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The Ocean Science Graduate Education Landscape:

A 2015 Perspective

By Susan B. Cook, Amanda Holloway, Matthew Lettrich, and Kristen Yarincik

ABSTRACT. This article draws on several sources to provide background information on the composition of the 2015 ocean science graduate education community. We identify 148 US institutions of higher education that offer graduate degrees in the marine and ocean related sciences. Using data on degree completions and program size, the balance between master's and doctoral programs, and the demographic characteristics of degree recipients for the 73 higher education institutions that report marine degree data to the federal government, we develop a descriptive snapshot of the 2015 ocean sciences graduate education landscape. For programs administered by members of the Ocean Sciences Educators' Retreat community within the Consortium for Ocean Leadership, we present time-series information on the "supply side" of program dynamics (i.e., applications, enrollment), including detailed demographics, as well as an overview of curricular patterns and administrative structures. This information provides a framework that the graduate education community can use for further reflection, discussion, and collaborative action focused on the future of post-baccalaureate education in the ocean sciences.

INTRODUCTION

Since the late 1960s and early 1970s, the ocean sciences graduate education community has grown larger and more diverse, expanding well beyond Farrington's (2001) description of a dozen or so programs offering graduate degrees in the four subdisciplines of oceanography (physical, biological, chemical, and geological) and ocean engineering as well as several excellent degree programs devoted to marine biology and biological oceanography. In this overview, we tap multiple sources to briefly describe ocean science graduate training in 2015—using a broad brush to include all programs that self-identify as marine or ocean focused. The resulting diverse and dynamic landscape has the potential to serve as a framework for better preparing current and future graduate students for a variety of careers.

INFORMATION SOURCES

To create this snapshot of graduate education in the ocean sciences, we draw on four resources, three of them available to the public via the Web and a fourth compiled and maintained for ocean science graduate deans and other program administrators by the Consortium for Ocean Leadership.

Integrated Postsecondary Education Data System (IPEDS)

http://nces.ed.gov/ipeds

This electronic resource, hosted by the US Department of Education's National Center for Education Statistics, contains a wealth of data from institutions of higher education that receive funding from the US government. Lettrich (2014) extracted and analyzed IPEDS degree completion and demographic data for MS and PhD degrees in the core marine sciences for the period 1993 to 2013. The 73 institutions in this analysis all report degrees using categories identified as "core marine science disciplines" (Classification of Instructional Programs-6 [CIP-6] codes 14.2401 ocean engineering, 26.1302 marine biology and biological oceanography, 30.3201 marine sciences, and 40.0607 oceanography, chemical and physical). Not included in the analysis are more applied degrees reported to IPEDS (along with freshwater and terrestrial degree programs) in the following categories: aquaculture; fishing and fisheries sciences and management; wildlife, fish, and wildlands science and management; water, wetlands, and marine resources management; ecology; aquatic biology/limnology; hydrology and water; resources science; geophysics and seismology; marine science/merchant marine officer; operational oceanography; maritime studies; and geological and Earth sciences/geosciences.

An issue with IPEDS coverage of the ocean sciences is that there is no CIP-6 coding category for geologically focused oceanography degrees. From informal conversations with deans and administrators who routinely deal with IPEDS, we have learned that a few institutions report these degrees as physical and chemical oceanography outcomes while others code them as geological and Earth sciences/geosciences with no link to the ocean sciences. Biologically focused marine programs also commonly report degrees under nonmarine disciplinary

labels such as biological or environmental science. The result is that some nationally recognized ocean sciences institutions such as the Lamont-Doherty Earth Observatory of Columbia University and the Oregon Institute of Marine Biology within the University of Oregon are not included in the IPEDS inventory. Other obvious gaps include the numerous ocean-focused master's degrees offered by Duke University and the PhD programs at Northeastern University and the University of Massachusetts at Boston.

