# Chapter 7
# Women in Statistics: Scientific Contributions Versus Rewards

**Lynne Billard and Karen Kafadar**

*Since the days of Snedecor and Cochran*
*the "best person" has frequently been a woman*

—Salsburg (2001, p.206)

## 7.1 Introduction

Despite the fact that the early years of statistics were dominated by men, who were more likely to be admitted to and receive advanced degrees from universities, a few notable women statisticians made extremely important and critical contributions to the diverse fields of science. As noted by Salzburg (2001, p.197), "Many women were working in the field, but they were almost all employed in doing the detailed calculations needed for statistical analysis, and were indeed called 'computers'." In fact, all the women we discuss in this chapter started their careers in exactly this way. Yet, some of these women broke out of their "computer" roles and rose to the most prestigious ranks of academe and government, where they made fundamental contributions to statistics and science. Due to the earlier accessibility of university admission to women in England and America (which, even there, was limited in many departments), most of these women came from these two countries. In this chapter, we describe briefly the careers of some of these women, noting their contributions and the influences that led them to make them. Regrettably, however, at least in the United States, salaries have not kept pace with the significance of the contributions of these women. In the second part of this chapter, we describe the

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data on salaries that have been collected only 20 years after the 1972 passage of Title IX Affirmative Action in the United States (Billard 1994), and more recently, in the 20 years since then.

## 7.2 Scientific Contributions of Some Women Statisticians

### *7.2.1 Florence Nightingale*

Florence Nightingale (1820–1910) was an English statistician and the first woman member of the Royal Statistical Society. Her name is most frequently associated by the lay public with her establishment of a nursing school in London, but her true love was mathematics and in quantifying social phenomena by objective measurement and analysis. In collecting mortality statistics and presenting them with informative displays, she was able to persuade influential nineteenth-century British Members of Parliament of the need for health policy reform among soldiers in the Crimean War. She developed clever displays of numerical information (e.g., pie charts) to emphasize her messages. She led the efforts to improve medical care in India, and later she provided a convincing report of sanitary reform: "Nightingale reported [in 1873] that mortality among the soldiers in India had declined from 69 to 18 per 1,000" (Cohen 1984). Her recognized success in this regard prompted the US government to consult her on matters of army health during the Civil War. Salsburg (2001, p.iv) colorfully opened his book with a quotation from her: "To understand God's thoughts, we must study statistics, for these are the measure of his purpose."

Interestingly, Florence Nightingale credited "the friendship of power men" with her success: "I have never found one woman who has altered her life by one iota for me or my opinions" (Wikipedia, accessed 30 December 2013, citing Cook (1913) and McDonald (2005)). She believed strongly that women had a responsibility to "bring the best that she has" regardless of "whether it is 'suitable for a woman' or not".[1]

### *7.2.2 F.N. David*

English mathematician and statistician F.N. David (1909–1993) was named for Florence Nightingale, whom her parents admired and knew well. Although she showed a remarkable aptitude for mathematics at an early age, she drifted into statistics because she wanted to do something practical with her mathematical training, which ultimately led her to Karl Pearson at University College, London.

F.N. David made theoretical contributions to the fields of combinatorics, probability, and statistics, most notably through her books *Table of Correlation Coefficients* (1938), *Combinatorial Chance* (with D.E. Barton 1962) and *Games, Gods, and*

[1] http://www.amstat.org/about/statisticiansinhistory/

*Gambling: A History of Probability and Statistical Ideas* (1962). She conducted critical work in London for the Home Office during World War II to estimate the effects of bombs on the public works systems as well as on the loss of lives. Her statistical models of these effects enabled the Allies to prepare effectively for the German offense in 1940–1941. She credits her remarkable career to her mentors, Karl Pearson, who hired her as his research assistant, and Jerzy Neyman, who encouraged her to submit her research papers for a Ph.D. degree and later hired her at University of California (UC) at Berkeley. She moved to UC Riverside in 1968, and in 1970 she founded and chaired the Department of Statistics where she continued to make fundamental contributions in mathematical statistics, as well as after her retirement in 1977. She spent her last years doing research at UC Berkeley.

### *7.2.3 Stella Cunliffe*

Stella V. Cunliffe (1917–2012) was the first woman President of the Royal Statistical Society (1975–1977) and the first woman Director of Statistics at the Home Office London UK. After her economics degree from the London School of Economics and 5 years employment at the Danish Bacon Company, she volunteered in Europe with the Guide International Service (1945–1947), with which she remained involved as a member of its Governing Council. A large part of her career was at Guinness brewery (1947–1970), "a community in which the attitude to the statistician, because of the reputation of one Gosset, was one of reverence" (Cunliffe 1976, p.2). Disqualified from being Director due to her gender (Dorking and Leatherhead *Advertiser*, 26 January 2012), she left the brewery to head the research unit on crime at the UK's Home Office. Two years later, she was promoted to Director of Statistics, the first woman to reach this rank in the British Government Statistical Service. Working closely with Home Office Secretary Roy Jenkins, "her research helped to influence many of his key decisions, including the abolition of capital punishment" (Dorking and Leatherhead *Advertiser*, 26 January 2012). She remained in this post at the Home Office until 1977, when she became Statistical Adviser to the Committee of Enquiry into the Engineering Profession (1978–1980). She was appointed Member of the Most Excellent Order of the British Empire in 1993, a prestigious honor in Britain's order of chivalry.

Stella Cunliffe was, by all accounts of those who knew her, an amazing and remarkable person with a formidable character. Her research and interaction with her superiors brought her great respect for her judgment which usually was accepted. Her Presidential address to the Royal Statistical Society focused on the practical aspects of statisticians making an impact on society: by interacting with others, "wherever they find themselves; with other disciplines and with society" (Cunliffe 1976, p.1). In her view, Gosset's "sign of true brilliance" was his "rare ability to explain, to the uninitiated, the intricacies of the discipline" (p.3); she emphasized that "we must explain our findings in their language and develop the powers of persuasion" (p.11). In his remarks following the address (p.16), former Royal

Statistical Society President H.E. Daniels "congratulat[ed] the Society on, for the first time, electing as its President one of our most distinguished woman Fellows. Perhaps I should also reprimand it for taking so long to come to its senses!"

### 7.2.4 Gertrude Cox

Gertrude M. Cox (1900–1978) is a well recognized name in statistics as chairman and Professor of statistics at North Carolina State University (NCSU). She graduated from Iowa State University (ISU) with a B.S. in mathematics (1929) and ISU's first M.S. in statistics (1931), after having been convinced by George Snedecor that "statistics was more interesting [than missionary service]" (Salsburg 2001, p.196). After spending 2 years doing graduate work at UC Berkeley, she returned to ISU to work with Snedecor in setting up a Computing Laboratory. During this time she met William G. Cochran, with whom she later coauthored the classic text, *Experimental Designs* (1950). When Snedecor showed Cox his list of recommendations for candidates to chair NCSU's Statistics Department, she asked him why he did not recommend her. So it was that Snedecor wrote back on September 7, 1940: "if you would consider a woman, I know of no one better qualified than Gertrude M. Cox"[2]. Cox arrived at NCSU 2 months later and ended up building one of the largest and most distinguished statistics departments in the United States.

Gertrude Cox made many significant contributions throughout her career to the field of agricultural sciences. She also was a brilliant organizer: in addition to her roles in North Carolina, she was one of the founders of the International Biometric Society and provided enormous support through her role as Editor of *Biometrics* (Billard 2014). She served as International President of the International Biometric Society (1968–1969). Having also served as American Statistical Association President in 1956, she was only the second person to be distinguished by this dual honor (after Cochran, her illustrious aforementioned coauthor). Although she retired from NCSU in 1965, she remained active in the profession as a consultant to promote the development of statistical programs. Her valuable contributions to science were acknowledged with her election to the National Academy of Sciences in 1975.

### 7.2.5 Elizabeth Scott

Elizabeth L. Scott (1917–1988) spent her professional career at UC Berkeley where she collaborated with many researchers. The most notable among them was Jerzy Neyman, with whom she published many papers in astronomy and weather modification. In astronomy, she modeled elements of the universe as random processes, which led to important advances in our scientific understanding about the geometry of the universe as well as about the various cosmological theories. (More recent work

[2] http://gmclife.blogspot.com

in this area has been possible through the collection of massive data via the Large Synoptic Survey Telescope.) She was the first to describe the observational bias that arises when more distant systems that contain more galaxies will be brighter and hence easier to detect, a phenomenon that is called the "Scott effect."

