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Women of the Academy and the Sea: 2000–2014

By Suzanne O'Connell

There is good news and bad news for twenty-first century women oceanographers. Tremendous progress has been made in breaking the glass ceiling, both in positions and in prestigious awards and medals (Table 1). There were many firsts, including the first woman to head the National Oceanic and Atmospheric Administration (NOAA; Jane Lubchenco) and the first woman to head the United States Geological Survey (USGS; Marcia McNutt). Commendably, other women are succeeding the first women in these very high level positions. Kathy Sullivan, the first woman to walk in space, succeeds Lubchenco. McNutt's successor at the USGS not been confirmed; however, Suzette Kimball, has been nominated to succeed her and is serving as Acting Director.

At the Environmental Systems Research Institute (ESRI), oceanographer Dawn Wright (Deep-Sea Dawn), a developer of Arc Marine, is the first woman to become chief scientist. Women now head three—half—of the six oceanographic institutions featured in our 2005 paper (O'Connell and Holmes, 2005): Margret Leinen is Director of the Scripps Institution of Oceanography, Virginia Armbrust is Director of the University of Washington College of Oceanography, and Susan Avery is President and Director of the Woods Hole Oceanographic Institution.

It is often difficult to decide which disciplines encompass "oceanography." Are marine biologists (e.g., Sylvia Earle?) or atmospheric chemists, who look at ocean/air interactions, oceanographers? Is a structural geologist who studies ocean crust on land (ophiolites) an oceanographer? In this paper, I attempt to be inclusive, but no doubt am biased by my knowledge of more oceanographers with an Earth science focus.

Since 2000, women oceanographers have begun to receive prestigious geoscience medals. In 2014, Maureen Raymo became first woman to receive the Wollaston Medal, established in 1831 by the Geological Society of London (GSL). Susan Kieffer became the first woman to be awarded the Geological Society of America's (GSA) Penrose Medal. Three women, Marcia McNutt (2007), Miriam Kastner (2008), and Ellen Thomas (2012), have now received the Maurice Ewing Medal, established in 1974 and given annually by the American Geophysical Union (AGU) to one honoree in recognition of "significant original contributions to the ocean sciences." Inez Fung received AGU's Revelle Medal in 2004, and remains the only woman to have received it. Ahead of the

Table 1. Medal citations for four oceanography-related scientific societies whose first female recipients were named in the twenty-first century. GSL = Geological Society of London. AGU = American Geophysical Union (AGU). AMS = American Meteorological Society. GSA = Geological Society of America.

Medal Name	Estab.	Society: Information
Wollaston	1831	GSL: "This medal is normally given to geologists who have had a significant influence by means of a substantial body of excellent research in either or both 'pure' and applied aspects of the science."
Penrose	1927	GSA: "To encourage original work in purely scientific geology."
Sverdrup	1964	AMD: "To researchers who make outstanding contributions to the scientific knowledge of interactions between the oceans and the atmosphere."
Ewing	1974	AGU: In recognition of "significant original contributions to the ocean sciences."
Revelle	1991	AGU: In recognition of "outstanding contributions in atmospheric sciences, atmosphere-ocean coupling, atmosphere-land coupling, biogeochemical cycles, climate or related aspects of the Earth system."

twenty-first century, Kristina Katsaros received the American Meteorological Society's (AMS) Sverdrup Medal in 1997.

Female scientists have also received an increasing number of national honors in the United States, such as being inducted into the National Academy of Sciences (NAS) and being awarded the National Medal of Science (Figure 1). The NAS was established in 1863 during the Lincoln administration to provide scientific and technical advice to the government. Membership is by election in "recognition of distinguished and continuing achievements in original research." There are approximately 2,200 members and 400 foreign associates. All 21 NAS presidents have been male. Fortunately, there are many female members. Disciplines are designated by "Section." Of the 31 sections, none is directly related to oceanography, marine science, or atmospheric science. Three sectional disciplines house most of the oceanography-related NAS members: Environmental Science and Ecology (e.g., Jane Lubchenco), Geophysics (e.g., Inez Fung), and Geology (e.g., Tanya Atwater, Terry Plank). I surveyed gender balance of the elected members of these sections and recorded the total percentages of female members by the decade in which they were elected. These numbers include men and women who are not oceanographers and range from 0% females in the 1960s to 28% females in the early 2010s (2010–2014).

