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Frontiers in Reproduction (FIR): An Assessment of Success¹

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ABSTRACT

The Frontiers in Reproduction (FIR) course has been held annually since 1998 at the Marine Biological Laboratories in Woods Hole, MA. The primary purpose of the course is to train young reproductive biologists in cutting-edge techniques that would strengthen their career opportunities. An initial evaluation of the FIR course was conducted by surveying the participants who took the course between 1998 and 2002. The findings of this survey were published in *Biology of Reproduction* in 2006, which highlighted the overall positive impact the course had on the training and upward career trajectory of the participants during the first 5 yr. The current study was designed to access the continued impact of FIR at the 10-yr mark by evaluating the participants who took the course between 1998 and 2008 using two different survey mechanisms. Based on these evaluations and feedback from the participants, it was evident that 1) FIR continues to have a significant positive impact on the careers of the participants, 2) the majority of the participants continue to be involved in research or administration related to the reproductive sciences, 3) nearly 90% of the attendees have been successful in obtaining funding for their research, and 4) most alumni have published at least five manuscripts in higher impact journals since they took the course. Therefore, it is evident that FIR participants are highly successful and continue to significantly impact the advances in the reproductive sciences worldwide.

science education

INTRODUCTION

The Frontiers in Reproduction (FIR) course was conceived as a result of an international workshop sponsored by the Reproductive Sciences Network (RSA-NET) held in Mexico City in 1995. This workshop highlighted the need for a mentored research and training program in the reproductive sciences [1]. The report also highlighted that the continued limitation for funding training programs had impaired the ability to support the research career development of young investigators. FIR was established as a result of these discussions and meetings of leaders in the reproductive

sciences that lead to the first offering of the course in 1998 [1]. FIR has been offered annually since then and is now entering its 19th yr; it has 328 alumni worldwide. Research training in both animal and human reproductive biology has widespread implications for human health, and the National Institute of Child Health and Human Development has identified high-priority vision themes as they relate to reproductive health in humans, making the training offered at FIR indispensable for training the future leaders in the reproductive sciences.

FIR is a 6-wk laboratory and lecture course designed for scientists-in-training who seek to improve their knowledge and experimental skills in order to pursue a career in the reproductive sciences. It is held annually, usually from the end of April to the middle of June, at the Marine Biological Laboratory (MBL) in Woods Hole, MA (www.mbl.edu). Twenty participants (informally known as FIRbees) are selected each year from a competitive pool of applicants composed of graduate students, postdoctoral and clinical fellows, and junior faculty.

FIR is divided into three 2-wk sections. Each section consists of lectures, discussions, informal seminars, laboratory exercises, demonstrations, and one-on-one tutorials. Section 1 covers signal transduction as well as transcriptional and posttranscriptional regulation of gene expression in the hypothalamic-pituitary-gonadal axis. Section 2 covers gametogenesis, fertilization, cloning, and stem cells. Section 3 covers transgenic technology, development of the reproductive tract and implantation and placental biology. Within each section of the course, students are usually divided into smaller groups (four to five students/group) to maximize the hands-on laboratory experience. The number and type of laboratory exercises vary between different sections. Sometimes the students, guided by teaching assistants, follow typical laboratory protocols that allow them to learn a given technique or approach. Other times specialized techniques are introduced by an instructor and then are practiced by the students.

The course meets 6 days/wk, and a typical day begins at 0900 h with a 2-h lecture. After a brief break, FIRbees, faculty, and teaching assistants convene in the laboratory for an introduction to the day's experiments or to a specialized resource for technological and theoretical training in an emerging research approach. After lunch, FIRbees begin laboratory exercises, which usually last all afternoon. After a short break and dinner, a second 2-h lecture is usually scheduled at 1900 h. Following this evening lecture, the group reconvenes in the laboratory where they may continue their experiments late into the night. Laboratories are open 24 h/day and 7 days/wk, and it is not uncommon to find the majority of FIRbees and many faculty and staff members in the laboratory well past midnight. A more comprehensive description of the FIR course can be found on our web site (<http://www.mbl.edu/fir/>), and the complete schedule for each section of FIR2016 is available online (section 1: <https://fir.egnyte.com/dl/>)

