

THE NSF GRADUATE FELLOWSHIP PROGRAM

AN ANALYSIS OF AWARDS IN THE OCEAN SCIENCES BY GENDER AND CAREER STAGE, 1996–2021

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ABSTRACT. The information published annually by the National Science Foundation on its Graduate Research Fellowship Program (GRFP) awardees was used to create an Awardees in Ocean Sciences (AOS) data set. This data set shows that women have been successful in receiving the fellowship award in the ocean sciences, receiving an overall 69% of the awards from 1996 through 2021 (458 women among 659 awardees). Women comprised at least 50% of awardees in the six ocean sciences disciplines listed as GRFP subfields of study. The highest percentages of awards to women (72%) were in biological oceanography and marine geology/geophysics, followed by marine biology and chemical oceanography (69%), physical oceanography (67%), and ocean engineering (61%). Women were successful both as undergraduate applicants (69% of undergraduate awardees) and as graduate applicants (71% of graduate awardees). We estimate that GRFP women awardees made up 17.8% of the women obtaining doctoral degrees in oceanography from 2017 to 2021, compared with GRFP men awardees comprising 8.5% of the male doctoral recipients for the same period. Our analysis suggests future directions for study of GRFP awardees and highlights the need for data that would help inform community outreach to underserved student populations.

INTRODUCTION

The global competitiveness of the United States in the twenty-first century depends on the readiness of the nation's STEM workforce. Investment in the development of future generations of researchers and a scientifically skilled workforce is a critical piece of the framework needed to achieve this national goal. The US National Academies of Sciences, Engineering and Medicine (NASEM) report on *Graduate STEM Education for the 21st Century* (NASEM, 2018) points out that engaging and educating a diverse pool of young women and minorities

in STEM is the first step toward achieving gender and racial parity, an important part of efforts to develop the nation's STEM workforce.

As the United States deals with the challenge of climate change, a diverse and well-educated workforce in the geosciences (including geological and Earth sciences, atmospheric sciences and meteorology, and ocean sciences) is especially critical. Recent National Center for Science and Engineering Statistics (NCSES) data for women in this workforce segment indicate that the percent of doctoral degrees awarded in

Earth, atmospheric, and ocean sciences to women US citizens and permanent residents has increased from 39% in 2008 to 49% in 2018 (NCSES, 2021a, Table 7.5). In 2018, 48% of the 9,652 US citizen and permanent resident graduate students in these fields were women (NCSES, 2021a, Table 3-1).

The outlook for women in the ocean sciences is more encouraging than for the atmospheric and Earth sciences. In 2018, women earned a greater percentage of master's and bachelor's degrees awarded in the ocean sciences (60% of both master's and bachelor's degrees) than in the atmospheric sciences (38% and 34% of master's and bachelor's degrees, respectively) and in the Earth sciences (43% and 38% of master's and bachelor's degrees (NCSES 2021a, Tables 6.2 and 5.3). Looking specifically at graduate programs in the ocean sciences, biennial survey data collected by the Consortium for Ocean Leadership¹ (COL; Cook et al., 2016; COL, 2020) suggest that member institutions with graduate programs in the ocean sciences are doing reasonably well in admitting and graduating women ocean scientists. Since the mid-1980s, the percentage of women applying to and enrolling in the Consortium's graduate programs increased from less than 30%

¹ The Consortium for Ocean Leadership (COL) has periodically surveyed its member institutions since 1978. Recent demographic data on students and faculty can be found at <https://oceanleadership.org/understanding/oser/>. These data are reported as percentages because the number of programs completing surveys varies from year to year. This number has ranged from 19 in the 2016–2017 survey to 37 in 2014–2015 and 2015–2016, with 22 COL members responding in the most recent 2019–2020 survey. The acronym OSER stands for the Ocean Science Educators Retreat and refers to the group of relevant COL members that meets every two years to discuss the data that have been collected.

in the 1986/1987 survey to above 53% by 2015 (Cook et al., 2016). Enrollment increased to 62% in 2019–2020 (COL, 2020, Figures 25 and 26). By 2020, women had achieved gender parity in the percentages of PhDs awarded by member institutions (COL, 2020, Figure 28).

For women climbing the academic career ladder, the Consortium's faculty surveys show that women have made significant progress in the last five years. In 2014–2015, men were about twice as likely to be represented as women in the ranks of pre-tenured faculty at COL institutions. The differential was even greater for tenured faculty: three to four times more men were granted tenure than women (Cook et al., 2016). The current reality is more encouraging; between the 2014–2015 and 2019–2020 COL surveys, the OSER graph shows a 5% increase in the percentage of women in tenured positions and a larger increase (about 10%) in the number of tenure track women (COL, 2020, Figure 30). In addition, Lima and Rheuban (2021) report that overall funding from the National Science Foundation (NSF) Division of Ocean Sciences (OCE) for women PIs and co-PIs increased significantly from 1997 to 2019, although parity with men has not yet been achieved.

