

A Moving Target

Matching Graduate Education with Available Careers for Ocean Scientists

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ABSTRACT. The objective of this paper is to look at past assessments and available data to examine the match (or mismatch) between university curricula and programs available to graduate students in the ocean sciences and the career possibilities available to those students. We conclude there is a need for fundamental change in how we educate graduate students in the ocean sciences. The change should accommodate the interests of students as well as the needs of a changing society; the change should not be constrained by the traditions or resource challenges of the graduate institutions themselves. The limited data we have been able to obtain from schools and employers are consistent with this view: desirable careers for ocean scientists are moving rapidly toward interdisciplinary, collaborative, societally relevant activities, away from traditional academic-research/professorial jobs, but the training available to the students is not keeping pace. We offer some suggestions to mitigate the mismatch. Most importantly, although anecdotes and “gut feelings” abound, the quantitative data backing our conclusions and suggestions are very sparse and barely compelling; we urge better data collection to support curricular revision, perhaps with the involvement of professional societies.

INTRODUCTION

It is only within the last few decades that the tradition of a student trained in a fundamental discipline and then going to graduate school to study some aspect of the ocean sciences has been the norm. Until the 1980s, most ocean scientists had earned an MS or a PhD in one of the fundamental science, technology, engineering, or mathematics (STEM) disciplines (e.g., physics, chemistry, biology, geology, engineering, math) and then applied their training to ocean subjects

after graduate school (Nowell, 2000). The ocean was a place, not a discipline.

Prior to the 1980s, there were plenty of career opportunities within the burgeoning field of ocean sciences and within the core disciplines themselves. Thus, the student emerging from graduate school generally had a variety of options for employment.

The world has changed for employment of ocean scientists, in part due to the great success of the university system that has produced graduates at a

faster rate than the academic job market has grown. In particular, academic positions in the ocean sciences are fewer¹, so those students expecting to find an academic research position running a lab full of bright graduate students with robust research funding are likely to be disappointed.

Analyses of statistics provided by oceanographic institutions in 2011 show that about 63% of their ocean science PhD graduates took academic positions as first jobs, although most of those positions were postdoctoral (Miller and McDuff, 2012). An update of this work (McDuff, 2014) concludes that only 43% of incoming ocean science graduate students continue into academia (including postdocs). Miller and McDuff’s flow model (using results from the 14 institutions that reported on the status of graduate students in their oceanography departments for the four years between 2007 and 2011) showed that half of the oceanography students graduating each year received MS degrees and about half received PhD degrees (Miller and McDuff, 2012). Most of those receiving PhD degrees went to academic jobs (generally postdocs), whereas most receiving

¹An example snapshot: The Jobs section of *EOS* in the May 2015 issue lists 77 positions, 19 of which are in the ocean sciences, most are for postdocs, and two are for faculty positions. The “Earth Sciences Jobs” list server for January–May 2015 lists about 260 positions, of which about 15% are faculty positions and about 40% are postdoc positions. A comment sometimes made by younger scientists is that senior professors never seem to retire, thus blocking possible advancement for the next generation. Even if faculty are retiring later, the effect will be small relative to the major problem: each professor produces 10, 20, 30, or more PhD students over time, a geometrical growth problem on the supply side that overwhelms the number of available faculty positions.

MS degrees went to nonacademic jobs or continued for PhD work.

We inject a note of caution here: although the original data collection on ocean science graduate education began in 1978 (Nowell and Hollister, 1988), it only covered the members of the Joint Oceanographic Institutions (JOI) consortium. Since then, the data collection has expanded to include approximately 30 institutions, but the biennial collection, results, and analyses are not consistent in their methodology nor their presentation, and have always been problematic due to evolving objectives, the rate of return of surveys, and changes in the ocean science field itself. The most recent results were summarized in a poster (Miller and McDuff, 2012) and in a Web-published presentation (McDuff, 2014); an article examining all the years and results is in preparation (Allison Miller, Schmidt Ocean Institute, *pers. comm.*, 2015). Sarah Schoedinger at the Consortium for Oceanographic Research and Education (CORE) did the best data collection—covering nearly all institutions granting degrees in oceanography, with a high return rate on surveys—on behalf of the US Commission on Ocean Policy (US Commission on Ocean Policy, 2004). In contrast to all the other collections and analyses, which were prepared by volunteers, this project was funded. Finally, these past efforts focused on the demographics of graduate students while in school, not on their job prospects or career trajectories. Even though the data we have available are mostly from the larger universities, and not from all the universities that issue degrees in an ocean science field, it still represents the bulk of the overall ocean-science student population (US Commission on Ocean Policy, 2004).