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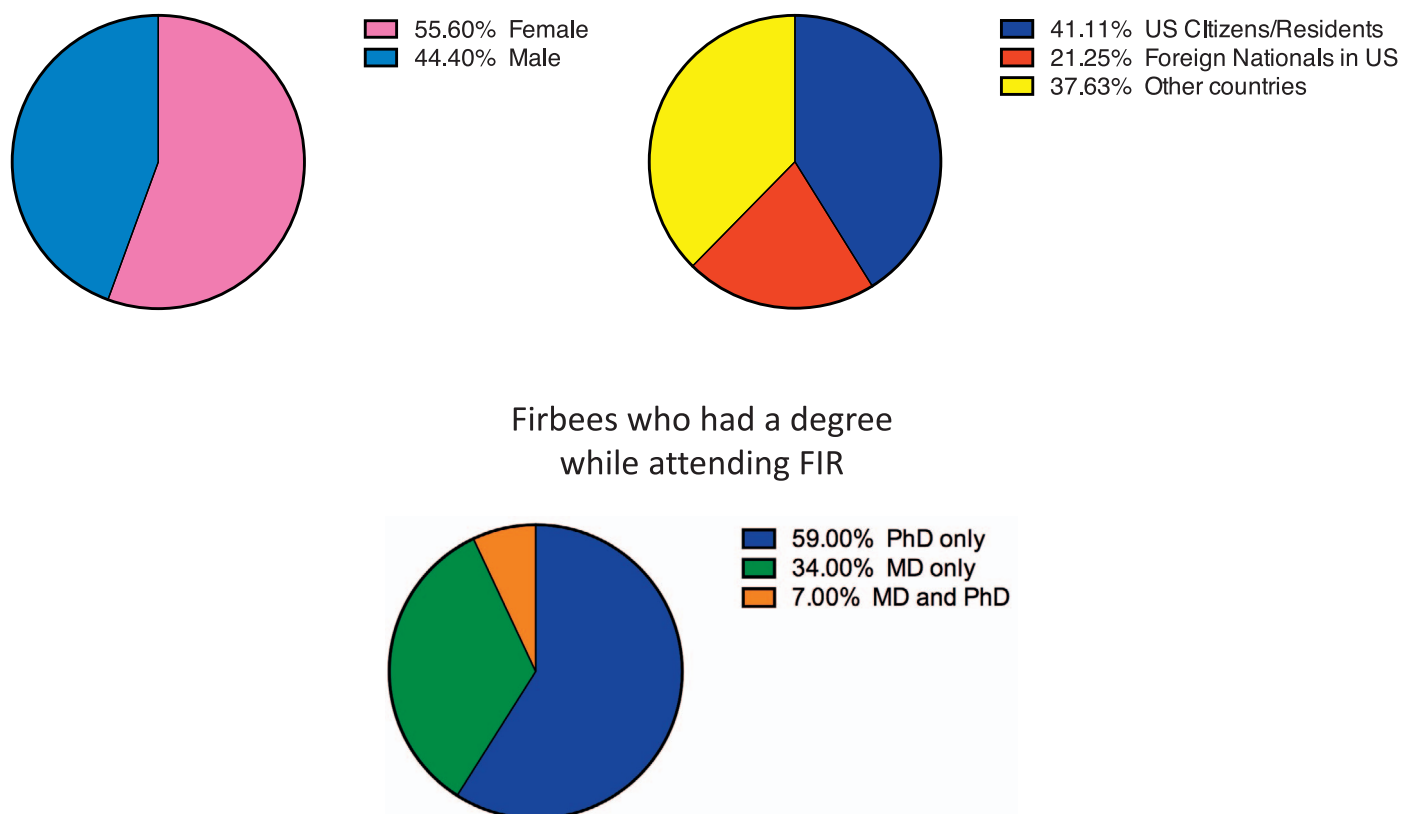


FIG. 1. Overall demographics of the 1998–2008 cohort of FIRbees based on the year they attended FIR.

