Proposal: Establishment of a Graduate Program
Memorial University of Newfoundland

Master of Science in Fisheries Science (Fisheries Science and Technology)
Master of Science in Fisheries Science (Stock Assessment)
Doctor of Philosophy in Fisheries Science

School of Fisheries
Fisheries and Marine Institute

Program Start: Fall 2017

Brett Favaro, School of Fisheries
Brett.Favaro@mi.mun.ca

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Name of proposed program:
M.Sc. Fisheries Science (Fisheries Science and Technology)
M.Sc. Fisheries Science (Stock Assessment)
Ph.D. Fisheries Science

Degree name and short form (e.g., Master of Arts (MA)):
Master of Science in Fisheries Science (MSc)
Doctorate of Philosophy (PhD)

Academic unit(s) offering the program:
School of Fisheries, Fisheries and Marine Institute of Memorial University of Newfoundland

Administrative home of program (if different from above): NA

Proponent name: Brett Favaro
Proponent email: Brett.Favaro@mi.mun.ca

Date: April 1, 2016

Anticipated start of new program (semester and year): Fall 2017

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1. Executive Summary

We are proposing to create three complementary programs in Fisheries Science within the School of Fisheries at the Marine Institute: 1) **Master of Science in Fisheries Science (Fisheries Science and Technology)**, 2) **Master of Science in Fisheries Science (Stock Assessment)**, and 3) **Doctor of Philosophy in Fisheries Science**. Hereafter, we will refer to these, collectively, as a single program.

Fisheries science is the discipline that studies the management, practice, and underlying ecosystem dynamics that support the extraction of living organisms from water by humans (i.e. fisheries). It is a broad scientific field that includes everything from stock assessment professionals and engineers to social scientists and historical ecologists – and everything in between.

We are proposing a program that focuses on developing the skills necessary to be an effective researcher within fisheries science. The program's core courses are designed to develop proficiencies in quantitative techniques, study design, and science communication that are necessary to be effective at fisheries research, regardless of the type of research project in which students will be engaged. For students in the stock assessment option, additional training specific to this field will be provided. A given student's specific program of study will be tailored by their supervisory committee to meet their needs, and may include the assignment of additional courses from other departments to attain breadth in training. Both M.Sc options will have target completion times of two years, and the Ph.D program will target a four year completion time.

This program is built around the understanding that graduates in fisheries may be employed in a wide variety of sectors, including private industry, government, and academia. Hence, the skills training in our program should equip students to pursue a variety of careers, while developing excellence in fisheries science. The stock assessment option will prepare graduates for specific careers in quantitative assessment of fisheries – a skillset that is in high demand across the world.

The courses in this program can be designed and delivered with existing faculty. We forecasted enrollment based on the rate at which researchers at the SOF recruit graduate students to their research groups. Based on these numbers, we forecast that program will roughly break even at the end of its third year, without imposing special program fees. This program will emphasize training on freely-available open source software, so computer resource requirements are minimal.

2. Program Description

2.1 Program Name

Master of Science in Fisheries Science (Fisheries Science and Technology)

Master of Science in Fisheries Science (Stock Assessment)

Doctorate of Philosophy in Fisheries Science

Proponent: Dr. Brett Favaro
Contact email: Brett.Favaro@mi.mun.ca

Date: April 1, 2016
Anticipated start of new program: Fall 2017

One of the most-cited fisheries scientists in the world is Prof. Ray Hilborn from the University of Washington. Famously, he made the following statement about fisheries science (Hilborn, 2007):

The expression 'this is not rocket science' has achieved popular use as an indication that solutions should be easy to find. I disagree. I believe that rocket scientists have it easy … Management of fisheries deals with much more complex biological systems and more complex human systems.

Fisheries science is the discipline that studies the management, practice, and underlying ecosystem dynamics that support the extraction of living organisms from water by humans (i.e. fisheries). Within this broad definition, a swath of research is conducted that cuts across the boundaries of scientific sub-disciplines. Sociologists study the history and cultural role of fisheries in society. Statistical modellers work with population biologists to generate models that tell us how much we can safely exploit marine ecosystems before they collapse. Engineers work with behavioural ecologists to design technology that efficiently and selectively captures animals from the ocean, with as little collateral impacts as possible. Geographers identify and map habitats that are too sensitive to be fished. Policy analysts and economists investigate how humans can maximize profits from these industries within the physical boundaries of productivity offered by aquatic ecosystems. And these only represent the tip of the proverbial iceberg that is fisheries science.