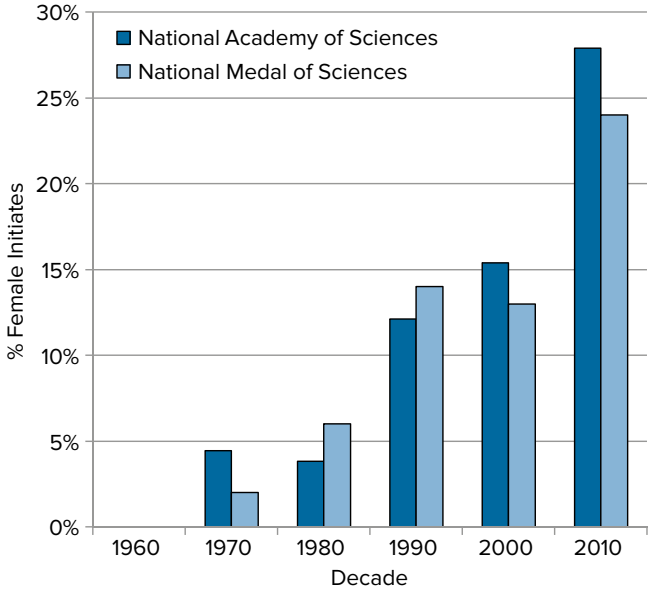

Figure 1. Plots of the percentages of women members inducted into the National Academy of Sciences (NAS) Sections of Geology, Geophysics, and Environmental Sciences and Ecology, and of all recipients of the National Medal of Sciences (NMS). NAS member data for 2010 includes 2010–2014, while corresponding NMS data includes 2010–2012 and begins in 1962.

In terms of scientific recognition and prestige, the National Medal of Science (NMS) is more exclusive. Established in 1959, its purpose is to acknowledge individuals "deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, or engineering sciences." Social and behavioral sciences were added in 1980. The first NMS was awarded in 1962 and the most recent in 2012. Awardees total 497. Again, there is no category for oceanography or marine science. Some women oceanographers, for example, Sallie (Penny) Chisholm, an MIT professor who studies the ecology and evolution of microbes in the ocean and their influence on biogeochemical cycles, have been honored with this medal. As with NAS membership, the percentages of female recipients in all fields have grown since the latter half of the twentieth century and range from 0% in the 1960s to 24% in the first three years of the 2010s.

Women oceanographers have been recognized beyond the scientific community. Two women ocean scientists have been named MacArthur Fellows in the twenty-first century. Kelly Benoit-Bird, a marine biologist at Oregon State University, received the award in 2010. She uses acoustic engineering to study the behavior of marine creatures and food chains. In 2012, Terry Plank, a geochemist at Columbia University who studies the chemical and thermal forces that drive plate motion, was also named a MacArthur Fellow. Several other female oceanographers have been awardees, including Jane Lubchenco in 1993.

Another indication of women's progress in oceanography is the selection of plenary speakers at international congresses and meetings. At the 2014 meeting of the International Association of Sedimentologists (IAS), all four plenary speakers were women. Two would be considered oceanographers: Carlotta Escutia from Spain has sailed on several scientific ocean drilling expeditions and was co-chief scientist on Expedition 318 to Antarctica. Anny Cazenave, from France (NAS Foreign Associate 2008), uses satellite altimetry to study sea level change and is a member of the Intergovernmental Panel on Climate Change. The two other plenary speakers were Isabel Montanez from UC Davis, who focuses on paleoclimate including paleo-oceans, and Marjorie Chan, University of Utah, who studies the sedimentology of marine and terrestrial environments through time on Earth and Mars. Chan was also the Geological Society of America's Distinguished International Speaker in 2014, the first female

in that position. Despite the progress, there is still work to do (see Kappel and Thompson, 2014, in this supplement).

Within societies, the title of "fellow" recognizes both scientific achievement and service to the society. Women have lagged behind their representation in societies' memberships as recipients of this recognition and as recipients of medals (Holmes et al., 2012; O'Connell, 2013). Professional societies that ocean scientists are likely to join include the American Geophysical Union (AGU), the American Meteorological Society (AMS), and the Geological Society of America (GSA). In 2014, women became fellows in these organizations at the rate of 18%, 18%, and 12% respectively, far below their percentages as society members and PhD recipients 20 years ago (Figure 2).