Guide to Marine Science and Technology Programs in Higher Education

https://www.mtsociety.org/publications/higherguide.aspx

This resource compiled by the Marine Technology Society (MTS, 2008) is a descriptive compendium of ocean-focused graduate programs in the United States and Canada as of 2008. We used it to identify an additional 33 institutions that educate future ocean scientists but report their degrees under more traditional biological, environmental, and geological labels. Even though the MTS inventory is text based (with limited search capacity), its detailed descriptions of a variety of programs make it a valuable resource for students and others seeking an information-rich overview of graduate (and bachelor's) degree programs in the marine sciences.

American Geophysical Union Database of PhD-Granting Institutions

http://sites.agu.org/careers/careers-in-science/phd-granting-institutions

This online resource hosted by the American Geophysical Union Career Center provides institutional contact information for students looking for PhD programs in the marine geosciences. We used it to identify an additional 31 ocean-relevant programs within the broad disciplinary umbrella of Earth system science.

Ocean Sciences Educators' Retreat (OSER) Database

The Consortium for Ocean Leadership is a Washington, DC-based nonprofit member organization of ocean-focused public and private institutions. Together with its predecessor organizations Joint Oceanographic Institutions (JOI) and the Consortium for Ocean Research and Education (CORE), Ocean Leadership has served as a data collection and convening body for institutional members of the oceanographic community since 1978. The OSER data set contains detailed information on member graduate programs (student application, enrollment, and retention rates; subdiscipline choices; demographic patterns) as well as data on the characteristics and concerns of faculty. It may represent the longest record available for the ocean sciences and forms the basis for biennial discussions of the opportunities and challenges faced by the OSER community.

Other Sources

Another four master's programs are listed in the inventory of marine-related graduate programs compiled in 2002 by CORE and published as Appendix A to the US Commission on Ocean Policy report *An Ocean Blueprint for the 21st Century* (USCOP, 2004). In addition to these relatively small programs, the authors are aware of eight newer programs that are not included in the above inventories. Three are affiliated with marine laboratories in the National Association of Marine Laboratories (NAML) and Ocean Leadership networks. Five PhD programs are linked to National Science Foundation (NSF)-funded coastal- or estuarine-focused Long-Term Ecosystem Research sites or other NSF-funded marine research. A complete list of the academic institutions in our 2015 snapshot can be found in the online supplementary materials.

To recap the information garnered from the above resources, the 148 US universities and colleges in this landscape portrait offer programs identified as ocean science, ocean engineering, oceanography, marine science, marine geology, or marine biology degrees, and well as those that provide a disciplinary umbrella over the ocean science subdisciplines (biological, chemical, physical, and/or geological), and marine biology degree programs with an organismal focus and geoscience/geophysics programs with a marine component. Of these 148 institutions, 48 are voting or associate members of the Consortium for Ocean Leadership. Many of these degree programs are also affiliated with the over 90 marine laboratories and ocean-focused academic units that are members of the NAML (Nancy Rabalais, Louisiana Universities Marine Consortium, *pers. comm.*, 2015). The remainder of this article summarizes the quantitative IPEDS degree information compiled by Lettrich (2014), and presents OSER information on application, enrollment, and retention rates, and OSER and IPEDS demographic information. We then outline the types of curricula and administrative structures in OSER graduate programs. The article concludes with a brief discussion of why collecting a comprehensive longitudinal data set is valuable to the community.

THE MARINE AND OCEAN SCIENCE GRADUATE DEGREE UNIVERSE

Using IPEDS data for the number of degrees awarded as an indicator of size, programs range from small academic units awarding fewer than 10 degrees from 1993 to 2013 to large internationally recognized institutions such as the Scripps Institution of Oceanography, which awarded 743 degrees over the same time period. Figure 1 (redrawn from Lettrich, 2014) shows the geographic distribution of the IPEDS institutions reporting degree data in 2012.

Of the 73 IPEDS reporting institutions, 49 grant PhDs in some aspect of marine science and/or ocean engineering. At the doctoral level, most degrees are in oceanography followed by marine biology and biological oceanography,

ocean engineering, and marine sciences. Across all IPEDS institutions, more master's degrees are awarded in marine biology and biological oceanography, with chemical and physical oceanography a close second followed by ocean engineering and marine sciences, a classification only added to the IPEDS labeling codes in 2010. Twenty-three institutions confine their offerings to master's degrees and focus on marine biology and biological oceanography, with a twenty-fourth offering a more physically and chemically focused program.