During the 1960s and 1970s, meteorologists were captivated by the possibility for weather modification, specifically for stimulating rainfall, which in turn led statisticians like Scott to characterize the significance of outcomes from "experiments" to stimulate rain. The design problem (Scott and Neyman 1961b) is extremely challenging, due to the presence of air navigation systems with which "treatments" cannot interfere. Moreover, weather patterns on given days hardly behave like typical random samples (they certainly are not "repeatable"), and the "treatment" (e.g., cloud seeding) will not take effect immediately, so treatment assignment and significance of effects can be evaluated only after several years and only via randomization tests. In a comprehensive study involving 23 experiments, Scott and Neyman (1961a) showed that cloud seeding increased rain in only six experiments, decreased rain in ten, and the effect was not significant in seven experiments. Later research suggested that "significance" was affected by cloud altitude and location, hence the need for properly randomized experiments to account for such factors (Breuer 1980). Scott also worked on the problem of modeling the effect of ultraviolet (UV) radiation on skin cancer incidence (Morita and Scott 1982), the results from which contributed to the current guidelines regarding UV exposure.

More than any others at the time, Scott worked tirelessly to promote the equal treatment of women in academe, with respect to both their professional advancement and their salaries (Billard and Ferber 1991). Mary Gray, a mathematician-statistician-lawyer who spent her career at American University, worked long and hard with Scott to implement procedures designed to bring equality and justice to women academicians overall, not just in statistics.

### *7.2.6 Margaret Martin*

Margaret E. Martin (1912–2012) was tremendously influential in coordinating the Federal Statistical Agencies during her government service at the Division of Statistical Standards (DSS) at the US Bureau of Budget (which later evolved into the Office of Statistical Policy at the Office of Management and Budget, presently under the leadership of Chief Statistician Katherine Wallman). At a time when few women held professional positions, Martin began her career in 1938 as a junior economist in New York's unemployment office in the office of research and statistics. (Coincidentally, one of her teachers was the mother of Joan R. Rosenblatt, an accomplished statistician in her own right who, during her career at the National Bureau of Standards (now National Institute of Standards of Technology), collaborated with physical scientists on numerous projects and on various electronic devices as well as, with colleague James J. Filliben, revised the procedures for the 1969 draft lottery; see Rosenblatt and Filliben (1971).

During World War II, Martin worked at the War Manpower Commission as a senior economist. At the DSS, she coordinated the development of key economic and labor surveys still in use today, most notably the Current Population Survey. When the accuracy of the government's unemployment statistics was challenged by *Reader's Digest* in September 1961, Martin collected most of the data from the various agencies for the President's Committee to Appraise Employment and Unemployment Statistics, which delivered its report to President Kennedy in 1962. The statistical information was found to be solid and in 1968 she received the Bureau of the Budget's Director's Exceptional Service Award (Muko 2011). She retired from government service in 1973 and directed the National Academies' Committee on National Statistics (CNSTAT) until 1978, and afterward continued her association through CNSTAT projects on surveys and research data sharing. She served as President of the American Statistical Association in 1980, and received its first Founders Award in 1989.

### *7.2.7 Janet Norwood*

Janet L. Norwood (1923–) pursued a career in economic and labor statistics primarily at the US Department of Labor's Bureau of Labor Statistics (BLS), charged with the development, conduct, and analysis of key surveys that characterize the economic health of the country. In less than 10 years at BLS, she rose to the office of Associate Deputy Commissioner for Data Analysis in 1972, followed shortly by Deputy Commissioner for Data Analysis (1973) and then Deputy Commissioner (1975) where she oversaw multiple programs. First as Acting Commissioner, Norwood was confirmed as BLS Commissioner in 1979, a post she retained through three administrations until 1991. During her term, she developed and launched the annual Consumer Expenditure Survey (CES), on which the Consumer Price Index (CPI) is based. Because of her exceptional technical expertise as a statistician, she commanded tremendous respect from both BLS employees and policy officials, and did much to establish the credibility of BLS' reports on the economy by insisting on independence of the Bureau in conducting its work. She oversaw many other surveys throughout the agency, including the resurrection of the National Longitudinal Survey and the Quarterly Census of Employment and Wages. Her conversations with legislators at both the state and federal levels led to increased respect and attention for the importance of statistical methods. As a result of her efforts, BLS, Bureau of the Census, and the National Center for Health Statistics cooperate effectively to ensure accurate and timely delivery of key information to the public.

While Norwood worked assiduously to maintain integrity of data, their presentation, and their interpretation, she was equally vigilant in supporting and encouraging women to achieve what their talents deserved. As quoted in Snider (2005), Norwood believed "Women have to take advantage of the opportunities presented to them; it often isn't quite as straight a career path (for women) as it is for men." Indeed, one of us (LB) well remembers having this very same conversation with

Norwood in the late 1980s when discussing the opportunities allowed to women during their career. Though ensconced in different professional sectors (government and academe), Norwood was insistent that the two meet when both were in Washington; such was Norwood's interest in promoting junior colleagues. Norwood strongly advocated for and worked assiduously towards the gender equality that exists today in government ranks.

### *7.2.8 Other Women Statisticians*

Several of the women previously mentioned served as President of their professional organizations. For the American Statistical Association, founded in 1839, women who served as President are: Helen Walker (in 1944, a statistical educator), Gertrude Cox (1956), Lynne Billard (1996), Mary Ellen Bock (2007), Marie Davidian (2013), as academic presidents; Aryness Joy Wickens (1952), Margaret Martin (1980), Barbara Bailar (1987), Janet Norwood (1989), Katherine Wallman (1992), Nancy Geller (2011), from government; and Sally Keller-McNulty (2006), Sally Morton (2009), elected as industry candidates. [The American Statistical Association's 3-year rotation for Presidents and Vice-Presidents through the academic-industrial-government sectors started in the mid-1980s.]

Women who have been elected International President of the International Biometric Society, formed in 1947, to date are: Gertrude Cox (1968, 1969), Lynne Billard (1994, 1995), Sue Wilson (1998, 1999), Nanny Wermuth (2000, 2001), Kaye Basford (2010, 2011), and Clarice Demetrio (2012, 2013). The International Biometric Society is organized into regions and groups worldwide, each with its own regional president. The two North American regions are being served increasingly by women, though only two members have gone on to serve as International President.

Founded in 1936, the Institute of Mathematical Statistics appointed Elizabeth Scott as its first woman President in 1978; Nancy Reid followed her almost 20 years later (1997). Since then, Nanny Wermuth (2009), Ruth Williams (2012), and Bin Yu (2014) have served as Institute of Mathematical Statistics Presidents. Denise Lievesley (2007–2009) has been the only woman among the 33 Presidents of the International Statistical Institute.

Though the oldest statistical society dating from 1834, it was not until 1975 that the Royal Statistical Society elected Stella Cunliffe as its first woman President (see above), followed 24 years later by Denise Lievesley (1999–2001) and by Valerie Isham (2011–2012). The Statistical Society of Canada appears to have had the highest proportion of women presidents, having elected five women among its 38 presidents since its formation in 1972: Agnes Herzberg (1990–1991), Jane Gentleman (1997–1998), Mary Thompson (2003–2004), Nancy Reid (2004–2005), and Charmaine Dean (2006–2007).

Apart from these women, rather few women have presided over statistical societies before the 21st Century. Until the mid-1980s when the American Statistical

Association established its rotation of candidates for President and Vice-President to come from academe, government and industry, almost all elected American Statistical Association Presidents come from academe. Yet as we show in Section 3, rewards in general remain scarce for women, and the greatest prize of election to a presidency is still particularly elusive for women statisticians. [Lists of society presidents can be found on the Wikipedia webpages, "List of Presidents of (name of society)."]

Election into prestigious national societies is even more elusive. Of the 21 statisticians elected to the National Academy of Science (under the encompassing named category "applied mathematics"), only four are women (Gertrude Cox 1975; Grace Wahba 2000; Elizabeth Thompson 2008; Bin Yu 2014). To date, no women statisticians have been elected to the UK's Royal Society.

## 7.3 Rewards

It is clear that, given opportunity and encouragement, women in statistics have made, and continue to make, significant contributions to science. Unfortunately, the rewards have not always followed women as directly as they have for their male counterparts. Despite the significance of the accomplishments by women in statistics, and the passage of Title IX legislation in 1972 that mandated equality in the United States, Billard (1994) showed 20 years later that salary discrepancies existed. Has the situation improved in the last 20 years?