While the discipline of fisheries science is incredibly broad, it is unified in two ways. First, all fisheries science is ultimately applied. Whether one studies the genetics of fish stocks, the

economics and management of an industry, the best way to design a trawl net so as to minimize seabed impacts, or the best seafood processing techniques to maximize value, all these discoveries ultimately have implications for the practice and conduct of fisheries. To translate research into practical action, the modern fisheries scientist must be able to conduct the work in a scientifically rigorous manner that passes the test of peer review, while also communicating that knowledge to a diverse range of stakeholders.

The structure of the School of Fisheries (SOF) at the Fisheries and Marine Institute (MI) reflects part of the diversity of fisheries science as a whole. Scientists in the Centre for Fisheries and Ecosystems Research (CFER) primarily study ecosystem dynamics that inform the management of fisheries. Researchers at the Centre for Sustainable Aquatic Resources (CSAR) develop and assess techniques for conducting fisheries sustainably – in essence, once the decision has been made to fish, they make sure that species are fished properly. Once captured, the organisms must be processed for human consumption. Research in that area falls under the mandate of the Centre for Aquaculture and Seafood Development (CASD). Researchers in each of these centres collaborate with engineers, social scientists, policy experts, economists, and members of many other disciplines in pursuit of their research objectives.

To make an impact in fisheries, graduates must have expertise in two broad components of science. First, they have to know how to conduct world-class research. This requires an ability to design studies, conduct experiments, analyze data, and publish results in peer-reviewed journals. Second, researchers must be able to communicate and mobilize their work effectively in the service of a diverse range of stakeholders, including resource managers in government, Non-Governmental Organizations (NGOs), community members, and the fishing and processing industries.

Here, we propose a graduate program in Fisheries Science, to be conducted within the SOF at MI. The first component of this program will be the **M.Sc. in Fisheries Science**, which will have two options. The **M.Sc. in Fisheries Science (*Fisheries Science and Technology*)** option will be the fisheries science training program that most students will enroll in. A second option, **M.Sc. in Fisheries Science (*Stock Assessment*)** will facilitate the development of specific skills needed for the discipline of stock assessment, which is critical to managing marine fisheries. The final component of the Fisheries Science program will be the **Ph.D in Fisheries Science**, which will be the doctoral program of the SOF.

The rationale for the names are as follows. First, it is either a *master's* program – meaning it will be completed by students in approximately two years, or a *doctorate of philosophy*, meaning the program will take four years to complete, and will include a comprehensive exam and defense.

Second, it is a *science* program, where students will conduct original research under the supervision of a scientist within the SOF. Third, student research programs will occur under the broad umbrella of the discipline of *fisheries science*. Students in this program may conduct research in any sub-discipline of fisheries science in which SOF scientists have the ability to mentor them.

Our stock assessment option represents a separate training pathway for students seeking a career in this sub-discipline of fisheries science. Stock assessment professionals use data derived from many sources to construct models that inform us about the biomass of organisms in the ocean, and how many we can catch sustainably. While stock assessment professionals must have many of the same proficiencies as other fisheries scientists, they have an additional requirement of being experts on the mathematics and statistics that underpin this heavily quantitative field.

2.2 Graduate Profile and Learning Outcomes

A) Graduates of the M.Sc. in Fisheries Science program will be able to:

- Conduct original research
- Collect, manage, and analyze data
- Display and interpret quantitative information
- Demonstrate adherence to the principles of scientific integrity (i.e. NOAA, 2011)
- Effectively communicate their research
    - Through peer-reviewed publications in reputable science journals
    - In oral and poster-based presentations at scientific conferences and meetings
    - In formats accessible to stakeholders, including popular media, industry publications, and in other relevant venues
- Explain how their research fits within the broader policy environment of fisheries at local, national, and international scales

B) Graduates who complete the ***Fisheries Science and Technology*** option will complete a thesis containing at least one chapter of original research that is of sufficient quality to be considered for publication in a peer-reviewed journal. In addition to A, they will be able to plan and execute studies that collect new data.

