universities, which explains the predominance of southeastern schools in Table 1. In our third year, we expanded advertising efforts nationwide, to benefit all of NMFS.

Participation from individual universities and colleges has varied greatly. Some large, well-known schools have not been represented, while lesser-known schools were. This is partially due to the rarity and patchy distribution of interested and qualified students. Another cause is likely the level of dissemination of workshop information on individual campuses. While the PDRP organizers worked hard on advertising, it was still up to the contacts at each school to spread the word. It became clear from talking with workshop participants that many found out about the workshop from a specific e-mail or conversation with a faculty member or advisor who targeted that student because of his or her strengths. We continue to personally contact faculty members and academic advisors at universities and colleges in an effort to ensure that they encourage their top students to apply for future workshops.

The use of standardized tests as indicators of ability has been controversial (e.g., Crouse and Trusheim 1988; Leonard and Jiang 1999; Zwick 2002). Test scores are used by the PDRP in admissions because grade point averages are not comparable across campuses. However, poor standardized test scores did not by themselves eliminate any student. If other factors indicated a good match for the program, the student was accepted. Similarly, strong test scores alone were not sufficient for admission.

Evaluation of applications has varied slightly each year, as we attempt to better identify excellent students likely to enter the field. For example, our efforts so far have been aimed at students with strong quantitative backgrounds and a basic understanding of ecology. However, the evaluation reported here indicates that 62% of the 13 in-discipline graduate students had been very interested in marine resources before the workshop, compared to 26% of all respondents, which suggests that prior interest is an important determinant of career path even for students who were influenced by the workshop. Therefore, we anticipate weighing applicants' interest in marine resources more heavily in future admissions than we have in the past.

Ultimate Evaluation

Because the ultimate goal of the PDRP is to increase the number of highly qualified applicants for stock assessment positions with NMFS, ultimate evaluation of the PDRP would be its contribution to this goal. Generally, stock assessment jobs with NMFS require a doctoral degree. Because the first PDRP workshop took place in 2004, it will be several years before workshop students, who participate as undergraduates, are ready to start professional careers. Therefore, it is too soon to make that ultimate evaluation of the PDRP.

The immediate goal of the PDRP is to improve the number of highly qualified applicants for graduate school in the discipline. The need for this comes from a survey of college and university marine fisheries program department heads in the Congressional report (DOC and DOE 2008). Once a significant number of our workshop students have entered graduate school, it will be informative to ask college and university department heads whether quantitative skills have improved, particularly among entrants from the PDRP. Because only 13 PDRP workshop students have entered graduate school in the discipline, it is also too soon to ask that question.

No evaluation can tell us how many of the PDRP participants would have entered the field if they had not attended a PDRP workshop. Still, the current evaluation demonstrates that the workshops have played a major role in decisions regarding the in-discipline graduate students' chosen career paths.

Benefits to Participants

The PDRP was designed to provide benefits to all workshop students, not just those entering marine resources population dynamics. The workshop is structured to educate all participants about the complexity of marine resources management, the roles of science within the process, and about themselves, so they can make better decisions about their futures. The program appears to have accomplished these goals.

Costs vs. Benefits

The first four workshops together cost approximately $200,000 plus personnel time. Given that the program has produced 13 in-discipline graduate students (as of spring 2008), the cost was $15,400 per workshop student who entered graduate school in the discipline. Including only the in-discipline graduate students who knew little about the discipline before the workshop (n = 9), the cost would be $22,200 per student. Including only students who responded that they learned this was a field they wanted to pursue because of the workshop (n = 11), the cost would be $18,100 per student. Accounting for personnel time would increase these figures by about 80%.

The number of past workshop participants from the first four years of the program who will enter the discipline of marine resources population dynamics will likely increase above the current number of 13. Past workshop participants may eventually enter graduate school in the discipline including:

1. Those who had not yet finished their bachelors degrees at the time of the questionnaire (n = 6),
2. Those who had completed their bachelors degrees but had not yet entered graduate school (n = 12), and
3. Those currently or previously enrolled in graduate school not focusing on marine resources population dynamics (n = 2) who may eventually focus on the discipline in a future degree.

Forty-five percent (22) of respondents stated that this was a field they wanted to pursue. As this happens, the cost per student recruited will decrease.

The workshops have successfully recruited into the field some highly promising individuals who otherwise would not have been there. The attendant costs can be considered nominal if one considers both the difficulty in recruiting such individuals and the expected career length of a NMFS biologist, about 20 to 40 years. No calculation can quantify the very high value of recruiting

exceptional individuals who will, in the years and decades ahead, move the field forward and provide strong science on which to base management of U.S. marine resources.

As a result of the workshop, some participants became knowledgeable about NMFS and interested in working for a marine agency, although not necessarily in population dynamics. Almost 60% of respondents stated that their interest in working for a marine resources agency increased as a result of the workshop. One-third of the respondents had worked with NMFS since their workshop. Given the outstanding quality of students in the program, recruiting participants into the agency, regardless of the discipline, provides additional rich benefits.

We conclude that the PDRP has motivated a new group of students to enter graduate school in population dynamics, increasing not only the quality of students entering the discipline, but also the number. In this way the PDRP has contributed to solving two of the three problems causing the critical shortage of stock assessment scientists.

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