We are not aware of a longitudinal study showing how many of those who initially take a postdoctoral position remain in

academia or in another research/teaching position. Ocean science graduates typically spend two to four years as postdocs, some even longer. Thus, it would be necessary to obtain career information for alumni who graduated at least four years prior to the survey date to determine job choices following the postdoctoral experience. Consequently, survey results may not accurately reflect current job-market conditions. The (limited) results presented in Box 1 indicate that most of the 121 PhD alumni of the Massachusetts Institute of Technology/Woods Hole Oceanographic Institution (MIT/WHOI) Joint Program receiving PhDs from 2004 to 2010 remained in academia following their postdocs. However, anecdotal evidence based on the first jobs of more recent alumni of the same program, and conversations with current students, suggest changes in the career path of new PhDs. For example, a new trend for the MIT/WHOI program is that about 10% are choosing a National Oceanic and Atmospheric Administration (NOAA) Sea Grant John A. Knauss Marine Policy Fellowship or similar position to gain exposure and experience in marine policy. About the same percentage of students are taking positions in consulting companies. Ocean conservation is also of increasing interest among biological oceanography students and alumni, while those graduating in ocean engineering are choosing positions at robotics companies, oil and gas companies, or defense-related federally funded research and development centers (FFRDC) for their first jobs, rather than university appointments.

A meta-analysis of existing data (Allison Miller, Schmidt Ocean Institute, *pers. comm.*, 2015) shows that:

- In 1988, ocean science graduate students were mainly within the fundamental disciplines, while by 2010 only about half fell into that category (the

other half were in conservation, policy, environmental studies, fisheries, and ocean engineering)

- As of 2009, graduating PhDs are now *least* likely to end up at a four-year university (except as a postdoc) compared to all the other possible careers. There are no data on what happens to an individual after the postdoctoral position ends.

Additional historical data and some interesting trends are reported in the American Geosciences Institute (AGI) workforce studies and in American Geophysical Union (AGU) reports based on AGI data. For example, Anderson et al. (2009) concluded that (for 2006 graduates) 57% of new PhD recipients went to postdoctoral positions in academic and government research facilities, an increase over 10 years from about 44%, and about 24% took academic positions. The most recent AGI report (Wilson, 2013) shows that 43% of PhD geoscience graduates accept initial positions at four-year universities, although this percentage includes postdoctoral positions. We note that the AGI data, covering all fields of geoscience, are remarkably similar to the data analyzed by Miller and McDuff (2012), covering just some of the oceanographic graduate schools.

Across STEM fields, “According to the latest Science and Engineering Indicators report, in 2010, in biology, engineering, and the physical sciences the proportion of PhD recipients going on to tenure-track positions was below 15%” (Nilsson, 2014). In more historical detail (National Science Board, 2012, Tables 3–20), the trend has been downward for tenure-track positions across all fields. Recent science and engineering statistics (National Science Board, 2014a) from the National Science Foundation (NSF) show that even among those employed at universities, there was a decline in the fraction in faculty

BOX 1. WHERE DO THEY GO AFTER THEIR POSTDOC?