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On a yearly basis, we currently have 50–60 faculty and 20–30 teaching assistants from about 20 different institutions in the United States and overseas. The faculty comes from many different institutions, and they are the leading experts in their fields. In addition, FIR faculty and FIRbees are free from other responsibilities found at home institutions, and their only commitment at FIR is to teach and to learn. Because faculty and students are housed on the MBL campus and they have their meals together, there are many opportunities for informal personal interactions. Such opportunities for intensive scientific and social exchanges with leading investigators are among the invaluable benefits of FIR, and many FIRbees cite this aspect of the course among the highlights of their FIR experience.

FIR closes with a 2-day symposium that features research presentations from the current class and selected FIRbees from previous years, along with additional distinguished guest speakers. This unique activity has proven to be an invaluable opportunity for the large community of FIRbees to meet each other, learn from each other, and establish scientific collaborations that would have been difficult to establish otherwise.

The involvement and passion of the faculty and FIRbees, the FIR symposium, the use of social media (such as Facebook and Twitter), and social gatherings at the annual meeting of the Society for the Study of Reproduction have also allowed us to form a worldwide community of FIRbees and maintain a reliable and robust database of contact information that we can use to conduct surveys to assess the success of the course. An initial survey was conducted in 2003 and included the 1998–2002 cohort of FIRbees and assessed the 5-yr impact of the course. The results of this survey were published in this journal

in 2006 [1]. Using a number of different criteria, this initial survey clearly documented that FIR had a positive influence on the training of reproductive scientists. In this paper, we present the combined results of two additional surveys conducted recently. The main objective of these studies was to determine to what extent FIR has achieved its goal of providing participants with the skills needed for conducting research in the reproductive sciences. The results obtained clearly show that FIR is accomplishing its goal of training the next generation of reproductive scientists.

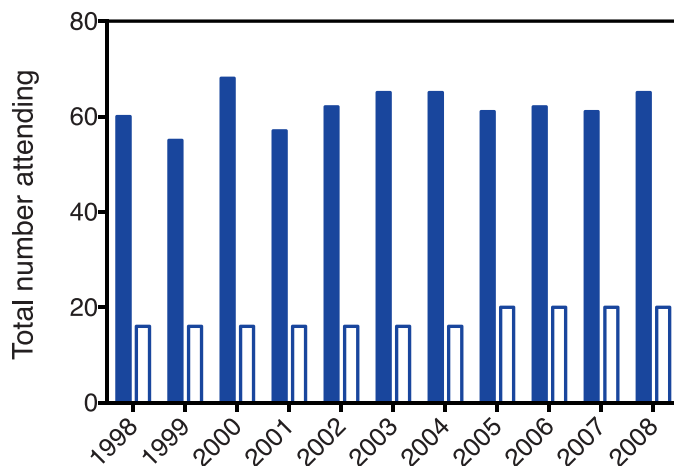


FIG. 2. The ratio of the number of faculty and students who participated in FIR between 1998 and 2008. The blue bars represent faculty plus teaching assistants, and the white bars represent students. Between 1998 and 2004, there were 16 students selected per year, which was increased to 20 in 2005.