The Federal Role

Federal government investment is key to the development of a competitive STEM workforce. Federal graduate fellowship programs such as NSF's Graduate Research Fellowship Program (GRFP) can foster gender and racial equity in STEM by providing support for talented young women and minorities at the beginnings of their careers. NSF awards GRFP fellowships directly to applicants who are undergraduate seniors or graduate students in the first or second years of their graduate programs. GRFP awardees are selected in a national yearly competition from a large pool (12,900 in 2020) of US citizens, permanent residents, and nationals who apply from all over the United States, its territories, and possessions, including the Commonwealth of

Puerto Rico and Guam.

GRFP fellowships have the potential to offer a better way to advance women and minorities than other federal support mechanisms for graduate students (research assistantships, traineeships). One reason for this is NSF's merit review process for selecting awardees. The reviewers are independent individuals who provide a service to NSF. They are trained to avoid gender and racial bias, and they assess applications using NSF's merit review criteria of Intellectual Merit and Broader Impacts. Holistic assessment by impartial reviewers, including evaluation of individual competencies, experiences, and other attributes, helps GRFP recruit and retain a diverse cohort of early career individuals with high potential. In addition, the fellowship's prestige, and NSF's acknowledgment of the awardees' potential for contributing to science and engineering, are important affirmations for students from underrepresented groups.

Because GRFP fellowships support individuals and not research projects, recipients have the flexibility and freedom to align their graduate work with their own interests and career choices rather than being constrained by the research interests and funding of their faculty advisors (Muller-Parker et al., 2020). Clear evidence that the program has been successful in recruiting and supporting more women and minorities overall can be found in NSF's most recent GRFP Evaluation Report. Among GRFP fellows completing PhDs in science and engineering, there were proportionally more women and individuals from underrepresented groups than in the national population of PhD recipients in STEM fields (NSF, 2014).

In disciplinary areas such as the ocean sciences, career opportunities are shifting away from a narrow set of research-focused university positions and employment at ocean research institutions toward a broader mix of options (Briscoe et al., 2016). In this context, the freedom that the GRFP program provides its recipients

to explore individual interests in graduate school and pursue a diversity of career pathways may be especially important. According to Hotaling and Spinrad (2021), such changes (in both individual educational pathways *and* the structure of graduate programs) are needed to help the United States meet the workforce needs of the emerging twenty-first century "blue economy" (NOAA, 2021) as well as the broader societal challenges that we face on a rapidly warming planet.

In this paper, we use public NSF GRFP awardee data to address the overarching question: How successful is the GRFP in offering support to women to begin their careers in the ocean sciences? We were not able to address this question for other demographic categories, including minorities, persons with disabilities, and veterans, because this information is not publicly available and is not easily derived for GRFP awardees.

We address this question by breaking it down into four more-detailed questions:

1. Has the number of GRFP awardees in the ocean sciences changed over time, and how have the awardees been distributed by gender?
2. Are there differences in the number of awards given to women and men in the GRFP ocean sciences subfields of study (marine biology; biological, chemical, and physical oceanography; marine geology and geophysics; and ocean engineering)?
3. Are there gender differences in the career stage (undergraduate or graduate) of ocean sciences awardees?
4. How do gender patterns for the ocean sciences compare with data for GRFP recipients as a whole?

To answer these questions, we downloaded publicly available information from the NSF website (<https://www.research.gov/grfp/Login.do>) and created a GRFP Awardees in Ocean Science (AOS) data set that we use to analyze and report on gender patterns over time and for specific subfields of ocean sciences.

NSF'S GRFP FROM AN OCEAN SCIENCE PERSPECTIVE

Public Information about GRFP Awardees

NSF publishes lists of Fellowship and Honorable Mention² recipients on the GRFP Module at <https://www.research.gov/grfp/Login.do> in early April of each year. The information includes name (first, middle, and last), baccalaureate institution, field of study,³ and current institution (the undergraduate or graduate institution of an enrolled student applicant at the time of GRFP application submission, if any). Field of study and current institution may be used to identify awardees in the ocean sciences planning to attend graduate school and those already enrolled in graduate school. Names can serve as a proxy for identifying women and men.