Looking more closely at the IPEDS degree data, the balance between PhD and MS degrees as expressed by the ratio of PhD/total degrees offered in the two engineering core areas falls along a continuum from 1.0 (for programs with PhD data only) to 0.0 (MS degrees only; no PhDs). Excluding programs awarding fewer than 10 total degrees (some of which may have been in existence for only a few years), the "degree emphasis landscape" can be divided into four categories: 13 programs with more PhD than MS degrees awarded (0.5–0.74), 19 programs with an intermediate ratio (0.25–0.49), seven programs with relatively few PhDs granted (0.25–0.4), and 15 programs with MS only degrees granted (ratio of 0). No programs offer PhD degrees only. Figure 2 identifies the IPEDS reporting organizations in each category.

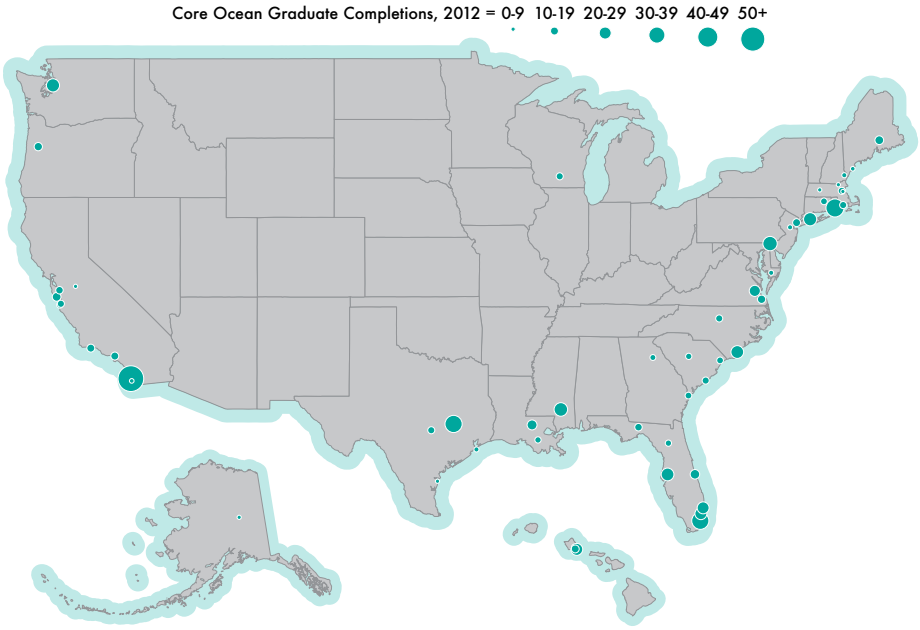

FIGURE 1. Locations of institutions reporting marine-focused graduate degrees included in the Integrated Postsecondary Education Data System (IPEDS) in 2012. Total 2012 IPEDS degrees = 653 (209 PhD and 444 master's).