DEGREE DATA

Women continue to receive increasing numbers of PhDs in Earth, atmospheric, and ocean sciences (EAOS). Between 2002 and 2012, female PhD recipients in EAOS disciplines increased from 177 in 2002 (32%) to 319 in 2012 (43%), primarily because of the increase in Earth science PhDs (Figure 3A; NSF, 2013). Overall, the percentage of female PhD recipients also continues to rise, with females receiving the highest percentages of PhDs in ocean sciences (40% in 2002 and 48% in 2012, with a peak of 54% in 2009) and the lowest in atmospheric sciences (31% in 2002 and 39% in 2012, with a nadir of 20% in 2008) (Figure 3B; NSF, 2013).

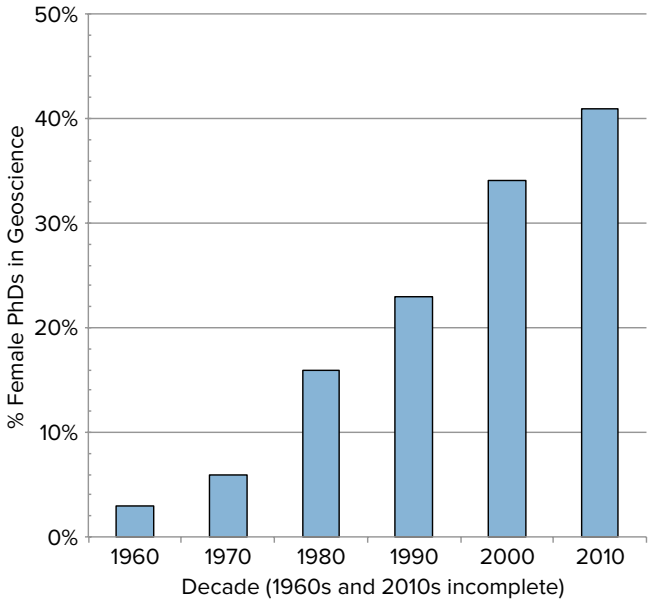

Figure 2. Percentages of females receiving PhDs in Earth, atmospheric, and ocean Sciences (EAOS) by decade (NSF, 2004, 2013).

Missing from female (and male) PhD recipients are underrepresented minorities (URMs), defined by the National Science Foundation (NSF) as US citizens and permanent residents from African-American, Hispanic, Native American, Alaskan Native, and Pacific Island ethnicities (Figure 4). For the past decade, URM women have earned about 12% of the EAOS PhDs awarded to female US citizens and permanent residents, far below their percentage in the US population. It is here that more direct attention needs to be focused, as the population of these demographic groups is growing at a higher rate than that of the white population. Federal attention to increasing diversity in science, technology, engineering, and mathematics (STEM) fields and, in particular, NSF's Opportunities for Enhancing Diversity in the Geosciences program that began in 2001 (Huntoon and Lane, 2007; Prendeville and Elthon, 2001), needs to be continued.

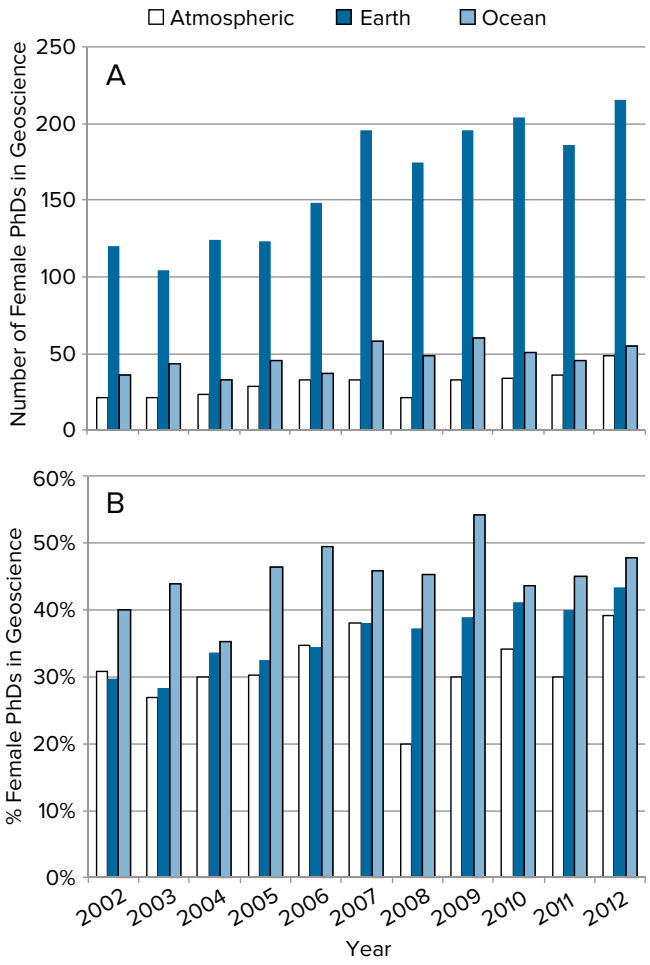

Figure 3. (A) Numbers of females by subdiscipline earning EAOS PhDs. (NSF 2013, Table 7-2). (B) Percentages of females earning PhDs in EAOS subdisciplines (NSF, 2013, Table 7-2).