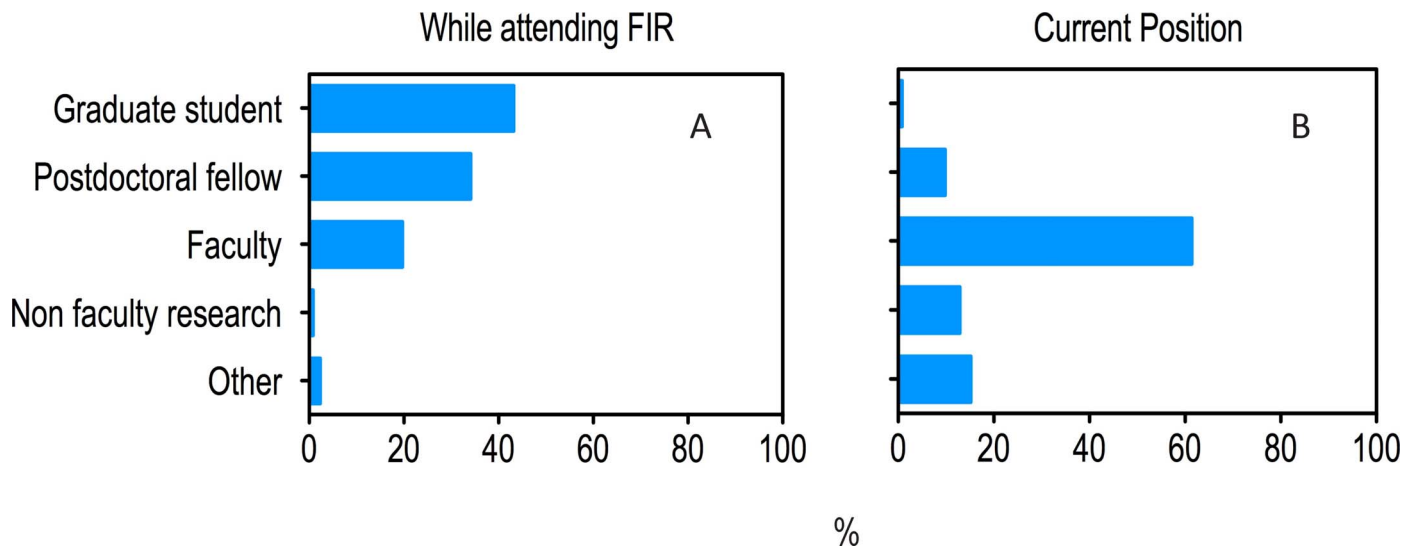


FIG. 3. The academic status of the 1998–2008 cohort of FIRbees in the year they attended FIR (A) and 5 yr later (B).

MATERIALS AND METHODS

Most of the data presented (Figs. 1–5 and 7) include FIRbees who took the course between 1998 and 2008. This survey was conducted in 2013 using an online tool where the FIRbees were asked to answer 10 simple questions. As part of this survey, we also used their names to interrogate PubMed to determine the number of FIRbees who had published a paper in 2013. The data presented in Table 1 and Figure 6, however, were obtained in 2011 and included only the FIRbees who took the course between 1998 and 2006. All the data generated for this survey was obtained using the names of the FIRbees to interrogate publicly available information in PubMed and the National Institutes of Health (NIH) Re-PORTER database. Information about the demographics of the FIRbees, faculty, and teaching assistants was obtained from our own records. This survey and analysis are exempt from institutional review board approval.

RESULTS

The main survey presented here was conducted in 2013 and included all FIRbees who had taken the course from its inception (1998) to 2008. The ending year of the cohort of FIRbees was chosen to be 5 yr prior to the survey's conduction to give at least a 5-yr window for the impact of the course on the careers of the FIRbees. To conduct this survey, we contacted the 192 individuals who took the course between 1998 and 2008. We were able to contact only 183 of these, and

we received 134 responses (73% response rate). The results presented in Table 1 and Figure 6 were obtained in 2011, however, and included only the 151 individuals who took the course between 1998 and 2006. Because this part of the survey was done exclusively using the names of the FIRbees to interrogate public databases, we were able to include all of them.