First, what constitutes a reward? Clearly, one such reward is that women are promoted and tenured at a rate comparable to the rate of their male counterparts, and that salary levels are equally comparable. Twenty-five years ago, Bailar (1989) showed data that suggested equity had been approximately achieved in governmental ranks. Our focus here will be on the comparison of men and women in academe.

Our data are drawn from *Academe* (1971–2013) in the annual "Report on the economic state of the profession" (or similar title, in varying months, but lately in the March-April issue). These data are averaged over all reporting institutions, the number of which varies slightly in a given year but basically covers all institutions in the United States. These data are not separated by discipline, so are averaged across all disciplines.[3] Category I institutions are those offering doctoral programs. Categories II–III include institutions which may have graduate programs in some disciplines but not all; most have a teaching, non-research, focus. In Categories I–III, faculty are listed as Professor, Associate Professor, Assistant Professor,

[3] The American Statistical Association provides salary data (10th, 25th, 50th, 75th, 90th percentiles) by gender for academic departments of statistics alone (www.amstat.org), but only for 2010–2011, 2011–2012, 2012–2013 annual surveys (2013–2014 forthcoming as of this writing). None of the counts for women in these categories on which these percentiles are based exceeds 20. Due to the uncertainties in these reported figures, and for only 3 years, we rely on the data from Academe.

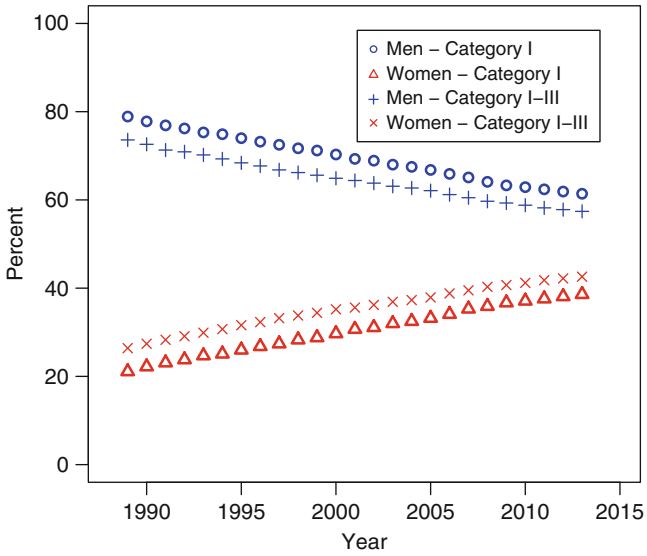


**Fig. 7.1** All ranks distribution, by gender—Category I and I–III

Instructor, Lecturer, No Rank, and All Ranks; our analysis here will be confined to data on Professor, Associate Professor, Assistant Professor, and All Ranks.

We first consider the distribution of men and women at academic institutions. Figure 7.1 shows the proportion of faculty who are men and women over all ranks, for Category I institutions (outermost—upper and lower plots, respectively; see figure legends), for the years 1989–2013, and for Categories I–III (innermost—upper and lower plots, respectively). Note that the percent of men and women together add to 100%. Thus, as proportionately more women are being hired, the proportion of men faculty perforce decreases. Figure 7.2 shows these proportions for Professor, Associate Professor, and Assistant Professor ranks in Category I; those for Categories I–III are similar. In Fig. 7.2, the outermost plots refer to Professors, the innermost plots are for Assistant Professors, and between them lie the plots for Associate Professors, as one would expect by the relative ranks. As in Fig. 7.1, proportional gains over time have been made. For example, the proportion of women Professors is increasing with a commensurate decrease in the proportion of male Professors, a trend that occurs at all ranks.

The rising proportion of women in academe does not suggest that they are supplanting men from these positions. The (right-side) upper two plots in Fig. 7.3 show the numbers of men (top plot) and women (lower plot) faculty in Category I–III institutions, while the (right-side) lower two plots show the corresponding numbers for Category I institutions, for the years 1989–2013. Regardless of category, the actual number of women faculty today in 2013 is still lower than the number of men back in 1989. More women are indeed being employed by academic institutions,

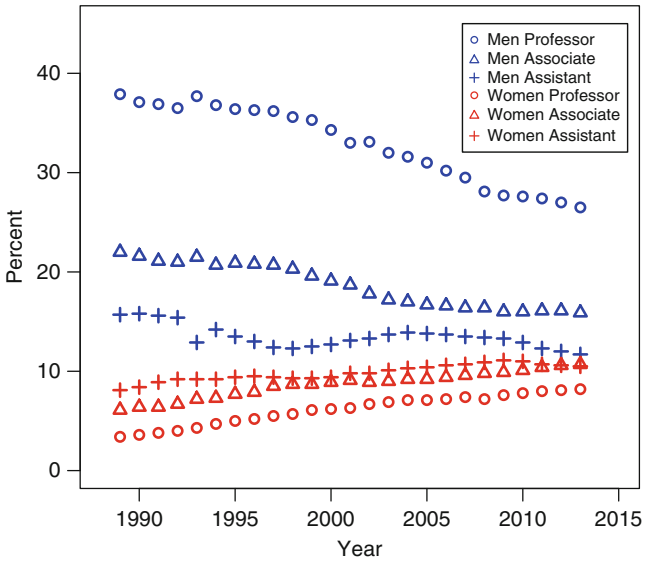


**Fig. 7.2** Rank distribution of full/associate/assistant professor, by gender—Category I

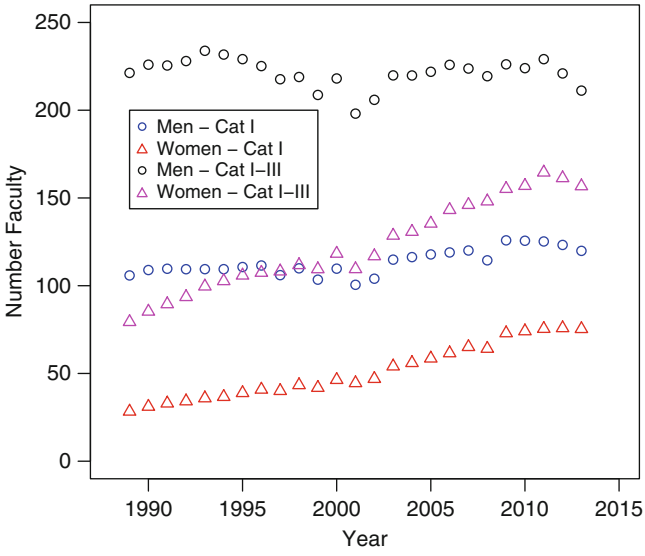


**Fig. 7.3** $10^{-5} \times$ Number of faculty, by gender—Category I and I–III

but evidently not at the expense of men. A more definitive analysis could be possible if data for hiring rates by gender were available.

While it is clear that women are being hired, a crucial question related to "rewards" is: "Are women being promoted and tenured?" Unfortunately, the data

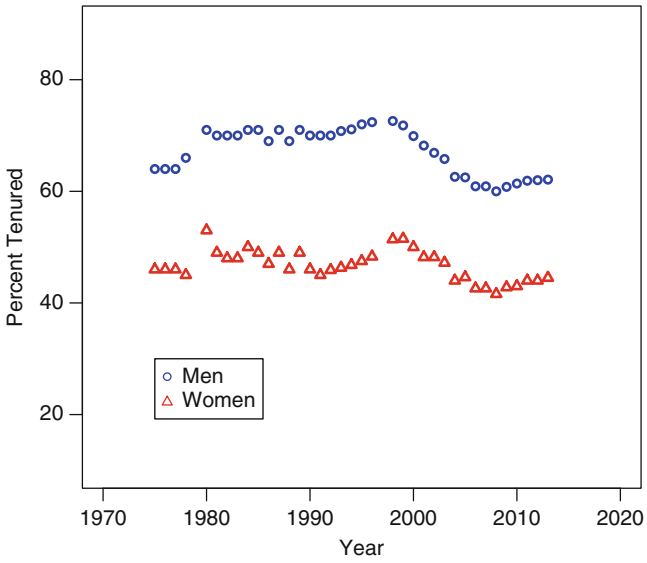


**Fig. 7.4** Tenure rates by gender—Category I

suggest little progress on this front. Figure 7.4 shows the proportion of men (upper line) and of women (lower line) who are tenured, from 1975 to 2013. Although Figs. 7.1–7.3 show more women (in absolute numbers) are employed in the tenure ranks, the proportion of women who are tenured has not changed in the last 40 years since the passage of Title IX. Since tenure allows a faculty member the security to conduct research as his/her intellectual endeavors lead him/her without the constraint of being dismissed for what may be perceived as unimportant research areas, these data suggest that women are still being denied the most important reward of academic freedom through the tenure rank.