The Awardees in Ocean Science Data Set

Our AOS data set contains information on 659 awardees from 1996 through 2021. To create the data set, we downloaded the awardee data for each year

from 1996 through 2021 for the following GRFP subfields of study: biological oceanography, chemical oceanography, marine biology, marine geology and geophysics, marine sciences (listed as a subfield from 1991 through 1997), ocean engineering, oceanography, and physical oceanography. In addition, eight individuals listed the following ocean-related disciplines as “Other”: paleoceanography, applied marine ecology and economics, naval architecture and marine engineering, coastal geology, coastal geomorphology, marine biogeochemistry, and applied ocean science.⁴ These awardees were included and are grouped with the awardees in the closest GRFP subfield. All GRFP ocean sciences subfields of study are currently classified under the GRFP Major Field of Study of Geosciences except for ocean engineering (an Engineering GRFP subfield). Biological oceanography and marine biology were subfields of the GRFP Major Field of Study Life Sciences through 2011.⁵

Because some of the individuals in our data set may have declined⁶ the award and did not become fellows, we refer to

awardees and not to fellows in this paper. For the 515 most recent awardees from 2005 through 2021, the database contains complete information on awardee name, baccalaureate institution, field of study, and current institution. NSF does not provide public data on current institution for the GRFP awardees from 1996 to 2005, so we do not have this information in our data set for 144 awardees. We did not include data for GRFP awardees from 1952 through 1995 because we discovered major omissions for the field of study and institutional affiliations of GRFP awardees for those years.

We assigned gender for each awardee using their first and middle names. For individuals with ambiguous names, online searches were used to assign gender. The method is limited in that binary gender identities based on names, pronouns, photos, and social media profiles may have been assigned to individuals with non-binary gender identities. The data set was standardized by making each institution's name consistent across all awardees and years. We determined the state (if US) for each baccalaureate and current (undergraduate or graduate) institution and added this information to the data set.

To identify the career stage (undergraduate or graduate) of the 515 awardees from 2005 through 2021, we used a multi-step process starting with a comparison of the baccalaureate institution and current institution for each individual and progressing to Google and LinkedIn searches on the names and disciplinary areas of a subset of awardees. The goal was to create two categories of awardees: (1) those who were graduate students when they applied, and (2) those who were either enrolled undergraduates when they applied or who applied for the program

BOX 1. USING GRFP DATA TO MOVE BEYOND GENDER

A review of our AOS data set suggests that the GRFP could be a valuable tool for helping administrators of ocean-focused graduate programs recruit a greater number of talented students from Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), and other institutions with diverse student enrollments. From 1996 through 2013, our AOS data set does not list any awards to students from HBCUs and TCUs. From 2014 through 2022, however, nine awards were made to students who had attended, or were attending at the time of the award, five HBCUs, and one award was made to a student at a TCU. Eight of these 10 awards were to women. The 10 awardees were 3.2% of the 317 ocean sciences awardees from 2014 to 2022. Although this percentage is low, it is higher than that for all awardees from HBCUs and TCUs for this nine-year period (0.9% of 18,669 awardees). Efforts to provide programmatic support for undergraduate research experiences and for the fellowship application process could result in more students at minority-serving institutions applying to graduate programs in the ocean sciences. If more of the talented undergraduates at such institutions learn about GRFP from graduate program recruiters, recognize its value, and apply for fellowships, such expanded outreach should help the ocean sciences do a better job attracting and retaining a greater diversity of ocean science professionals than is currently the case.

² NSF accords Honorable Mention to meritorious applicants who do not receive fellowship offers.

³ Selection of a GRFP Major Field of Study (as defined in the Appendix to the GRFP Solicitation) determines the application deadline, the disciplinary expertise of the reviewers, and the discipline of the graduate program if the fellowship is accepted (NSF, 2022).

⁴ The “Other” subfield category is selected by the applicant only if the proposed subfield is not covered by one of the listed GRFP subfields. Marine topics under “Other” were subfields of three Major GRFP Fields of Study: Geosciences, Engineering, and Life Sciences.

⁵ The GRFP Major Fields of Study are independent subject lists. In most cases, they existed before the NSF research directorates were created. The move of two subfields, biological oceanography and marine biology, from Life Sciences to Geosciences was done to better align the GRFP Major Fields of Study with the disciplines of the NSF directorates.

⁶ The public awardee lists include the fellowship offers. NSF does not adjust the public awardee lists for any fellowship declinations.

after they graduated and before they entered a graduate program. We termed the undergraduate/post baccalaureate awardees “the undergraduate pool” (see Methods in the online supplementary materials for details about how individuals were assigned to these two categories).

For the 515 awardees with baccalaureate and current institutions listed, a total of 230 (45%) were considered undergraduates, and a total of 285 (55%) were considered graduate students when they applied.