Demographics of the FIR Students and Faculty

The demographics of the 1998–2008 cohort of FIRbees are presented in Figure 1 and show that the majority of the FIRbees are female. About 60% of the FIRbees were U.S. citizens/residents or foreign nationals training in U.S. institutions. Regarding their career status, only about 60% of the FIRbees had graduate degrees (see below) because we accept graduate students, postdoctoral and clinical fellows, and faculty. Of those who have degrees, 59% had a Ph.D., 34% had an MD, and 7% had a combined (MD and Ph.D.) degree. Thus, the representation of clinician scientists was a healthy 41%. Lastly, about 10% of the FIRbees were members of an underrepresented minority group (not shown in the figure). All of these latter statistics have remained relatively constant since 2009

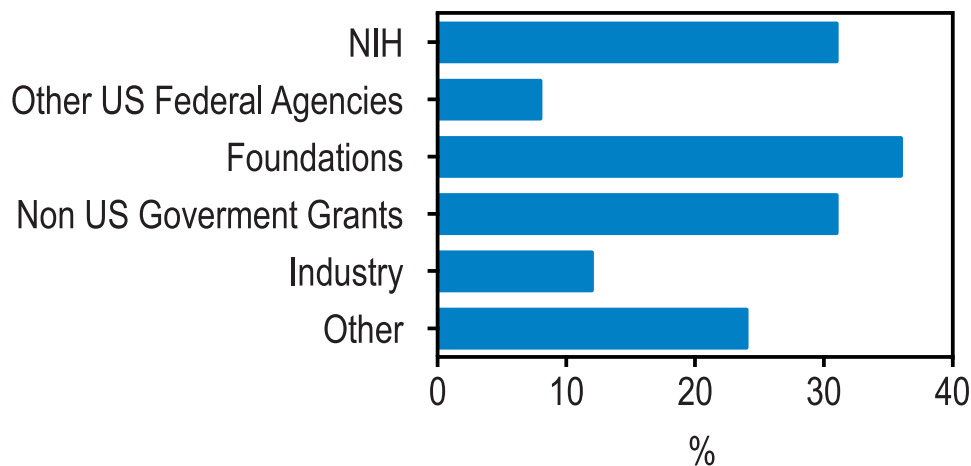


FIG. 4. Sources of grants and fellowships awarded to the 1998–2008 cohort of FIRbees.

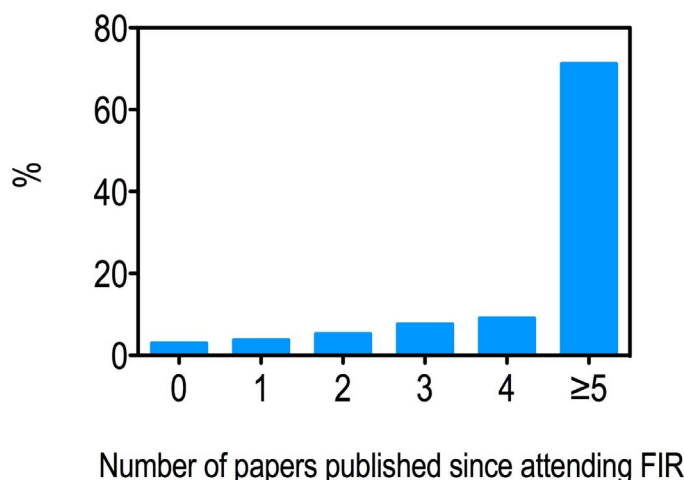


FIG. 5. The number of papers published by the 1998–2008 cohort of FIRbees since they attended FIR.

except for the gender distribution. When tabulated from 2009 to the present, female representation has now increased to about 64%.

One of the unique properties of FIR is the diversity of the faculty (and teaching assistants) who contribute to FIR. Figure 2 shows the number of faculty plus teaching assistants and the number of FIRbees from 1998 to 2008. During this period, we had ~40 faculty/yr, and thus, the ratio of faculty to FIRbees was ~2. Because we also had ~20 teaching assistants/yr, the ratio of teachers (faculty plus teaching assistants) to FIRbees was ~3. During this period, the faculty and teaching assistants came from 20 to 30 different institutions (mostly in the United States) and FIRbees from 11 to 20 different institutions from all continents except Antarctica. In more recent years (after 2008), the number of faculty has risen to 50–60 and the number of teaching assistants to 20–30. Thus, the ratio of teachers to FIRbees is currently 4 or higher. The institutions represented by the faculty, teaching assistants, and FIRbees has, however, remained relatively constant.

