

University of Washington

Self-Study Document

of the

Interdisciplinary Graduate Program in

QUANTITATIVE ECOLOGY AND RESOURCE MANAGEMENT

Prepared by faculty, students, and administrators of the Program  
October 1996

**University of Washington  
Interdisciplinary Graduate Program in  
Quantitative Ecology and Resource Management  
Program Self-Study, October 1996**

**Contents**

	<b>Page</b>
<b>I. A SHORT HISTORY</b>	<b>1</b>
1. Prior to 1990 and the establishment of the QERM program	1
2. Principal academic units involved and important events since 1990	2
<b>II. THE ACADEMIC PROGRAM</b>	<b>7</b>
1. Basic Structure and Design Objectives	7
2. First Year Course Work	8
3. Qualifying Examinations	9
4. Master's and PhD Pathways	10
5. Developments in the program	10
<b>III. STUDENT INTAKE PERFORMANCE AND PLACEMENT</b>	<b>12</b>
1. Recruitment	12
2. Financial support	12
3. Performance on Qualifying Examination	12
4. Research performance	13
5. Placement	13
<b>IV. RESOURCES AVAILABLE TO THE QERM PROGRAM</b>	<b>14</b>
<b>V. RECOMMENDATIONS OF THE 1990 QERM REVIEW COMMITTEE</b>	<b>15</b>
1. General position in relation to the 1990 Review Committee's recommendations	16
2. Response to the 1990 Review Committee's specific recommendations and suggested actions.	17
<b>VI. PROGRAMMATIC QUESTIONS FACING QERM</b>	<b>19</b>
1. As students pass through the program, from the admissions process to employment, what are their perceptions of the program?	19
2. Is the academic balance of the program correct?	23
3. Are the requirements for academic progress through the program correct and effective?	25
<b>VII. FUTURE TASKS FOR THE QERM PROGRAM AND ADVICE SOUGHT FROM THE REVIEW COMMITTEE</b>	<b>29</b>
1. Improving interdisciplinary education in QERM	29
2. Governance and administration of QERM	30
3. Defining an interdisciplinary standard for QERM within the University of Washington	32
<b>VIII FACULTY RESEARCH INTERESTS</b>	

**Appendices**

- I. Correspondence regarding CQS Administration
- II. QERM Students' Letter to Dale Johnson, Acting Dean, Graduate School
- III. Statistical Theory Qualifying Examinations, 1993-96
- IV. QERM Applied Qualifying Examinations, 1993-96
- V. QERM Laboratory Rotations
- VI. Recommendations of the 1990 QERM Graduate School Review
- VII. Correspondence from QERM Alumni
- VIII. Degree Timetable Information

Quantitative Ecology and Resource Management  
Graduate School Review - Self-Study  
**EXECUTIVE SUMMARY**

1. The Interdisciplinary Graduate program in Quantitative Ecology and Resource Management (QERM) is administered through the Graduate School and brings together 34 faculty from 12 departments and 4 colleges. The interdisciplinary program has a required first year of course work followed by a qualifying examination. Students then proceed through a Masters research program or a Master by-pass, to a doctoral research program.
2. QERM attracts extremely well qualified, quantitatively oriented students with the ideals of applying their quantitative skills to natural resource problems. On average, 4 students per year are admitted and graduates find employment in the natural resources.
3. QERM has reached a cross-roads in its development. For the past six years, it has been housed in the Center for Quantitative Science (CQS) which was seen by the 1990 Graduate School Review Committee as QERM's academic parent. CQS has been reconstituted as an entirely undergraduate teaching program, its building is being knocked down and not replaced. The QERM program must find a new home and new resources.
4. The QERM program is rigorous both in its qualifying and research requirements. Its principal academic challenge is to achieve a more effective academic balance between ecology and natural resources, statistics and applied mathematics. At present, statistical aspects of the program are strongest.
5. Three tasks are identified for the Program along with resources needed to achieve them:
  1. Improving interdisciplinary education.  
Particular attention must be paid to integrating modeling, ecology, and resource management into course work more effectively. We are requesting two quarters of salary release time per academic year to facilitate this.
  2. Governance, administration, and resources for the Program.  
With the change in status of CQS, the QERM program requires facilities to administer the program and its courses, a future physical location, and computing equipment. We request that an administrative structure and budget for supporting QERM be established directly through the Graduate School and a physical location for the nucleus of the program in space that is not coveted by any department.
  3. Defining an interdisciplinary standard for QERM within the University of Washington.  
QERM was identified as a model for interdisciplinary environmental education during the debate engendered by the President's Task Force on Environmental Education. However, the QERM program has experienced serious problems in part because it is a successful, interdisciplinary program. A way needs to be found for interdisciplinary, environmentally oriented programs to thrive.

## I. A SHORT HISTORY

The Interdisciplinary Graduate Program in Quantitative Ecology and Resource Management (QERM) has truly reached a cross-roads in its development. The building that has been its home is being demolished and the unit that has been its parent is being completely reconstituted. To understand the problems faced by QERM and possible solutions to them, it is necessary to understand something of our history.

### 1. Prior to 1990 and establishment of the QERM program

Quantitative ecology and resource management have an interdisciplinary programmatic history at the University of Washington extending back to the formation of the graduate Biomathematics Program in 1969. This program included faculty from the Colleges of Arts and Sciences, Forest Resources, and Ocean and Fishery Sciences. Interest in ecology and natural resources within the Biomathematics Program was fostered by faculty in the Center for Quantitative Science (CQS). In 1968 funding from the Ford Foundation established CQS as an undergraduate teaching program in mathematics and statistics for natural resources students. Over a five-year period it brought eight quantitative faculty to the campus with origins, or interests, in the natural resources. These faculty were physically housed in CQS but their faculty positions were in either the College of Forest Resources or the School (then a College) of Fisheries. At the termination of the Ford Foundation grant, in 1977, the University adopted the financing of CQS including the faculty and administrative positions established under the grant. The day-to-day administration of CQS, including finance, was then taken through the School of Fisheries, though the program remained joint between Fisheries and Forest Resources. Some CQS faculty, particularly those having their faculty positions in the College of Forest Resources, left the CQS building to be housed in their College. In 1981 Fisheries became a School within the College of Ocean Fishery Sciences, and those CQS faculty who were in CQS were administered as a Division within the School.

The Department of Statistics formed in the College of Arts and Sciences in 1979 and obtained its own degree granting authority in 1980, but all Statistics graduate faculty remained members of the Biomathematics Program. In the late 1970's, the Biomathematics Program developed three pathways of study: Health Sciences Biology (HSB), and Quantitative Ecology (QE), which were both oriented towards applied statistics, and an applied mathematics/differential equations study option. Faculty in the growing Department of Biostatistics, in the School of Public Health, were the principal contributors to the HSB pathway and that part of the Biomathematics Program flourished, increasing its student numbers substantially, while those coming to the program to study ecology declined.

In 1985, the Biostatistics Department applied to the Graduate School to establish their own degree program. This was granted in 1986 and an agreement was made that responsibility for the whole of the Biomathematics Program should be transferred from the Graduate School to the Biostatistics Department while faculty in the Center for Quantitative Science planned for, and developed, a graduate program. Faculty in Statistics ceased to be members of the Biomathematics Program. The number of students in Quantitative Ecology increased between 1987 and 1990, the CQS building was remodeled and re-equipped with computers, and a new graduate program was developed. That program was reviewed in 1990 and became the Interdisciplinary Graduate Program in Quantitative Ecology and Resource Management. The Graduate School has responsibility for interdisciplinary graduate programs on campus and administers QERM. The Deans of those Colleges with faculty involved in QERM (principally Arts & Sciences, Forest

Resources, and Ocean & Fishery Sciences) concurred with the establishment of the QERM interdisciplinary program.

## 2. Principal academic units involved and important events since 1990

### *The Center for Quantitative Science*

The Center is a group of faculty, elected from both the College of Forest Resources and the School of Fisheries. They have taught quantitative courses (with the QSCI designation), at the 200 and 300 level, for undergraduate biology and natural resources students, at the 400 level for beginning graduate and undergraduate students. QSCI courses have a high reputation for teaching mathematics and statistics from "within" students' disciplinary interests and QSCI courses are well attended by students from outside of Forest Resources and Fisheries, and earn substantial credit hours for the College or School of the faculty teaching them. There are also specialized courses in quantitative fisheries management at both the 400 and 500 level. Since the establishment of the QERM program, one applied statistics and three modeling QSCI courses have been established at the 500 level. Most importantly, the 1990 QERM Review Committee viewed CQS as the unit that would administer QERM and some of its recommendations (Section V) were directed specifically towards CQS.

Dr. Vincent Gallucci was Acting Director of CQS between 1980 and 1985. Dr. David Ford was appointed Director in 1985. In 1993 Dr. Ford resigned his position as Director of the Center. A new director was not appointed but Dr. John Skalski was asked to be faculty coordinator for the Center. He remained in this position until mid-summer 1995, resigning then because he felt the position of coordinator was not satisfactory and that a director should be appointed (Appendix I). The College of Forest Resources (CFR), College of Ocean & Fishery Sciences (COFS), and School of Fisheries (SOF) decided that CQS would be administered by a non-faculty Administrative Assistant. The Administrative Assistant then in post resigned and a new Administrative Assistant was appointed. The Center's faculty wrote to the Deans of both Colleges, and the Director of the School of Fisheries, urging that a Director should be appointed (Appendix I). Debates about the future of the Center continued and, after discussions with academic administrators, a proposal was made by the CQS faculty, and agreed to by the Deans of CFR and COFS, and the Director of SOF, that the Office of Undergraduate Education should administer CQS (Appendix I). The Office of Undergraduate Education is responsible for interdisciplinary undergraduate education and is headed by Dean Fred Campbell. He has now requested (August 1996) that the CQS faculty send him nominations for the position of Director of CQS which the CQS faculty has done.

