IS IT TIME TO REDEFINE THE "ALTERNATIVE" CAREER PATH FOR ECOLOGISTS?

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Graduate programs in ecology tend to emphasize academic careers for Ph.D. candidates, while viewing non-academic careers (e.g., those in government, non-governmental organizations, and industry) as "alternatives." Here, we demonstrate that although the number of Ph.D.'s granted in ecology has increased nearly 3-fold since 1966, less than 20% of those graduates obtain jobs in academia within 5 years of graduation. Furthermore, while it takes a median of 3 years following receipt of a Ph.D. to obtain a tenure-track job in ecology, high variability in recent decades means that Ph.D. graduates have an approximately equal chance of spending anywhere from one to more than five years in soft-money, post-doctoral positions. In sum, the majority of Ph.D. graduates in ecology do not end up in academic careers, and those that eventually do will spend a significant yet variable amount of time in soft-money and temporary positions. We therefore argue that academia is the new alternative career, and that ecology as a discipline would benefit from tailoring graduate training to include skills relevant to non-academic careers while also increasing transparency about the career paths of Ph.D. recipients.

Obtaining a Ph.D. is a serious commitment for students in time, energy, and years of reduced potential earnings; as well as a significant investment for society, with costs for training a graduate student in ecology averaging $150,000[1] (Oklahoma State University 2012). In many graduate programs, the main career goal following a Ph.D. is an academic, tenure-track position, and student training reflects this goal (Freeman et al. 2011, Sauerman and Roach 2012). Non-academic positions, including science positions within government, non-governmental organizations, and the private sector, are perceived by many as less desirable or prestigious, and such positions have traditionally been characterized as "alternatives" to the primary career path for doctoral students.

The emphasis on academic positions, however, reflects neither the reality of today's job market nor the preferences of many Ph.D. graduates (Sauermann and Roach 2012). As a result, a system focused primarily on preparing students to be competitive in academia may provide training misaligned with what students want or need to succeed in non-academic careers (Blickley et al. 2012). If so-called alternative careers (Jaschik 2013) are in fact those most sought after (and obtained) by Ph.D. recipients in the ecological sciences, then continued emphasis on academic research careers may be providing a disservice to graduate students in ecology.

1 Calculated based on the average graduate stipend in ecology and evolutionary biology, assuming 14% fringe benefits, 30% overhead, and 5.5 years of study.

To determine how career pathways of Ph.D's in ecological sciences have shifted over time, we examined both the proportion of Ph.D. graduates in ecology that obtained tenure-track academic positions and the length of time between obtaining the Ph.D. and securing a tenure-track position. We focused on academic positions not because we believe they should be the gold standard for career paths for ecologists, but rather to frame our results in terms of the existing paradigm that emphasizes academic careers over all others. We hope this analysis will spur further discussion on how academic training can most effectively meet the needs of new doctorate holders amid a shifting career landscape.

HAS THE NUMBER OF NEW PH.D.'S AWARDED IN ECOLOGY CHANGED IN RELATION TO THE PROPORTION OF TENURE-TRACK POSITIONS AVAILABLE?

We collected time series data on the number of doctorates awarded from the National Science Foundation (NSF) online database WebCASPAR (https://webcaspar.nsf.gov/). Data were aggregated at two levels: the broad level of Life Sciences, including biological, agricultural, environmental, and health sciences; and the more refined level of Ecology, including ecology, evolution, and population biology. Both levels were included to compare the proportion of doctorates in post-doctoral and tenure track positions, which were only available at the broader level of Life Sciences.

The number of people earning doctorate degrees in the Life Sciences has increased nearly threefold between 1966 and 2010 (Fig. 1A). In general, periods of increase were punctuated by periods of little or no growth. The steepest increase in number of new doctorates awarded occurred recently; between 2003 and 2010 there was a 33% increase in the field. Trends in the Life Sciences as a whole and the subfield of Ecology were strongly correlated ($r = 0.89$; $n=19$; $p<0.0001$). Ecology showed a slightly higher rate of growth than the broader categorization, especially in more recent years (2003 to 2010) when the number of Ph.D. ecology degrees awarded increased by 77%.

We also examined time series data on the proportion of Life Science doctorates employed in post-doctoral and tenure track positions from the NSF Survey of Doctorate Recipients (SDR). The SDR collects longitudinal data on individuals who earn science, engineering, or health (SEH) doctorates from U.S. academic institutions (NSB-12-01). In contrast to the growth in new doctorates awarded, the proportion of doctorates in the Life Sciences employed in tenure track academic positions declined between 1993 and 2008 (Fig. 1B). A total decline of

2.5% - 3.0% was similar for those graduates 1-3 years and 3-5 years following completion, respectively (1-3 year $R^2 = 0.74$, $F_{1,7} = 17.41$, $p = 0.006$; 3-5 year $R^2 = 0.73$, $F_{1,7} = 16.60$, $p = 0.007$).