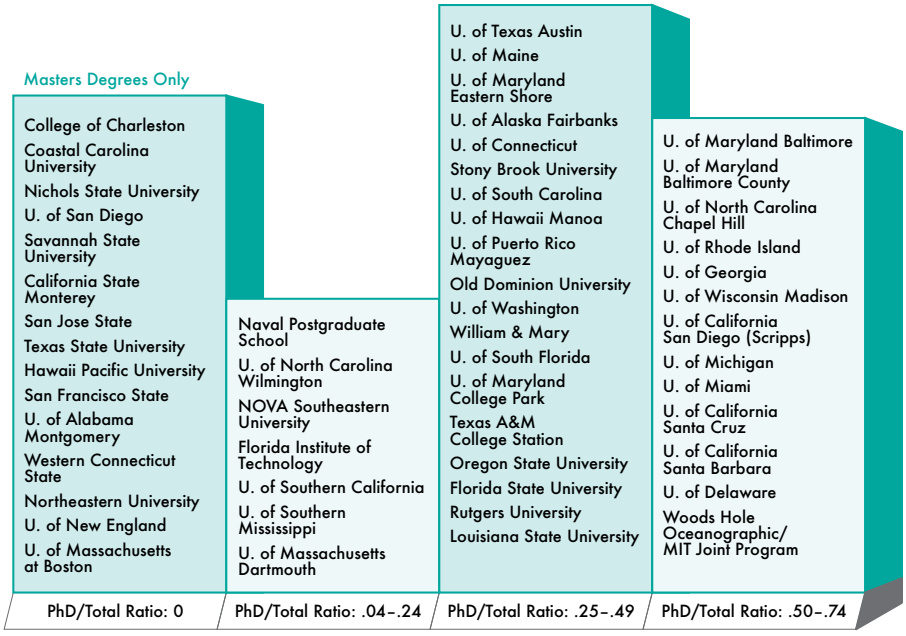

FIGURE 2. PhD/Total (MS + PhD) degrees from 1993 to 2013 from Lettrich (2014). Ocean engineering degrees excluded.

OSER TIME SERIES

In 1978, JOI began collecting data annually on graduate education in the ocean sciences from its 10 member institutions. Analyzed data were presented and discussed at the first JOI Deans' Retreat in 1980. Since then, similar retreats have been held every two to three years to review the cumulative data and discuss the current ocean sciences graduate school landscape (they are now Ocean Leadership's OSER meetings). Over the past 38 years, both the institutions reporting and the survey questions have varied. The number and types of respondents increased in the 1990s when the survey was opened to institutions outside of the initial JOI members. Although the survey questions have varied, the core focus of OSER data collection over the years has remained on application and enrollment numbers, demographics, completion rates and funding. To deal with the varying number of institutions supplying data from one year to the next, both averages and totals are recorded and reported for various parameters.

Overall, the OSER data show that there has been a decline in applications to ocean science graduate programs despite a spike in the mid-1990s (Figure 3). There has been a steady increase of women in ocean sciences from 1978 to the early 2000s, leveling off between 50% and

60% representation in ocean sciences graduate programs (Figure 4). This figure correlates with a general increase of women in science, technology, engineering, and mathematics (STEM) fields. However, despite achieving parity in the pursuit of degrees, women continue to represent only about 20% of tenured faculty (Figure 5).

Returning to the IPEDS data set, program completion (i.e., degree) data also show that women are no longer underrepresented in the core marine sciences. Lettrich (2014) provides more detail about the timing of this achievement for a larger set of institutions. In about 2005, women overtook men in the number of master's degrees earned (though the numbers were equal in 2013), and in 2012 at the doctoral level. At the master's level, the increase in women's degree achievement began in the early 2000s, principally in marine biology and biological oceanography. At the doctoral level, increases began in the 1990s, principally in oceanography.

In contrast to the progress made by women, OSER data show that the percentage of underrepresented minorities (URMs) enrolling in ocean sciences programs (based on US citizen applications, offers, and students in residence; Figure 6) has increased modestly over the past five years (compared to the lower but relatively steady level below10% for previous decades); both OSER and IPEDS degree completion data indicate that African Americans, Pacific Islanders, Alaska Natives, and American Indians remain underrepresented in the ranks of degree recipients relative to the proportions in other STEM disciplines. All nonwhite groups other than Asian Americans (American Indian/Alaska Native, Asian/Pacific Islander, Black/African American, Hispanic/Latino, two or more races, non-resident alien, unknown race) cumulatively represent about 30% of STEM degrees and 10% of core ocean science degree completions. Drilling down further into the enrollment/degree data in IPEDS for African Americans, Pacific Islanders, Alaska Natives, and American Indians reveals that the nonresident aliens are the largest subgroup in this cohort at the doctoral level, accounting for 50% of ocean science nonwhite degree completions (Lettrich, 2014). At the master's level, non-US citizens receive 10% of the degrees awarded to individuals in the nonwhite category. Minorities also continue to be highly underrepresented in academic faculty, with recent OSER data showing little or no growth (Figure 7).