In preparation for a five-year review, Woods Hole Oceanographic Institution (WHOI) determined where recent PhD alumni from the MIT/WHOI Joint Program end up after their postdoctoral experiences. Efforts were initiated several decades ago to collect ocean science graduate student demographics by WHOI dean Charley Hollister and associate dean Jake Pierson and University of Washington (UW) dean Arthur Nowell (later continued by UW's Russ McDuff), with help first from the Consortium for Oceanographic Research and Education (CORE) and then from the Consortium for Ocean Leadership. Because of these efforts, our ocean science community has good information on where ocean science MS and PhD alumni go immediately after receiving their degrees. Many, if not most, recent ocean science PhD graduates go into postdoctoral positions in academia.

However, do those who start in academia with a postdoctoral position stay in academic or other research positions after their postdocs? The best way to answer this question is with a longitudinal study that tracks all alumni for some years after their PhD work or tracks a random sample. To our knowledge, this has not been done for the field of ocean science nor for Joint Program graduates, at least not in recent years. An alternative approach is to choose recent graduating classes (but not too recent, since many recent graduates will still be on a postdoc), and track down the alumni from those classes to determine where they are currently working. This approach is now much easier because of the almost ubiquitous nature of personal and professional information on the Internet, although former thesis advisers often still know where their students are.

In fall 2014, WHOI used adviser knowledge and search engines to locate 121 of 133 PhD alumni graduating from the Joint Program during the years 2004–2010. Those who were located were assigned to one of seven job categories, as listed below, with the percentages of the total Joint Program alumni from that era also indicated.

1	Teaching or research faculty at an academic institution (including research/education nonprofit institutions, e.g., WHOI)	59%
2	Nonacademic or government research position (e.g., NOAA researchers)	10%
3	For-profit companies or institutions (e.g., ExxonMobil)	10%
4	Other scientific/technical positions (e.g., WHOI technical staff or program officers)	10%
5	K–12 teaching or outreach (e.g., high school teachers or, in one case, independent radio producer)	3%
6	Navy (many MS; only one PhD Naval officer since 2004)	1%
7	Postdocs (still several from the 2010 alumni)	7%

For this particular ocean science and engineering graduate program, during 2004–2010, most (69%) of the PhD alumni located were in either teaching or research positions (categories 1 and 2) following their postdoctoral experiences. However, based on interviews with current Joint Program students, recent alumni, and WHOI postdocs, WHOI expects that the outcomes for graduates could be different for the 2011–2016 alumni.

positions: “The percentage of S&E doctorate holders employed in academia who held full-time faculty positions declined from about 90% in the early 1970s to less than 75% in 2010.” Postdocs are included in these percentages.

Two related developments arguably drive these recent choices: a slowdown in hiring at research universities, particularly state universities, following the severe mid-2000s recession, and the current federal funding situation of flat or decreasing budgets combined with increasing costs (National Research Council, 2015). For the latter, graduate students personally see the pressure on their advisers to obtain funding. They also see the amount of time their advisers spend writing proposals, many of which will not be funded, as well as time spent juggling multiple grants to keep their research programs alive. A National Science Board report (2014b) observed that: “A 2005 Federal Demonstration Partnership (FDP) survey of investigators found that principal investigators (PIs) of federally sponsored research projects spend, on average, 42 percent of their time on associated administrative tasks. Seven years later, and despite collective Federal reform efforts, a 2012 FDP survey found the average remained at 42 percent.” The obvious frustration associated with time spent on research overhead is not very attractive to graduate students, whereas lifestyle/quality of life is very important to the current generation (Howe and Strauss, 2000).

Based on interviews with recent alumni and others who served on career panels for current graduate students and postdocs during the past 10 years, the following two skills gained with an ocean science PhD are most attractive to employers outside of academia: the ability to solve complex problems (implies strong quantitative skills) and communication skills (both oral and writing). Ability to work with a team is also important. Some employers do not seem to be particularly interested in the specific field in which an ocean science PhD received his or her degree, so long as the individual can

solve problems and communicate. For example, senior people at two FFRDCs (MITRE and Center for Naval Analysis) stressed communication and problem solving skills rather than the specific academic background of a PhD-level candidate. Education-related background and experience (the most common response in NSF-funded efforts to the requirement to address “broader impact”) does not seem to be of much interest to employers, except for academic positions that include outreach and successful grant writing as part of professorial evaluations. Miller and Briscoe (2012) also discuss mismatches between typical graduate student backgrounds and desirable employment qualifications.