HAS THE LENGTH OF TIME BETWEEN OBTAINING A PH.D. AND A TENURE TRACK POSITION CHANGED IN THE PAST 4 DECADES?

We administered a web-based survey to quantify the length of time between obtaining a Ph.D. and a tenure track position in ecology. The survey consisted of 10 questions and respondents were asked to self-identify as ecologists by stating their area(s) of expertise. The survey link was emailed to several ecological organizations, social media pages, and to faculty, departmental, and professional society list-serves. The intended audience was Ph.D. recipients in ecology in North America who had obtained tenured or tenure-track academic positions in the ecological sciences, and survey responses were filtered to meet these criteria. Respondents were included only if their Ph.D. was received prior to 2009. Our survey was intended to measure the time it takes to get a tenure-track academic position, assuming that the respondent was attempting to obtain such a position for the entire period of interest. As a result, responses indicating >10 year gaps between receipt of the Ph.D. and tenure-track position were removed given comments indicating that these people had followed "non-traditional" career paths, i.e. employment outside academia prior to a later return.

A total of 903 respondents responded to the survey, of which 454 met the filtering criteria. The median time between receiving a Ph.D. and obtaining a tenure-track academic position increased from a minimum of 0-1 year in the 1970's to a maximum of 4-7 years in the mid-1980's, and has remained fairly constant at 3 years since about 1990 (Fig. 2). Variability across all years was high. Not surprisingly, trends in the duration of years spent in post-doctoral positions followed similar patterns. Median time spent in a post-doctoral position was lowest in the 1970's and, using either metric, the time spent between obtaining a Ph.D. and a tenure-track position was highly variable, particularly for people who received their Ph.D.'s after the 1970's (Fig. 3). As a result, ecology Ph.D. recipients since the 1980's have had an approximately equal chance of spending one year or more than five years in post-doctoral positions (Fig. 3). In contrast, ecology Ph.D. recipients prior to 1980 were much more likely to spend less than three years in post-doctoral roles. Low sample size for people receiving Ph.D.'s prior to 1975 (n = 17), however, suggests that additional research is needed to fully characterize these patterns.

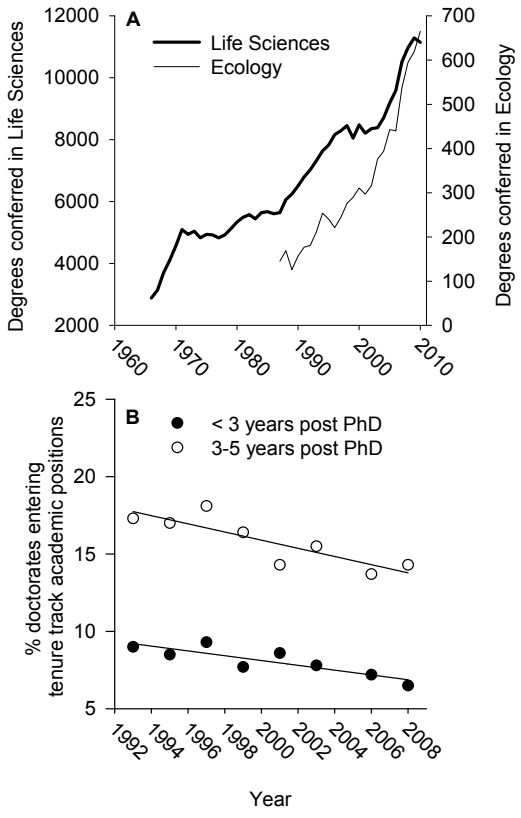

Fig 1A. The number of doctorate degrees awarded in the Life Sciences (left axis; biological, agricultural, environmental, and health sciences) and the subgroup Ecology (right axis; ecology, evolution, and population biology) have increased nearly threefold between 1966 and 2010. **Fig 1B**. The proportion of new doctorate holders entering traditionally academic positions has declined since 1992. Source: WebCASPAR query of IPEDS completion survey data and Table 3-20 (NSB-12-01)