WHAT WE LEARNED

Overall Characteristics of the General Population of Ocean Sciences GRFP Awardees

From 1996 through 2021, the 659 ocean sciences awardees in the AOS data set attended 223 baccalaureate institutions. As noted above, the NSF data from 1996 through 2005 lacks information about current institutions. From 2005 through 2021, the subset of 515 awardees (78% of the total) attended 195 baccalaureate and 113 current institutions. These 515 awardees were concentrated in several coastal states. California had the highest percentage of awardees who obtained their baccalaureate degrees in the state, as well as the highest percentage of awardees attending graduate institutions in the state. Twenty-three percent of the total (2005–2021) awardees’ baccalaureate institutions are in California, 8% in Massachusetts, 7% in New York, and 6% in Florida. Of the awardees in graduate school, 40% attended institutions in California, followed by 15% in Massachusetts, 11% in Washington, and 7% in Oregon.

Gender Patterns in the Awardees in Ocean Science Data Set (1996–2021)

QUESTION 1. Has the number of GRFP awardees in the ocean sciences changed over time, and how have they been distributed by gender?

In the 26 years since 1996, the overall number of awards in the ocean sciences has increased significantly (Figure 1,

$r^2 = 0.513$, $p < 0.001$) with a low of eight awards in 2000 and a high of 45 in 2016. The increased number of awards (44) in 2009 represents investments of American Recovery and Reinvestment Act (ARRA) funds in GRFP fellowships, while increases starting in 2010 resulted from the doubling in the number of all GRFP awards. During this time, the majority of GRFP awards in ocean science fields were given to women (69% of all awards; $N = 659$). In all but one year (2001), women received at least 50% of the awards. There was no change in the percentage of awards to women (conversely, to men) over this period (Figure 1; $r^2 = 0.048$ for both, $p > 0.05$).

QUESTION 2. Are there differences in the number of awards given to women and men in the GRFP ocean sciences subfields of study (marine biology; biological, chemical, and physical oceanography; marine geology and geophysics; and ocean engineering)?

Table 1 shows the total number of GRFP awardees and the number of awards to women and men in each of the GRFP ocean sciences subfields of study from 1996 through 2021. Women represented over 50% of the awardees in each sub-

field, and overall were 69% of the total awardees. Biological oceanography and marine geology/geophysics had the highest percentage of awards to women (72%), followed by marine biology and chemical oceanography (69%), physical oceanography (67%), and ocean engineering (61%).

To examine the distribution of awards by gender over time, we calculated the percentage of women and men awardees for the subfields of study in five-year cohorts from 1996 through 2021, except for the single year of 2021 (Figure 2). In working with time-series percentage data that contain very small numbers of observations or individuals each year, it is common practice to group data into multiyear cohorts to increase the number of cases on which each percentage is based. Awardees who specified their field as “oceanography” were added to the physical oceanography group. The seven awardees from 1996 and 1997 who specified their field as “marine science” were not included in this analysis.

The percentage of awards to women was greater than parity for all five-year cohorts for biological oceanography and marine biology, at parity or greater for marine geology and geophysics and

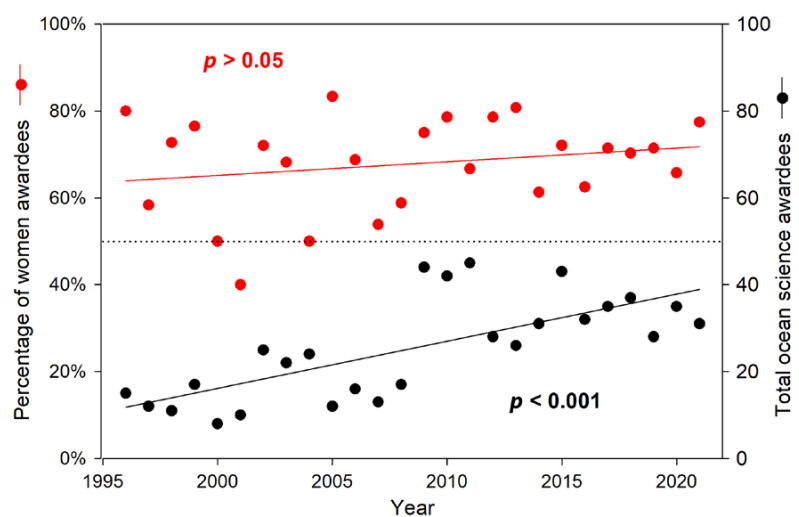


FIGURE 1. National Science Foundation (NSF) Graduate Research Fellowship Program (GRFP) awardees in the ocean sciences from 1996 through 2021. The black symbols indicate the total number of awardees, and the percentage of women awardees is indicated by red symbols. The black dotted line represents 50% (for percentage of women awardees) and 50 (for total ocean science awardees). Linear regression lines and the significance of the regressions are given for each plot.

ocean engineering, and at parity or greater except for one five-year cohort (2001–2005) for chemical oceanography and physical oceanography (Figure 2; data are available in Table S1 in the online supplementary materials).