HOW DID WE GET HERE, AND WHERE ARE WE?

We identify four somewhat overlapping ocean science research and education phases, leading to the current fifth phase (e.g., Farrington, 2001).

1 Prior to World War II, it was a period of classical disciplines applied to the ocean, with little formal ocean training. The career opportunities in the field of ocean sciences were yet undefined (Nowell, 2000).

2 Academic and research institutions (like WHOI) responded to specific needs of the US Navy (beginning with World War II, but continuing through the Cold War) and brought together experts from different fields to solve problems related to ocean acoustics, bioluminescence, and natural sound sources (e.g., whales, shrimp). Along with their research, they trained some graduate students who would continue their careers within either academic or government laboratories. In the 1950s, the Office of Naval Research (ONR) even established a program to overtly fund and foster ocean science in the universities in an effort to build a solid ocean understanding in support of anti-submarine warfare (Weir, 2001).

3 In the 1970s, research funds to expand knowledge of the ocean also began to flow from NSF, and significant support for graduate student training was included in funding for the International Decade of Ocean Exploration. A national need to train oceanographers was identified following the 1969 publication of the Stratton Commission Report (Knauss, 1990; Merrell et al., 2001). The “Scripps model” (Knauss, 2003) for ocean science graduate education had been exported to the University of Washington, Oregon State University, the University of Delaware, and the University of Rhode Island and its Graduate School of Oceanography (GSO), for example. These programs had a special status within university systems in that they were primarily research departments that brought in a significant amount of funding. For example, GSO brought in at least half of the University of Rhode Island’s research funds for many years, although this is no longer the case. These were departments with little, if any, responsibility for undergraduate teaching; faculty members were expected to undertake externally funded research and train graduate students. US career opportunities in the ocean sciences were strengthened through the establishment of agencies such as the Environmental Sciences Services Agency (ESSA) in 1965, later incorporated into the new NOAA in 1970.

4 Beginning in the 1980s, but continuing strongly into the 1990s, other fields began to bring in as much research funding as ocean science, if not more. Ocean science funding leveled off due to decreased emphasis at ONR and NSF (Navy interest decreased rapidly after the fall of the Berlin Wall, beginning in 1989). The ocean science graduate education and research programs at many universities began losing their special graduate student-only status. Pressure built to include undergraduate teaching in order to justify the number of full-time faculty positions. One of

the motivations to embed ocean science within geoscience colleges or colleges of the environment (see, e.g., Abbott, 2008) along with programs that traditionally had undergraduate majors (e.g., geology, botany, environmental sciences) was to bring ocean research scientists into contact with undergraduates, thus helping to deliver oceanographic knowledge to geoscience/environmental science/sustainability undergraduate majors and courses. Since the year 2000, this merger also occurred at the University of Delaware, Oregon State University, and the University of Washington. Scripps Institution of Oceanography is participating much more in undergraduate education than in the past. GSO resisted a merger into an environmental college 15 years ago, although it is now under pressure to expand undergraduate teaching. Contact between ocean science students and students in other fields and subjects led to expansion of possible career opportunities for the ocean scientists, by providing them with a broader context for their studies.

5 We propose that the emerging phase will refocus ocean science education to include increased training and emphasis on solving societal problems, as well as on job creation through the Blue Economy (see, for example, Sullivan, 2015; also, Michael B. Jones, The Maritime Alliance, *pers. comm.*, 2013). This current era will include both graduate and undergraduate training, although with more consideration as to what graduates will do with their degrees and how they will contribute to society.