CQS has been physically located in the south of campus and is scheduled for demolition in November 1996 to make way for buildings that are part of the University South Campus Plan. The CQS building has housed nearly all of the QERM students.

### *The School of Fisheries*

The School of Fisheries has some 31 resident faculty (23 teaching, 8 research). In 1991 a Graduate School review was very critical and recommended substantial changes in the School. Among the most important was that it should be less divided and in particular, that the Divisional structure then in place should be abolished and "the resources and functions currently under the responsibility of the divisions should be returned to the office of the Director." The

School of Fisheries review did not make explicit recommendations about CQS or QERM. It did recommend that both the Fisheries Research Institute (FRI) and Institute for Food Science and Technology (IFST) should only be retained for public relations and their Directors should have no more authority than other faculty. Immediately following the review, the then Director, Dr. Robert Stickney, was instructed to resign and Dr. Marsha Landolt who had been Associate Dean of the College of Ocean and Fishery Sciences (COFS), was appointed to succeed him. One of the first actions was to abolish the divisional administrative structure of the School.

In practice, though it was never stated explicitly, administrators of SOF and COFS seemed to have considered CQS simply as a division of the School of Fisheries. There was a failure to recognize that CQS was truly an intercollege unit and the functions of CQS had never belonged, institutionally, to the Director of the School of Fisheries. Numerous attempts were made to explain this.

#### *Interdisciplinary Teaching and Research at the University of Washington*

Interdisciplinary teaching and research at large universities frequently encounters problems-- and the University of Washington is no exception. In 1992 the University of Washington Interdisciplinary Research Committee (UWIRC) was established and reported the principal barriers as follows:

Seen from the perspective of the central administration, the problems facing the University in responding to the challenge of new interdisciplinary opportunities include: a) the UW is much more decentralized than its peers, i.e., the central administration has less authority and resources at its disposal and change is harder to achieve; b) state funding is allocated principally to Colleges and Schools with most of it earmarked for instruction and almost none available for research; c) there is little discretionary money to start new things, and d) the University must essentially work against tradition if it is to adapt itself to this rapidly changing world.

From the perspectives of center directors, participating faculty, and graduate students, administrative and cultural barriers impede the free flow of people and ideas across disciplinary boundaries. Among these are:

- a) junior faculty at risk in promotion and tenure decisions;
- b) faculty at risk on merit increases due to complaints from their senior colleagues, Department Chairs, or Deans that the work they are doing is not in the mainstream of development thrusts within their department(s)/college(s);
- c) faculty facing criticism and lack of support from Deans for recruiting significant proportions of non-College students for interdisciplinary courses;
- d) graduate students subject to problems of lack of identity, absence of institutional sponsorship and responsibility; and difficulties in securing adequate faculty supervision and mentoring for interdisciplinary Ph.D. studies; and
- e) lack of discretionary resources (money and space) held by center directors for seeding new initiatives.

The negative aspects accompanying the conduct of interdisciplinary research referred to above do not equally apply to all colleges within the University and, where they do occur, may vary in degree from college to college. However, the obstacles so amply documented by a substantial number of faculty who try to foster interdisciplinary research and teaching at the University indicate that these problems are sufficiently widespread to warrant a concerted University commitment to correct them.

In practice, and in various ways, faculty and students associated with CQS and QERM have experienced each of these cataloged barriers.

The UWIRC continued with recommendations.

Accordingly, the Committee wishes unequivocally to affirm the following three principles:

- 1) interdisciplinary research and teaching are worth doing and worth doing well;
- 2) the heart of interdisciplinary research and teaching is the faculty's motivation and energy; and
- 3) the University of Washington must remove obstacles and provide mechanisms to facilitate more effective interdisciplinary research and teaching.

We urge the central administration (President and Provost) of the University to adopt the following basic declaration as a matter of University policy:

The University of Washington gives high priority to fostering innovation and change through interdisciplinary research and teaching on a University-wide basis. To this end resources will be set aside to permit the Provost to encourage and support significant innovation in interdisciplinary research and teaching on a continuing basis. Deans and Department Chairs will be evaluated on their effectiveness in promoting interdisciplinary work. In addition, interdisciplinary research and teaching activities are legitimate aspects of the academic agenda and should be treated as such in faculty promotion and tenure decisions.

The intent of this policy declaration is to signal to the faculty and academic leadership at every level that the University as a whole is committed to such a course of action and that the Provost will provide the leadership and support that is required from the central administration in order to effect change on the necessary scale. Leadership and resources are both necessary, hence the need to set aside funds for this purpose. Moreover, since considerable initiative and responsibility lies with Deans and Department Chairs, they need to agree to the value of interdisciplinary research and teaching and provide a nurturing environment for both to occur.

The report was forwarded to the Provost, considered by the Board of Deans -- and shelved.

Since that time President McCormick has been appointed. He has made public statements about the importance of interdisciplinary teaching and research and a new initiative in interdisciplinary

activities is to be established but it is not clear how this will be administered--nor if QERM could be part of that.

#### *Impact of Recent Developments on the QERM Program*

Over the period since the 1990 review of the QERM program, and during the time when it had been asked to extend its involvement with faculty outside CQS, administrators in the School of Fisheries and the College of Ocean & Fishery Sciences were seeking to condense and concentrate the activities of the School. For QERM this has led to an inflammation of some of the natural difficulties that interdisciplinary programs experience as listed in the UWIRC report. This applied to both CQS and QERM with perhaps the most important circumstance being the failure to appoint a Director of CQS.

There was clear concern that CQS/QERM was detracting from the School of Fisheries. Dr. Landolt, who was Director of the School of Fisheries 1991-96, asked whether the QERM program could be merged with the Quantitative Fisheries Management graduate option in the School of Fisheries, and whether the QERM students could take the School of Fisheries graduate program qualifying examination.

In the period 1991-95, CQS faculty from the School of Fisheries held a number of administrative positions in the School and College and chaired important committees: Associate Dean in the College, Associate Director for Instruction- with responsibilities for implementing many changes following the SOF 1991 review, Chair of the Recruitment, Admissions, and Scholarship Committee, Chair of the Qualifying Examination Committee. They have also taught quantitative courses earning substantial student credit hours for the School. Despite their administrative positions and teaching responsibilities, and the knowledge and understanding of School and College that comes with them, these faculty had extreme difficulty in communicating to the Director of the School of Fisheries, and the Dean of the COFS:

- (a) that QERM is an interdisciplinary program that extends beyond the confines of the School of Fisheries;
- (b) that QERM recruits a type of student necessary for their research but not attracted to the School of Fisheries graduate program;
- (c) that teaching and research are interdependent, and that interdisciplinary activity in one promotes and benefits interdisciplinary activity in the other; that faculty involvement in CQS and QERM are complementary.

Two specific actions by the Graduate School eased some of the explicit points of concern of the School of Fisheries. First, the assumption by the Graduate School of 50% of the cost of the Administrative Assistant working on the QERM program. Second, that credit for the supervision of QERM graduate students should accrue to a faculty member's home department without that student being noted against the graduate student allotment for that department.

#### *The Link Between CQS and QERM*

Up until Autumn 1996, CQS has been housed in a remodeled 3-story apartment building. Six CQS (also members of QERM) faculty have been housed in the building and incoming QERM students were given room there. Few QERM students moved from that building to be with faculty supervisors housed in other departments. The aggregation of students has been beneficial in providing students in an interdisciplinary program a very real center and sense of



community which is frequently lacking in interdisciplinary programs and often identified as an important problem for them. An appreciation of students' views on this is apparent from a letter they wrote to the Dean of the Graduate School about the future of the QERM program (Appendix II). However, housing the students in CQS has had the disadvantage of not facilitating movement of students to be more integrated with a faculty members' other students when that faculty member was not housed in CQS--though space in other departments tends to be difficult to find. In some cases faculty involvement in the QERM program has been conditional on student space not being requested in that faculty member's home department. In addition to there being a central focus and an esprit de corps associated with that, the QERM students have had two other advantages of being housed in CQS:

(1) Computing equipment-

Over the past decade, faculty and faculty administrators of CQS have paid great attention to creating and maintaining a high quality computing environment through initiatives with foundations, university programs, salary recapture, research support funds (a portion of the overhead from grants and contracts that is returned to colleges and departments), and directly from the School of Fisheries. A UNIX-based computer laboratory (8 seats) was established; by 1996 two Sun servers were in use, supported through the School of Fisheries, and many X-terminals and workstations throughout the building. Extensive use of this equipment has been made by the School of Fisheries, and some use by students in the College of Forest Resources.

(2) Teaching Assistantships and Instructors-

In recent years there have been three teaching assistantships (previously four) associated with the CQS teaching program and some additional TA support through the Office of Undergraduate Education. QERM students are among the best qualified graduate students for these Teaching Assistantships. Indeed although TA's have been appointed from among senior graduate students in Forest Resources, Fisheries, Statistics, and Applied Mathematics, the CQS teaching program would be extremely hard pressed to run effectively were it not for QERM students. QERM students provided 67% of TA instructional support in CQS classes for the period Winter 1994 through Summer 1996. Some QERM students with TA experience and good course evaluations have also taught Summer Quarter offerings of the CQS courses most in demand.