C) Graduates who complete the ***Stock Assessment*** option will complete a thesis containing at least one chapter of original research that is of sufficient quality to be considered for publication in a peer-reviewed journal. In addition to A, they will demonstrate an advanced understanding of quantitative stock assessment.

D) Graduates who complete the **Ph.D. in Fisheries Science** program will complete a thesis containing three or more chapters of original research, as approved by their Supervisory Committee. In addition to A, and B or C, they will be able to:

- Craft impactful research questions that advance their discipline
- Lead the planning and execution of a research program
- Normally submit at least one chapter for publication to a peer-reviewed journal before submitting their thesis for examination

2.3 Requirements for Admission

M.Sc. in Fisheries Science (*Fisheries Science and Technology*)

To be considered for admission an applicant will normally hold at least a high second class Honours Degree, or an M.D. Degree, or the equivalent of either, both in achievement and depth of study, from an institution recognized by the Senate.

Any other applicant may be considered for admission provided that:

1. The applicant's undergraduate record after the first year shows an average of at least Grade B in courses in the proposed field of specialization;
2. The applicant's overall undergraduate record after the first year shows an average of at least Grade B in all courses taken; and
3. The applicant demonstrates a commitment and passion for aquatic science, ideally in fisheries, through employment or experience in field schools, research programs, the fishing industry, regulatory agencies or government departments, non-governmental organizations, consulting activities, or other relevant activities.

Admission requirement related to English proficiency requirements follow the SGS General Regulations – English Proficiency Requirements 4.1.5.

M.Sc. in Fisheries Science (*Stock Assessment*)

To be considered for admission an applicant will normally hold at least a high second class Honours Degree, or an M.D. Degree, or the equivalent of either, both in achievement and depth of study, from an institution recognized by the Senate.

Any other applicant may be considered for admission provided that:

1. The applicant's undergraduate record after the first year shows an average of at least Grade B in courses in the proposed field of specialization;
2. The applicant's overall undergraduate record after the first year shows an average of at least Grade B in all courses taken; and
3. The applicant demonstrates a commitment and passion for mathematics or statistics, through employment or experience in field schools, research programs, regulatory agencies or government departments, non-governmental organizations, consulting activities, or other relevant activities.

Applicants must be able to demonstrate a satisfactory knowledge of mathematics, statistics, and scientific computing.

Admission requirement related to English proficiency requirements follow the SGS General Regulations – English Proficiency Requirements 4.1.5.

Ph.D. in Fisheries Science

Admission into the Ph.D. program in Fisheries Science is normally restricted to candidates holding a Master's Degree or its equivalent. In exceptional circumstances, a candidate with a B.Sc. Degree who has spent not less than 12 months in an M.Sc. Degree program may be recommended for transfer into a Ph.D. program. For this transfer to be accepted, the candidate must demonstrate, to the satisfaction of the Supervisor and Supervisory Committee, their ability to pursue research at the doctoral level.

All programs

Students applying the program will need to have identified a supervisor, who must be either a research scientist within the SOF, a cross-appointed or adjunct faculty within the SOF, or an actively-publishing researcher within the SOF who holds a Ph.D. (this may include instructors or directors). Students will also need a supervisory committee, and a committee meeting must be held within the first three months of registration in their program (See Calendar regulations).

2.4 Program Overview

Specific requirements are outlined in Appendix B.

M.Sc. in Fisheries Science *(Fisheries Science and Technology)*

Students must complete 12 credit hours of course work and a thesis containing at least one chapter of original research. Coursework (Table 1) includes four program courses:

- FISH 6000: Science Communication for Fisheries
- FISH 6001: Ecology, Management, and Practice of North Atlantic Fisheries
- FISH 6002: Data Collection, Management, and Display
- FISH 6003: Statistics and Study Design for Fisheries Science

Students will usually complete FISH 6000, 6001, and 6002 in the **fall** semester, and FISH 6003 in the **winter** semester. They will normally complete their thesis within two years (six semesters) of enrolling in the program.