ADMINISTRATIVE AND CURRICULAR MODELS

Given the range of host institution types, sizes, and geographic locations, and the heterogeneity of faculty interests in the ocean science educational universe, we have not attempted to describe the content and focus of specific programs. Instead, we reviewed the doctoral program information available on the Web for 30 Ocean Leadership member institutions that report marine-related doctoral degree data

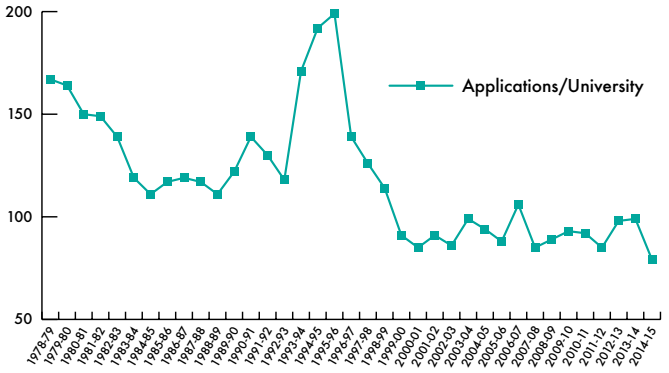

FIGURE 3. Average of total reported applications over the number of institutions reporting for a given year.

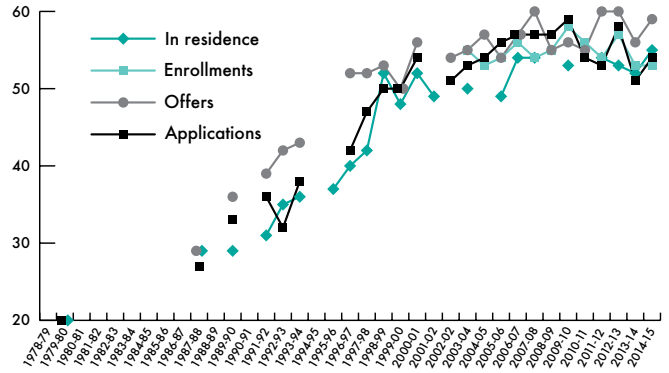

FIGURE 4. Percentage of women in applications, offers, enrollments, and in-residence categories.

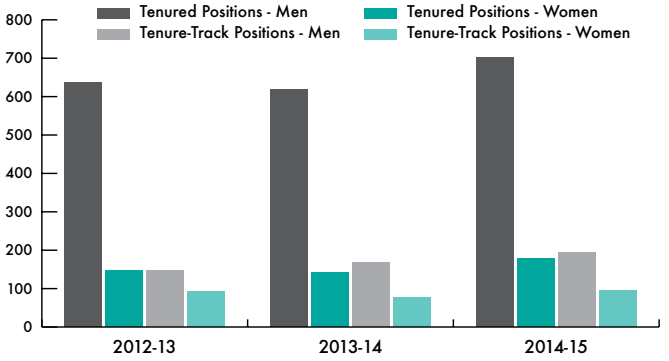

FIGURE 5. Total reported tenure and tenure-track positions by gender.

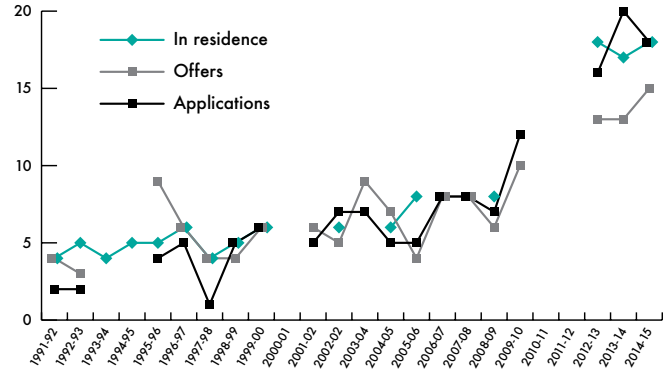

FIGURE 6. Percentage of US citizens that identified as minorities in applications, offers, enrollments, and in-residence categories. Minority designations are Hispanic/Latino, American Indian/Native Alaskan, Asian American, African American, Native Hawaiian/Other Pacific Islander, and multiracial.

to IPEDS and an additional six Ocean Leadership institutions that offer marine- or ocean-focused doctoral degrees but do not report these data to IPEDS using the core marine science codes.