QUESTION 3. Are there gender differences in the career stages (undergraduate or graduate) of the ocean sciences awardees?

Prior to 2005, the lack of GRFP data on current institution did not allow

us to distinguish between undergraduate and graduate student awardees. Figure 3a shows the data for undergraduates between 2005 and 2021. During this period, women were at least 57% of the total undergraduate awardee pool during every year except for 2008, when their percentage was 43%. In 2005 and 2006 the total awards going to undergraduates was small (four awards in 2005 and two in 2006) and all went to women. Averaged over this entire period, 69% of the GRFP awards to undergraduates went to women. There was no overall change in the percentage of women undergraduate awardees from 2005 to 2021 ($p > 0.05$).

The percentage of women graduate students who received GRFP awards in the ocean sciences during this period (Figure 3b) shows a similar pattern. The percentage of women graduate awardees exceeded 50% in every year except 2007. Overall, 71% of the graduate student awardees were women, close to the value for women undergraduate awardees (69%). As with the undergraduate awardees, there was no significant change in percentage of women receiving GRFP awards during this period ($p > 0.05$).

TABLE 1. Number (and percent) of GRFP awardees in each of the ocean science related GRFP subfields of study over 26 years (1996–2021).

GRFP SUBFIELD OF STUDY	TOTAL GRFP AWARDS (1996–2021)		NUMBER OF AWARDS BY GENDER	PERCENTAGE OF AWARDS BY GENDER
Biological Oceanography	149	Women	108	72%
		Men	41	28%
Chemical Oceanography	88	Women	61	69%
		Men	27	31%
Marine Biology	275	Women	191	69%
		Men	84	31%
Marine Geology and Geophysics	36	Women	26	72%
		Men	10	28%
Marine Sciences (1996, 1997)	7	Women	4	57%
		Men	3	43%
Ocean Engineering	41	Women	25	61%
		Men	16	39%
Physical Oceanography	49	Women	33	67%
		Men	16	33%
Oceanography	14	Women	10	71%
		Men	4	29%
Grand Total	659	Women	458	69%
		Men	201	31%