Are women being rewarded commensurately with respect to salary? Figure 7.5 shows the deficit of women's salaries relative to those of men as a percentage of their own salaries (i.e., men–women)/women $\times$ 100%) between 1975 and 2013, for Professors, Associate Professors, and Assistant Professors at Category I institutions; i.e., the average percentage raise a women has to receive to gain salary equity. The percentages lie around 10% for Professors today. The trend deficit is closer to 15% for Professors when all three Categories (I–III) are combined (Fig. 7.6). When looking at all ranks, these deficits hover around 30% for Category I and 24% for Categories I–III, again reflecting the fact that women constitute a disproportionately larger number of the faculty at the lower ranks.

The salary deficit in dollars (men's salary less women's salary) is shown in Fig. 7.7 for Category I, also for the years 1975–2013. (One recognizes that different styles of universities will offer different salary levels. *Academe* does break down institutions into public, private, and religious-affiliated so average salary deficits could be calculated within these three institution types. The data in Fig. 7.7 are averaged over

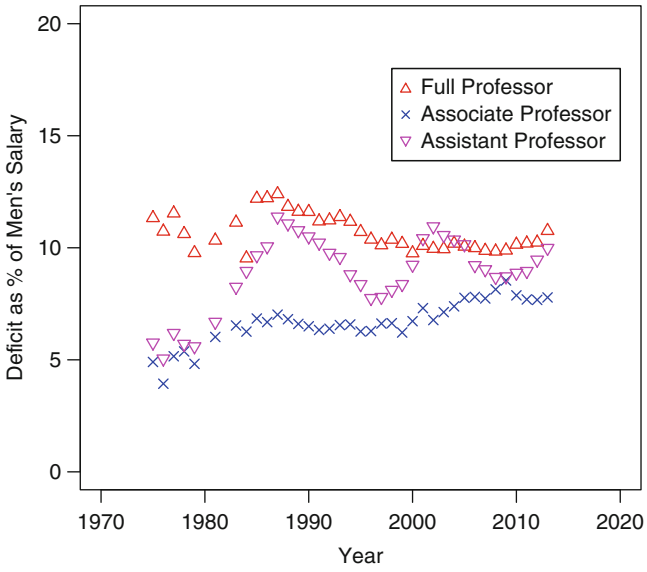


**Fig. 7.5** Women salary deficit as % of women salary, by rank—Category I

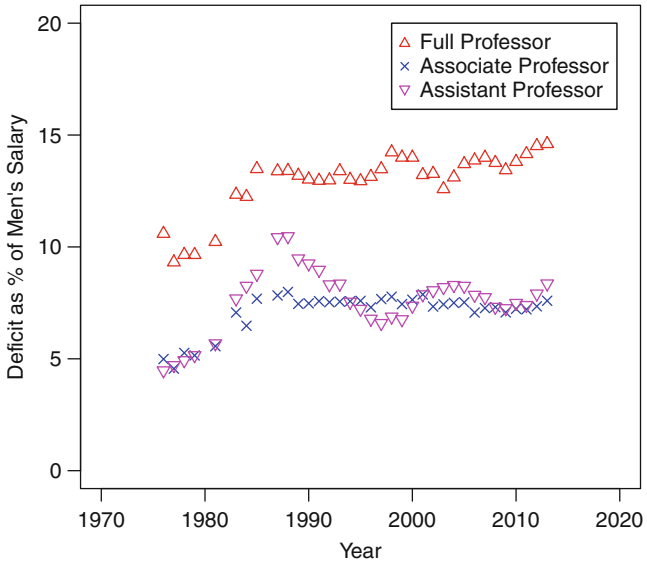


**Fig. 7.6** Women salary deficit as % of women salary, by rank—Category I–III

all institution combined.) Similar trends pertain to Categories I–III combined, shown in Fig. 7.8, which reveals that the inequities have widened over the years, especially in take-home pay. The cumulative impact of these deficits over a career and on retirement income is obviously substantial.

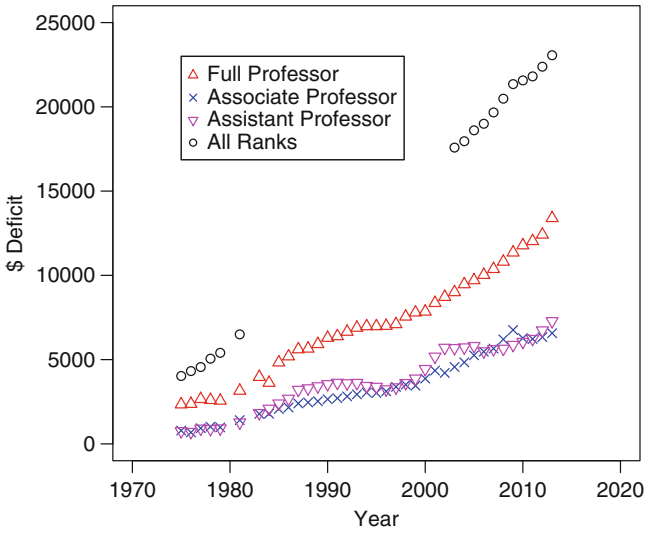


**Fig. 7.7** Women $ salary deficit relative to men, by rank—Category I

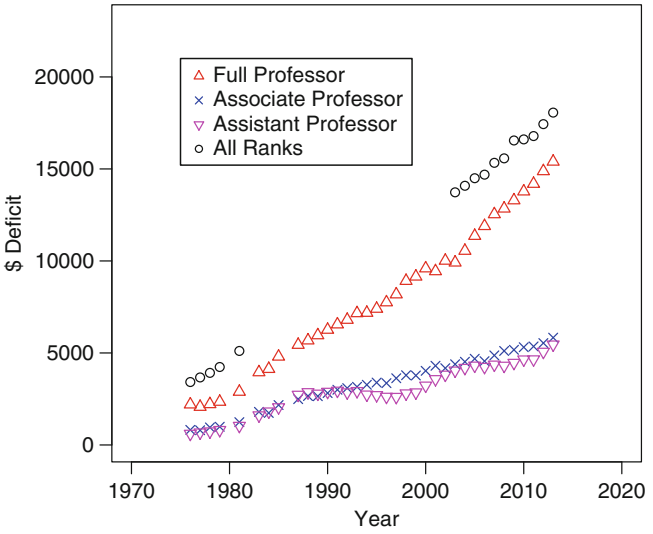


**Fig. 7.8** Women $ salary deficit relative to men, by rank—Category I–III

A different type of reward applies to major awards and to invitation to present one's research in special sessions at research meetings and conferences. In its 50-year history, the Samuel Wilks Award (the American Statistical Association's most prestigious award for research contributions broadly defined[4]) has been awarded

[4] http://www.amstat.org/awards/samuelwilksaward.cfm

to only two women (Lynne Billard 1999; Nan M. Laird 2011). None of the 27 US Army Wilks Awards (for contribution to the practice of statistics in the Army[5]) has been awarded to a woman. More recently, among the 13 prestigious invited plenary lectures at the 2013 Joint Statistical Meetings, none were women. At its August 2013 Council Meeting, the Institute of Mathematical Statistics resolved to redress this imbalance with a series of proposed measures. Perhaps other societies will take similar steps to address this imbalance.

Until then, data such as these from *Academe* are valuable for raising awareness of the problem, and time will tell if such focused efforts will help to ensure that women are rewarded commensurately with men on these measures of rewards for research excellence. As Salsburg (2001) noted, sometimes the "best person" for the job really could be a woman.