Some may argue that there are too many oceanographers, too many students are being trained in the ocean sciences, and/or job growth has not kept pace with the supply of talent. Those who make this argument often conclude that we need to put a cap on student production, to get supply and demand back into balance; Ausubel (1996) discussed this two

decades ago. Others argue that the poor economy has been a contributor, and that positions will increase when the economy grows (but “hope is not a strategy”). However, a countervailing view (that we share) is that the entire research university system is unsustainable, and that continuing to produce graduates who expect to stay in academia will throw the system further out of balance. Job growth, particularly faculty jobs at the large research universities that emphasize research and training of graduate students over teaching of undergraduates, cannot keep up with geometrical growth on the supply side (Howard and Laird, 2013). The career issues that affect ocean sciences graduates are common issues across all academic fields. Graduate training in the ocean sciences as well as in other fields needs to be more than a research apprenticeship—a point made previously by Nowell (2000).

PhD graduates in the sciences are trained within their disciplines to define a problem, collect information, analyze data (often quite large amounts), and reach conclusions. Along the way to a PhD, students learn communication skills; they can recognize strengths and shortcomings of various approaches to a problem; they sometimes plan logistics for complex programs; and they often gain experience in working in teams. The cohorts of one author moved into computational fields—a byproduct of working with large data sets and learning processing and programming skills. All of these, especially the ability to work successfully as part of a group, are “skills that are relevant to the non-lab working world” (McNutt, 2014). Nevertheless, the fundamental reward system in graduate school is based on independent scholarship—the PhD thesis. Generally, students are neither deliberately trained nor rewarded for their collaboration skills (Briscoe, 2008).

“Collaboration” (sometimes called partnering) has many meanings, but it is sometimes used (in an overly simplistic way) to mean just working with someone else, even if that consists only of

sharing a ship or talking about a model. Within the field of collaboration—an academic field of study for some and a way of making a living for many consultants—there is a spectrum of collaboration: from Independent to Networking to Cooperating to Coordinating to Collaborating to Integrating/Merging (Briscoe, 2008). Although a graduate student may have participated in a multi-person, multi-institutional research program or cruise, such programs usually sit on the collaboration spectrum at the Cooperating-Coordinating point. Rarely, if ever, do they incorporate some of the best practices of a full collaboration, such as formal and written agreements on who will do what and how potential problems will be addressed, clear and strong leadership (as opposed to diffused or assumed), or shared benchmarks, milestones, and joint budgets. If the student has not been part of a formal, real collaboration, how can he or she claim experience in how to do it?

WHERE DO WE GO NOW?

Consider a simple two-by-two matrix:

	<i>Career in a fundamental discipline</i>	<i>Career in the ocean sciences</i>
<i>Graduate school training in a fundamental discipline</i>	Yesterday's paradigm	
<i>Graduate school training in the ocean sciences</i>		Today's paradigm

The matrix suggests that being trained in a fundamental discipline gives a student more possible career opportunities, so an initial suggestion (see below) is that (1) undergraduate oceanographers consider double majoring in their fundamental discipline as well as oceanography, and (2) that graduate students consider strengthening their core oceanography classes and research with continued studies in their discipline. This would complement our present training in the ocean sciences, because the depth and integration

of ocean sciences requires transfer of both specific knowledge (e.g., things that happen in the ocean and not elsewhere) and culture (e.g., going to sea). We also need to continue recruiting scientists from fundamental disciplines into the ocean sciences, because fresh perspectives will move science forward faster. This is not to suggest we should return to the days of no graduate training in the ocean sciences; there is great value in the interdisciplinary approach of graduate training in ocean topics and issues that would be lost with a return to on-the-job-training and serendipity. Rather, we argue for increased breadth (and effort) beyond training only in ocean science, to enhance the value of both the training and the career possibilities for the graduates.

Most doctoral programs strongly emphasize training students for research positions in academia. Among some faculty, this bias may stem from limited knowledge of other positions available to PhD-trained scientists, or from the mindset that academic research is a more prestigious career (Rosenberg, 2012). In addition, relentless university pressure to train many graduate students to enhance faculty productivity and stature, regardless of job opportunities, could contribute to a culture that emphasizes academic research to the detriment of other career options.