Impact of FIR on Career Advancement and Research Productivity of the FIRbees

Figure 3 shows a clear shift of the FIRbees toward higher-level positions after they attended the course. Nearly 80% of the FIRbees were graduate students or postdocs while attending FIR, but by the time the survey was conducted, nearly 80% of the FIRbees had advanced to higher-level positions, including faculty positions. About 60% of the FIRbees now hold faculty positions, and another 30% hold nonfaculty, research-oriented positions or other similar positions at research institutions as well as in pharmaceutical and biotechnology companies, and zoological gardens. Some of the more senior FIRbees have already risen to positions of leadership. There are FIRbees who are directors of research institutions, associate deans, department chairs, and division chiefs as well as others who hold high-level administrative positions in research institutions, including the NIH. Many FIRbees are also now members of the editorial boards of the top journals that cover reproductive sciences and the editor-in-chief of one of these journals is a FIRbee.

Eighty-eight percent of the FIRbees have been successful in obtaining research grants and/or fellowships in the reproductive sciences since attending FIR. The source of these grants and fellowships is shown in Figure 4. The finding that only about

TABLE 1. Impact of papers published by FIRbees before and after taking FIR.

Type of journal ^a	Average number of papers (mean ± SD) ^b	
	Precourse ^c	Postcourse ^{d,e}
All journals	3.34 ± 5.01	5.41 ± 5.42***
Reproductive biology journals in the top quartile	0.50 ± 1.04	1.20 ± 1.77***
Journals in the top quartile in other fields	1.26 ± 2.33	2.13 ± 2.30***
Reproductive biology journals not in the top quartile	0.34 ± 0.74	0.52 ± 0.92*
Other journals not in the top quartile	1.25 ± 3.26	1.56 ± 2.32**

^a The Institute of Scientific Information (ISI) classifies 26 journals as being in reproductive biology, 70 journals as being in obstetrics and gynecology, and six as being in andrology, but some journals can be classified in multiple fields. For the purposes of this table, reproductive biology journals include these three categories. The ranking of journals is determined by the journal's impact factor, which can be viewed as the frequency with which the average article in a journal has been cited within 2 yr after publication.

^b The average number of papers is from a 4-yr period.

^c Precourse publications include papers published in the 3 yr prior to participation in the FIR course and the year of the FIR course.

^d Postcourse publications are those articles that were published at some time during the 4 yr following course participation.

^e Because the distributions of numbers of publications were strongly skewed, significance tests (*t*-tests for dependent samples) were done on the log transformations of these variables. **P* < 0.05; ***P* < 0.01; ****P* < 0.001.

40% of these come from the NIH or other U.S. federal agencies is to some extent a reflection of the international composition of the FIRbees (see Fig. 1).

Perhaps the most compelling data of the impact of FIR are those documenting the productivity of the FIRbees in terms of the number and quality of the manuscripts they have published since attending FIR. Ninety-seven percent of the 1998–2008 FIRbees have published at least one paper since attending FIR, and most FIRbees (nearly 70%) have published at least five papers since attending FIR (Fig. 5). Whereas the data in Figure 5 were obtained from the questionnaire sent to the FIRbees, there are several other ways to independently document the number and impact of FIRbee publications and the continued involvement of the FIRbees in the reproductive sciences. One way is to simply interrogate PubMed with the names of each of the FIRbees to determine the number and type of papers published by them in a given year. When we interrogated PubMed for 2013 publications with the names of the 1998–2008 cohort of FIRbees, we found that 53% of the 192 FIRbees who attended the course during that time span had published at least one paper in 2013. This analysis also revealed that the number of publications for a given FIRbee on 2013 varied from one to 14, and the percent of FIRbees of a given class who published in 2013 varied from 38% to 81%. To confirm that the authors of these papers were indeed FIRbees we cross-checked their names with their academic affiliation (if known), country of origin, their complete names (as listed in Pub Med), and/or their complete set of names or initials if they have a second name.