## II. THE ACADEMIC PROGRAM

The academic program designed prior to the 1990 QERM review was based on the structure inherited from the Biomathematics Program. There have been some modifications and adjustments in implementation which will be detailed. Full details of the academic program and recommendations for how it should be followed by a student, are given in the accompanying Graduate Student Guide.

### 1. Basic Structure and Design Objectives

There are two objectives for an interdisciplinary program:

- (i) to achieve an effective integration of the component disciplines and approaches;
- (ii) to establish and maintain academic rigor.

In the design of a course work schedule the first objective tends toward breadth and taking many courses. If rigor is to be maintained then, at the extreme, students might be expected to pass qualifying examinations in each of the component subjects. This is the structure of some interdisciplinary programs, though as the component subjects increase beyond two, as in the case of QERM, it is difficult to implement as well as placing the onus of integration almost entirely on the student.

The second objective tends towards focus and limiting course work. It is essential for an interdisciplinary program to demonstrate that it provides a rigorous education--one that ensures that students understand the depth and intricacies of the subject and can work its complex problems.

In addition to balancing between these objectives, the QERM faculty were faced with the knowledge that most student financial support would come from grant and contract research assistantships--that two years of pre-research study that would facilitate a larger rather than smaller number of required courses was unlikely to be possible for many students.

After considerable debate the faculty decided:

- (i) To follow the structure (established in the Biomathematics Program and then used by the Statistics and Biostatistics Departments) of a qualifying examination in both theory and applied work and to implement this after the first year of graduate course work;
- (ii) To require QERM students to take the same MS qualifying theory examination in statistics as taken by Biostatistics and Statistics MS students;
- (iii) To develop a QERM applied qualifying examination, based both on available course work in the University and courses designed largely for QERM students;
- (iv) To require no program-wide course work or examinations after the first year. This differed from the structure of the old QE option in the Biomathematics program, and what was then in operation in Biostatistics and Statistics which had common second-year qualifying examinations in theory and applied work designed for students wishing to proceed to a Ph.D.

## 2. First Year Course work

The effect of this is an intensive first year of scheduled course work. While there is time for optional courses, in terms of usual credit loads, few students take them.

The first year required courses are:

### Theory

#### STAT 512, 513 (4,4) - Statistical Inference

*General theory of statistical inference; estimation and hypothesis testing.*

*Prerequisites: 395 and 421, 423, or BIOSTAT 512.*

### Applied

#### CIVE 491 (3) - Deterministic Systems

*Development of quantitative methods for mathematical problem solving with emphasis on computer applications. Linear programming, mathematics of the simplex algorithm, sensitivity analysis, dynamic programming, systems simulation, and goal programming. Class project required. Prerequisite: 390 or equivalent or permission of instructor.*

#### QSCI 514 (3) - Analysis of Ecological and Environmental Data I

*Factors affecting optimal growth of individuals in their habitat. Estimation of growth and mortality parameters. Response of organisms to changes in environment, bioassay, environmental monitoring. Stochastic viewpoint emphasized. Research design issues for ecological or environmental studies. Analysis of unwieldy data sets. Prerequisites: STAT 512 or STAT 341, 342; and knowledge of calculus.*

#### QSCI 550 (4) - Applied Ecological Modeling

*Methods of applied ecological modeling at individual community and ecosystem levels. Analysis of ecological problems suitable for modeling and assessment of models. Students construct a model of their own.*

The purpose of CIVE has been to introduce students to optimization which was strongly felt by the faculty to be an important topic. Initially AMATH 515 was the course taken but was not appropriate as it did not contain sufficient practical applications for 1st year QERM students and they were not prepared for its level.

In practice, Dr. Conquest and Dr. Skalski who teach QSCI 514, have also required many students taking QSCI 514 to first take

#### QSCI 482 (5) - Statistical Inference in Applied Research I

*Analysis of variance and covariance; chi square tests; nonparametric procedures multiple and curvilinear regression; experimental design and power of tests. Application to biological problems. Use of computer programs in standard statistical problems. Prerequisites: 381 or permission of instructor.*

A recent development has been that some few students postpone taking STAT 512/513, and the theory examination, from their first to second year, and take preparatory courses according to the student's background. This was implemented because it was recognized that some excellent students were applying to the program with good practical experience and excellent motivation but without sufficient background to tackle STAT 512 and 513 in their first year of graduate study.

### 3. Qualifying Examinations

Both theory and applied examinations are set and marked by committees. The theory committee is established in rotation by the Biostatistics and Statistics Departments and the current instructor of the STAT 512/513 is a member. Examination is closed book, lasts for 3-hours, and question papers for the past three years are given in the Appendix III. Dr. Guttorp and Dr. Thompson, both active members of QERM, have sat on the committee regularly. Each student answer is marked by two faculty and grades are averaged. At a combined Biostatistics/Statistics/QERM faculty meeting the ordered list of students is examined. The QERM policy has been to follow the ranking and classifications of the unified list and QERM students are ranked as a Ph.D. pass, Master's pass, or failure. Borderline cases have been discussed with the course instructor and/or Dr. Thompson or Dr. Guttorp who have been instructors for STAT 512/513.

The examination committee for the Applied Examination comprises the chair of the program, the instructors of QSCI 514 and QSCI 550, and one other QERM faculty member competent in each of the subject covered by these courses. The objective of the examination is to test the students ability to analyze practical applied statistics and modeling questions. The examination is open book, lasts for 5-1/2 days, and two practical questions are set. Examination papers for the last three years are given in Appendix IV. Success rate in theory and applied examinations in given in Table 1.

Table 1-A. Statistical Theory Examinations

Exam Year	No. Q-students taking exam	Pass- PHD	Pass-MS	Fail
1996	6	5		1
1995	5	2	2	1
1994	5	1	2	2
1993	5	4		1
1992	5	4		1
1991	4	2	2	
1990	5	2	3	
1989	4	3	1	

Table 1-B. QERM Applied Examinations

Exam Year	No. students taking exam	Pass- PHD	Pass-MS	Fail
1996	6	4	2	
1995	7	5		2
1994	4	2	1	1

1993	7	4	2	1
1992	3	3		
1991	4	3	1	
1990	7	6		1
1989	5	5		

Students may take both examinations twice. Students who pass at the Masters level may re-take the examinations to attempt a Ph.D. pass if they wish.

#### 4. Masters and Ph.D. pathways

Progress after the first year follows student interest and committee recommendations and requirements. The form of the general examination is left to the committee though generally there is both a written and verbal part. Course work pathways are recommended in the QERM Graduate Student Guide -- but these have been used as examples that can be followed, rather than rigorous schedules.

#### 5. Developments in the program

There have been three initiatives in response to experience within the program:

- (i) An initiative to require students to have two laboratory rotations where they would work with a faculty member on particular problems for a quarter. This was proposed in order to smooth the transition from course work to research;
- (ii) An initiative to postpone the applied qualifying examination from the end of the first year of study to some time in the second year (the end of each quarter was discussed as a possible option) in order to allow the students more time to take ecology, natural resources, and/or other applied courses and to develop practical skills;
- (iii) An initiative to require students to complete an MS thesis before proceeding to a Ph.D., or for a student's committee and the QERM program to approve some research as a Master's by-pass.

#### *Laboratory Rotations*

The initiative for laboratory rotations was first defeated by a faculty vote as a requirement. For students working on an RA-ship it was considered as not necessary and too demanding and deflecting. Subsequently, it was accepted on a voluntary basis. These are largely taken up by students after their first year. Guidelines, faculty-student contract, and examples of laboratory rotations in QERM are presented in Appendix V.

#### *Timing of the Qualifying Examination*

The initiative to postpone the qualifying examination was defeated by a large margin. The feeling was that it would postpone still further students' transition from course work to research and individual study. Required course work should be confined to the first year of study and qualifying examinations should be based on that.

*Requirement for a Masters before proceeding to Doctoral Study*

The initiative to require a Master's degree to be taken prior to a Ph.D. was adopted by the faculty by a large majority with the proviso that a student's committee could authorize a Master's by-pass on demonstration of written research capability. The current regulation is:

Students admitted at the pre-Master's level may, under exceptional circumstances, apply to proceed directly to post-Master's study. Application should be made to the Graduate Program Coordinator.

This must include the following:

From the student:

1. A statement that all course work for the Master's degree has been completed and a completed transcript.
2. A Ph.D. dissertation proposal.
3. Passing the 1st year applied and theory exam at the Ph.D. level.

From the Master's committee:

1. A letter indicating approval to bypass the Master's degree and agreement to serve on the student's Ph.D. committee.
2. Evidence that the student has reached a Master's level of competence in written completion of research. This will take the form of a paper accepted for publication in a peer-reviewed journal.

The complete application will be submitted to a 4-member Graduate Standards Committee for their decision on the transfer. The Graduate Standards Committee will be composed of 3 QERM faculty and the Graduate Program Coordinator who are not members of the student's graduate committee

(effective: Summer 1995)

### III. STUDENT INTAKE PERFORMANCE AND PLACEMENT

#### 1. Recruitment

Students interested in QERM are likely to be mathematics and statistics graduates looking for an application of their skills that is neither industrial nor commercial as well as ecologists and resource managers, often with some professional experience, who have decided that quantitative skills are essential for what they want to do. Both groups are drawn to this program because it is interdisciplinary --they can learn something new, develop their existing knowledge, and become a different sort of person.