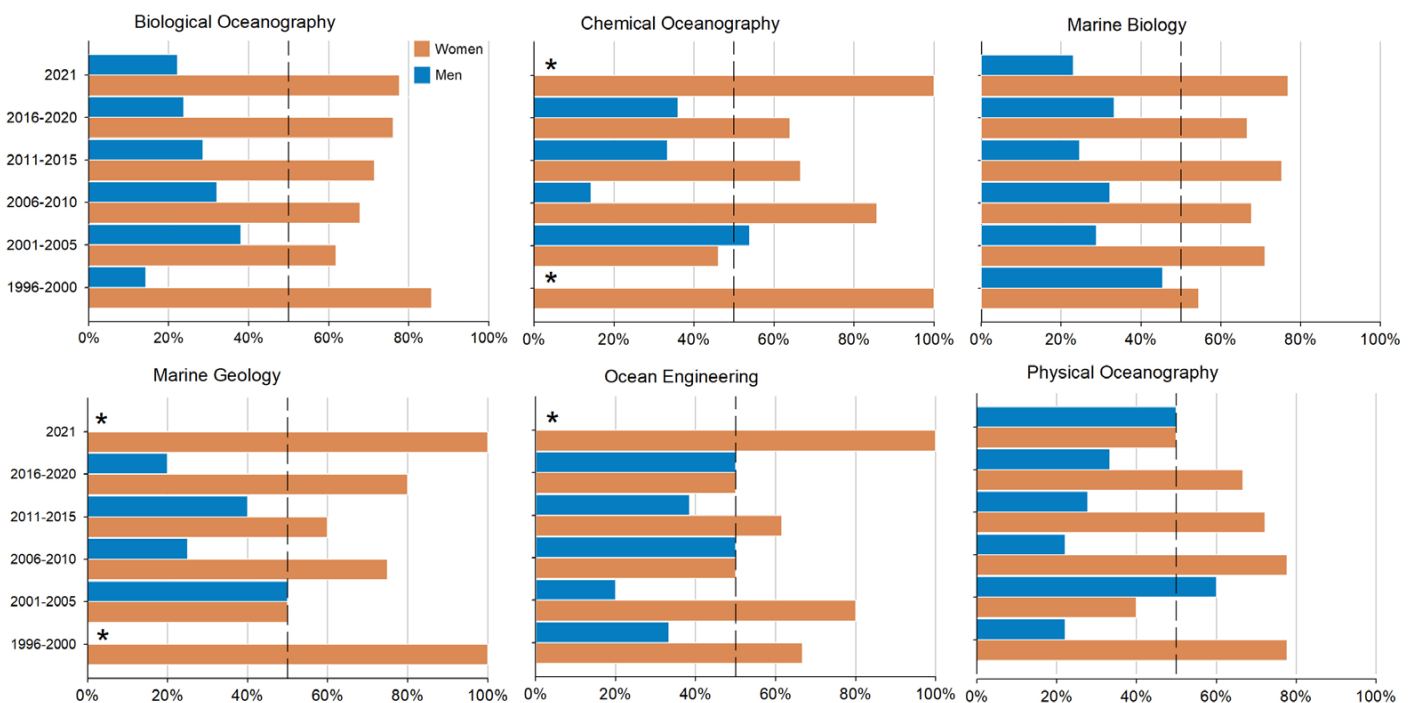


FIGURE 2. The percentage of GRFP awards in ocean sciences disciplines to women and men (1996–2021) in five-year cohorts; 2021 is a sole data point representing that year. Asterisks (*) indicate zero values. Dashed lines represent the 50% level.

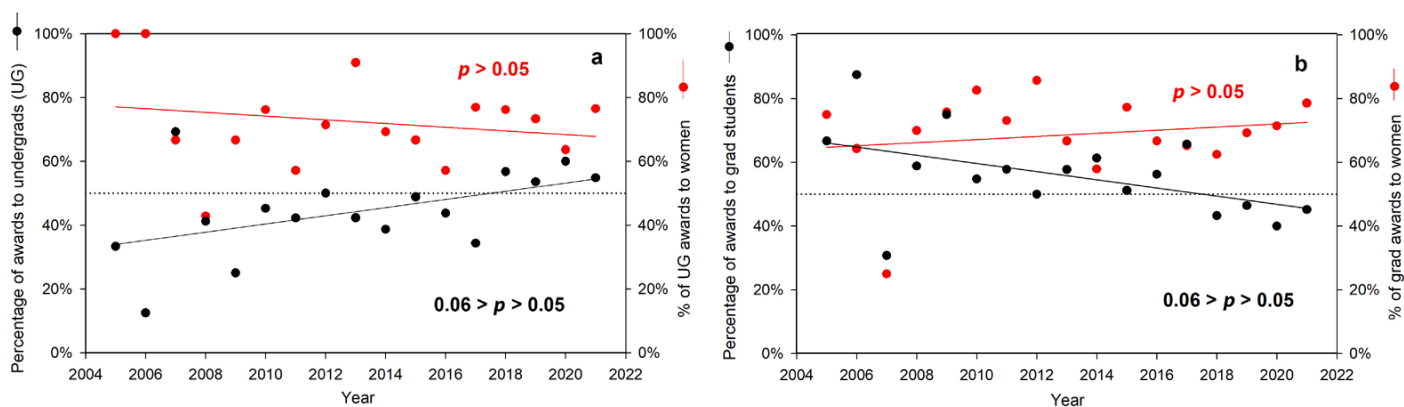


FIGURE 3. Undergraduate and graduate GRFP awardees in ocean sciences, and the percentages of awardees who were women in each group. (a) Percentage of undergraduate awardees and the percentage of women in this group. (b) Percentage of ocean sciences awards to graduate students and the percentage of awards to women in this group. Least squares regression lines and the significance of each regression are given for each plot. Dotted lines represent 50% levels.

Examining the career stage (undergraduate vs. graduate student) of awardees over this period, from 2008 to 2017 the undergraduate share of the awards dropped and remained below or just at 50% with a low of 13% in 2006 (Figure 3a). The exception was in 2007, with a high of 69% of awards to undergraduates. The yearly mean of ocean science GRFP awards to undergraduates over the 2005–2021 period was 13.5 ± 5.8 ($\bar{x} \pm \text{sd}$), while that for graduate students was 16.8 ± 7.0 . However, this difference is not significant (two-sample *t*-test, $p > 0.05$). The data in Figure 3a,b suggest that there has been an increase in the percentage of awards to undergraduates over the entire period, but this is only marginally significant ($0.05 < p < 0.06$). From 2018 to 2021, 57% of the awards went to undergraduates. This increase may be associated with a GRFP eligibility change for graduate students, effective with the 2017 competition, that restricts the number of times that they can apply for the fellowship (NSF, 2016). This change in eligibility and the recent trend in awards to undergraduates suggest that more ocean science GRFP awards will be made to undergraduates in the future.

QUESTION 4. How do gender patterns for ocean sciences awardees compare with data for GRFP recipients as a whole? NSF does not provide the public with access to regular data on the proportion

of GRFP awards to women, or any information about the career stage and demographic composition of individual awardees, either overall or by field of study. The only public data are those provided in NSF news releases that are published at irregular intervals. The most recent GRFP NSF news release (NSF, 2018) includes the following numbers for 2,000 awardees (in all fields) in 2018: 1,156 women (58%), 461 members of underrepresented groups (23%), and 780 undergraduates (39% of the awardees). In contrast, 70% of ocean sciences awards in 2018 were given to women (Figure 1). Ocean sciences awardees also represented a higher percentage of undergraduates (57% in 2018) than the percentage of undergraduate awardees across all fields in 2018 (39%).