THE ROLE OF ACADEMIC TRAINING AMID A SHIFTING CAREER LANDSCAPE FOR NEW ECOLOGISTS

In ecology, as in most scientific disciplines, the number of Ph.D.'s granted has increased dramatically over the past 50 years. In the life sciences, this increase has occurred without a concomitant increase in tenure track academic positions, and therefore an ever-decreasing percentage of Ph.D. graduates obtain the academic jobs for which they were primarily trained. Less than one in five (< 20%) Ph.D. graduates obtained academic positions at any time between 1993 and 2008 (Fig 1B). This trend is even more apparent in the biological sciences as a whole over the past 40 years; while 55% of Ph.D.'s in biological sciences entered academic jobs in 1973, in 2008 the percentage of Ph.D. recipients in academic positions had dropped to 14% (Cyranowski et al. 2011). These statistics belie a simple fact: there are more Ph.D. graduates than there are academic positions available in ecology. Although we were unable to obtain data on a similar scale documenting career paths of Ph.D. recipients in oceanography, a smaller scale study on oceanographers reported that approximately 50% of Ph.D. recipients in ocean sciences and 65% of Ph.D. graduates in physical oceanography were employed by educational institutions following graduation (Brix et al. 2003). These proportions, despite only representing a single year (for ocean sciences) or a single institution (for physical oceanography), suggest that oceanographers may have a greater chance of obtaining tenure-track positions than their ecologist or life-science counterparts. Still, these data suggest that up to half of Ph.D. recipients in the broader field of ocean sciences are pursuing careers outside of academia. This trend will likely continue, as overextended principal investigators rely on graduate students and post-doctoral positions to produce the publications required

by granting agencies and promotion committees (Freeman et al. 2010, Cyranowski et al. 2011).

For those who obtain tenure-track positions, it currently takes a median of 3 years following completion of a Ph.D. to get an academic job, with that time often spent in post-doctoral positions. This is not a particularly new phenomenon; the median time between Ph.D. and tenure track has remained nearly constant since the 1980's. However, the high degree of variability in the time between Ph.D. completion and employment in academia means that some people will get job offers immediately following (or even prior to) defending their dissertation, while an approximately equal number may spend five or more years as soft-money researchers before obtaining a tenure-track academic position.

The declining availability of academic jobs per Ph.D. graduate and the several years lag between Ph.D. and tenure track positions are not necessarily reasons for despair. However, a lack of awareness of the career prospects that await new Ph.D. recipients and the strong institutional emphasis on skills required for academic jobs to the detriment of other valuable skills may leave new ecologists surprised at their inability to obtain permanent positions following graduation. Several steps are necessary to improve graduate training and align expectations of new Ph.D. students to the current status of career options for ecologists. To this end, we offer recommendations for prospective students, Ph.D. candidates, advisors, department heads, and university deans to move forward in training Ph.D. students.

First, graduate programs and graduate advisors must increase transparency about their capacity to prepare students for success in the contemporary job market. To do so, graduate programs in ecology should provide up-to-date data on the career paths of program alumni 2, 5, and 10 years post-graduation. This type of information is almost always freely available for law schools and business schools, but seldom available in Bioscience departments (Freeman et al. 2001). Individual advisors also must encourage honest discussion about expectations of search committees filling an academic position. For example, potential Ph.D. candidates with academic aspirations should know that to publish the number of peer-reviewed articles expected to successfully compete for research positions in ecology could take up to 8 years publishing in journals with an approximately 80% rejection rate (Statzner and Resh 2010). Such information could possibly deter some potential Ph.D. candidates from enrolling in graduate study in ecology. Indeed, some have argued that the current levels of Ph.D. enrollment are neither justified nor sustainable given the current job market, and that the time has likely come for institutions to rethink Ph.D. programs, perhaps drastically reducing the number of students admitted and degrees granted (Taylor 2011). Such top down controls have already been proposed at some institutions. For example, the recent draft strategic plan for the Krieger School of Arts and Sciences at Johns Hopkins University proposes reducing graduate student enrollment across all departments by about 25% over five years, while concurrently increasing graduate student support for those enrolled (Flaherty 2013). While reductions in enrollment should increase the likelihood of an academic career path for those with doctorates, a Ph.D. offers the opportunity to develop valuable skills that are relevant to a wide range of career options. Thus, independent of reductions in admissions to graduate programs, increased transparency about academic job prospects and adaptation of graduate training to the realities of the career landscape for ecologists are desirable.