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[5] http://www.armyconference.org/wilks.htm

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# *Vignette 7.1*
# A Glimpse into Women Who Lay the Foundation for the Development of Statistics in Canada

**C.B. Dean, David Bellhouse, Steve Brown, Susie Fortier, Sorana Froda, and Nancy Heckman**

This vignette focuses on the early development of statistics in Canada, and specifically on five female statisticians who pioneered its advancement in the late 1970s and early 1980s. This period follows immediately the 1970 recommendation of the Royal Commission on the Status of Women that gender-based discrimination be prohibited across Canada. Vignettes on Estelle Dagum (*written by Susie Fortier*),

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Priscilla Greenwood (*by Nancy Heckman*), Agnez Herzberg (*by David Bellhouse*), Mary Thompson (*by Steve Brown*), and Constance van Eeden (*by Sorana Froda*) showcase the outstanding contributions made in an era when women were just beginning to enter scientific disciplines and when role models were practically non-existent. There have been contributions made even earlier; for example, Isobel Loutit, born in Manitoba in 1909, obtained a B.A. in mathematics at the University of Manitoba in 1929 and went on to become chair of the Montréal Section of the American Society for Quality Control in 1969. As well, it is also notable that Sylvia Ostry, an economist, was the first woman working in Canada to be elected Fellow of the American Statistical Association; she was Chief Statistician of Canada from 1972 to 1975. And Audrey Duthie of the University of Regina, Kathleen Kocherlakota of the University of Manitoba and Gail Eyssen, now of the University of Toronto, provided leadership in the mid-1970s for the development of the Statistical Society of Canada.

## 7.4 Estelle Bee Dagum

Dr. Estelle Bee Dagum is a highly skilled specialist of Time Series Analysis and a prolific author. Her career includes more than 20 years in leadership and research at Statistics Canada (1972–1993). As the Director of the Time Series Research and Analysis Centre of Statistics Canada, she expertly led the development of the *X11ARIMA seasonal adjustment method*. This method was later incorporated into *X-12-ARIMA* which is currently used at Statistics Canada and at many other agencies for the seasonal adjustment of key economic indicators such as the Gross Domestic Product and unemployment rates. From 2007 to 2009, she returned to Statistics Canada as a Distinguished Alumna and worked as a consultant on various time series issues, including trend estimation and benchmarking. She also contributed to the training and development of the next wave of Time Series statisticians by leading a series of specialized lectures.

Being taught by Dr. Dagum was a privilege from which many of her students report to still benefit on a daily basis. Even now, her legacy is present in current work at Statistics Canada. As that agency is currently reviewing trend estimation techniques, it is impressive to see how the massive literature produced by Dr. Dagum continues to be both expanding and relevant to their current needs. Finally, the leadership and guidance provided her allowed not only the development of statistics but also provided an excellent role model for other women in statistics, economics and managerial positions at the agency and elsewhere. More often than not after Dr. Dagum's departure from her Director's position at Statistics Canada, the head position of the Time Series Centre was held by a woman, and her principles have followed through in various leadership roles there.

## 7.5 Priscilla Greenwood

Priscilla Greenwood, known to all as Cindy Greenwood, was born in 1937 in Lawrence, Kansas. She received her Bachelors degree at Duke in 1959, majoring in Mathematics and minoring in Physics. She received her Master's (1961) and Ph.D. (1963) degrees from the Mathematics Department of the University of Wisconsin, supervised with Joshua Chover, with her Ph.D. thesis entitled "A convolution equation on a compact interval." After a short time teaching at North Carolina College, Dr. Greenwood moved to the University of British Columbia's Department of Mathematics in 1966. She was the only female faculty member until the 1980s. In 2000, she retired from the University of British Columbia but did not retire from research. After 10 years as a visiting professor in the Mathematics and Statistics Department at Arizona State University, Dr. Greenwood returned to Vancouver and to the University of British Columbia, where she now divides her time between the Mathematics and Statistics Departments.

She is known for her research contributions in a range of topics, with the foundation being her expertise in stochastic processes. Dr. Greenwood's initial training in stochastic processes, in 1960 at MIT, is noteworthy and sets the historical stage for her work: she was taught by Henry P. McKean, of Ito-McKean fame. In her early years, her work centered on Levy processes, the Wiener-Hopf factorization and functional convergence in the context of evolving random fields.

Famous for her collaborative research style, Dr. Greenwood cultivates research collaborations around the globe via extensive travelling and hosting research visitors to the University of British Columbia. In the mid-1980s, she collaborated with many Russian researchers, including Albert Shiryaev, Mikhail Nikulin, Ildar Ibragimov, Alexander Novikov, and Igor Evstigneev. Her most long-standing collaboration is with Wolfgang Wefelmeyer on statistical problems for semimartingales, focusing on asymptotically efficient estimation in Le Cam's sense. Her more recent research centers on stochastic dynamical systems. With her formation of the Crisis Points group in the mid-1990s, she led a group of mathematicians, statisticians, and subject area researchers in studying physical systems via stochastic dynamic models with critical points. This research has been fruitful, driven by her enthusiasm, the novelty of the mathematics, and the recognized utility of the approach by subject area researchers.

On her 70th birthday, Dr. Greenwood was honored with a Festschrift. The resulting volume, edited by Egor Evstigneev, Nicholas H. Bingham, and Jim Pitman, highlights the many aspects of her work, research in stochastic processes, often at the interface of statistics and probability—she is a rare person who is at home in both environments, who has the "big picture" view of fundamental ideas and important questions, and the technical skills to move that interface forward.

## 7.6 Agnes M. Herzberg

Born in Saskatoon in 1938, Dr. Agnes Herzberg was the younger child of scientists Gerhard Herzberg and Luise Oettinger. When the family moved to Ottawa in 1948, where her father took up a senior research position in the National Research Council of Canada, she received the usual elementary and high school formal education. Less formally, through her parents' many illustrious and varied scientific friends, she received a very broad and general education in science. What she experienced in childhood, she practiced with great success over her academic career.

After completing high school, Herzberg went to Queen's University in Kingston where she obtained her B.A. (Honors). She earned her M.A. in 1963 and Ph.D. in 1966 from the University of Saskatchewan, the latter under the supervision of Norman Shklov, the first president of the Statistical Science Association of Canada, the precursor to the Statistical Society of Canada. Her thesis entitled, "On rotatable and cylindrically rotatable designs," and subsequent publications in the *Annals of Mathematical Statistics* stemming from the thesis, serve as a harbinger for many of her later publications in two ways. First, it announced to the statistical world that here was a serious researcher in experimental design. Second, from the acknowledgements in her papers, it showed her budding connections with leaders in the field. There, for example, she expressed her appreciation to Norman Draper for his comments on the paper. Later, she coauthored at least three papers with Draper and coauthored papers with several other leaders in the area of experimental design such as David Cox, David Finney, Cuthbert Daniel, and Henry Wynn. Subsequently, she contributed extensively to the theory of optimal experimental design, robust designs, experimental designs for medical experiments and model selection in regression.

During her academic career, Dr. Herzberg has made several contributions to the profession. For 26 years, she was Editor of *Short Book Reviews* published by the International Statistical Institute. In that position, she demonstrated her wide-ranging knowledge of statistics. Additionally, Dr. Herzberg served as an Associate Editor of the *Annals of Statistics* and *Biometrika* and was President of the Statistical Society of Canada in 1991–1992.

Dr. Herzberg has been instrumental in providing a forum for discussion and action in the wider sphere of science and public policy. Since 1996, she has organized and managed the annual international Conference on Statistics, Science and Public Policy. It is a small, elite conference held by invitation only at Herstmonceux Castle in the south of England. The success of the conference stems from Dr. Herzberg's ability to hand pick and bring together a widely diverse group of individuals—academics, public servants, elected officials, and representatives of government agencies, independent research laboratories and the media—to discuss an important topic to focus upon. The proceedings of each conference are published.

She went to Birkbeck College in February 1966 where David Cox and some others had positions. In September 1966 Cox, Agnes and others transferred from Birkbeck to Imperial College. In 1988, she returned to Canada to take up an academic position at her alma mater, Queen's University. Since 2004 she has been Emerita at Queen's.

## 7.7 Mary Thompson

Dr. Mary Thompson received a B.Sc. degree from the University of Toronto (1965) and completed graduate training at the University of Illinois (Master's degree, 1966 and Ph.D. degree, 1969). Upon graduation, she joined the Department of Statistics (currently the Department of Statistics and Actuarial Science) at the University of Waterloo where she spent her career, remaining actively involved even after her retirement in 2009.

Over the course of her distinguished career, Dr. Thompson made many important contributions to statistical methods for survey sampling, the theory of estimating equations, and statistical modeling and inference for stochastic processes. A novel aspect of her research is the integration of these themes, as exemplified in her work on the design and analysis of longitudinal surveys. Her book *Theory of Sample Surveys*, published by Chapman and Hall in 1997, deals with mathematical and foundational aspects of the theory of survey sampling, the use of estimating functions, and the role of the sampling design when survey data are used for analytical purposes. In addition to publishing highly influential statistical papers, Dr. Thompson has contributed widely to other areas of science, including gerontology, public health, sociology, biology, and medicine. Since 2002, she has been a lead investigator on a large *International Tobacco Control Survey*; as part of this work she has addressed issues associated with the design of longitudinal surveys to support causal inference.