DISCUSSION

How Has NSF's GRFP Contributed to the Representation of Women in the Ocean Sciences?

Effect on Gender Parity for AOS Awardees

The GRFP has been quite successful in offering support to women as they begin their careers in the ocean sciences. Our analysis shows that over the past 26 years the program has made 458 awards to women seeking to enter ocean focused graduate programs, in contrast to the 201 awards offered to men. Parity or greater has been achieved in nearly all cases of

awards among the five GRFP ocean sciences subfields of geosciences and the one subfield of engineering, and the proportion of women is similar for both undergraduate and graduate awardees.

Although women awardees predominated in the six GRFP subfields of study that we examined (Figure 2), the data suggest that subtle differences exist across disciplines. On average, the highest percentages of women were awardees in biological oceanography and marine geology/geophysics (72%), with slightly lower percentages for marine biology and chemical oceanography (69%), and physical oceanography (67%); the lowest percentage of women awardees (61%) was in ocean engineering (Table S1). However, this percentage is much greater than that of women graduate students who were US citizens and permanent residents in engineering fields in 2018 (25%; 19,320 of 76,770; NCSSES, 2021a, Table 3-1).

To what extent is the greater representation of women in our data set a function of “proposal pressure” (i.e., do more women submit GRFP applications than men?). Currently, it is not possible to answer this question because NSF does not provide information to the public on annual application numbers—either overall numbers or data disaggregated by gender. The gender ratios in Ocean Leadership’s OSER data on graduate program application rates (COL, 2020, Figure 25) indicate that, in this

population at least, women apply to programs at a higher rate than men. However, the extent to which this community pattern applies to the GRFP is not known.

Contribution to Gender Patterns for Ocean-Focused Doctoral Recipients

To what extent do GRFP women awardees contribute to the pool of ocean-focused⁷ doctoral recipients in the NCSSES Survey of Earned Doctorates? To approach this question, we used internet data (LinkedIn, Dissertation Abstracts, other sources) to determine how many awardees (women, men, total) from the 1996–2000 AOS cohort completed doctoral programs and how many did not and used these data to calculate the percent completion for this cohort. Next, we used these values to estimate the number of awardees in the 2011–2015 GRFP cohort who completed their degrees. And finally, to estimate the proportion of ocean science doctorates who were GRFP awardees, we used this number to calculate the percentage of GRFP awardees in the total number of ocean science doctorates reported in the NCSSES survey of earned doctorates for 2017–2020 (NCSSES, 2021b). These calculations are summarized in **Table S2**.

There are two reasons for using the

1996–2000 cohort in these calculations. One is to ensure that awardees who may take a longer than average time to complete their degrees were not excluded from our analysis. This practice follows the time frames used to derive PhD completion rates for fellows in the last two evaluations of GRFP (NSF, 2002: 11 years; NSF, 2014: 10 years). The second reason is that the number of awardees in this cohort (63) was small enough to be manageable and large enough to provide a reasonably robust estimate of degree completion.

In this early cohort (1996–2000; **Table S2**), we determined that 75.7% of the women awardees in biological oceanography, marine biology, chemical oceanography, physical oceanography, and oceanography completed their doctorates. Men GRFP awardees had similar percentages for PhD completion (75.0%).⁸ For both women and men awardees in the 1996–2000 cohort, the length of time between the year the doctorate was received and the year the GRFP was awarded averaged about six years. Because of the large number of women awardees, more than twice as many women as men in this cohort completed PhDs (**Table S2**).

In the second step of this analysis, we

applied our PhD completion percentages for women and men to our 2011–2015 cohort (**Table S1**), excluding ocean engineering awardees and awardees in marine geology/geophysics for the reason noted above. We predict that 82 (out of 109) women and 30 (out of 40) men awardees in this cohort are likely to have completed their doctorates (**Table S2**) between 2017 and 2021.

Finally, we compared these estimated doctoral completion numbers for the 2011–2015 cohort to the doctoral award numbers reported by NCSSES for marine biology and biological, chemical, and physical oceanography for both women and men in 2017–2020 (and estimated for 2021; see **Table S2** for full details). Of the total of 459 women and 353 men doctoral recipients, we estimate that GRFP women awardees made up 17.8% of the women obtaining degrees from 2017 to 2021, compared with GRFP men awardees comprising 8.5% of the men for the same period.⁹ In this last step of our doctoral pool contribution estimation, we assume that all of the 2011–2015 awardees who earned a doctorate received their degrees from 2017 to 2021.