M.Sc. in Fisheries Science *(Stock Assessment)*

Students must complete 15 credit hours of course work and a thesis containing at least one chapter of original research, which should include content of direct relevance to the practice of quantitative stock assessment. Coursework includes five program courses:

- FISH 6000: Science Communication for Fisheries
- FISH 6001: Ecology, Management, and Practice of North Atlantic Fisheries
- FISH 6002: Data Collection, Management, and Display
- FISH 6004: Overview of Statistical Stock Assessment
- FISH 6005: Advanced Statistical Stock Assessment

Students will usually complete FISH 6000, 6001, and 6002 in the **fall** semester, and FISH 6004 in the **winter** semester. FISH 6005 will be delivered in the **fall** semester, and students will take it in their second year. They will usually complete their thesis within two years (six semesters) of enrolling in the program.

Ph.D. in Fisheries Science

Students must complete a thesis containing three or more chapters of original research, as approved by their supervisory committee. In addition, students will be required to take FISH 6000, 6001, and 6002. Depending on the student's background, their Supervisor and Supervisory Committee may deem the student to be exempt from completing any or all of these courses. Students may be required by their Supervisor and Supervisory Committee to take FISH 6003, 6004, and/or 6005. Students will complete a comprehensive exam as governed by the general regulations.

Students will usually complete all requirements thesis within four years (twelve semesters) of enrolling in the program.

For all three programs, evaluation of the thesis will be carried out in accordance with **Thesis and Reports** of the **general regulations** governing all students. In addition, in all three programs, the student's supervisory committee may assign additional courses above the core requirements, if they feel the student needs these courses to achieve proficiency in their research area.

Students enrolled in all of these programs will normally be full-time students.

Table 1. Course sequence for each program

Program	Semester	Course
M.Sc. in Fisheries Science (*Fisheries Science and Technology*)	Fall	FISH 6000
		FISH 6001
		FISH 6002
	Winter	FISH 6003
M.Sc. in Fisheries Science (*Stock Assessment*)	Fall	FISH 6000
		FISH 6001
		FISH 6002
	Winter	FISH 6004
	Fall (Year 2)	FISH 6005
Ph.D. in Fisheries Science	Fall	FISH 6000*
		FISH 6001
		FISH 6002*
		FISH 6005†
	Winter	FISH 6003†
		FISH 6004†

*Ph.D. students will normally take these courses unless they are so proficient in the subject matter that their committee deems taking the course to be unnecessary.

†Ph.D. students should take at least one quantitative statistics course, unless their committee determines they are already extremely proficient, or if they have already taken these courses as part of an M.Sc. program. If their research pertains to stock assessment, they should take FISH 6004 and 6005.

2.5 Departments Offering Courses

SOF will develop and deliver FISH 6000, 6001, 6002, 6003, 6004, and 6005 for this program. Each course will be offered every year by the School of Fisheries. FISH 6005 will first be offered in the Fall of 2018, and then every year thereafter.

Supervisory committees may assign additional courses if it is determined that the student has a knowledge gap that should be filled by targeted coursework. This reflects the fact that fisheries science is broad, students may be working across disciplines, and that it would therefore be impossible (and undesirable) for us to attempt to offer courses that could cover every conceivable aspect of the discipline. In these cases, we prefer that committees send students to departments with specific subject matter expertise in areas not covered by our proposed program.

Likewise, we anticipate that there will be students in other programs that will desire the skills training offered in FISH 6000, 6002, and 6003. While we will prioritize students in our program for enrollment, other students will be able to take these courses as well (see, for example, T. Branch comments in Appendix D). This will strengthen linkages between departments.

2.6 Theoretical/Practical Balance

This program recognizes that fisheries science is a broad discipline that is applied in nature, and requires a high degree of skills to be done well. It also recognizes that science graduates in all disciplines face a challenging job market, are likely to pursue careers outside of academia (Munro, 2015), and therefore must be proficient at the transferable skills that underpin many modern science-based careers.