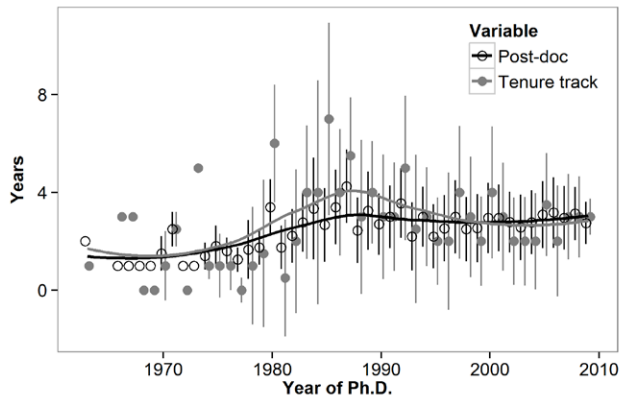

Fig 2. Median (+/- standard deviation) number of years between receiving a Ph.D. and obtaining an academic, tenure-track position (grey, closed circles) and years spent in post-doctoral positions (black, open circles) from survey of 454 ecologists. The median time spent in a post-doctoral position was lowest in the 1970's although the time spent between obtaining a Ph.D. and a tenure-track position has remained highly variable. Lines are smoothed polynomial regression. Points are dodged for clarity.

Our second recommendation is that graduate training of ecologists should emphasize skills relevant to job prospects both within and outside of academia. The latter may be difficult for many faculty graduate advisors, as they are by definition part of the ever-decreasing percentage of those who obtained academic professorships and often have not been widely exposed to other career options. Graduate programs should provide alternatives to over-specialization while promoting cross-disciplinary study, collaboration, and opportunities to develop practical skills and outputs (Taylor 2011). Emphasis on a narrow set of skills most relevant for academia is not only to the detriment of young scientists who may ultimately end up in non-academic fields, it can also reduce the quality of science as creativity is diluted, risks are minimized, and the dissemination of scientific knowledge becomes less effective (Brischoux and Cook 2009, Statzner and Resh 2010). By offering training that is relevant to a wide range of disciplines, adaptive graduate programs have the opportunity to prepare their alumni to produce far-reaching impacts to science and society.

Finally, and perhaps most importantly, the onus falls on Ph.D. students themselves to tailor their training in order to maximize the benefits of their degree and prepare for the current job market. As our data underscore, most Ph.D. students will follow a career path that differs from that of their advisors. Students must therefore understand what skills will be most important in their future careers and proactively seek mentorship and training to gain skills to increase their cross-sector marketability (see Blickley et al. 2012). High-level skills such as critical

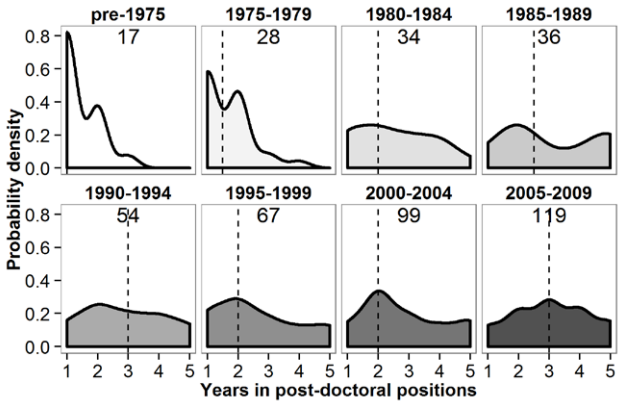

Fig 3. Probability density of duration of time spent in post-doctoral positions prior to obtaining an academic, tenure-track position in ecology. Ecology Ph.D. recipients were more likely to spend less than three years in a post-doctoral position prior to 1980 than since. Dashed lines are medians (note that the median for pre-1975 is 1), numbers in panels are sample size for each time period.

thinking and problem solving; technical skills in statistics, computer programing, and writing; and experience teaching, supervising employees, and managing projects are all important components of most Ph.D. programs that are relevant to a wide range of career options. Opportunities for professional development and training in such areas are often available to graduate students through the broader university community, professional society meetings, and other venues, and students should be encouraged to take advantage of these opportunities. As a contributor to an online career discussion board for graduate students succinctly summarized (Check 2007): "If you aren't thinking about 'alternative careers' before ever setting foot in graduate school, then you're being foolish."

It is imperative that those interested in pursuing a Ph.D. in ecology educate themselves and approach their graduate career with an open mind about the myriad career options following degree completion. It is equally important for mentors, graduate programs, and institutions to recognize the reality of academic career paths and encourage the development of skills necessary to succeed in a range of potential careers. As academia becomes the new "alternative" career for ecology Ph.D.'s, graduate programs and institutions must adapt to reflect this reality.

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