As outlined in Table 1, we identified five primary institutional administrative categories ranging from cross-institutional programmatic umbrellas, such as the University of Maryland's Marine Estuarine Environmental Science program, at one end of the spectrum to academic departments in arts and sciences colleges at the other; an example of the latter is the University of Southern California Graduate Program in Ocean Sciences administered by the Earth Sciences Department in conjunction with faculty in the Marine Environmental Biology Program of the Biological Sciences Department. Thirty-one percent of the programs require all students receiving degrees to complete courses in all four ocean science subdisciplines (biological, chemical, physical, and geological) or to document core competency before beginning their studies. Forty-seven percent use modifications of this model that involve three of the subdisciplines instead of four, combine multiple core topics into fewer foundational courses, or have a four-core requirement for some but not all degrees. As Sharp (1995) pointed out, the breadth of knowledge associated with the interdisciplinary core approach provides graduates with experience and expertise that prepares them for a wide range of careers.

Twenty percent of the institutional programs reviewed do not require an interdisciplinary core, but students must meet breadth requirements in their disciplinary areas (i.e., biology, geology, or environmental science). Two programs (labeled beyond-disciplinary core in Table 1) emphasize professional and technical skills and require at least one course outside of the disciplinary arena (i.e., social science in one case and natural science/ethics/policy/law in the other). In addition, in at least 10 institutions, separate doctoral programs in marine biology exist in parallel with the programs reviewed in Table 1 bearing marine or ocean science labels.

Fifteen (42%) of the 36 institutions have affiliations with "satellite research units" that are members of the NAML. Students in a variety of US and international programs conduct immersive field research at these facilities and benefit from collaborations not possible on traditional campuses (National Research Council, 2014).

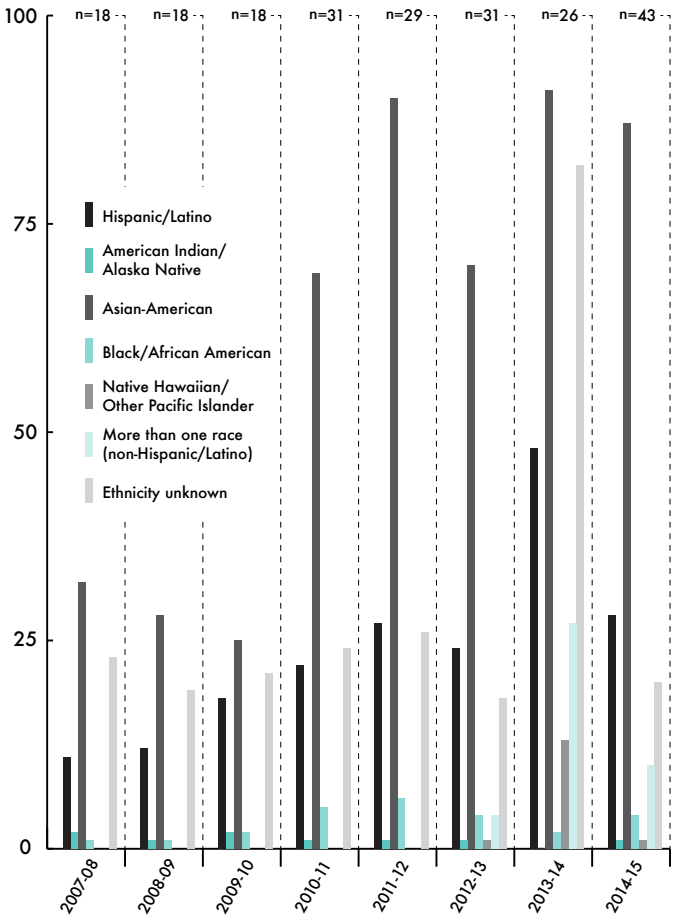

FIGURE 7. Faculty that identified as minorities (n = the number of survey respondents for a given year).