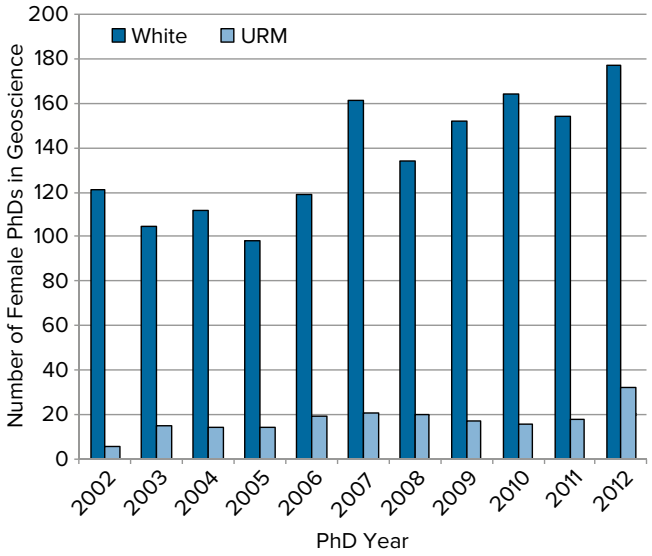

Figure 4. Numbers of white and under-represented minority (URM) females (US citizens and permanent residents) receiving PhDs in EAOS (NSF, 2013, Table 7-7).

ACADEMIC EMPLOYMENT

Women are still not faring as well as their degree numbers might suggest in securing tenured and tenure-track academic positions. This problem is compounded by the lack of positions. There are several ways to dissect the data. Here, I've looked at the employment at six oceanographic institutions, the same six O'Connell and Holmes (2005) considered (Table 2). These six institutions employ about half of the academic-based oceanographic faculty in the United States. A more complete assessment, including data from more schools, can be found in Orcutt and Cetinić (2014, in this supplement).

All tenured and tenure-track faculty were counted at the six institutions (adjuncts, lecturers, and researchers were not included). Associate professors/scientists without tenure were included with assistant professors, so associate means the faculty member has been awarded tenure. Faculty in departments that were only present at one institution (e.g., ocean engineering or atmospheric sciences) were not included. These six institutions employ approximately 500 faculty. The percentages of women in each subdiscipline by rank show that, with the exception of physical oceanography, women are continuing to make progress in securing tenure-track jobs and tenure (Figure 5). Over 30% of the assistant professors in the four disciplines at these six oceanographic institutions are women.

Table 2. Six oceanographic institutions for which faculty were counted.

Oregon State University College of Earth, Ocean and Atmospheric Sciences
Scripps Institution of Oceanography, University of California, San Diego
Rosenstiel School of Marine and Atmospheric Science, University of Miami
University of Rhode Island Graduate School of Oceanography
University of Washington School of Oceanography
Woods Hole Oceanographic Institution

Thompson et al. (2011) addressed the decline in tenure-track positions in physical oceanography by examining the numbers of male and female PhD recipients at 17 institutions offering a physical oceanography degree. They found that as a percentage, women were actually losing ground in obtaining tenure-track positions. For PhDs awarded between 1980 and 1995, 28% of the men and 15% of the women held tenure-track positions. For PhDs awarded between 1996 and 2009, 27% of men held tenure-track positions, while only 8% of women PhDs held tenure-track positions. The reasons for this decline are only speculative, but it is hoped that programs such as Mentoring Physical Oceanographers to Increase Retention (MPOWIR; see Lozier, 2006; Clem et al., 2014, in this supplement) will help more women to navigate the intricacies of the academy.

