TEN YEAR REVIEW:
QUANTITATIVE ECOLOGY AND RESOURCE MANAGEMENT (QERM)

Janneke Hille Ris Lambers (chair); jhrl@uw.edu
Biology Department, University of Washington

Jim Bence (bence@msu.edu)
Michigan State University

Jon Wakefield (jonno@uw.edu)
Statistics Department, University of Washington

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I. Executive Summary

We recommend that the Quantitative Ecology and Resource Management Program be continued, with its' next programmatic review in ten years. The review committee was impressed by the strength of this unique program, including the rigorous quantitative training it provides to future resource managers, the breadth of environmental and quantitative approaches it exposes its students to, and the success of the QERM alumni in environmental and natural resource fields.

At the same time, we recognize several challenges that the QERM program faces in maintaining its strengths:

- The QERM program is on the edge of being too small.
- The success of the QERM program depends disproportionately on the engagement and time commitment of the program director.
- Course availability and content for QERM students fluctuate over time.
- QERM is not always as interdisciplinary as it could be.
- QERM students and faculty do not reflect the diversity of the US population.
- A significant fraction of QERM students take longer than desired to finish their degrees.

The review committee believes that all these challenges can be addressed, some with relatively minor changes that can be addressed by QERM leadership and faculty, and some with larger efforts that will need to be enacted over the long-term and are more likely to achieve success through a partnership between QERM and the College of the Environment (COE). A summary of our recommendations are:

- Increase the QERM yearly program size to at least 4, and ideally 5. This can be done by continuing a hybrid funding model recently piloted by QERM, requiring 1st year students to teach 1 quarter and /or with a greater financial commitment from COE. In the longer term, additional funding opportunities (e.g. training grants and endowment opportunities from alumni and other interested donors) could also be explored (QERM, COE).
- Involve more QERM faculty in leadership through the creation of an executive committee and / or associate director positions (QERM).
- Regularly evaluate course content and change course requirements when content no longer aligns with QERM goals, and as new opportunities arise (both those offered by QERM faculty and QERM-affiliated departments) (QERM).
- Ensure availability in the critical optimization courses (QERM, COE)
- Explore ways to ensure the involvement of many units (both within COE and across other Colleges) in QERM student training and hosting, and increase the breadth of ecology-focused graduate students involved in QERM activities (QERM)
- Make recruitment efforts of both faculty and graduate students more targeted and strategic to increase diversity (QERM, COE).
- Provide more structured mentoring and career advice to QERM students beyond their 1st year (QERM).

II. Strengths of the Program

The Quantitative Ecology and Resource Management Program is a small graduate program at University of Washington, recently moved from the Graduate Program to the College of the Environment. It has several important strengths:

- It provides rigorous training in both quantitative skills and resource management (this was recognized by both current students and alumni of the program).
- The graduate students form an extremely cohesive and collegial group, both while in graduate school and afterwards. 'QERMies' are very invested in the program.
- Perhaps most importantly, QERM is successfully recruiting a strong cadre of students into federal and local resource management agencies.
- Although quantitative skills are increasingly emphasized by ecology and natural resource programs around the country, QERM still provides a relatively unique training environment. Despite its' small size, QERM is known around the country in particular for the rigor and depth of its training.

III. Specific Challenges Faced by QERM

Below, we describe the main challenges we see facing QERM. Many of these challenges are ongoing challenges QERM has faced throughout its' existence (and in many cases, has moved to address).

1) <u>The QERM program is on the edge of being too small.</u>
   QERM provides funding for all first year students during the academic year (3 quarters), so that they can focus on taking courses. Because the base funding for first year QERM students provided by the COE is 9 total quarters (down from 12 provided by the graduate school in 2012), this limits the incoming size of the QERM program (the floor is at 3 students per year). QERM has been flexible and creative and has generally brought in more than 3 students (4 on average, with about 16 students currently in the program), although some cohorts have been as small as two students. We heard from graduate students and alumni that although they valued the smaller size of the program, that cohort sizes of two or even three are marginal for maintaining a critical mass and providing the synergy the students highly value, and is a hallmark of the program. The review team also felt that a conspiracy of chance events could well lead to back to back small cohorts, which could negatively influence student experiences, and thus cause cascading effects such as a decrease in success of recruiting top students in subsequent years.