OSER DATA AS A CATALYST FOR CHANGE

Discussion of the enrollment, degree completion, and demographic trends at recent OSER meetings has led to efforts to mentor and retain women in the ocean sciences and greater appreciation for the need to effectively recruit and retain underrepresented minorities. Faculty in ocean sciences departments are also becoming more aware of the value of building and strengthening the relationships between majority-serving research institutions and historically black colleges and universities, Hispanic-serving institutions, and minority-serving institutions.

During the most recent OSER meeting in 2014, discussions focused on declining enrollment in more specialized programs, a trend that is driving universities to consolidate academic departments and provide a broader curricular scope. To increase enrollment while meeting the need for applied research areas and expertise, many programs are redesigning their curricula, becoming more interdisciplinary, and offering more applied content. At the same time, low enrollment for some specialized courses associated with a larger, more varied student body makes it difficult for institutions to maintain this training on their own, and many are considering teaming with peer institutions to offer in-depth classes or workshops. Schools have also increased their remote course offerings, enabled by new and emerging technologies.

Finally, discussions with industry and preliminary surveys of academic faculty, students, non-academic employers, and early career employees indicate that there is a disconnect

TABLE 1. Doctoral program administrative and curricular models (n = 36) for 29 Integrated Postsecondary Education Data System (IPEDS)-reporting Consortium for Ocean Leadership (COL) member institutions with PhD/total degree ratios above .10 and seven non-IPEDS reporting COL institutions

Administrative model	Number/% in category	Four traditional subdisciplinary core courses	Modified core	Beyond-disciplinary core	Within discipline breadth
Cross-institutional umbrella	2/6%	1	1	0	0
Umbrella school or college level broader than marine science	18/50%	2	13	2	1
Umbrella at level of school or college of marine science	3/8%	2	1	0	0
College of science type umbrella; department broader than marine science	4/11%	2	0	0	2
Science college umbrella; marine/ocean science at or within department level	9/25%	4	2	0	3
Totals	**36**	**11 (31%)**	**17 (47%)**	**2 (5%)**	**6 (17%)**

between skills identified as important for the workforce and skills being taught effectively in graduate programs (Miller and Briscoe, 2012; Briscoe et al., 2016, in this issue). Graduate programs should consider how they are aligning with and training students for evolving workforce needs, particularly because the data indicate a greater percentage of terminal MS degree and PhD recipients who are not continuing in academia (Miller and McDuff, 2010). With its academic and industry members, Ocean Leadership will be playing a coordinating role in addressing this disconnect.

CONCLUSIONS

Databases such as OSER and IPEDS are crucial for identifying ocean science education trends so that the community can target areas such as enrollment and retention, program structure, and faculty hiring that would benefit from new approaches. Improvements in OSER data, such as addressing the inconsistency in the number of respondents from year to year and between the ocean sciences field titles identified for OSER and those used in IPEDS, will go a long way toward building a more comprehensive and consistent picture of the ocean sciences graduate landscape. We urge all of the institutions in the Consortium for Ocean Leadership's OSER family to recognize the importance of these data to the community and complete the survey each year so that we have a comprehensive and consistent data set moving forward. At the next OSER meeting at Louisiana State University in Baton Rouge, Louisiana, in November 2016, next steps for the evolution of the data set will be discussed along with contributions that the Consortium for Ocean Leadership can make to the broader community discussion called for in this special issue.

SUPPLEMENTARY MATERIALS

A complete list of the academic institutions in this article's 2015 snapshot can be found online at http://dx.doi.org/10.5670/oceanog.2016.04.

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