The percentage data do not show how few tenure-track

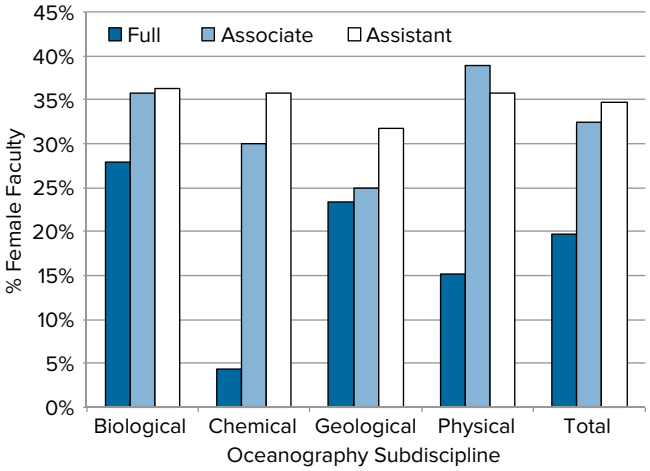

Figure 5. Percentages of faculty at six oceanographic institutions (Table 2), by rank and subdiscipline. Not all oceanographic subdisciplines could be identified at each institution. For example, at Scripps Institution of Oceanography, the Climate, Atmospheric and Physical Oceanography (CASPO) department was included under physical oceanography, and there was no distinct chemical oceanography department. Data were collected from institutional websites in fall 2014.

positions there are. The total number and percentages of women faculty at the six oceanographic institutions has increased, but there are few positions for any gender (Table 3). In fact, there are fewer than 100 assistant professors at all 26 institutions tabulated by Orcutt and Cetinić (2014, in this supplement).

Elsewhere in the EAOS academy, the representation of female faculty is not doing as well. Glass (2015) compiled information on faculty at the top 106 geoscience research departments, as reported by *US News and World Report*, that had five to 50 faculty during the 2010–2011 academic year (Figure 6). Compared to oceanographic institution data presented by Orcutt and Cetinić (2014, in this supplement), which show that 20% of women are at the full professor level, 30% at associate professor level, and 40% at the assistant professor level, Glass' percentages show an even lower concentration of female faculty at the rank of full (13%), associate (24%), and assistant (36%) professor. This result is surprising because Glass' data (Figure 6) include both research and tenure-track faculty, so it might be expected that her percentages of women would be higher because female faculty are less likely than males to be in tenure-track positions.

Among the 106 institutions reviewed by Glass (2015), the percentages of female faculty ranged from 0% to 40%. The institutions with the highest percentages of female faculty, in order, are: the University at Buffalo, Louisiana State University at Baton Rouge, University of New Hampshire, University of Massachusetts, and University of Nevada-Las Vegas. Of these five institutions, only the University of New Hampshire offers a graduate degree with an oceanography specialization.

Oceanographic and research universities are not the only educational institutions with limited openings for tenure-track faculty. According to the American Federation of Teachers (AFT, 2009), between 1997 and 2007, the number of full-time tenured and tenure-track faculty declined from roughly one-third of post-high school instructional staff to slightly more than one-quarter. Women were more likely to have part-time and adjunct positions (AFT, 2009), which does not bode well for the large numbers of women currently earning PhDs.

The reasons women are less likely to enter and stay in the academy are multidimensional. Some impediments, especially thanks to the ADVANCE program (see Holmes, 2014, in this supplement), are being overcome. Many institutions now stop the tenure clock for family needs (e.g., childbirth, adoption, care for a sick family member), and departments educate faculty search committees about ways to counteract implicit bias (Banaji and Greenwald, 2013) and deal with stereotype issues (Steele, 1997). Despite this, because of the subtle changes that are needed to deal with the accumulated disadvantage of being part of an under-represented group, it may take more time for both women and minorities to reach parity in the oceanographic community. However, the abundance of women and minorities with EAOS PhDs means that it is possible to change the demographics of the academy to look more like those of the United States. This is an opportunity that should be vigorously pursued.

Table 3. Number of tenure-track women faculty by rank in four subdisciplines at the six oceanographic institutions listed in Table 2. Even though the percentage of female faculty is rising (Figure 5), the absolute numbers at the assistant and associate level have only increased slightly.

Rank	2004	2014
Full	24	52
Associate with tenure	26	30
Assistant	20	26
Totals	**70**	**108**

SCIENTIFIC OCEAN DRILLING

Scientific ocean drilling is a thread that connects many women in oceanography, especially chemical oceanography and marine geology and geophysics. Of the women named in the introduction as major awardees or directors of institutions, five have participated in a scientific ocean drilling expedition:

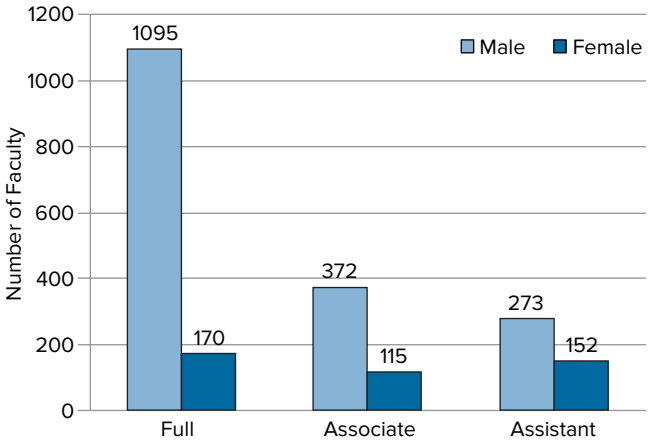

Figure 6. Numbers of women in faculty positions (research and tenure track) at the top 106 US Earth science departments in 2010–2011 (from Glass, 2015).

Table 4. Co-Chief scientists by gender and platform for Integrated Ocean Drilling Program Expeditions 301–346 (2004–2013), excluding 328, which was a short "School of Rock" program for educators. CC = co-chief scientist. MCC = male co-chief scientist. FCC = female co-chief scientist. Drilling components that make up the IODP platforms: *Chikyu* = Japanese riser drilling vessel. JR = US-operated drillship *JOIDES Resolution*. MSP = Mission Specific Platforms operated by a European science consortium. Some of the *Chikyu* expeditions (e.g., Nantroseize Project) had more than two co-chief scientists.

Platform	# of Expeditions	Total CC	Total MCC	Total FCC	USA		Japan		Other		Total % FCC	% Non-Japanese FCC
					MCC	FCC	MCC	FCC	MCC	FCC		
Chikyu	13	30	28	2	10	1	12	0	6	1	7%	11%
JR	29	58	49	9	17	4	18	0	14	5	16%	23%
MSP	5	10	9	1	1	1	2	0	6	0	10%	13%
Total	**47**	**98**	**86**	**12**	**28**	**6**	**32**	**0**	**26**	**6**	**12%**	**18%**

Miriam Kastner, Margaret Leinen, Maureen Raymo, Ellen Thomas, and Dawn Wright. The power of this program is what attracted me to this field over 40 years ago, offering opportunities to go to sea and explore Earth's history recorded in ocean sediments, to connect the ocean and the land, and to work with colleagues from other disciplines to understand Earth's behavior. And the male geology faculty at my undergraduate college spoke in awe of Helen Forman, a researcher in the department, who sailed as a radiolarian micropaleontologist on several *Glomar Challenger* expeditions.

In O'Connell and Holmes (2005), we were optimistic about the progress made in increasing women's participation in scientific ocean drilling. Although women weren't common as co-chief scientists, their percentages of shipboard scientific parties had grown from about 15% in the early 1980s at the end of the Deep Sea Drilling Project (DSDP) to over 25% in the early years of the twentieth century Ocean Drilling Program (ODP; 1985–2003). Then, ODP expanded into the multiplatform Integrated Ocean Drilling Program (IODP) that operated from June 2004 to September 2013. IODP encompassed Expeditions 301 through 348. Expedition numbers are consecutive, but the actual expeditions did not always occur in sequence and were on different platforms (Table 4). The majority of expeditions (29) were on *JOIDES Resolution*, followed by *Chikyu* (13), with five on Mission Specific Platforms (MSP).

Assembling a scientific party is a complicated task. Expedition staffing requires specific disciplinary expertise be present on the ship to ensure the scientific objectives are met, for example, a micropaleontologist with expertise in a specific time interval and microfossil, or a geochemist adept in organic geochemistry. In addition, under IODP memoranda of understanding between government funders, each member country was allotted a certain number of co-chief scientists and shipboard positions. National interests need to accommodate disciplinary requirements for an expedition and this requires staffing flexibility.

On *JOIDES Resolution*, which had the highest number of participants, the percentage of females in the scientific party ranged from 15% to 45%, and for all 29 expeditions averaged 30% (Figure 7A). During these same expeditions, the percentage of graduate students in the scientific party ranged from 14% to 50%, averaging 26% (Figure 7B). Of the graduate students, as few as 14% (one) to as many as 100% (six) were females, with an average of 45%. Forty-five percent is slightly higher than the percentage of female Earth science PhD graduate students (Figure 2) during the past decade. This suggests that a large number of women (almost 100) have participated as graduate students as part of the *JOIDES Resolution* scientific party. Over 100 have participated when all three platforms are considered. These women could be a tremendous resource for gender equity in future scientific ocean drilling expeditions as both shipboard participants and co-chief scientists.