Table 2. Admissions information

	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
No. Applications	18	37	44	38	31	32
% Denials	50%	67.6%	84.1%	71.1%	74.2%	87.5%
% GRE-Quant 700+	N/A	N/A	65%	65%	57%	75%
% GRE-Anal 700+	N/A	N/A	41%	50%	43%	50%
% GRE-Verbal 700+	N/A	N/A	14%	25%	10%	11%
No. new students enrolled:	6	4	4	5	3	2
% Applicants offered/enrolled	85.7%	50.0%	100.0%	100.0%	60.0%	50.0%
Avg. GRE-Quant. -enrolled	780	800	760	780	720	770
Avg. GRE- Anal. -enrolled	742	660	790	747	667	800
Avg. GRE-Verbal -enrolled	665	620	690	723	567	665
Average GRE scores for:						
Denials						
-Quantitative:	665	676	679	693	681	720
-Analytical:	633	630	626	698	638	672
-Verbal:	575	561	538	606	536	554
Accepted but not enrolled						
-Quantitative:	800	753	757	740	720	765
-Analytical:	800	693	763	635	775	755
-Verbal:	800	664	657	700	670	690

#### 2. Financial Support

A concerted effort is made to have support for all QERM students. In Spring 1996, of 20 students, 8 had RA's with their supervisory chair or faculty advisor, 6 had an RA's with other faculty members, 3 had TA-support. Of the 3 remaining students, 1 had stipend support from the Graduate School, 1 had support from the International Pacific Halibut Commission, and 1 had support from the Greenlandic Home Rule Government.

#### 3. Performance on Qualifying Examination

Success rate in theory and applied examinations in given in Section II - Table 1.

#### 4. Research Performance

Some picture of graduate student research can be seen in recent titles of students thesis work:

- Assessing Hazards in Wild Populations Using Auxiliary Variables in Tag-Release Models;
- Spatial and Temporal Models of Migrating Juvenile Salmonids with Applications;
- Statistical Models for Estimating Salmon Escapement and Stream Residence Time Based on Stream Survey Data;
- Optimization Models for Understanding Migration Patterns of Juvenile Chinook Salmon;
- Chaos in Aquatic Systems;
- Use of Lin- and Quadrovarian Estimators in Analyzing the Autocorrelation Structure in Transect Data;
- Evaluation of Methods for Estimating the Hurst Coefficient of a Time Series;
- Bayesian Estimation of Genealogical Structure in Small Populations;
- Quantifying Selection in Wild Populations Using Known-Fate and Mark-Recapture Designs.

#### 5. Placement

Graduates from the QERM program have pursued accomplishment in continued academic study, continuing and expanded roles in research projects from graduate student work, consulting work for private and state agencies. A group of recent graduates have formed their own environmental consulting group and have been successful in this effort.



#### IV. RESOURCES AVAILABLE TO THE QERM PROGRAM

For the last two biennia QERM has received an allocation from the Graduate School for recruitment of students, including posters and other publicity, 50% support of the Graduate Program Assistant and funds for some RA-support and corresponding tuition/operating fees. The budget allocation for 1995-97 was: \$85,145.

The costs associated with occupying the building at 3737 -15th NE have been administered through the School of Fisheries. The building has been the home of both the Center for Quantitative Science and the QERM program and the two have shared common facilities and so it is difficult to apportion space between them precisely. As a general estimate the 20 or so students usually present have occupied some 1450 square feet with common room and library facilities being 692 square feet.

The most important resource for the program has been computing and computer support, through UNIX based SUN workstations and servers. Currently, including workstations and servers, there is about \$50,000 worth of equipment (replacement cost) used by QERM students in day-to-day operations. In addition there is a computer laboratory with 8 workstations that uses the same servers.

Computer support, particularly software, has been provided through the School of Fisheries and College of Ocean and Fishery Sciences. One systems support position has been 50% shared between CQS and the School of Fisheries.

The future of space, operating budget, computer equipment and computing support are major questions for the QERM program with, at the time of writing, no resolution in sight. The separation of QERM and CQS, while ardently wished for by administrators in Ocean and Fishery Sciences, removes much operational capacity from QERM.

One long-term solution to ensure continuing resources to the QERM program is to re-constitute programmatic and administrative linkage between QERM and CQS. Opposition to a continued CQS-QERM link has been expressed in private meetings between administrators and not directly to either the CQS or QERM faculty. The opposition to this is probably based on the view that it is incipient departmentalization, and so would entail a "loss" of faculty positions, though there has never been a clear enunciation of this. There have been proposals within the central administration of the university that undergraduate and graduate interdisciplinary programs should be linked. To the CQS and some of the QERM faculty this would seem natural, particularly in regard to some educational matters, and certainly an attempt to threaten no one. Unfortunately there is at present no coherent philosophy for administering and supporting interdisciplinary research and teaching at the University of Washington.

## V. RECOMMENDATIONS OF THE 1990 QERM REVIEW

The membership, and full report, of the reviewing committee is in Appendix VI. The self-study document prepared for the report is available on request. The Review Committee recommended that the QERM option be approved on a temporary basis (i) to allow time to stabilize a broader group of faculty than the CQS faculty and (ii) to allow enough time to determine if there was a real long term student interest in the program. They made the following specific recommendations (direct quotations):

- a. The Graduate School should contribute to the funding of up to one FTE of support staff to administer the QERM program and advertise and recruit students.
- b. The Graduate School should provide funds to help recruit and retain exceptional QERM students.
- c. Given that studies in quantitative ecology are vital to the national interests, and given that the QERM program is a UW focal point for such efforts and is gaining in national recognition, the University and the colleges should provide at least one more FTE. This should permit QERM faculty to provide the modeling and systems analysis courses and provide a balanced synthesis of systems analysis and biometrical applied to ecosystem analysis.
- d. The QERM Ph.D. program should be one that synthesizes the knowledge of systems analysis and modeling, statistical analysis and design, and biological/ecological/physical systems as applied to natural resource management and analysis.

The Review Committee went on to recommend that the QERM program be reviewed after five years:

1. to establish that the high quality of excellence in entering students, graduates and faculty had been maintained,
2. to establish that the student interest provides a critical mass of more than five students entering per year, and
3. to determine if a broader BIOMATH group of faculty has been activated.

They also recommended the following actions:

- a. The CQS faculty should focus on synthesizing mathematics (systems analysis and modeling), statistics, and ecosystem analysis in their teaching and research.
- b. The teaching and research objectives of CQS must be clearly established for the 1990s.

- c. A clear plan must be established that will strengthen the systems analysis/modeling capabilities of CQS and resources allocated to implement this plan.

#### 1. General position in relation to the 1990 Review Committee's recommendations

The faculty involved in the QERM program has broadened considerably since 1990 in teaching of courses, specific involvement in graduate student supervision, experiential learning for graduate students, and involvement in the QERM qualifying examination.

Over the period since 1990, 36% of committee chairs, and 65% of committee members, have not been CQS faculty.

Many courses that QERM students take, and depend on for the core of their research, are taught by non-CQS faculty. This is particularly true of courses in the Statistics Department. Relationships between QERM and the Statistics Department are excellent; statistics faculty regularly attend QERM faculty meetings, express positive suggestions for the progress of the QERM program, and continually provide sound educational guidance to QERM students. This latter is particularly true for students who enter the QERM program with a more biological than mathematical background. Recently, following an intense national competition, the University of Washington was awarded a major grant from the Environmental Protection Agency (EPA) to establish a National Center for Environmental Statistics. QERM faculty, with primary appointments in Statistics, Fisheries, and Forest Resources are involved in this Center and we confidently hope this will develop the links we already have. The EPA has stated that an important attribute in favor of awarding the Center to the University of Washington was the close and demonstrable links between the Statistics, Biostatistics, and QERM programs.

Involvement of faculty in biological subjects and Applied Mathematics have been individual. Dr. Mark Kot (Applied Mathematics) was particularly active in the QERM program. He left the University of Washington following the hiatus over the future of the Applied Mathematics department in 1994-95 and he is sorely missed by QERM students and faculty alike. Unfortunately he has not yet been replaced. Links to the Applied Mathematics Department are discussed in Section VII.

Development of the QERM 1st year Qualifying Applied Examination has been particularly fruitful for faculty activity. Dr. Kot, Dr. Patrick Sullivan (International Pacific Halibut Commission) and Dr. Thomas Leschine (School of Marine Affairs) have played substantial roles. Discussion over the examination has not just been about student qualifications but an important venue where the faculty discuss the content of the QERM program and its future.

The laboratory rotations were introduced into the program in 1994-95 in an attempt to assist students in understanding and selecting a research topic. This has widened involvement of faculty. (See Appendix V.)

Despite these positive elements, involvement of faculty in QERM remains the program's number one issue (see Sections VI and VII). The problems are characteristic of interdisciplinary programs at the University of Washington.

The program's greatest strength is its students. We have many excellent applicants and accept few (See Section III - Admissions information - Table 2). The quality of our applicants is particularly high (as noted by GRE scores, Admissions information- Table 2). But most important is their idealism and sense of purpose. The QERM students organized the 1995 Annual Pacific Ecology Conference at the Friday Harbor Laboratories. The conference was attended by 110 graduate students from universities in northern California, Oregon, Washington, and British Columbia. A comment on the number of students entering the program is given below. An example of how the students view themselves, and the program, is given in a letter they wrote to the Dean of the Graduate School (Appendix II).

The 1990 review committee made the specific recommendation that a critical mass of more than five students per year should enter the program. The mean number of students entering the program is 4.0. We feel this has been sufficient to establish a critical mass, partly because we have found "critical mass" to depend upon other things than just numbers, particularly the range of interests and interaction between students themselves.