This analysis indicates that GRFP has made and will continue to make a significant contribution to doctoral gender patterns in the ocean sciences. In the most recent NCSSES surveys (2017–2020), women obtained 63% of the doctoral degrees awarded in marine biology and biological oceanography and 50% of the doctoral degrees awarded in chemical oceanography and physical oceanography. These percentages of women doctorate recipients are lower than the overall (1996–2021) percentages of GRFP awards to women in these subfields (71% of awards in marine biology and biological oceanography; 69% of

BOX 2. WANTED: GRFP DATA FROM NSF

If NSF shared annual data about the demographics of GRFP applicants and awardees, such information would provide greater accountability and transparency for this large program as well as inform community outreach. Although we believe our approach could be a useful model for our community, and for scientists in other STEM disciplines who wish to examine data on gender parity and assess the investment that the GRFP makes to graduate education in their fields, such laborious and time-consuming analyses would not be necessary if NSF provided annual data. GRFP data could be reported to the National Science Board for inclusion in its annual Merit Review Report¹⁰ to the public as an indicator of agency investment in developing STEM talent for America. The data could be disaggregated by both discipline and demographic category (women, men, veterans, the disabled and underrepresented groups, such as American Indian/Alaska Native, Black/African American, Hispanic or Latino, and Native Hawaiian/Pacific Islanders).

⁷ Throughout this analysis, our calculations exclude awardees who list their disciplines as ocean engineering and marine geology in their applications. We have done this because the earned doctorate data collected by the NCSSES for the ocean sciences do not include these ocean science subdisciplines.

⁸ As a spot check on the temporal stability of our completion percentage metric, we did an internet search to examine the completion percentage for women awardees in 2011 and found that 75% of these awardees received their doctorates, a value almost identical to our 1996–2000 proportion.

⁹ The comparison has one caveat. The NCSSES data include non-US citizens and non-permanent residents, who are not eligible to apply to the GRFP.

¹⁰ Published annually since 1996, the NSF Merit Review Reports are available at <https://www.nsf.gov/nsb/publications/pubmeritreview.jsp>. Standard tables are updated with each year's merit review results for proposals submitted to NSF. The National Science Board uses the annual Merit Review Report (Digest) to ensure that NSF implements the merit review process with integrity and in a fair, competitive, and transparent manner.


awards in chemical and physical oceanography; data in [Table 1](#)). If a greater percentage of women GRFP awardees continues to enter the doctoral pool, this should help maintain and potentially increase representation of women in ocean science-related fields.

What Happens to GRFP Awardees in Ocean Sciences After They Leave Graduate School?

How successful are GRFP ocean science awardees in their careers after graduate school? Are GRFP-supported women more likely than GRFP men and non-fellowship recipients to enter and succeed in academic and research positions? We know of no data that relate to these questions for the ocean sciences. In their summary of NSF (2014) evaluation findings based on surveys of GRFP fellows from all disciplines and both genders, Le and Bartolone (2015) report that fellows were more likely than the national population of PhD recipients to be employed in higher education institutions and to report research and development and teaching as primary work activities.

One measure of success is the ability to secure extramural funding for research activities. In Lima and Rheuban's (2021) comprehensive study of research awards made by NSF OCE since 1987, women PIs and co-PIs have become increasingly successful in obtaining funding. Looking at outcomes for OCE's five research-focused programs, women have been most successful in competing for Biological Oceanography funding. Marine Geology and Geophysics, Chemical Oceanography, and the Ocean Drilling programs occupy an intermediate position, and Physical Oceanography is the lowest of the five disciplines in the representation of women PIs. As more GRFP women awardees (and more women PhDs in general) enter the ocean science-related workforce, these trends are likely to continue.

To assess the effect that the GRFP has had on the career outcomes of both men and women ocean scientists requires a

well-designed longitudinal study of the career trajectories and experiences of fellows. The results of such a study (including a focus on underrepresented minorities, veterans, and the disabled as well as gender) could help ocean science graduate program administrators evaluate the extent to which fellowships such as the GRFP are an effective way to support and develop a more diverse pool of talent for the twenty-first century blue economy workforce. 

SUPPLEMENTARY MATERIALS

The supplementary materials are available online at <https://doi.org/10.5670/oceanog.2022.212>.

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AUTHOR CONTRIBUTIONS

As co-first authors, Gisèle Muller-Parker and Susan B. Cook contributed equally to this work and are listed alphabetically. SBC conceived the original idea for this project. GMP acquired the data and created the AOS data set. SBC and GMP designed the research questions. CBC did the data analysis. The three of us worked together as a collaborative team to interpret the data and write the paper. All three authors have approved the submitted version.

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