Of the 98 co-chiefs on all expedition platforms, only 12 were female (12%), but when the percentage of female co-chiefs without Japanese co-chiefs or just the percentage of female US co-chiefs is considered, the percentage of female co-chiefs increases to 18% for both. *JOIDES Resolution*, with US management, has the highest percentage of female co-chief scientists (16%) and the riser drilling ship *Chikyu*, under Japanese management, has the lowest (Table 4, Figure 8).

In the new International Ocean Discovery Program (also IODP), there are no constraints on nationalities of co-chief scientists on any platform. Sadly, even without national

constraints, women co-chief scientists have continued to fare poorly. Of the 16 co-chief scientists that have been selected for *JOIDES Resolution* Expeditions 349–356, only one (6%) is a female. The European-run MSP program is doing considerably better. Although its last old IODP Expedition 347 (Baltic Sea Basin Paleoenvironment) had two male co-chief scientists, its first expedition in the new IODP Expedition 357 (Atlantic Massif) will have two female co-chief scientists. No new expeditions are currently scheduled for the riser drilling ship *Chikyu* (see http://iodp.tamu.edu/scienceops/expeditions.html). When they do get scheduled, it would be wonderful to select a female Japanese co-chief scientist to head the expedition.

Beyond Expedition 358, funding is not guaranteed, but the expedition objectives are known and coring sites have been selected for Expeditions 359–363 on *JOIDES Resolution*. Co-chief scientists have also been chosen. Three of the 10 are women, one from the United States and two from Europe.

How does someone become a co-chief scientist? "Co-chief scientist" is not an honorary position. These men and women are usually among the lead scientists who have been active in planning for a particular research expedition for a long time and are principal investigators on the proposals submitted to IODP. This requires participating in activities such organizing pre-cruise site surveys and assembling the necessary data to frame the questions that will be addressed during the expedition. Much of the groundwork for these expeditions is formulated at workshops supported by the agencies that fund the program. Early career female scientists need to be at these workshops so that they can become leaders for addressing specific scientific questions and be recognized as potential co-chief scientists. There are over 100 graduate student and early career women with shipboard scientific drilling experience who should be encouraged to take a leadership role in planning the future of scientific ocean drilling.

SUMMARY

The twenty-first century has seen women oceanographers assume several prominent roles in the scientific community, and there have been many firsts, with women receiving prestigious professional society award medals. However, the ocean sciences remain far from gender parity, especially when it comes to academic positions.

Several actions can be taken to reach gender parity. PhD advisors need to make sure that female students are mentored so that they will learn the skills needed to assume