Constraints on the number of students entering the program include likely time to degree and finance. QERM Admissions Committees have found that some of the most motivated students are those with biology or resource management backgrounds. We have also found that students with extremely strong mathematics backgrounds, but with a less sound basis for entering an interdisciplinary program, have struggled with the purpose and nature of the program. Consequently, a few students are admitted who, despite having excellent GRE scores, may take two years to pass the qualifying examination and may actually take a year's preliminary study. While this is in the spirit of the interdisciplinary program, it prolongs the time to graduation and increases the demand on financial resources. Some students who enter with strong mathematical backgrounds take a considerable time to establish their research capability in natural resources. Over the 5 years since the last review funding for QERM students has been excellent. If anything, we would have admitted more students if funding alone were the regulator.

## 2. Responses to the 1990 Review Committee's Specific recommendations and suggested actions:

### *Response to recommendations:*

- a. The Graduate School contributes one-half an FTE to administer the program. Funds are provided for advertising and recruiting students.
- b. The Graduate School has provided a recruitment fellowship each year, and one three-year Hall-Ammerer Fellowship, specifically designed for interdisciplinary work.
- c. Immediately following the QERM review, the Director of CQS and Chair of QERM, with the support of Dr. Stickney, then Director of the School of Fisheries, approached the Dean of COFS about the recommendation that "at least one more FTE" should be made available. Since CQS had been the parent of QERM, and was administered through COFS, this was the correct line for such a request. The Dean's answer was that consideration would have to await the Fisheries Graduate program review. A subsequent request was refused. In practice, the presence of Dr. Kot and

Dr. Jim Murray in the Applied Mathematics Department greatly aided modeling course work and faculty involvement in the QERM program. But with the departure of Dr. Kot and the imminent retirement of Dr. Murray, there will be a substantial vacuum. Ways that this may be filled are discussed in Section VII.

- d. The recommended synthesis is the one that faculty and students pursue-- though there is debate and discussion about what the balance should be. It remains the major programmatic challenge faced by the QERM program. Recent developments in teaching QSCI 550 involving Dr. Leschine are very positive, but it is clear that both further course work is necessary and must be effectively integrated into the program.

*Response to suggested actions:*

- a. see "d" above.
- b. The whole idea that CQS should itself develop teaching and research objectives has not been accepted either by the School of Fisheries and the College of Ocean and Fishery Sciences or the College of Forest Resources. Failure to appoint a Director of CQS and the attempt to run CQS by an Administrative Assistant, has been seen by the faculty, and others, as an explicit attempt to usurp faculty governance, and this has had a detrimental influence on QERM. There has been a complete failure by past administrators of Forest Resources and Ocean and Fishery Sciences to understand, even when it was repeatedly described in detail, that the very qualities of breadth of interest, combined with rigor, that make some faculty truly excellent teachers of applied quantitative courses, are the very same qualities making them seek these interdisciplinary research interests in the QERM program.
- c. The continuing requirement for yet another plan to strengthen systems analysis/modeling capabilities is discussed in Section VII.

## VI. PROGRAMMATIC QUESTIONS FACING QERM

This core of our self-study has been joint faculty-student discussion. This was first initiated as an e-mail discussion forum to establish what questions faculty and students, jointly and separately, felt were important. Three major questions were identified for further discussion between faculty and students. These are:

1. As students pass through the program, from the admissions process to employment, what are their perceptions of the program?
2. Is the academic balance of the program correct?
3. Are the requirements for academic progress through the program correct and effective?

A faculty-student discussion meeting was held and groups of 3 faculty and 3 students were formed to discuss with others in QERM and prepare a written analysis of each of the three questions. Drafts were circulated and a final faculty-student meeting was held when other questions were discussed and alternatives were put forward. The intention was to identify problems, issues, and possible solutions. Some of the suggestions are discussed further in Section VII along with requests for advice sought from the review committee.

### 1. As students pass through the program, from the admissions process to employment, what are their perceptions of the program?

It became apparent from faculty-student discussions that perceptions of the QERM program changed as people progressed from applicant, to new student, to older student, and then graduate.

The QERM program attracts students with a mix of skills from mathematical and biological sciences. The "math types" tend to be enjoying their mathematics but seek exposure to more ecologically and environmentally oriented applications. They want to use it as a tool to solve problems, and not just the more traditional applications of engineering, other industrial, or actuarial issues. They view themselves as having strong analytical skills and want to use these skills in ecological, environmental, and natural resource systems.

QERM applicants have often become interested in the natural world through some type of job or volunteer experience. These include involvement with such organizations as the Audubon Society, Nature Conservancy, Earthwatch, Peace Corps, university recycling programs, positions with parks or recreation areas, positions with firms (e.g., poultry processing, pulp and paper, chemical industries). Many have a natural love for the outdoors and a strong conservation ethic. Some are biology majors with fieldwork experience in ecology. They have already done some research in ecological systems and wish to continue such research (these students tend to be more detailed about possible thesis topics in their Statements of Interest.)

The nature of the QERM program intrigues them (according to the applicants); they are usually thrilled to find a program that demands quantitative skills and uses them in problems about natural resource management and ecology. They have actively sought such a program and view the QERM program as quite unique. The QERM program uses both mathematics and biology but, with its emphasis on natural resource management, it is quite different from a graduate program in

theoretical ecology. They view themselves using their quantitative skills to resolve environmental conflicts.

Some of the current students expressed why they came to the QERM program as follows:

"...An interdisciplinary program would be more encouraging of individualistic approaches to problems. I had thought that I would be able to continue developing the more mechanistic type tools that I had been pursuing prior to entering the program."

"...[I] came to QERM because of a growing interest in the use of mathematical modeling in ecology. [I] didn't want to do clinical/medical research (the biomath program I came from focused on that). QERM was recommended to me by a professor at UCLA who was a former UW Forestry grad. Upon visiting Seattle, I was 'won over' by the program. There was nothing to compare with it on the US Pacific Coast (I didn't really know about SFU or UBC)."

"QERM attracted me as an opportunity to use what I was good at (math & statistics) to do work that I might find more interesting (biological, ecological) than that found in most math/stat programs."

"The broad range of interests shown on the list of affiliated faculty members. Just the level of diversity from which those faculty are drawn. QERM is a program that combines the practical with the theoretical. I was a biology major and wanted to get a double major with math. This seemed to be *the* program for me, especially since I wanted to be in the Pacific Northwest."

"I was attracted to the mix of biology math and statistics which I had been working towards myself. Also a more mundane reason: I did not want to live in a big city, but Seattle seemed like a livable place, for a big city that is. And an interdisciplinary program like this is only likely to be found in a big place. I applied to this program only, if I had not gained admission I would have taken a break and probably applied to Colorado State's Ecology department."

"QERM attracts idealistic talented people who want to apply their math skills to ecological problems. For a lot of people with science and quantitative backgrounds, it's the perception that crossing over to biology/ ecology will be fairly easy that is such a draw."

"I entered QERM with the idea that I would be able to pursue interdisciplinary research while at the same time building a foundation in quantitative methods."

"I was attracted to QERM because I am interested in doing ecology. I have math/stat background, I am interested in learning more about math/stat and in using those tools in ecology."

#### *Student admission to QERM*

In part due to the small size of the program, admission to QERM is competitive; high GRE scores are necessary, especially the quantitative and analytical GRE scores. A student's transcript needs to be strong. In the Statements of Purpose, the faculty look for students who can take a lot of personal responsibility for getting out and attending seminars, meeting faculty and graduate students outside their own program. Previous research experience helps but will not necessarily get one in (an applicant who had publications in statistical journals but low GRE scores was not

admitted). Due to funding issues, naturally, there are always qualified students who do not gain admission to QERM, but this is no different from a number of other graduate departments.

*How does QERM live up to the expectations of the students?*

Frequently, students found that the reality of QERM differed from their expectations. Some students expected to do ecology or resource management, using statistics and mathematics as tools, and have found it difficult to do so. There were students who expected more structure after the first year. A few students expected more faculty collaborating with each other and more hands on work, either in the lab or in the field. Some students expected to be collaborating with faculty rather than in a strict employer-employee relationship.

A few of first and second year students, currently taking the core courses, felt that QERM should be presented as a statistical ecology program rather than an multi-disciplinary program. Also, these students said that the first year courses got in the way of their research, and the courses they thought they should be focusing on for their work. On the other hand, one student who entered with an interest in modeling and said that he has really benefited from being introduced to statistics. More senior students have a somewhat different perspective, and they see the direction their research takes to be their own responsibility. These students do realize that the responsibility of directing one's own research is a difficult task. Students felt that while the statistical component of QERM is strong, and is well defined, the other pillars of the program are not clearly defined, and that program balance suffers as result. Many students expected equally structured course paths for modeling, ecology, and resource management.

Two other interrelated issues raised are finding research projects and funding. There is a sense that the need for funding inhibits the pursuit of interesting and appropriate research topics. One student described "the 'process' of finding a research project" as "nasty double edged sword of funding vs. really 'finding something you are interested in', but that one can rarely have both." Many students start working on a project that is already in existence and therefore, do not get a chance to develop ideas from the beginning. One might expect this for a master's, but a Ph.D. is supposed to be original research. The students who do come up with their own research often have to struggle to get funding. There are also students who are quite happy and have been satisfied with QERM.

The best way to resolve these differences is to make sure there is "truth in advertising". The program needs to ensure that the program brochure sent out to prospective students accurately reflects what they will find when they get here. What QERM does, it does well. The prospective students need to realize what QERM does. There are two points that are important to emphasize in the brochure.