We believe that this focus on proficiencies will not detract from the depth of knowledge that students will have the opportunity to develop in this program. On the contrary, students will have the ability to apply this focused training to their research programs, which is the venue in which they will be best positioned to gain breadth.

Our goal is for students to gain practical skills through the courses, while developing their theoretical understanding through supervised research, and through their interactions as an active participant within the scientific community. Focused skills training will empower them to do this well.

Within this program, PIs will foster a collaborative research culture by encouraging lab meetings, reading groups, and other activities that will expose students to the depth of the field of fisheries science. Guest lectures will be encouraged as well.

2.7 Program Delivery Model

Program courses will be delivered at MI. M.Sc. research projects should be of a scope that can reasonably be completed in two years, including coursework. Ph.D. programs should be four years in scope.

M.Sc. and Ph.D. students should complete their program courses in the first year of the program. Students in the stock assessment M.Sc., or in a Ph.D. that focuses on stock assessment, will also take the Advanced Statistical Stock Assessment course in their second year.

Internships may be a part of any student's research program, provided the supervisor and supervisory committee are supportive. MI's Placement Office is a resource that could be available to students, or they could seek the internships themselves with the support of their mentorship team.

3. Statement of Justification

3.1 Introduction

About 71% of Earth is covered by oceans, and fishing is one of the most impactful activities that occurs in this environment. Between capture fisheries and aquaculture, about 158 Mt of seafood was extracted from the ocean in 2012, which represented 16.7% of global animal protein intake by humans, and more than $200 billion in economic activity (FAO, 2014). Few industries are more dependent on an intact environment than fisheries. Ironically, there are few ecosystems that are more complicated and under-studied than those in the ocean.

Here, we propose the creation of a research-based Fisheries Science program that will provide students with specific training that will enable them to pursue a career in fisheries science. This program will recognize that in fisheries science, producing world-class research in peer-reviewed journals is a necessary, but insufficient step to improving the way we manage and practice fisheries here and abroad. Practitioners must be prepared to communicate their work to a variety of stakeholder groups, and mobilize this information in a way that can be used effectively. It also requires research that cuts across disciplines: Prof. Ray Hilborn of the University of Washington has famously declared that “managing fisheries is managing people” (Hilborn, 2007).

While the research that is conducted under the auspices of fisheries science is broad, all fisheries science research programs require that practitioners are capable of designing, executing, and analyzing the results of powerful studies. Therefore, our program focuses on developing these core proficiencies that will enable them to conduct world-class research under the umbrella of a broad fisheries science program. In addition, this program will provide additional focused training to students interested in pursuing a career within the specific discipline of stock assessment.

3.2 Need for the Program and Academic Rationale

In 2006, the United States Government reauthorized the Magnuson-Stevens Fishery Conservation and Management Act. As part of that re-authorization, they commissioned a report to study whether a shortage existed in trained experts in fishery science, and what to do about it (NOAA, 2008). Focusing especially on stock assessment, they found that over a ten-year period, a cumulative shortage of as many as 180 stock assessment experts could be expected (NOAA, 2008). Filling this gap would require specific programs be put in place to train people in fisheries science.

More recently, Maunder and Piner (2014) demonstrated that there remains serious deficiencies in fisheries science that have not been resolving themselves over time. The authors of that paper argue that the number of qualified scientists being trained is insufficient even to replace retiring scientists, let alone increase the size of the discipline to resolve many of the scientific gaps that exist today. They identify that a lack of quantitative skills and engagement of scientists with the public are serious barriers to resolving existing problems in the discipline.

The need for a combination of technical and engagement skills was further demonstrated by Langholz and Abeles (2014), who surveyed 30 top scientists in marine conservation on what they thought were the most important skills to develop in postgraduate education. They collectively identified that written and oral communication skills, along with creative thinking were tied as the most important skills to be developed in a marine science program.

In the interests of advancing fisheries science and management, it is therefore critical to produce a program that simultaneously increases the number of trained professionals in the field, while equipping them the skills necessary to be successful in this unique but broad discipline. More generally, this program will reflect the modern needs of people pursuing careers in science. One such need is to publish peer-reviewed literature during one's time in graduate school. It has been argued that the best predictor of post-graduate success for academic careers is one's publication record during their Ph.D. (Laurance et al., 2013). This finding was recently supported by research in the biomedical field, demonstrating that people who published prolifically within their first decade of their career fared better than those who did not, regardless of the identity of the journal in which they published (von Bartheld et al., 2015).