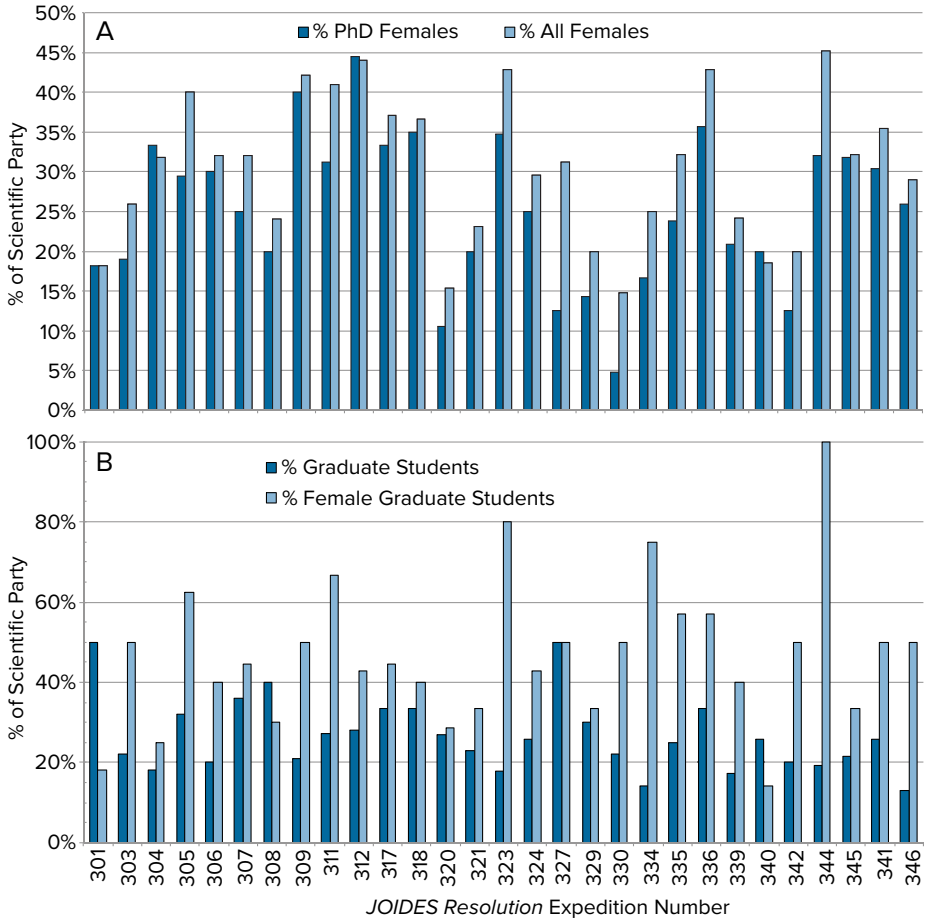

Figure 7. (A) Percentages of women in *JOIDES Resolution* scientific parties by expedition as a percentage of non-students (e.g., participants with PhDs) and as a percentage of the total party including female graduate students. Integrated Ocean Drilling Program (IODP) Expedition 301 sailed from June 27–August 21, 2004, and Expedition 346 sailed from July 29–September 27, 2013. (B) Percentages of graduate students in *JOIDES Resolution* scientific parties by expedition and percentages of graduate students who are women.

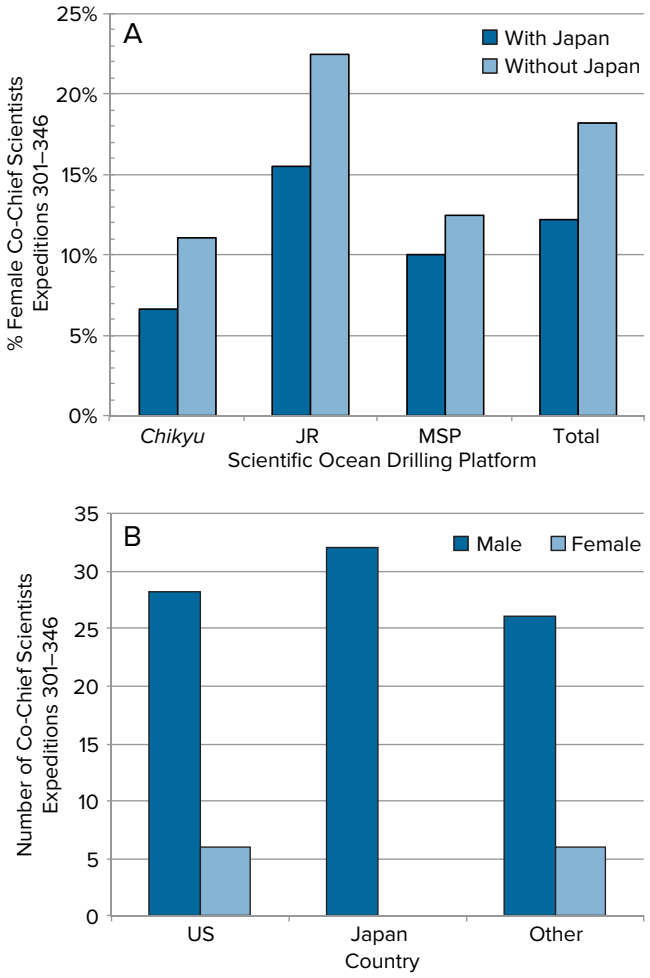

Figure 8. (A) Percentages of female co-chief scientists on IODP Expeditions 301–346 (June 2004–September 2013) by platform and percentages of female co-chief scientists by platform when Japanese co-chief scientists are not included. (B) Numbers of male and female co-chief scientists on IODP Expeditions 301–346 by country (June 2004-September 2013). Drilling components that make up the IODP platforms: *Chikyu* = Japanese riser drilling vessel. JR = US-operated drillship *JOIDES Resolution*. MSP = Mission Specific Platforms operated by a European science consortium.

leadership positions in the ocean sciences. Both men and women on academic search committees should be educated about gender-implicit associations and the resulting gender bias (Moss-Racusin et al., 2012) and be aware of specific strategies to reduce gender bias (Holmes et al., 2015). Once women enter the academy, departments and administrations should follow the many practices developed through the NSF ADVANCE program to retain and promote their female faculty. With so many female EAOS PhD recipients, meeting the challenge of gender parity within the next half decade can be accomplished. It is an exciting time to be involved in oceanography, and women will be equal participants.

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