1. There is a heavy emphasis in statistics in the first year and the course work is very rigorous. Some students expected this, but not everyone did, and some students did not realize how rigorous the first year statistics is. The emphasis on biology should either be enhanced in the program, or lessened in the brochure.

2. The direction a student's graduate career takes IS the responsibility of the student. The students should not expect the faculty to do this for them because it may not happen, at least not in the way that the student wants. It is important to state that the interdisciplinary nature of the program requires students to be assertive, if not aggressive, in charting their course at the university. There is no single guiding hand for incoming students, nor should there be.



In general, some students are happy and some are not. One of the biggest reasons for unhappy students is that QERM is different from what they expected.

*What types of jobs or fields of research do students wish to enter upon graduation?*

Many of the students were interested in teaching. One student wants to "teach and conduct research at the university level" while being "the in-house statistician in a forestry, zoology, ecology, biology, etc. department". Another student wants to leave academia for a while, and possibly do consulting or bioremediation and maybe teach later in life. A third student is focusing on a biometrics position.

*How well does QERM prepare students for both their short term and long term career goals (depth and breadth of knowledge, flexibility, etc.)?*

Many of the students stated that they are not in a position to answer this question and there are various opinions. One student mentioned that a degree from a nontraditional program is difficult to market but that the nontraditional component of this program is also a benefit because it gave him the freedom to do what he wanted, something he likely wouldn't have done elsewhere. Another student responded that QERM doesn't prepare students for jobs and that QERM "prepares students to do their exams and then pushes hard to get them out the door." One student stated that he did not think that QERM prepared students to be resource managers.

#### *The Perspective of QERM Graduates*

A survey was conducted among QERM alumni in Autumn 1995 to determine their satisfaction with, and perspective on, the QERM program. Four questions were asked of the graduates regarding attributes of the program and subsequent career opportunities. There have been, to date, eleven M.S. graduates and six Ph.D. graduates from the program. Questionnaires were sent to all graduates as of November 1995 and follow up correspondence was conducted to promote feedback. Seven graduates responded in all, three Masters level and four Doctorate level. The letters are in Appendix VII and their replies are summarized below.

Question 1: Did your education at QERM help you find your present position?

Respondents represent a variety of occupations: some academic research positions, some at resource agencies, some as consultants or self-employed, and one as a biostatistician for a health group. Most feel positive about the preparation the program provided them in their present position, and in particular in the quantitative aspects of their work. The training in statistics provided a "strong foundation" for handling work related problems, and the education led directly to employment. The QERM program offers "unique opportunities" that cannot be found elsewhere. It is seen to fill a niche that is "in-between" statistics and ecology. Sometimes, unfortunately, potential employers see the degree as representing neither field. Employers recognize academic strength based on the reputation of the school, but the program itself did little in the way of job placement. Although an emphasis in statistics was not sought out, it proved to be a worthwhile influence in preparation for later challenges. Many put to good use the applied experiences they garnered as a student and found it to be beneficial for research and consulting.

Question 2: Do you think your career prospects may be influenced by your QERM degree?

Most graduates believed that the interdisciplinary nature of the program provided an opportunity to develop and apply their quantitative skills in a variety of fields. The program was influential in building the needed quantitative background, and while remaining autonomous, provided valuable interaction with different departments.

Question 3: What changes would you make to the QERM program?

Responses to the suggestion of changes and improvements were varied. Some wanted to see more opportunities made available to do consulting. Some wished to see greater faculty support from departments outside of Fisheries. One graduate believed that the faculties' primary allegiances were focused toward their home department, and felt that some incentive should be given to faculty to increase participation in the program. Along a similar line, given the changes that have occurred recently in the department level at the University, one graduate suggested that the Applied Math Department should be encouraged to maintain or expand its level of participation.

More consistency in the requirements for graduation would be helpful, so would more funding. Some would like greater guidance from faculty on curriculum, and others to be better informed of the program's rigors preferably prior to program entry. Several would like to see the modeling curriculum developed and made more rigorous along the line of statistics curriculum, while one thought modeling was over emphasized.

Some felt that the qualifying exams were necessary and promoted competency as well as confidence. One went so far as to say that the second-year exam be reinstated. Others, felt that the exams were an overburden and a detriment to their academic development.

All would have liked more interaction with faculty.

Question 4: Was the position of QERM, as an interdisciplinary graduate program appropriate, and was it valuable for the education you received?

Graduates feel that the "characteristic and strength" of the QERM program is that it is interdisciplinary. It facilitates interaction with different departments. It provides the experience necessary to have a "global" perspective in problem solving. And though some find discomfort in the broad nature of curriculum that is made available through participating departments, others feel that this is the kind of flexibility that is needed to make them quantitative generalists ready to take on the world.

2. Is the academic balance of the program correct?

The general consensus is that the focus is slanted towards statistics rather than modeling and ecology. Some felt that this was a major problem while others felt that it could be overcome on one's own after the first year. In any case, people felt there should be a greater focus upon ecology, resource management, and mathematical modeling in the core of the program.

"The program has no real ecological bent. That's a serious problem. The main attraction of the program is the opportunity to combine math and biology in societally meaningful ways."

"The balance that is dictated by the first year classes is quite biased towards statistics, but I think that a strong theoretical statistical background is a prerequisite for applied mathematics and modeling, and I see nothing that prevents students from pursuing whatever they want after the quals."

"The university has a very well respected Zoology department and the same can be said for Oceanography, and both of these area areas that are not utilized to their full extent even though they could make great contributions to our program."

*Which disciplines should be incorporated into the program and how should they be balanced or emphasized?*

Statistics, Ecology, Mathematical Modeling and Resource Management are the areas that people felt should be incorporated into the program. The feeling is that there should be an introduction to each of these in the first year. The particular emphasis after the first year should be up to the individual student and his advisor and committee, though there should be some requirements for quantitative competency.

"Drop the awful CIVE 491 the first quarter and put in a biology or zoology requirement instead (An ecology course, or a course in a particular area such as invertebrates, or forests or whatever. We could have a list of twenty or so courses to select from, for example). When we move to upper campus the program will be more visible, which should make it easier to strengthen ties across departments."

"While Ecology is in the name of the program it is not very present in the course-work or in the interactions with faculty, there needs to be a much stronger emphasis on both theoretical and applied Ecology."

"Breadth of education is important across the scientific disciplines..."

*While QERM has rigorous first year statistics, modeling is not rigorous. What courses should be taught that are presently not?*

Some felt the mathematical modeling sequence needs to be brought up to the level of the statistics courses. Perhaps there should be an option of taking less rigorous statistics courses and replacing them with more rigorous applied mathematics courses which could be a basis for an alternative exam. Others felt that the Statistics sequence should continue to be required for all, and simply that the modeling portion of the program needs to be augmented. Because of differences in background, different courses are appropriate for different students in the first year. Some students postpone STAT 512 and 513 a year, and a rigorous mathematical modeling sequence might require the option of taking background courses in the first year as well.

"I don't know that there is anyone who can replace the kind of classes previously taught by Mark Kot. One result of not having had a rigorous modeling class is that I am not even sure what we are missing. I suppose some class in ode's and pde's might be good. I wonder if modeling is something that people are not exposed to before they get here, whether it is even possible to teach at more than a basic level the first year."

"A strong class that bridges the gap between theoretical modeling and how to fit models to data is simply not there (or if it is I haven't seen it in the catalogue)."

3. Are the requirements for academic progress through the program correct and effective?

*Entry to QERM*

QERM is the synthesis of ecological/biological knowledge base and theory with the probability and stochastic modeling framework of statistical inference and analysis, and with the mathematical tools required for applied mathematical modeling and deterministic analysis. All students entering the program must have an interest in ecological problems, but whereas some may have a more mathematical training and wish to apply this in the areas of ecology and resource management, others may be coming from the ecology area wishing to obtain quantitative skills that will enhance their research in an area of which they already have substantial knowledge. Both types of students are appropriate to QERM; both types of faculty also.

To see just where QERM's current interests lie, we propose that all QERM faculty and students be asked to place themselves on Jay Johnson's graphical representation of QERM's intellectual topic domain (Fig. 1). A student-faculty comparison might be quite enlightening. For the students it would be interesting also to see the positions on entry to the program, and expected/hoped for positions on graduation; how has their QERM program education changed their position in the domain. Among the faculty, we anticipate that the mathematical sciences are better represented than the biological. It would be good if more ecology faculty could be involved; how can they best be welcomed? Currently the focus is more towards Statistics; the departure of Mark Kot has been a serious blow to the balance in QERM.

On another aspect of entry, it was felt strongly by many students that there should be a clear distinction made between the M.S. and Ph.D. track on entry. Certainly, earlier guidance as to the individual expectations and requirements for each student would be beneficial; the initial supervisory committee proposed below may help here. Also, the discussion below of whether an M.S. is to be required of all students is an issue here.