The need for a research-based program at MI

MI currently offers two course-dominated Master's degrees that pertain to fisheries: The Master of Marine Studies (Marine Spatial Planning and Management), and the Master of Marine Studies (Fisheries Resource Management). These programs are designed to produce highly skilled practitioners in integrated coastal and ocean management, but do not emphasize the conduct of novel research.

Currently, there are about 30 graduate students pursuing research-based M.Sc. and Ph.D. degrees under the supervision of scientists in the SOF at MI. These include the research scientists at CFER, CSAR, and CASD, as well as three other researchers that supervise graduate students, but hold different classifications (total N = 9, see Appendix E). To date, these students have been enrolled in a variety of programs, including Biology, Environmental Science, Marine Biology, and several others.

Current MUN programs promote scientific excellence, and with our proposed programs we hope to build on that excellence by providing specific skills training that empowers graduates to conduct research within fisheries science.

Our program will introduce a dedicated science communication course. We view explicit training in this field as necessary, as scientific writing and presentation skills are core components of any career in science. Fisheries science in particular requires the further step of communicating this work 'outside the ivory tower' in a manner that is accessible by stakeholders in the field.

We will also introduce novel courses that train students to conduct data-heavy research that has become the norm in fisheries science, using industry-standard open-source software such as R Statistical Software (R Development Core Team, 2011). These are skills that are necessary no matter what sub-discipline of research a student works in. They are also extremely valuable skills that students will carry forward into future careers, whether or not those careers are in academia. Importantly, our program will teach students to keep abreast of the latest trends in scientific software, as this is a field that is constantly evolving.

For students in the stock assessment option, we will offer two statistical stock assessment courses that will provide specific training in this field. The need for this is reflected by the fact that stock assessment scientists must be extremely proficient in mathematics and statistics, while being able to apply these models to living biological systems that are complex in nature.

Finally we will offer a breadth-course in which scientists within the SOF will deliver short blocks of content on the areas in which they are subject matter experts. This course will have two goals. First, to expose students to the breadth of research in fisheries that is conducted at MI and MUN. Second, to teach students to start thinking like active researchers early in their program, rather than passive consumers of course content.

Summary

The proposed fisheries science program is needed and timely because there is an **urgent national and international need for trained fishery scientists** that has been identified by a broad range of stakeholders. The stock assessment option is important because it represents a specific skill deficit that has been outlined in the scientific literature, and one for which there is great potential in hiring.

In addition, there are a large number of graduate students pursuing fisheries science research here at MI. Researchers interested in fisheries science will benefit from a program dedicated to

supporting their work and research interests. This program will meet the specific needs of fisheries scientists, by offering core training in quantitative skills and science communication (two skillsets identified as critical to the success of applied marine scientists), on top of a course that provides breadth of knowledge in the management and practice of North Atlantic fisheries.

3.3 Relationship to Other Programs at MI, and Unique Attributes of the Proposed Program

MI currently offers a Master of Marine Studies (Fisheries Resource Management), as well as a Master of Marine Studies (Marine Spatial Planning and Management). These programs are primarily course-based, although they do bear thesis requirements. The FRM program is described as:

"This innovative program will enhance your work or career progression by providing a wealth of knowledge with real world applications. You will develop, through formal education, those skills that are essential to the management of fisheries resources.

This multidisciplinary program will provide an understanding of relevant concepts in biology, economics and business, as well as fisheries policy and planning. While focused primarily on the North Atlantic, the program also deals with major world fisheries as well as quantitative assessment methods."

The marine spatial planning program is described as:

"You want to work collaboratively to analyze how development impacts the ecological, economic, social and cultural aspects of coastal and marine areas. Graduates of this program will balance the demands of economic development and environmental conservation placed on our oceans and coastal areas to create a spatial vision and comprehensive management plans for their use."