2) <u>The success of the QERM program depends disproportionately on an invested and motivated program director.</u>
   It was clear to the review team that the current director is critical to the current success of QERM, and (as is common within academia) that his efforts are probably far from compensated by the modest fiscal support he gains. From what current QERM members tell us, this was also the case for past QERM directors. The current director, Tim Essington, is doing a first-rate job, but the time commitment is clearly large. Other QERM faculty are involved in governance through relatively infrequent faculty meetings (generally held in

Autumn) and two faculty committees appointed annually, the admissions committee and qualifying exam committee. However, the responsibility for the day-to-day running of the program, as well as advising of first year QERM students, rests largely on the program director. The review team was concerned about this on two counts; first, that a future director may not be able to put as much into the program, and second, that an inevitable transition to a new director at some future date could be rocky.

3) Course availability and content for QERM students fluctuate over time.
Graduate students and faculty reported that courses required for first year QERM students (see Table 1) were not always available to graduate students, and additionally, that the relevancy of the course content fluctuated. As background, QERM students are required to take core courses in their first year that provide them with foundations in statistics, applied mathematics and optimization– course requirements are intense and cover a wide variety of material. This foundational training was emphasized as a key component of the program by the alumni who participated in the program review. Since QERM lacks dedicated faculty lines, these courses are offered across multiple departments. While this is an advantage in that high quality teaching can be received from faculty in highly-ranked departments, the disadvantage is a lack of control over the content and availability of courses.

Table 1. Required Courses for QERM students

Course Number	Description	Credits
STAT 516 (Statistics)	Stochastic Modeling of Scientific Data I	3
STAT 517 (Statistics)	Stochastic Modeling of Scientific Data II	3
IND E 513 (Electrical Engineering)	Linear Optimization Models in Engineering	3
SEFS 540 (SEFS)	Optimization Techniques for Natural Resources	5
QERM 597 (two quarters)	QERM seminar	2
QERM 514	Analysis of Ecological and Environmental Data	4
BIOL/SEFS/FISH 567	Topics in Advanced Ecology	3
AMATH 512 or A MATH535	Mathematical Analysis in Biology and Medicine / Mathematical Ecology	5

Two specific courses / areas were mentioned as particularly problematic. The first is the required introductory optimization course (IND E 512), which QERM students have had difficulty enrolling in, resulting (in some cases) in a delay in the timing of qualifying exams by one year. The second problematic area mentioned was the statistics sequence (STAT 516/517), particularly the second offering. Course content is reported to be inconsistent and not always directly relevant to QERM. This likely results from the recent departure from UW of Vladimir Minin, a professor with a joint appointment in Statistics and Biology, who was a strong advocate of the QERM program within the Department of Statistics and was a regular teacher of these two classes.

4) QERM is not always as interdisciplinary as it could be.
QERM has always involved faculty from many units (e.g. Applied Math, Biology, School of Aquatic and Fisheries Sciences, School of Environment and Forestry Sciences, Statistics)

by placing students into their labs and involving faculty in their program. Every one of the students (16 total) and alumni (8 total) we met with identified the interdisciplinary training students receive as an enormous strength of the program. However, there was also concern that the shift from the graduate school to the College of the Environment could mean less involvement from the departments not in that college (e.g. Applied Math, Biology and Statistics, amongst others). A high proportion of current graduate students are in just one unit (2/3 of current graduate students are in SAFS labs). Possibly, this is because funding for QERM students after the first year is more secure in SAFS. While no current (or past) graduate students indicated dissatisfaction with the research labs they landed, many of them said they wanted to continue to see greater interdisciplinary breadth in terms of the students and faculty they interacted with and potential research projects they could have access to.

5) QERM students and faculty do not reflect the diversity of the US population.
QERM faculty and students are and have been overwhelmingly Caucasian. The gender ratio among graduate students was, until recently, weighted towards male, but will be at parity as of 2018. However, the gender diversity of faculty is low, with only ~25% of core faculty being female (according to the QERM website). Although increasing diversity remains a challenge for many STEM departments, it remains problematic for a University and College that prize diversity and inclusion.

6) A significant fraction of QERM students take longer than desired to finish their degrees.
Approximately ⅓ of QERM students take longer than 3 years to complete an MSc, and more than ½ of QERM PhD students take longer than 5 years to complete a PhD. Although a common challenge for graduate programs, it is one that should be minimized.

IV. Recommendations to Strengthen the QERM Program

Here we describe several actions the QERM director (currently, Tim Essington), the QERM graduate program assistant (currently, Erica Owens), QERM faculty, and the College of the Environment could take to strengthen the QERM program and address the challenges described above. We believe that many of the recommendations will address more than one of the challenges we identify above.