*Qualifying exams*

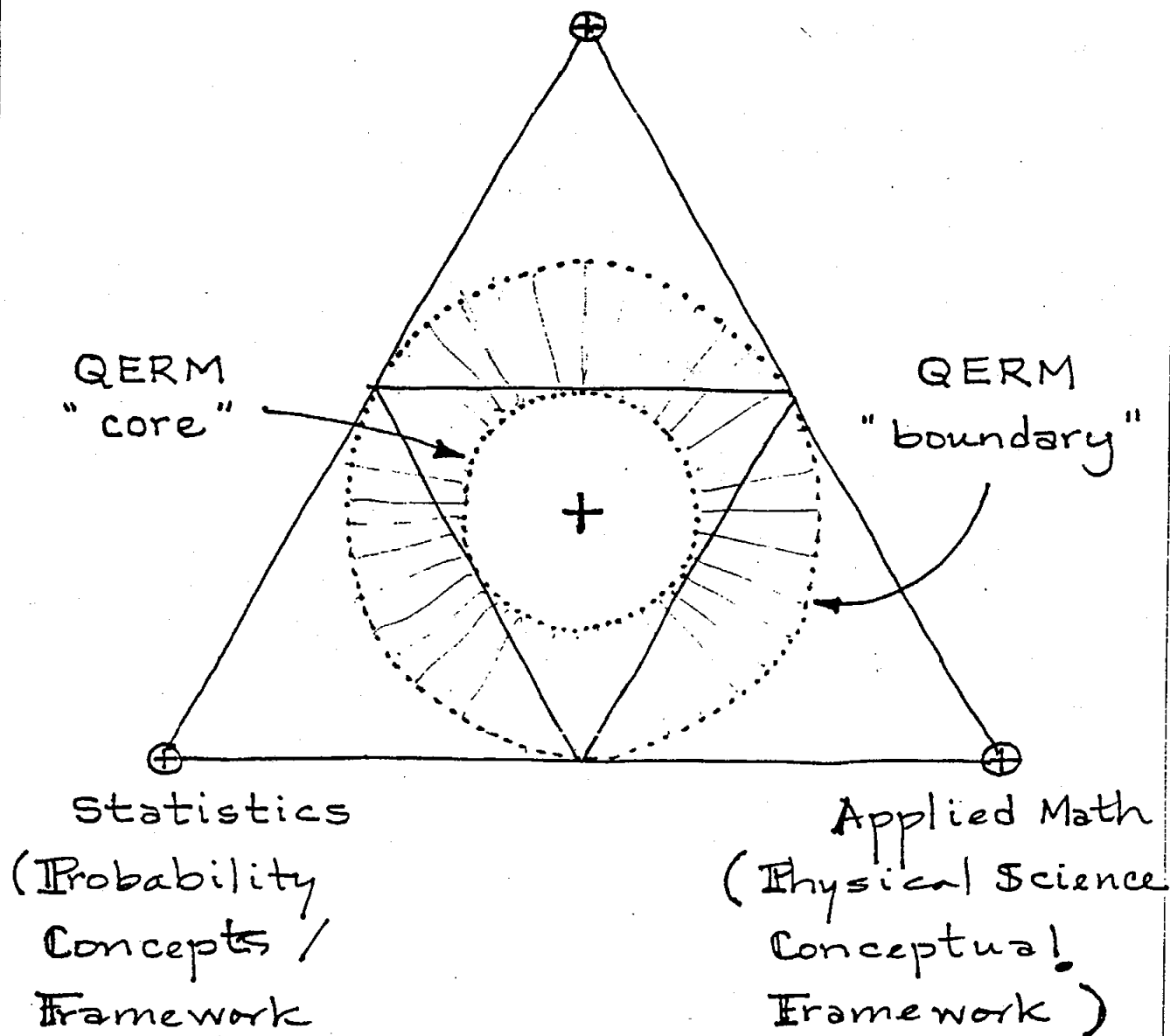
It is difficult to discuss qualifying exams, without discussing curriculum, but curriculum was the topic of question 2. Our discussion was therefore rather general but focused on the following points.

It was agreed, by almost all students and faculty, that for an interdisciplinary program like QERM there need to be qualifying exams in the basic skills and knowledge to be taken by all students. In a field which is the synthesis of three disciplines, there is a risk of becoming, and/or of appearing to be, mediocre in three fields unless exam standards are adhered to. However, given the variety of backgrounds of QERM students, a common schedule of qualifying exams may not be appropriate.

With regard to mathematical and statistical skills, it was widely felt that use of the qualifying exams of other graduate programs is the best approach. In this context, use of the Statistics MS Theory exam works well, but it was widely felt that one or more of the AMATH qualifying exams should be available as an alternative (or, a very few felt, additionally required).

# GRAPHICAL REPRESENTATION of the INTELLECTUAL TOPIC DOMAIN of QERM

Resource Management  
Ecology Science  
(Biology Discipline)



: jjohnson@u : 1 May 96 :

QERM's own "applied exam" is crucial in defining the basic skills and knowledge expected of all QERM students. While there was some criticism of perceived variability of standards and the "competitive" nature of the exam, overall the students felt that the style and level of the exam are appropriate. As a qualifying exam, which assesses the readiness and ability of students for research, many students felt that greater feedback after the exam would be helpful in pursuing that research.

QERM's "applied exam" needs a better balance of the subject matter represented in QERM. First (especially, if STAT and AMATH theory qualifying exams are to become alternatives), this exam must define the basic level of applied statistics and applied mathematical modeling skills to be required of ALL students. Second, and more importantly, it seems this exam provides the opportunity to assess knowledge and understanding of ecological problems. Students entering from the ecology focus feel frustrated that they must put those interests aside while they learn statistics and applied mathematics. Students entering from the mathematical sciences get little rigorous exposure to ecology. A more ecological focus to the QERM qualifying exam would help to provide a better balance.

### *Transition Into Research*

The transition to research is a big hurdle in any graduate program, but in QERM there are particular difficulties due to the diffused location of faculty and the very wide variety of research interests represented. There is no doubt that this is currently taking too long, and is too big a hurdle for many students. We have 3 specific suggestions for future discussion:

- (i) More student-faculty contact in the first two years of a student's program, through increased use of the lab rotation opportunities, and through seminars by QERM faculty about their research -- see also funding below.
- (ii) We question whether a M.S. degree should be required of all students. A Ph.D. thesis should not be the first complete research experience, from problem conception, to modeling, to analysis and computation, to write-up. However, a full thesis M.S. is in many cases a big price in terms of time, energy and direction, for a student to pay for an initial research experience. Too many students do not start to think about their Ph.D. research until their M.S. project is complete. For students accepted into the Ph.D. track, there is a strong feeling a M.S. should not be required. The Masters by-pass is the currently available approach.<sup>1</sup> An alternative based on a limited research project (lab rotations could play a big role here), including presentation and write-up, should be developed. Transition between the M.S. and Ph.D. "tracks" (in both directions) must be facilitated; it must be possible for those who find that independent research is not for them to complete a good M.S. thesis.
- (iii) Student committees: For many disciplinary programs, assignment of a single faculty advisor in addition to the Graduate Program Coordinator works well. For an

---

<sup>1</sup> See Section II.5

interdisciplinary program with a diffuse faculty, the committee felt strongly that assignment of a full academic advising committee (of 3?) representing the diverse interests of QERM should be assigned on entry to the program (distinct from the thesis committee). These three individuals should each approve the student's course of study (as the Forestry "green sheets," for example). The primary purpose however would be to facilitate greater student-faculty contact. A student feels it much easier to call on a member of their committee than a "random unknown faculty member". There will be more incentive to form a "real" committee, both from the faculty on the initial committee, and by the student who may wish to have advisors more related to their research interests. The initial committee members will be able to suggest other faculty to call on in seeking a "real" committee, or in seeking funding. A willingness to serve (and serve usefully) on the initial committee of at least one QERM student would be a good indicator of a faculty member's true interest in the QERM program.

### *Funding*

Of the 20 current (Spring 1996) students in QERM, 8 are RA's with their thesis advisor, 6 are RA's with other faculty, 3 are TA's and the remaining 3 have other support (e.g., fellowships). This is a very healthy situation, and if it could be maintained there would be little cause for concern. However, as funds become tighter, student research funding is an increasingly greater concern for the students in an interdisciplinary program, and for the faculty whose first priorities must often be given to their own disciplinary programs. There are currently feelings of instability in funding, both among students and among faculty.

There can never be a single simple formula that will enable a student to find funding for their research project. It is the nature of research funding that most funding is in large established projects, and the time frame of a degree is such that the majority of students will necessarily be supported on grants that were written before their entry into the program. More open discussion with students about the facts (how, when, why) of research funding, from the time of a student's acceptance into the program, is a good idea. A seminar in which QERM faculty talk about their funded research opportunities was also proposed by some; this would help to increase the accessibility of faculty and foster student-faculty connections which can only help.

The base of TA support (3 CQS TA's soon to be OUE TA's ?) is small, and this is a problem in recruiting incoming students. In most programs, students are typically not supported as RA's in their first year. For students beyond their initial year, several students mentioned guidance from faculty; the more contact with faculty a student can have, the easier it will be (although it will probably never be easy). The initial student committee proposed under (c) above would help here, as would increased use of lab rotation opportunities. There are a number of training grant fellowship opportunities in the quantitative biological sciences around campus; greater contact with QERM faculty, many of whom are involved also in these training grants, would assist QERM students in seeking funding for their research.

### *Timetables*

The achieved timetables in the appended information (Appendix VIII) bear little relationship to the idealized figures in the Graduate Student Guide. Both for M.S. and Ph.D. the times to form a Committee, to schedule a General Exam, and to graduate, are too long. While

there may be some comfort in that the times for current students are less than for graduates of the program, the former is a censored distribution, and graduation times achieved by current students may be no smaller than for those already graduated. On the other hand, noting the variety of backgrounds of QERM students and the synthesis of mathematical and biological sciences that must be achieved, the times in the Graduate Student Guide are probably unrealistic for many students.