So we have a new one-by-two matrix:

	<i>Career in a research university</i>	<i>Career outside a research university</i>
<i>Graduate school training in the ocean sciences</i>	Today's paradigm	Not fostered or supported

While this bias may continue to exist within universities and oceanographic institutions, graduate students from the last decade have moved ahead in evaluating and expanding their career choices. Graduate students want to learn about careers outside of the research university, and in many instances are organizing their own career panels for these discussions (e.g., Böttjer et al., 2014). Among

many students in the top-ranked ocean science institutions, which have traditionally placed most of their PhD alumni in research positions, there is increasing interest in ocean policy, ocean conservation, environmental consulting, and faculty positions that emphasize undergraduate teaching. The increasing popularity of science policy fellowships, for example, NOAA's Sea Grant John A. Knauss Fellowship², the American Academy of Arts and Sciences' (AAAS) Science and Technology Policy Fellowship³, and the National Academies of Sciences (NAS), Engineering, and Medicine's Mirzayan Science and Technology Policy Fellowship⁴, speaks to the interest for research-trained scientists to understand how the federal government and nonprofit sectors work and to search for careers beyond the lab bench.

Current graduate students may also wish to consider the new "Blue Economy" when thinking about future job opportunities (see slide set on this topic assembled by author Spinrad at <http://dels.nas.edu/resources/static-assets/materials-based-on-reports/presentations/osb-presentation.pdf>). By some estimates, a multibillion-dollar economy looms in the immediate future, building not on the provision of extractable goods from the marine environment but rather on the production of environmental intelligence (forecasts of economically valuable information regarding environmental parameters of interest). A major conference entitled World Ocean Summit 2015: Blue Economy; Blue Growth, sponsored by *The Economist* and National Geographic, was held in June 2015⁵. Whether through new business development or monetization of intellectual property, ocean science graduates are an important part of the engine that will drive this economic surge. Some universities have recognized the possibilities for educating students

in both ocean science and business. For example, the University of Rhode Island has created the "Blue MBA," a non-thesis master's degree option that combines graduate business and ocean science courses, involving both GSO and the College of Business. The degree "provides a unique educational opportunity for students interested in the application of strategic management, leadership, and science skills to important real-world problems" (Moran et al., 2009). Scripps Institution of Oceanography now offers PhD students the option of pursuing both an ocean science PhD degree plus an MBA through University of California, San Diego's Rady School of Management. The list of alternatives—especially at the master's level—is growing rapidly.

The current NOAA administrator, Kathy Sullivan, wrote recently "...we are poised on the edge of explosive growth in the economic value of the sea, a development that could be a boon to the global economy, but only if we do it right. 'Right,' means balancing economic aims with responsible stewardship and rigorous use of information derived from ocean monitoring and observing" (Sullivan, 2015). The Blue Economy is also interpreted more broadly to mean the "economic value of the sea" and is an emerging concept within the business world. In the broader context, it generally refers to a group of industries, including shipping, shipbuilding, seabed mining, fishing, energy, submarine cables, aquaculture, robotics, marine biomedicine, marine ecotourism, and weather/observation science (World Ocean Council, 2014). Some of these industries are growing rapidly within some regions of the United States and the world. For example, a recent study showed that in 2012, the maritime industry in the San Diego area involved 1,400 companies and organizations, 46,000 jobs, and \$14B in annual direct sales (Jones,

2013). In San Diego, the technology sector was the fastest growing subgroup, with 19,000 jobs and \$6.2B in annual revenue. In 2009, the marine technology industry cluster in New England involved more than 400 businesses, 25,000 employees, and \$3.5B in sales (Doliner, 2014). It would seem that ocean engineers or ocean technologists are well positioned to take advantage of the growth in the technology sector of the Blue Economy, but offshore energy, seabed mining, fishing, aquaculture, ecotourism, and weather/ocean observation science will also involve the sciences and scientists.