Dr. Thompson has received numerous awards during her career. She is a Fellow of the Royal Society of Canada (2006), winner of the Gold Medal of the Statistical Society of Canada (2003), a Fellow of the American Statistical Association (1985), and a Fellow of the Institute of Mathematical Statistics (1998). In 2008, she was awarded the *Journal of Survey Methodology's* Waksberg Award, and 2 years later the Committee of Presidents of Statistical Societies Elizabeth L. Scott Award in recognition of her efforts to further the careers of women in academia. For work on the International Tobacco Control Project, she and colleagues G. Fong and D. Hammond received the Canadian Institutes of Health Research/Canadian Medical Association Journal Top Canadian Achievements in Health Research Award in 2009, and the 2012 Statistical Society of Canada Lise Manchester Award for excellence in statistical research that considers problems of public interest and public policy. She has been very active at the University of Waterloo. There, her research contributions were recognized by the award of a University Professorship (2004) and, upon her retirement, the designation of Distinguished Professor Emerita (2009). Dr. Thompson has supervised more than 25 Ph.D. students and numerous Master's students. For her exceptional support, encouragement and mentoring of graduate students, she received the Award of Excellence in Graduate Supervision from the University of Waterloo in 2007.

Dr. Thompson has also served the statistical sciences community in many other ways. She served as President of the Statistical Society of Canada (2003–2004), and held several other leadership positions in the Society including President of the

Survey Methods Section. In 2012, she was selected as the inaugural Scientific Director of the Canadian Statistical Sciences Institute. She has served as Associate Editor for the *Journal of the American Statistical Association* and the *Canadian Journal of Statistics* and *Survey Methodology*. She has chaired and served on the Statistical Sciences Grant Selection Committee of the Canadian Natural Sciences and Engineering Research Council and twice has served on the Advisory Committee on Statistical Methods for Statistics Canada. Within the University of Waterloo, Dr. Thompson served as Chair of the Department of Statistics and Actuarial Science, Associate Dean for Graduate Studies and Research, and Acting Dean of the Faculty of Mathematics. She was the founding Co-Director of the Survey Research Centre, and continued as Associate Director after her retirement. She has been an active member of many University-level committees, including the Advisory Committee for Women's Studies of which she was Chair in 1984–1985.

## 7.8 Constance van Eeden

Dr. Constance van Eeden was born on April 6, 1927, in The Netherlands. All of her studies were undertaken in The Netherlands: she passed the *candidaats examen* in 1949 at the Universiteit van Amsterdam, worked on her *doctoraal examen* and Ph.D. while being employed by the Mathematisch Centrum (now Centrum voor Wiskunde en Informatica) in Amsterdam; finally, she earned her Ph.D. *cum laude* in 1958 as one of David van Dantzig. After a period in the United States, she spent between 1965 and 1988 at Université de Montréal. In 1965, Montréal became a vibrant center for academic statistics thanks to her arrival and that of her husband, Charles Kraft, who died in 1985. Since 1998, the "Prix Constance van Eeden" is awarded yearly to the best B.Sc. graduate in statistics or actuarial science, in recognition of her contributions to the department. After her retirement in 1989, she became Professeure émérite at Université de Montréal, Professeure Associée at the Université de Québec à Montréal, and Honorary Professor (Adjunct in 1990–1995) at the University of British Columbia, where she has spent the fall term regularly for more than 20 years. In 1998, she established the Constance van Eeden Fund for Honouring Distinguished Achievement in Statistics at the University of British Columbia. The Fund promotes learning in statistical science, recognizes distinguished statistical scholars at all levels and celebrates extraordinary achievement in the discipline.

Her research career spans over 50 years. Dr. van Eeden's main fields of interest are estimation in restricted parameter spaces, decision theory, nonparametrics, and selection procedures. Her main coauthors are Charles Kraft and Jim Zidek. She published more than 80 articles (over 70 papers in refereed journals), wrote several sets of course notes, and contributed to the Encyclopedia of Statistical Sciences. Her thesis and subsequent published work establish her as a pioneer in estimation for order restricted parameters. In 2006 she published the book *Restricted-parameter-space Estimation Problems*, in the Springer Lecture Notes Series. In 1968, her book

*A Nonparametric Introduction to Statistics* (with C. Kraft) was published, a field where she has made many seminal contributions, published in first class journals. She contributed substantively to founding the Québec school in nonparametrics, as many of her students continue her work.

She has contributed to the statistical community as an Associate Editor for the *Annals of Statistics*, the *Canadian Journal of Statistics*, and *les Annales des Sciences Mathématiques du Québec*, as a General Editor of *Statistical Theory and Methods Abstracts*, as well as an active member of many committees and research councils. Dr. van Eeden has been an exemplary supervisor and mentor: she supervised more than 30 graduate students, but advised many more junior researchers. In Canada, her Ph.D. students held academic positions from Vancouver to St. John's, Newfoundland, in accordance with Canada's motto: *A Mari usque ad Mare*!

All her contributions received many awards: Institute of Mathematical Statistics and American Statistical Association (1972) Fellowships, Elected membership of the International Statistical Institute (1979) and that Institute's "Henri Willem Methorst Medal" (1999), and two Honorary memberships: the Statistical Society of Canada (2011) and the Dutch Statistical and Operations Research Society (2013). In 1990, Dr. van Eeden was awarded the Gold Medal of the Statistical Society of Canada, crowning a distinguished career in statistical research. Dr. van Eeden's 75th birthday was celebrated in 2002, in May (Montréal, Centre de recherches mathématiques) and November (Vancouver, University of British Columbia), reflecting her strong support of statistics in these two cities, and in 2003 a Festschrift in her honor was published in the Institute of Mathematical Statistics Lecture Notes and Monograph Series, Volume 42.

# *Vignette 7.2*
# The Status of Women Faculty in Departments of Statistics and Biostatistics in the United States

**Marcia L. Gumpertz and Jacqueline M. Hughes-Oliver**

According to the *2011 Survey of Earned Doctorates* (NSF 2012), 42% of doctoral degrees in Statistics granted in the United States were awarded to women. How does this translate to faculty in Departments of Statistics and Biostatistics? Data on faculty demographics from 29 departments,[6] including 21 departments of Statistics and 8 departments of Biostatistics, show that women do not make up as large a proportion of the overall faculty, comprising just 26% of tenured and tenure track faculty (Table 7.1). Twenty one percent of the departments have fewer than 15% women and 69% have fewer than 30% women; 15 and 30% are considered by many to be points of critical mass, where a qualitative shift occurs in the environment for women (Etzkowitz et al. 2002; Nelson and Brammer 2010). Biostatistics

[6] Departments include Boston University Biostatistics, Colorado State University Statistics, Columbia University Statistics, Emory University Biostatistics and Bioinformatics, Florida State University Statistics, George Mason University Statistics, George Washington University Statistics, Johns Hopkins University Biostatistics, Kansas State University Statistics, Michigan State University Statistics and Probability, North Carolina State University Statistics, Oregon State University Statistics, Penn State University Statistics, Purdue University Statistics, Rice University Statistics, Stanford University Statistics, University of California—Berkeley Statistics, UCLA Statistics, University of Connecticut Statistics, University of Florida Statistics, University of Georgia Statistics, University of Illinois—Urbana Champaign Statistics, University of Iowa Statistics and Actuarial Science, University of Minnesota Biostatistics, University of North Carolina Chapel Hill Biostatistics, University of Pittsburgh Biostatistics, University of Pittsburgh Statistics, University of Washington Biostatistics, University of Wisconsin Biostatistics and Medical Informatics.

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**Table 7.1** Faculty demographics of 28 US Departments of Statistics and Biostatistics (number of faculty)

| | US permanent resident | | | | | | Non-US resident | |
|---|---|---|---|---|---|---|---|---|
| | Asian | | White | | Other | | | |
| | F | M | F | M | F | M | F | M |
| Non-tenure track faculty | 13 | 12 | 66 | 80 | 6 | 4 | 5 | 18 |
| Tenured/Tenure track assistant professor | 9.25 | 22 | 17 | 31 | 3 | 7 | 14 | 23 |
| Tenured/Tenure track associate professor | 20 | 49 | 15 | 34 | 4 | 10.25 | 1 | 0 |
| Tenured/Tenure track full professor | 10 | 57 | 37 | 135 | 2 | 12.49 | 2 | 0 |

departments have higher proportions of female tenured and tenure track faculty than Statistics departments ($p = .04$); the estimated proportion female among Biostatistics departments is 32%, compared with 24% for Statistics departments.