Both the specific proposals made under (c) above may help to reduce graduation times. The requirement that a full thesis M.S. be completed by Ph.D. students undoubtedly is a big factor in increasing graduation times. The assigning of a full academic advisory committee on entry into the program (with the expectation that this will be different from the thesis committee), will also assist in speeding up the progress into research.



## VII. FUTURE TASKS FOR THE QERM PROGRAM AND ADVICE SOUGHT FROM THE REVIEW COMMITTEE

In its first five years the Interdisciplinary Graduate Program in Quantitative Ecology and Resource Management has established itself as a rigorous program attracting very high quality students from different backgrounds. The students we have graduated have found employment in the natural resources professions, where they were intent on doing so, or in posts where they can pursue work they find interesting. Faculty involvement has spread substantially beyond what was the core CQS faculty.

The QERM program was developed by the CQS faculty and the 1990 review committee clearly saw that much of the immediate development should be by CQS. Now CQS, as an organization in the University, is changing its function and organization. It will be administered through the Office of Undergraduate Education and its activities will be restricted to undergraduate education. CQS will have no building.

The QERM program faces three, interrelated, problems. First, to make a more effective integration of the component subjects of Quantitative Ecology and Resource Management and define this for graduate education. Second, to establish an effective relationship between faculty self-governance of the interdisciplinary program and the administrative structure of the University and that can provide adequate resources and infrastructure. Third, to define a standard and method of practice for our interdisciplinary activity, that is accepted and not questioned as a matter of principle.

We make suggestions on solutions to these problems and hope the Review Committee can offer comments:

### 1. Improving interdisciplinary education in QERM

The modeling, ecology, and resource management components of the program need to be strengthened. We have need to define both the qualifying aspect, i.e., what students need to know and will be examined on, and the integrative aspects, i.e., how the components of the program can be synthesized. In particular the first year requirements in ecology and modeling need to be considered.

There are some excellent courses already in existence that might be suitable for entering QERM students, e.g.:

ZOOL 470	(3)	Techniques for Mathematical Biology
ZOOL 471	(4)	Models in Biology
ESC 501	(5)	Forest Ecosystems-Community Ecology
ESC 502	(5)	Structure and Function of Forest Ecosystems
FISH 450	(4)	Salmonid Behavior and Life History
BIOL 472	(5)	Principles of Ecology

However, each of these is specialized, or slanted in a particular direction, and seem more appropriate as possible electives given the range of interests among the QERM students.

The most appropriate solution for course development in the qualifying year is that modeling, ecology, and resource management faculty in QERM develop equivalent courses to QSCI 514 and the STAT 512/513 sequence. Two types of course seem required, (i) a technically oriented course extending beyond QSCI 550, and (ii) a course illustrating how models have been used in ecology and management. The available faculty might include, but not be limited to, Jim Anderson, David Ford, Jay Johnson, Tom Leschine, and Gordon Swartzman, and possibly a new faculty member in the Applied Mathematics department. As things stand, Johnson, Ford, and Leschine already each have substantial teaching in their home units- particularly of required classes in their home units -and each could contribute some part but perhaps not all of such courses. Anderson and Swartzman are both research faculty in the School of Fisheries who would require financial support to make a sustained teaching effort.

Improved course work in the qualifying year is only the first and most obvious requirement. The faculty must sustain and develop interdisciplinary course contributions and use these to advance interactions among QERM students and between QERM and other programs. This integrated teaching effort would have value and importance beyond QERM. The construction of ecological and environmental models and how to use them are important topics for many other subjects. In particular, the recommendation of the President's Task Force on Environmental Education includes development of Masters' programs that these courses could contribute to.

#### Request:

We request two quarters of faculty support for each academic year so that faculty can develop and teach courses and enhance interdisciplinary activity. Without that, the educational problems we face will continue.

## 2. Governance, administration, and resources for the Program

The faculty involved in QERM has widened since 1990 to beyond that in CQS and some of these faculty play pivotal roles in QERM. The question now is what type of administration should there be, and what type of support and requirements should be asked for. The QERM program requires facilities to administer the program and its courses, a future physical location, and computing equipment. Interdisciplinary teaching and research must not be something that faculty can engage in when they have finished all the disciplinary work that might be given to them.

### *Administration of the program and its courses*

The condition of transferring CQS into the Office of Undergraduate Education is that only its 400-level classes and below should be so transferred. The future of the 500- level classes needs to be discussed by the responsible faculty and at present most seem to favor those classes be designated as QERM. This means that QERM becomes responsible for class scheduling and designation of instructors, something it has not done up to now. Associated with the 500-level classes is the need to ensure adequate computing equipment and support. In the past this has been achieved through CQS and the School of Fisheries.

During the past five years QERM has received some resources from the Graduate School, but other support, particularly Systems Support and computing equipment through its association and collocation with CQS.

Request:

An administrative structure and budget for supporting QERM should be established directly through the Graduate School. This should include computing equipment for a nucleus of QERM graduate students.

Rather than be responsible to the Graduate School, an alternative proposal is that QERM should be responsible to the contributing units in which QERM faculty have their primary appointments (Arts and Sciences, Forest Resources, Ocean and Fishery Sciences, and Engineering). It has been suggested that, for example, the School of Medicine contains, and is directly responsible for, interdisciplinary programs and QERM could follow that model. The position of QERM is entirely different from these medical programs:

- (i) QERM is not supported by a large Training Grant program from NIH which is the basis for some medical interdisciplinary programs and ensures their financial viability;
- (ii) the range of faculty input, in both academic content and degree of involvement is greater than in the medical programs, i.e., faculty from many different units are involved and the contributions range from occasional lectures, involvement in laboratory rotations, to full support of students. Direct responsibility for QERM by one or other of the Colleges of contributing faculty (whether Arts & Sciences, Engineering, Forest Resources, or Ocean and Fishery Sciences) would lead to a similar set of problems as when the School of Fisheries became the administrative home for CQS.

*Physical location*

Demolition of the CQS building leaves the QERM program with no central focus or housing for its students. Some change in the pattern of location of senior students may be possible, i.e., that when students have formed a supervisory committee, the chair of that committee should be responsible for housing the student. This may work in some instances but in an interdisciplinary program the process of selecting a committee chair is rarely as clear cut as in a disciplinary oriented department (see Appendix II). Requirement that chairs are responsible for a student's space may retard committee formation.

The QERM program needs a central facility where a core group of students can be housed, and faculty and students can interact. It is essential that this be not space owned, or potentially coveted, by any department.

A clear majority of QERM faculty (Faculty meeting, March 1996) consider that the core of the program should be physically located on upper campus. Bagley Hall is the current practical solution, but space there is viewed by the Office of Capital Budget and Planning as surge (temporary) space. A recent development is the award of the EPA National Center for Environmental Statistics (NCES) to the University of Washington. Collocation of NCES and the core of the QERM program would have many advantages.

Request:

Space for housing 14 students, access to a seminar room, and a common area for discussions.

3. Defining an interdisciplinary standard for QERM within the University of Washington

The faculty of QERM view their task as exciting and very definitely interdisciplinary and requiring true collaboration and at a programmatic level between different departments, schools, and colleges, across campus. They consider that bringing together mathematicians, statisticians, ecologists, and natural resource scientists, in the way the QERM program does, as sufficient justification in itself. They see unique academic problems, regionally, nationally, and internationally, that QERM students will be equipped to deal with. Working outside of one, or even two, disciplines is likely to be exactly what a practicing biometrician or modeler faces in the natural resources world. During the discussions of the President's Task Force on Environmental Education, the QERM program was referred to, on a number of occasions, as the very model of what environmental education should be like at the University of Washington. Unfortunately there is a huge gap between the ideal and successful implementation.

An important problem has been that the very energy and activity that QERM faculty have put into the program has been seen by some as a distraction from the activity of home units. Over the last five years the concern has been mainly expressed by the School of Fisheries, but in the late 1970's, when the College of Forest Resources withdrew its faculty from CQS, despite them having been appointed to the Center, the same issues were at work. The concerns are not really technical ones about student credit hours, or student numbers that may be "lost", although they may be dressed in those clothes. Rather that energetic activity should be devoted solely to a faculty member's "home" department. The basic attitude is, "It's a zero-sum game" -- what is put into QERM is a distraction from, or even competitor with, the home department. From the perspective of the QERM faculty they do contribute energetically to their home departments, through teaching, administration, and particularly by bringing a new research dimension that is facilitated through the QERM program.

All truly interdisciplinary teaching, where there is detailed involvement of faculty from a number of units, raises concerns about faculty involvement in, and self-governance of, academic programs. The faculty in QERM see their initiative as entirely in line with the developing educational program of the University -- and the creation of the President's Task Force on Environmental Education substantiates that view. In practice, jealousies arise over faculty time and resources and in conversation, Dean Heath was adamant that the Board of Deans should say who was, and was not, to participate in interdisciplinary programs and how they would be organized. Unfortunately no dialog was possible with Dean Heath, yet interdisciplinary teaching does need support and more active, positive, and creative support than the QERM program has received in recent years. This still seems a University-wide issue of great importance since the Task Force on Environmental Education has recommended a structure similar to the one in QERM for environmental programs, i.e., faculty residing in "home" departments yet engaged in interdisciplinary work.

Request:

For the QERM program these have been important issues absorbing both time and energy. Our request is that the recommendations in the University of Washington Interdisciplinary Research Committee Report be reconsidered, specifically with regard to the QERM program. However,

QERM simply cannot wait for University recognition of the worth of interdisciplinary teaching and research. As a faculty, we need to establish our standards of what we do, and communicate them to administrators and other faculty.