The complete citations of these papers identifying the FIRbee authors are provided in Supplemental Data S1 (Supplemental Data are available online at www.biolreprod.org). These results clearly show that the overwhelming majority of these papers are in the reproductive sciences.

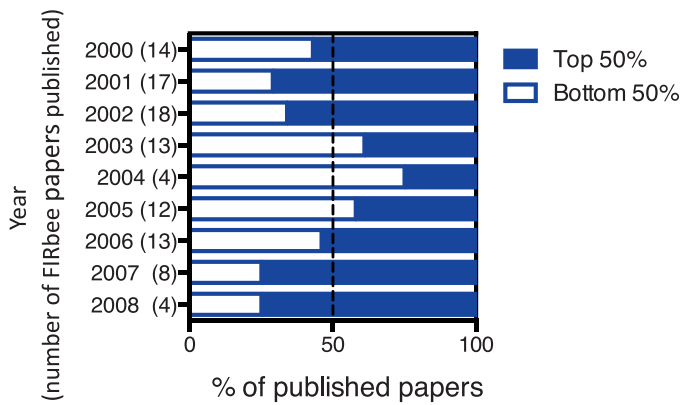


FIG. 6. Impact of papers published by FIRbees in *Biology of Reproduction*. The number of papers published each year by the 1998–2006 FIRbees in *Biology of Reproduction* from 2000 to 2008 is shown in parentheses on the left. Each bar shows the percent of these papers that ranked in the bottom two (white portions) or top two (blue portion) quartiles of citations compared to all articles published in the same year in *Biology of Reproduction* (see text for details). In 6 of the 9 yr analyzed (2000–2002, 2006–2007, and 2008) more than 50% of the papers published by FIRbees in *Biology of Reproduction* were in the top two quartiles.

A more formal, comprehensive, and quantitative assessment of publications was also done in 2011 and included only data for the 1998–2006 cohort of FIRbees. Interrogation of public databases with the 151 names of these FIRbees revealed that they had co-authored 1321 articles (approximately nine articles/FIRbee). Thirty-eight percent of these articles were published during the 3 yr prior to and including their FIR year, and 62% were published in the 4 yr following their FIR year. A comparison of the journals where these articles were published revealed that, in addition to a significant increase in the average number of papers/FIRbee published postcourse, there was also a significant increase in the number of papers/FIRbee published in higher ranked journals including *Biology of Reproduction* (Table 1).

In addition to a journal's impact factor, the number of citations that an individual article receives is often viewed as a measure of research quality. Although this can be accomplished by comparing papers published in different journals, this comparison is not always fair because the average number

of citations/article varies widely among different fields. Thus, a fairer approach is to assess citations for an article in terms of how it ranks for articles published in the same journal. Within any journal, some articles get heavily cited whereas others may receive few citations. Although it was not feasible to apply this strategy for all journals in which FIR participants published, the performance of FIR participants was compared for *Biology of Reproduction* for several reasons: 1) it is classified in the field of reproductive biology, which is a major focus of the FIR course; 2) it ranks in the top quartile of journals in reproductive biology; and 3) it was the journal in which the largest number of FIRbees had published ($n = 103$ articles). For each article published in *Biology of Reproduction* between 2000 and 2008, the total number of citations received from the time of publication through December 2010 was gathered. For example, in 2000, 470 articles were published in *Biology of Reproduction*; the minimum number of citations received by an article was zero, the maximum was 282, and the average number of citations per article was 34.11. Approximately 25 percent of the articles received between zero and 15 citations (quartile 1), 25 percent received between 16 and 26 citations (quartile 2), another 25 percent were cited between 27 and 44 times (quartile 3), and the top quartile (quartile 4) received between 45 and 282 citations. For each year, it was then determined what percent of articles authored by FIRbees who published in *Biology of Reproduction* fell in each quartile of citations received for all articles published in *Biology of Reproduction* for a given year. This analysis (Fig. 6) showed that in 6 of the 9 yr covered by this study more than 50% of the papers published by FIRbees were among the published *Biology of Reproduction* papers that received the top half of citations. For the other 3 yr, more than 25%, but less than 50%, of the papers published by FIRbees were among the published *Biology of Reproduction* papers that received the top half of citations. These data indicate that the research conducted by FIRbees is among the most cited relative to all research published in *Biology of Reproduction*.