Is the typical training one receives in ocean sciences graduate programs well matched to future opportunities such as undergraduate teaching, consulting, program management, the Blue Economy, or advocacy? The evidence (e.g., Miller and Briscoe, 2012) says no. Broadly speaking, ocean science graduate education today is primarily designed to produce students best suited to do research in universities, and preparation for other careers is rarely being promoted or supported. For example, training a Blue Economy workforce is unlikely to be accomplished through the current curriculum and research experience of an ocean sciences graduate student. The incorporation of business, economics, finance, and risk analysis (as has been done quite successfully in other disciplines, such as engineering and agriculture) will be essential. It is fair to question whether a PhD is even the right degree for some of these careers; for example, there are programs like Duke University's Master of Environmental Management⁶ and the University of California, Santa Barbara, Bren School's Master of Environmental Science & Management⁷. Another possibility would be a combined degree, something akin to an MD-PhD, which places less emphasis on developing research credentials, but still includes

² <http://seagrant.noaa.gov/fundingfellowships/knaussfellowship/prospectivefellows.aspx>

³ <http://www.aaas.org/program/science-technology-policy-fellowships>

⁴ <http://sites.nationalacademies.org/PGA/policyfellows/index.htm>

⁵ <http://www.economistinsights.com/opinion/charting-sustainable-course-ocean-economy>

⁶ <https://nicholas.duke.edu/programs/mem>

⁷ <http://www.esm.ucsb.edu>

preparation of a thesis based on independent research.

Therefore, the one-by-two matrix above can be expanded to a new two-by-two matrix:

	Career in a research university	Career outside a research university
Graduate school training in the ocean sciences	Today's paradigm	
Graduate school training in the ocean sciences plus additional material	Tomorrow's paradigm	

TRACKS

Ocean science graduate students who are considering careers other than in academia or in oceanographic research will likely need different programs of study, thesis topics, and other preparation than those who are preparing for academic/research positions. This can be a particularly difficult challenge when students (“crossover students”) are crossing the boundaries of large university units (e.g., university colleges) to take courses and do thesis research across multiple fields such as ocean science, science policy, resource management, ocean conservation, or ocean business. Ocean science and business, for example, are generally in different university colleges with very different cultures. The challenges for a crossover student include the need for a faculty adviser(s) willing to support intellectually and financially the student’s thesis research. Crossover students can also be burdened with a large course load, when both of the colleges or departments insist that the student meet all course requirements generally recommended for students in only one of the departments. This extra burden will likely mean extra time to a graduate degree, thus making the degree less attractive to students and

to those providing intellectual and financial support for the students.

A better approach might be to recognize that not all graduate students with a primary home in an ocean science program need to be trained as if they were to become ocean science researchers. Different educational tracks can instead be designed for ocean science graduate students who have different career interests. This approach recognizes that crossover students will not need the same preparation as students whose singular focus is on ocean science research, because the crossover students require different preparation. One possible disadvantage of this approach is that it will force students to make career choices and take appropriate action early in their quest for a graduate degree. However, is encouraging careful thought about career choices early in a graduate student’s program such a bad thing? Too many graduate students wait until the end of their education program before seriously thinking about a career. Many just assume that the faculty researcher option of their advisers and their university colleagues is their only and best option.

To help foster early thinking about career choices, graduate programs could be up front about the preparation or track required for different careers within all the possibilities that can benefit from training in the ocean sciences, and they could include formal advice and guidance from those employed within the various careers. Offering and describing different tracks in the recruiting literature and websites of ocean science graduate programs will help legitimize careers other than that of the faculty researcher.

A better choice than a PhD for some careers could be two master’s degrees, one of which would not need to be a thesis option. Potential combinations could be a thesis-option MS in ocean sciences with an MBA, master’s in marine affairs, or a master’s in conservation or related

science. One barrier to this approach is that students in PhD programs generally have a higher priority for funding than MS candidates. Students can be lured away from MS programs into PhD programs simply because of the funding preference. In the 1950s and 1960s, support for PhD programs in the sciences led to a rapid expansion of PhD candidates, and master’s programs lost financial support. In the 1970s, funding for higher education waned and “master’s programs everywhere found themselves starved for support,” given the priority for supporting PhD programs and PhD students (Cassuto, 2015). Master’s students are capable of doing publishable work, and many master’s theses lead to peer-reviewed publication (the coin of the realm for academia). Thus, ocean science two-year, thesis-option MS students could and should be supported on research grants and in other ways, because they also contribute to the research productivity of the investigator.