A. Increase the incoming QERM program size to at least 4, and ideally 5.
We recommend that the targeted number of first year QERM students be increased, ideally to five students. Based on our discussions with the QERM Director and QERM administrator, the number of qualified applicants for the program does not appear to be limiting. Placement of more 2nd year QERM students in interested labs also appeared to be feasible. Finally, both the program director and graduate program advisor indicated that a modest increase in the QERM program size would not require additional administrative resources, although there could be some space issues that might need to be addressed. In addition to increasing the student experience and guarding against chance events (e.g. low recruitment success in one year), we also believe that a larger program size would likely

increase the breadth of the QERM experience for students (most students and alumni mentioned they gained much of their interdisciplinary breadth by learning from each other's projects) and perhaps help diversify the student body. We describe both short-term and longer-term approaches to increasing the size of the program:

i. Recently, a hybrid funding mechanism has allowed QERM faculty members to support part of the costs of additional students during their first year. A few QERM faculty members have also taken on additional highly ranked students if they fully fund their first year costs. Combined, these approaches have recently allowed QERM to sustain a slightly larger size of the program (above base funding), although this has been highly dependent on individual faculty member funding and interests of students. We encourage QERM to continue this hybrid funding mechanism, as long as it does not restrict QERM students in their choice of labs to join after their first year, as the ability to flexibly select an advisor and research topic after joining the program were deemed essential positive aspects of the program.
ii. With the move of QERM to COE and close association with CQS (the Center for Quantitative Sciences), we understand that there may be more access to CQS teaching assistantships that can provide funding for QERM students. We recommend that QERM consider having first students teach one quarter during their first year. With this change alone, QERM would then have funding for 4 incoming students. QERM students thought this might be feasible (especially in winter quarter), even with the fairly high level of course work in the first year.
iii. While we recognize that University and College budgets are limiting, we do encourage that the COE consider allocating funds or providing backstop funds to help QERM pursue a higher first year student total. For example, COE could provide a safety net to provide first year funding in years when fewer than expected numbers of hybrid model faculty funds were obtained. If COE were able to provide one additional quarter of support (i.e. 10 total quarters instead of 9), and QERM had first year students teach one quarter each their first year, five incoming QERM students could be supported without relying on individual faculty funds.
iv. Other mechanisms for funding that are more difficult to obtain should additionally be explored in the long-term. This includes building up QERM specific endowments, pursuing training grants (e.g. NSF NRT), and potentially obtaining agency or other unit funding for first year QERM students. Alumni mentioned wanting to hear more from QERM, and although the base is small, they could form a reliable funding base for the QERM program. COE may be able to provide support in both these endeavors, for example by providing support and advice through their Advancement Team for fund raising or providing teaching release to faculty writing training grants. Successful competition for existing COE or other fellowship funds for incoming students (e.g. the NSF GRFP) could also be pursued by QERM.

B. <u>Involve more QERM faculty in leadership through the creation of an executive committee and / or associate director positions (QERM).</u>

The review team strongly supports expanding the leadership team of the QERM program, perhaps through the formation of an executive committee (something we believe QERM is

already considering) with a term that is longer than a year. Core faculty (perhaps those who have had QERM students) should in particular be encouraged to participate. This will serve several purposes. First, it would allow for training of the next generation of QERM leadership. It would also allow QERM to strengthen its program, as an executive committee could help execute many of the recommendations we provide in this report (e.g. writing training grants, evaluating course content, mentoring of QERM students beyond their 1st year, recruiting a diverse student body, etc).

C. Regularly evaluate course content and change course requirements when content no longer aligns with QERM goals, and as new opportunities arise.
Overall, it would be beneficial to have a committee (e.g. the executive committee) that meets every few years to discuss how first year course requirements (Table 1) align with the goals of the QERM program (which may change over time). This committee should include a range of faculty with representatives from the core units in School of Aquatic and Fisheries Sciences and School of Environmental and Forestry Sciences within the College of the Environment, and Statistics and Applied Math within the College of Arts and Sciences, and perhaps additionally QERM alumni. This would allow QERM to assess current course content (to determine whether they still meet current needs) and make changes in requirements as new opportunities arise (e.g. as new faculty are hired and offer other courses). For example, the creation of the relatively new eScience Institute at UW (which offers Data Science courses, hackweeks, Data incubators) could provide QERM students with additional opportunities within UW. We understand that QERM may need to be practical and live with slightly less than ideal but available courses in the short-term, but clearly defining what is desired will help in making both short and long term curricular decisions.