These programs are fundamentally different from the proposed Fisheries Science programs, as they are dominated by coursework rather than by a thesis of original research. While they train students well to be practitioners in the field, there is not a focus on the development of new knowledge, which is a core aspect of fisheries science.

The critical novelty of our program is that it will equip student-researchers with the core skills needed to excel as a modern fisheries scientist. Many traditional research-based graduate programs offer courses that primarily cover academic content (See 4.2). Our belief is that the value we can bring to MUN through our program is to focus more on skills development, rather than adding many additional breadth courses that are already offered in other departments. In most programs, students get academic content through courses, but have to self-teach the critical skills that go into conducting their research programs. Here, we take the approach of focusing on skills in courses, while developing student's breadth through mentorship and their own activities as active researchers that participate in the scientific community.

3.4 National and International Comparison, and Unique Attributes

The American Fisheries Society maintains a list of universities in Canada and the United States that offer degree programs in fisheries science (Myrick et al., 2013). There are currently 173 institutions or departments on this list, 93 of which offer Ph.D. programs and 112 of which offer M.Sc. programs. There are an additional 269 institutions listed (including Mexico) that offer programs related to fisheries (such as marine biology).

We conducted a scan of institutions in this list when developing our program, through a full comparison of all of them is beyond the scope of this proposal. However, we highlighted the top four universities in the world based on citation count, measured as Web of Science publications between 2000-2015 that include the term "fisheries." We conducted this search in October 2015. These were: the University of British Columbia (UBC: 24K), the University of Washington (UW: 21K), the University of California Santa Barbara (USCB: 11K), and Simon Fraser University (SFU: 7K).

Despite their status as world-leaders in fisheries, not all of these universities offer explicit training in fisheries science itself. For example, a university may have a biology department with faculty members that publish a substantial amount of fisheries literature, but lack a formal fisheries program (e.g. Simon Fraser University, which houses fisheries content within the Resource and Environmental Management program and the Department of Biological Sciences). Nevertheless, this represents the diversity of top academic institutions that influence the discipline of fisheries science.

Broadly speaking, these programs are similar in that they include at least one course that offers breadth, with titles such as *Issues in Fisheries Research*. UBC offers a course entitled Fisheries Conservation, Governance, and Evaluation, which is a module-based course taught by six faculty members whose teaching model served as the inspiration for our proposed Ecology, Management, and Practice of North Atlantic Fisheries course. UBC also offers a science communication course, which is open to senior undergraduates as well as graduate students, but is not core to the program.

UW offers a wider range of courses, and is nearer to our proposed model of having courses that focus on skills training. Some of their courses include 'Research Proposal Writing for Graduate Students,' 'Intro to R programming,' 'Advanced R programming,' and 'Beautiful graphics in R.' The UW program's course focus is arguably more quantitative than the UBC program, although the research produced at both institutions is heavily quantitative. It is noteworthy that the University of Washington divides its students into two categories – students in the School of

Aquatic and Fisheries Sciences, and the Quantitative Ecology and Resource Management program. These two programs are complementary and share courses, but the QERM program involves additional quantitative training (our proposed stock assessment program bears similarities with this model).

The UCSB Bren School of Environmental Science and Management offers a very different model. Masters students here take a large number of breadth courses, followed by a group thesis or an 'eco-entrepreneurship' project. Their Ph.D. program diverges significantly from their M.Sc. program. Students pursuing a Ph.D. pursue three courses, one of which is devoted to science communication and statistics. Other than that, their programs are completely individualized, and their program of study is determined by their supervisory committee. This culture of assigning courses based on student need inspired the flexibility we have built into our own program.

It is important to note that each of these programs have far larger pools of researchers than does the SOF at MI (e.g. the UBC Institute for the Oceans and Fisheries has 17 core faculty, 10 research faculty, three associate faculty, and 22 adjunct faculty. UW SAFS has 30 core faculty plus a wide range of people who hold other designations), so we should not attempt to replicate the breadth of course content offered in these programs. Rather, we should focus on building excellent skills-based courses, and encourage students and researchers to collaborate within the broader MUN community and abroad.