Fifty seven departments of Statistics or Biostatistics were invited to submit faculty and graduate degree demographic data, 14 Biostatistics and 43 Statistics departments. All departments listed in the 2013 *U.S. News and World Report* (2010) top 50 departments of Statistics and Biostatistics were invited, along with all the departments profiled in the book *Strength in Numbers: The Rising of Academic Statistics Departments in the U.S.* (Agresti and Meng 2013). Twenty nine departments provided data. There was no significant difference in response rate between Biostatistics and Statistics departments ($p = .59$ Chi-square test).

Even at the rank of assistant professor women do not make up as large a fraction of the faculty as might be expected based on the national production of Ph.D.s. In this group of 29 institutions, women comprise 34% of the tenure track assistant professors. The proportion of women decreases with seniority to 30% of tenured associate professors and only 20% of tenured full professors. At the same time, women make up 44% of non-tenure track faculty, which is very similar to the fraction of doctoral degrees awarded to women in the United States.

Interesting relationships emerge when both gender and race are simultaneously considered while comparing department composition across different position types. Among US permanent residents, composition profiles across non-tenure track, tenure track assistant, tenured/tenure track associate, and tenured/tenure track full professors show significant differences according to whether faculty are Asian female or male, and White female or male ($p < .0001$, chi-squared test). More specifically:

- White females have *much* higher representation in non-tenure track positions than would be expected, and lower representation as tenure track full and associate professors.
- Asian females have higher representation as tenured associate professors than would be expected, and lower representation in tenured full professor positions.
- White males have higher representation as tenured full professors than would be expected, and lower representation in tenured associate professor positions.

**Table 7.2** Demographics of Ph.D.s awarded in 29 departments of Statistics and Biostatistics

| Demographic groups | Number of Ph.D.s awarded | Percent |
|---|---|---|
| White | 51 | 25 |
| Asian/International | 121 | 60 |
| Other race/ethnicity | 29 | 14 |
| Men | 124 | 62 |
| Women | 77 | 38 |

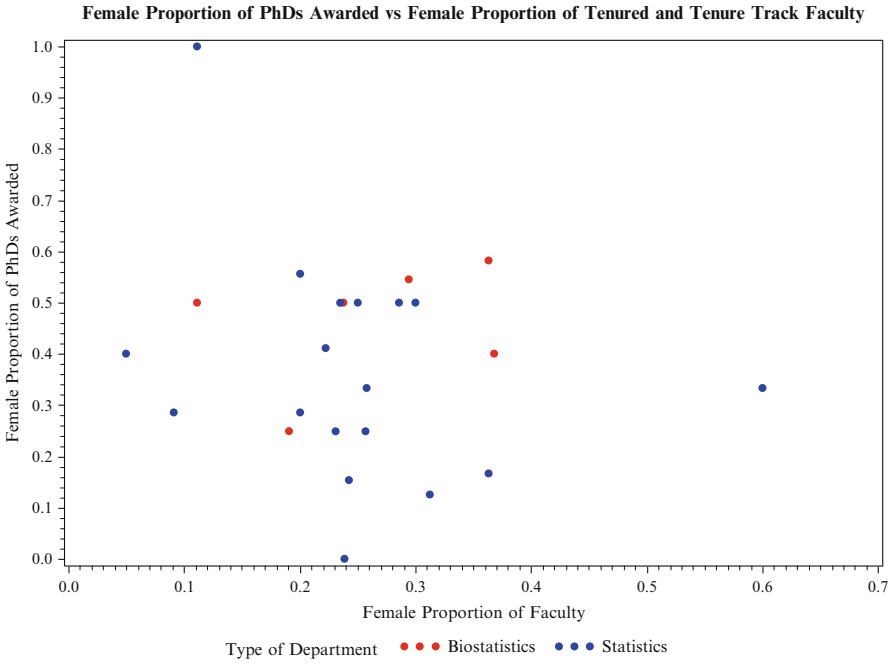


**Fig. 7.9** Proportion of Ph.D.s awarded to women plotted against the female proportion of tenured and tenure track faculty. Biostatistics departments are shown in *red*; Statistics departments in *blue*

- Asian males have higher representation as tenured associate professors than would be expected, and *much* lower representation in non-tenure track positions.

In this group of highly ranked Statistics and Biostatistics Departments, women received 38% of the Ph.D.s awarded in 2012–2013 (Table 7.2), which is lower than the fraction reported in the *Survey of Earned Doctorates*. Asian and international students earned 60% of the Ph.D.s awarded by this group of institutions, whereas US white students received only 25% of the degrees. Students of all other racial and ethnic groups accounted for only 14% of the Ph.D. degrees awarded in Statistics and Biostatistics in 2012–2013.

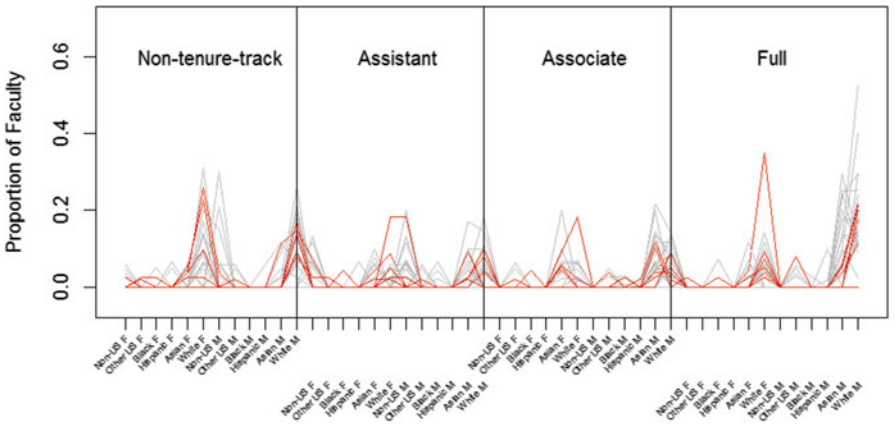


**Fig. 7.10** Faculty composition according to position type and demographics for 28 departments (one department is missing). Departments with female leadership are shown with *red* profiles

There appears to be no relationship between the proportion of degrees awarded to women by a department and the proportion of women among tenured and tenure track faculty in that department (Fig. 7.9. *Note*: 5 departments did not award any Ph.D.s in 2012–2013).

We are particularly interested in female leadership and the question of whether having a female department chair and the presence of more than one or two female tenured full professors is associated with larger numbers of female junior faculty and doctoral degrees awarded to female graduate students. Neither the gender of the department chair nor the number of female senior faculty appeared to be associated with the proportion of Ph.D. degrees awarded to women. However, departments with female chairs *do* have significantly higher proportions of female tenure track assistant professors (logistic regression, $p = .032$). The proportion of tenure track assistant professors that are female also increases as the number of female full professors in the department increases (logistic regression, $p = .030$).

More generally, departments with a female chair have significantly larger proportions of tenured and tenure track faculty who are women ($p = .003$). The ratio of female-to-male tenured and tenure track faculty is 90% higher for departments with female chairs than with male chairs. Department distribution profiles (Fig. 7.10) suggest considerable overlap across departments, but with noticeable differences associated with female leadership.

With regards to female leadership and female tenured/tenure track faculty, one may ask "Is the gender of the chair a reflection of the fact that there is a larger proportion of females? After all, if there are no women, then the chair can't be female. Does the chair being female indicate that the department is already receptive to women?" With regards to female over-representation in non-tenure track positions, is this because women, based on personal situations, are choosing to pursue nontraditional academic positions? Or are women deliberately avoiding tenure track

positions because of the roles that will be expected of them in such positions, i.e., tenure track positions are undesirable?