CONCLUSIONS

What are some actions that both students and faculty can take to help graduates find satisfying careers? Not in any particular order, some possibilities include:

1 Career counseling to help students understand the breadth of possibilities for working in ocean sciences, other than being a research professor in a university. Faculty can encourage counseling to start in the first year. Several professional societies (e.g., The Marine Technology Society, The Oceanography Society, and the American Meteorological Society) have begun to develop materials supporting this kind of counseling⁸. These additional career opportunities used to be called “alternative” careers, but the very term is misrepresentative. Given that most students now graduating are not ending up as research professors, perhaps it is the professorial positions that ought

⁸ There was a combined effort in 2009 by TOS, AMS, and MTS to look at a possible certification program for professional oceanographers, together with a study funded by NOAA. The issue received lukewarm support from the councils of the societies, probably due to there being no perceived value of the program in a community used to research careers. The certification program was ahead of its time, and likely would be received differently today.

to be called alternative! Current graduate students are excited to learn about non-academic careers, and as a community, we need to do a better job of providing this information (Nilsson, 2014).

2 Curriculum revision to provide some modern background and training in project management, oral communications, writing (beyond research papers), personnel management, economics and business practices, budgeting and fiscal reporting, grant preparation, and even best practices in collaboration, skills employers say are often lacking in their new employees. Major universities and programs provide courses that emphasize such skills. Good mentors will encourage their students to look for them, or even point them in the right direction.

3 Rethink the MS-PhD-postdoc sequence and encourage those with appropriate career interests to consider a terminal ocean science MS degree in combination with an MBA or some other master's degree. Universities could require an MS before starting a PhD and include solid career-development training (as in #2 above), thereby limiting the number of PhD candidates to those more interested in academia, and narrowing the pipeline for postdocs to those committed to the university track. Funding agencies would have to get on board with this approach, because they provide most of the post-doctoral funding. Grant-funded postdoctoral positions are increasingly directed toward those who will provide the most help for a specific project rather than toward providing training and expertise in a new area for the postdoc.

4 Expose students to a variety of employment opportunities through internship and externship programs. Just as the Knauss, AAAS, and NAS fellowships afford graduate students the chance to engage personally in

policy development or program management, similar “embedding” experiences with the private sector (e.g., profit-making corporations or nonprofit advocacy groups) would help students gain knowledge about possible career options. We note that engineering schools have had good success with “co-op” programs where the student spends some time on the job and some time in school, alternating back and forth; these programs have many of the same goals as internships, but perhaps with more attention to future employment.

A growing number of good career resources exist on the Internet (e.g., Earth Science Women's Network⁹). In addition, there are biographies of people who have had very satisfying, rewarding, and contributory careers that have not at all or not entirely been devoted to professional positions in universities; see, for example, the Career Profiles¹⁰ series in *Oceanography* magazine.

To the students pursuing graduate training and a career, we hope this background, status, discussion of issues, and recommendations help you find a productive and satisfying way of using your ocean science knowledge and interests. It is a challenging world, but your knowledge, passion, and tenacity are the tools to address it. The movements afoot in many master's programs give us optimism that the PhD programs will eventually adjust to today's many career options.

To the faculties and universities, listen to your student's needs.

We encourage development of a database for university graduate training that includes demographics and career trajectories to address the woeful lack of information on ocean science careers. Although this task may appear daunting, a partnership among the professional societies for ocean scientists and academic institutions could bring together the necessary resources for a successful and sustained endeavor. ☐

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⁹ <http://eswnonline.org>

¹⁰ <http://tos.org/career-profiles>

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