D. Ensure availability in the critical optimization courses
The review committee was surprised that access to one course (IND E 513) was so limiting to QERM, to the extent that some students have had to postpone completing their qualifying exam by a year. We strongly suggest that QERM leadership and the COE have a conversation with the department that provides this course and ensure that there is space for the few (3-5) QERM students who require this course annually.

E. Explore ways to increase diversity of units involved in QERM student training, to maintain and increase interdisciplinarity.
We see a few potential routes QERM can take to ensure that QERM students continue to interact with a diversity of units, as has always been a traditional strength of QERM.
    i. Instead of primarily relying on faculty to self-nominate into QERM, QERM leadership could strategically seek out new faculty, especially those in units outside the COE. An additional benefit may be increased diversity of faculty - women and underrepresented minorities are generally less likely to self-nominate themselves for opportunities. Paying attention to units where current representation is very low may be particularly beneficial in increasing disciplinary breadth.

ii. We suggest that the QERM program assistant task core QERM faculty to share (e.g. via email, the website, etc) potential projects and opportunities in their labs around the same time QERM students are considering their options. There were mixed reports on how useful the first year advisors were in helping QERM students navigate the transition into host labs, and current QERM students mentioned feeling uncertain about the potential opportunities available to them when transitioning from their first year to a project. Few QERM students recall having heard directly from QERM faculty about potential opportunities.
iii. We suggest requiring QERM students to initiate conversations about 2nd year placement earlier. Some QERM students mentioned that the timing of their search for a project was poorly aligned with the funding structure of some units. Although QERM students are encouraged to start exploring their options in the middle of their first year, most are completing that process in late winter or early spring quarter – sometimes after faculty have committed funds or resources (e.g. RAships, TAships) to recruiting new graduate students. Requiring students to meet specific deadlines (e.g. identify a list of potential faculty by November, set up 4 meetings with PI's and their grads by January, etc) and providing a format for these (e.g. a list of questions to ask faculty, a short rubric to fill out on each lab) could be helpful.
iv. We suggest continued exploration of ways to encourage QERM students to integrate themselves into graduate student communities within other units, where interests align (e.g. PCC - the Program on Climate Change, eScience). This could also help increase the breadth of interdisciplinary experiences for QERM students. Additionally, recruiting quantitatively minded graduate students in units besides QERM and SAFS to be involved in QERM related activities (e.g. the QERM seminar) is another mechanism to increase interdisciplinary breadth.
v. If QERM could provide bridge funding or arrange/assist for such funding for some students during the summer for internships, this might allow some faculty from a wider range of departments to interact with QERM students. An internship program is one possible avenue for assisting with summer funding, and there may be potential to secure such funding from industry and agencies.

F. <u>Recruitment efforts of both faculty and graduate students should be more targeted and strategic.</u>

We believe there are ways in which QERM could, over the long term, increase the diversity of its faculty and student body (which has largely been Caucasian, and has tended towards being male).

i. Although QERM has no direct mechanism by which to increase the diversity of its faculty, it can be more strategic, rather than relying on self-nomination.
ii. An effort should be made to increase the diversity of the graduate student applicant pool and the QERM student body. For example, QERM should partner with local and national organizations (e.g. UW OMAD, SACNAS) to determine strategies to advertise QERM graduate opportunities to diverse applicants, successfully recruit, and retain them. Building relationships with UW based organizations dedicated to increasing STEM diversity at the undergraduate level (PNW Louis-Stokes Alliance –

PNW LSAMP, GeNOM Alva Program, UW McNair Program, Doris Duke Conservation Scholars) could also allow QERM to recruit promising undergraduates to their program. The College of the Environment Diversity Committee should provide some resources to QERM in this regard. The QERM program assistant, Erica Owens, has already mentioned prioritizing this in future years, and we commend these efforts.