For more insight into the role of department leadership, respondents were asked to comment on the effect of department leadership on the gender composition of their department. Eighteen chairs provided comments, and without exception, all responses indicated a desire to have a more diverse department, and most implied there are difficulties achieving this goal. The responses ranged from "There is no effect of department leadership on gender composition of our department." to this statement from a Biostatistics chair about the ways that department leadership can influence the direction of the department:

> Department leadership has the power to move the needle a great deal on gender composition—through effects such as setting a cultural tone, creating recruitment packages that attend to flexibility needs, energetic outreach and inclusion of women in the recruitment process, and attentiveness to subtle and subconscious biases in the assessment process. However there are pipeline issues that are beyond department leadership to address fully whereby applications to tenure track positions in leading universities seem to not reflect the gender composition of those emerging with doctoral degrees in our fields, and the profession as a whole must address in the mentorship of graduate students and postdoctoral fellows.

One department chair made this comment showing how a chair can advocate for increasing the number of women faculty.

> When I started as chair of statistics in …, we had 11 male ladder faculty and 0 female. I considered dealing with our gender imbalance at the very top of my list of priorities, as I made clear in my initial greeting in our newsletter. This year we hired our lone female ladder faculty. So, sad as it may seem, 10 to 1 is actually a step in the right direction.

Discussing the issue of critical mass, one department chair mentioned faculty resistance to hiring more women faculty and also the change in climate that may come with more female faculty:

> Our department had 1 tenured/tenure track female ... [up until] 2006. Current tenured/tenure track female = 3. Critical mass for females seemed to be very important. The single female was not able to convince the faculty to hire more females. When a 2nd female came (in a spousal accommodation), that completely changed the climate and we were able to increase our numbers. We've had 3 or 4 female faculty since 2007. This change was not due to department leadership. There has never been much leadership about diversity from the department chair or by the college administration.

This study has revealed several interesting associations that can inform future practices and policy development. Causation, however, requires further study. We can say that departments headed by women have more female tenure-track assistant professors than departments headed by men. Department chairs pointed out several ways that senior faculty and chairs can "move the needle": (1) setting department tone and expectations about department climate and recruitment efforts, (2) energetic outreach to potential women faculty, (3) flexible department policies and recruitment packages attending to the needs of faculty with families, (4) educating search committees about unconscious biases, and (5) mentoring female graduate students and postdoctoral scholars to prepare for faculty careers.

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*Vignette 7.3*

# Women in Biostatistics: A Case of Success in the United States

**Camille M. Moore, Brandie D. Wagner, Miranda Kroehl, Stephanie A. Santorico, Elizabeth Juarez-Colunga, Sharon Lutz, and Anna E. Barón**

Anecdotal evidence suggests that women have rapidly become better represented and enjoy more favorable career paths in biostatistics compared to many other STEM disciplines. Up to the early 1980s, our department faculty at the University of Colorado, Denver was entirely male. Today, however, women comprise 71% of tenure track faculty and 67% of the department faculty overall. In the United States, the proportion of women earning doctorates in biostatistics and biometrics rose from 38% in 1992 (NAS 2013) to 57% in 2011 (ASA 2013). While these estimates are similar to those in all bioscience fields, they are much more favorable than in other mathematics fields (see Chap. 6). According to a recent American Statistical Association (ASA 2013) survey of Ph.D. granting departments, 39% of biostatistics faculty were female compared to only 26% in statistics departments (see Fig. 7.11). Seven of the 13 biostatistics departments consisted of greater than 40% female faculty, while two reported more than 50% female faculty (ASA 2013). Despite the increase in female faculty members, only 16% of chairs of Ph.D. granting statistics and biostatistics departments are women (Palta 2010).

Since 2010, the ASA has reported similar median salaries for male and female assistant and associate professors in academic biostatistics and biometrics departments (ASA 2002–2012). While these trends are encouraging, it is unclear whether similar advancements have been made in the government and private sectors of

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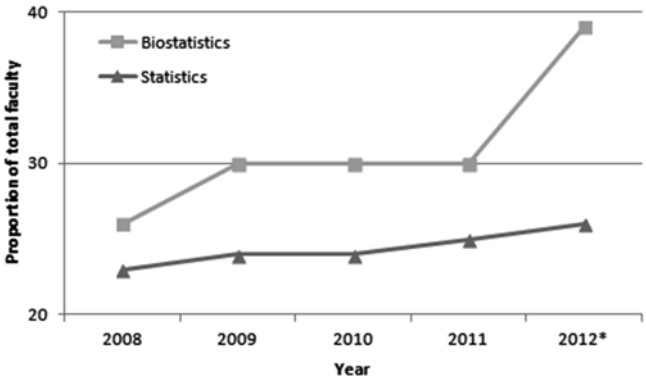


**Fig. 7.11** Proportion of female full-time faculty at Ph.D. granting departments of statistics and biostatistics. *Note*: 2012 estimates from draft report (ASA 2013)

biostatistics, and many women in biostatistics still share similar concerns as women in other STEM disciplines. Gender disparities in salaries, career advancement and promotion, striving for work-life and work-family balance, recognition from and leadership roles in professional associations, as well as treatment, particularly in interactions with collaborators from predominantly male STEM fields, are still relevant issues for women in biostatistics. We spoke with women in our biostatistics department at the University of Colorado Denver, as well as colleagues working in industry and in other academic biostatistics and biometrics departments across the United States to better understand how female biostatisticians became attracted to the field and if and how gender has influenced their careers.

## 7.9 Educational Paths

The women we spoke with came to study biostatistics in a variety of ways. Biostatistics is a relatively new field, and there are few formal undergraduate programs. While some studied mathematics, applied mathematics or statistics as undergraduates, others had backgrounds in biology, chemistry, physics, engineering, computer science, psychology, economics, and even art history. Reasons for pursuing a graduate degree in biostatistics were equally varied, but commonly included a desire to combine mathematics with medicine and to utilize mathematics to impact society, excellent job opportunities, and a feeling that the field of biostatistics was more welcoming to women and students with diverse educational backgrounds. Many attributed their initial interest in STEM and biostatistics to supportive high school teachers, college professors, and other mentors who took notice of their aptitude in STEM disciplines and actively encouraged them to pursue degrees in mathematics and science.

## 7.10 Career Choices

Careers in biostatistics are attractive for a variety of reasons, including well paid and flexible job opportunities, the opportunity to work on interesting and important medical, epidemiological, and public health problems, and the collaborative nature of working in an interdisciplinary field. The biostatisticians in academia and industry who we interviewed felt they had excellent career opportunities. While none indicated that gender played a conscious role in their career decisions, many did note the difficulties in achieving a balance between work and family life while pursuing an academic career. Faculty in all fields work longer hours than their predecessors, with the proportion reporting working more than 55 h per week growing from 13% in 1972 to 44% in 2003, for men and women alike (Schuster and Finkelstein 2006). While both men and women are impacted by the stress of a demanding career, often a larger proportion of family and domestic responsibilities fall on women. Among university professors, the gender imbalance in the higher ranks can be largely explained by the reduction or halting of work responsibilities for women starting families, and in the STEM fields, women who were not currently working were far more likely than men to cite family responsibilities as the reason for not working (NSF 2013). The biostatisticians with whom we spoke felt their jobs were more flexible than most in terms of allowing for flexible working hours and telecommuting, perhaps due to the current high demand for qualified biostatisticians. However, many stated that they took breaks from their academic careers, moved closer to family, or had to hire outside help in order to start families and fulfill household responsibilities. Others noted that their spouses had more flexible jobs or worked from home, which allowed them to pursue more demanding career paths, or that they postponed having families in order to pursue their career goals.

While the proportion of women earning doctorates in biostatistics has rapidly risen over the past 20 years and numbers of women in biostatistics departments have increased, many women we spoke with found it difficult to maintain work family life balance while pursuing an academic career, and indicated a need for better maternity leave and family policies. We hope that as family friendly policies are more widely adopted, better gender balance will be achieved in the higher ranks in both university departments and industry. In recent years, women in biostatistics have assumed high profile roles, such as President of the American Statistical Association, Directors of NIH branches, Chairs of academic departments and study sections, and university Deans. It is our hope that the advancement of more women to higher level positions in our field provides encouragement to women in other STEM careers.

Many young women lose interest in math and science during middle school (James 2009), making role models and mentoring of female students, particularly at younger ages, very important. Graduate students and faculty in our Biostatistics and Informatics department at the University of Colorado Denver have become active over the last 3 years in pipeline activities designed for middle and high school students. We introduce them to key concepts in biostatistics, familiarize them with

some ways to visualize data, and engage them with interactive individual and group activities. We also tell them about our current research projects and what got us excited about studying and working in the field. Encouraging young women in math and science and exposing them to interesting STEM career opportunities through avenues like this may motivate them to continue taking math and science courses throughout high school and college, bringing greater gender balance to all STEM fields.

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