The programs we analyzed vary widely in the number of core and elective courses that they require students to take (Figure 1). We are proposing not to require students to take electives as part of the program requirements. Rather, our programs outline M.Sc. programs of study, and strongly recommend a program of study for Ph.D. students, that serves as the foundation for their fisheries science training. Additional training will be assigned by the supervisory committees as needed, following the model outlined by UCSB.

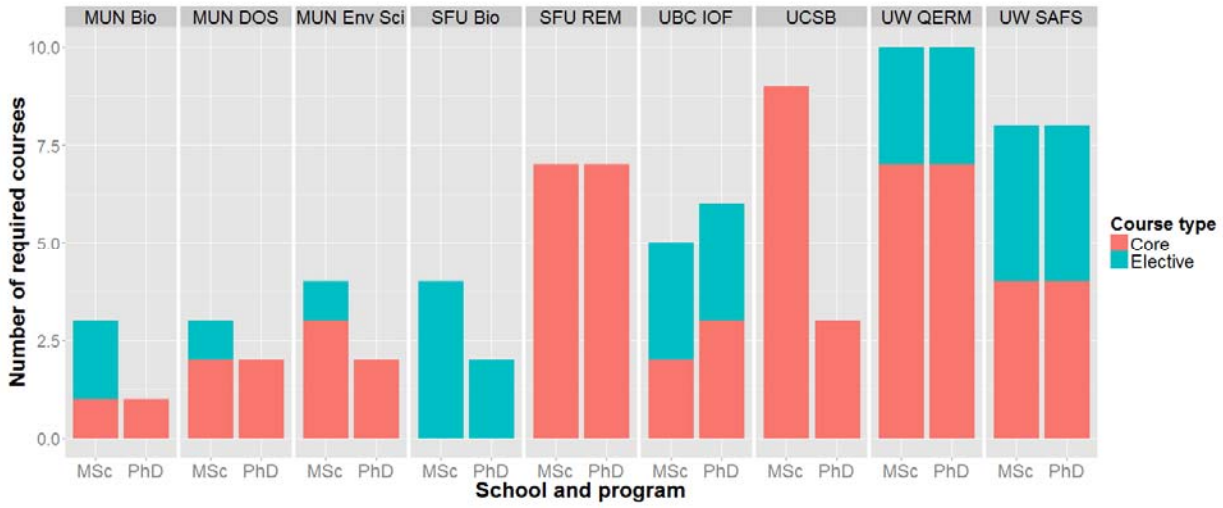

Figure 1: Approximate number of courses that graduate students must take in research-based programs included in our comparison. We collected these data from the departmental websites of each program. We assumed that three credit hours represented a single course for universities in this sample. Some programs have specific rules about credit hours that may not have been captured in this simple analysis, so the course numbers should be interpreted as approximate.

3.5 Contribution to Srategic Goals of University

The Marine Institute's strategic plan is outlined in the Vision 2020 document, published in 2009. The Institute identified the following vision statement:

Our vision for the future is simple... ***to be a world oceans institute, setting the standards for education, training, innovation, and research***.

These elements make this vision achievable:

- *our central focus is oceans, including all aquatic environments such as the global oceans, seas and the waterways leading to them;*
- *our education programs and research and development align with sustainable development priorities and the realities and needs of the ocean industry; and*
- *the Marine Institute is an integral part of Memorial University, collaborating fully with its facilities and schools in education and research.*

MUN's institutional motto is *Launch forth into the deep*. Every year, we collectively launch forth millions of hooks, pots, traps, and nets into the coastal waters of Newfoundland and Labrador. The animals caught by these gears feed the world while providing critical sources of income to coastal Newfoundlanders and Labradorians. But this can only be sustained if marine ecosystems are healthy, intact, and resilient.

The reality is that fisheries represent the biggest single impact on biodiversity in the oceans (though that could be overtaken by climate change in the future), and the influence of fisheries on the economics and culture of coastal communities is tremendously important. Our program will train students to be world-class researchers that can communicate and mobilize their work in this critical area. By offering focused skills-training, we will aim to serve as a resource so that we can positively contribute to the research done by other departments and faculties in the area of fisheries. This will help develop fisheries science as an area of strategic advantage within MUN – namely that of being a leader in research

As NL's sole university, we have an obligation to be leaders in this space.