G. Provide more structured mentoring to QERM students beyond their first year

QERM students generally mentioned feeling well supported, but the review committee was concerned about the sometimes lengthy tenure of some graduate students in the program. It is our understanding that QERM students are absorbed into PI's labs in their second year, and that the assumption is that PI's will ensure they make adequate process. Many units rely on annual department-wide reviews of all their graduate students to identify unsatisfactory progress and problematic advisor / student relationships, but it is our understanding that QERM students might not receive these to the same extent as other graduate students. Thus, the review committee foresees a potential for some QERM students to slip through the cracks. We suggest the following three potential strategies to increase mechanisms to monitor progress of QERM students beyond their first year.

i. The program director already meets annually with the graduate students. Expanding this meeting to involve the advisor and perhaps the executive committee to discuss progress and hurdles could be useful. Alternatively, the program director or a member of the executive committee could attend the student's annual committee meeting.
ii. The program could put structures in place (both carrots and sticks) to incentivize progress on the part of both the graduate student and the advisor. For example, only providing QSCI TAships to students that have had an annual meeting in the last 12 months (with satisfactory progress) could provide a consistent message about the importance of milestones.
iii. Requiring graduate students to fill out an Individualized Development Plans (e.g. see myidp.sciencecareers.org) is increasingly considered as a 'best practice' in graduate education, and could also be helpful in monitoring QERM student progress and career goals. It would additionally help drive conversations towards future careers, especially helpful in the latter stages of a graduate career. These IDP's could be shared with the QERM students' advisor, their committee, and the QERM faculty / leadership.

V. Review Committees Response to the Self-Study Questions

The following User Defined Questions, broken into Strategic and Tactical groups, were provided to the review team as part of the QERM self-study. Here we summarize our views regarding these questions and the answers provided in the self-study.

Strategic Questions

1. How does QERM maintain its unique niche given the increasing bar for quantitative competency in ecology and natural resource management programs in general? How does QERM stay ahead of the bar in a rapidly changing field?

   The basic answer provided by QERM is that intense and broad first year quantitative courses, the interdisciplinary nature of the program, and the strong math/stats background (rather than an ecology/natural resources emphasis) of incoming students continues to put the program in a unique place that makes the graduates highly valued. The review committee agrees with this view, especially the first two points above. As described above (IV C & IV E), we recommend that QERM take actions to ensure these unique characteristics are maintained, by instituting regular curricular reviews (to ensure that courses required remain rigorous and relevant) and by exploring approaches to maintain and perhaps even increase interdisciplinarity.

2. Are the core curriculum requirements adequately preparing students to be at the cutting edge in quantitative science?

   Based on our interactions with faculty, current graduate students, and alumni, we believe the QERM program is generally providing students the background needed to work at the cutting edge of quantitative applications in natural resources and ecology. However, we feel that a more strategic approach to regularly evaluating course content (relative to what is available at UW and what is required to keep the program running), in contrast with the current opportunistic/reactive one of responding to current issues related to changing course offerings and course content, would be important in ensuring this in the long run. Perhaps including alumni (both recent and not so recent) on the QERM committee charged with evaluating curricular content would be helpful – they can provide some perspective on up and coming areas that are particularly useful to QERM students.

3. As an interdisciplinary training program, are we effectively leveraging the graduate training program to enhance interdisciplinary quantitative research?

   We generally agree with the thesis of the self-study, that increased interdisciplinary work by PhD students should be achieved by opportunity, encouragement, and reward, rather than by a specific requirement, although we did not necessarily agree that QERM could

not require work ‘above that required by their academic appointment’ (both RAships and TAships come with 20 hour / week time commitment). We suggest that one way to encourage interdisciplinary work without an unacceptably large time commitment for students would be to make it the regular focus of the QERM seminar class (recruiting faculty from different units to identify potential ‘problems’ to address for a quarter). For example, students could be asked to develop an interdisciplinary proposal (individually or in a small group) that they could follow up on with faculty guidance outside the classroom, if they desire. In the absence of research operational funding one could see resulting side projects being of a review or quantitative methods evaluation nature rather than involving data collection. The committee had additional recommendations to increase interdisciplinarity we will not repeat here (detailed above – see IV E).

Tactical Questions

1. How can QERM best address challenges of being a small program?

   The self-study breaks this down into specific issues related to gaining access to heavily subscribed courses, limited ability to finely tune courses or course content, and the danger of losing critical mass due to a small first year cohort. We have addressed all these questions above in detail and do not repeat that material here (IV A, C, & D).

2. Does the current first year funding and course work model still provide the best ways of attracting and preparing students?

   We think the model of departmental support for first year students while they are taking intense core course work works well for attracting and preparing students. The primary issue is whether the funding needed for this model while maintaining a critical mass of students, is available. We believe if some TAships and a small amount of additional fellowship funds were available the current model could be made more stable and able to support a larger program size, which is desirable. This is described in detail in previous sections of the report (IV A).