Impact of FIR on Collaborative Research

Figure 7 shows that 58% of the 1998–2008 FIRbees have established research collaborations not only with other FIRbees but with FIR faculty as well. Although the data in Figure 7 were self-reported, a large number of collaborations was also

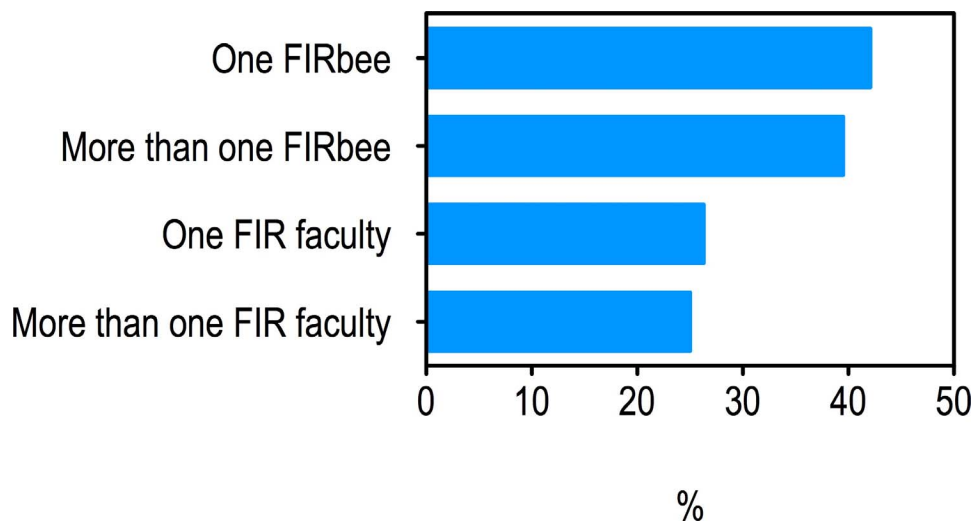


FIG. 7. Research collaborations among FIRbees and FIR faculty since 1998.

evident from co-authorships of publications culled from Pub Med on 2013 (see above). There are in fact an increasing number of publications that have resulted from these collaborations, but we have not yet quantitated them.

DISCUSSION AND CONCLUSIONS

In addition to securing funding as well as organizing and offering FIR on an annual basis, an important responsibility of the FIR leadership is to ensure that FIR is a successful training enterprise. These data are important to ensure that the course content stays current, to recruit faculty and students, and to secure the funds needed to guarantee the continued operation of FIR. To this end, we conduct yearly surveys to obtain feedback from the students and faculty, we conduct frequent external reviews of the scientific content of the course, and we conduct periodical quantitative surveys to assess the impact of the course on the career trajectory of the FIRbees. The first quantitative survey was conducted in 2003, and it included the 1998–2002 cohort of FIRbees. The results of this survey were published here in *Biology of Reproduction* in 2006 and clearly documented that FIR had a positive influence on the training of reproductive scientists [1].

In this follow-up review, we present the combined results of two surveys conducted on the 1998–2006 and the 1998–2008 cohort of FIRbees. The data presented clearly show that after 18 yr of operation, FIR has been successful. FIR continues to uphold its charter, which is to provide a rich, high quality, total immersion training experience that cannot be duplicated in the nation's universities, medical schools, research institutes, or the corporate biotechnology sector. Over the past 18 yr, FIR has been attended by 328 individuals who are now pursuing high-quality research in the reproductive sciences and contributing frequently to the advances in this field.

The FIR course and our previous [1] and current analyses of its impact on the career trajectories of our trainees serves as a

good example of what can be accomplished in this type of learning environment, specially because there is increased emphasis on career development [2], hands on learning [3], and short courses/workshops designed to cover specialized topics [3–5].

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