National Assessment of Aquaculture Education at Postsecondary Institutions in the United States

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Introduction

Education and training are the driving forces to develop and maintain any skilled workforce required to realize the global challenge of providing increased sustainable food to meet the forecasted growth in population. Diverse and available educational opportunities are critical for the success and expansion of aquaculture locally and globally. Competent personnel are needed to fulfill a wide variety of roles including business owner/producer, research scientist, extension educator, government policy specialist, and many more roles. Quality training linked to real-world experiences creates the core skills, knowledge and abilities essential for long-term sustainable development. Unlike well-established areas of agriculture or capture fisheries, aquaculture is a relatively new field of science and is considered today as one of the fastest-growing animal protein production sectors worldwide. Aquaculture education blends many different sciences and technical fields that characterize the complexities of managing an aquatic biological production system whether inland, coastal or offshore marine environments with evolving technology adaptations and advances.

Prior to the 1970s, there were few postsecondary institutions in the U.S. that offered educational training and degree programs specific to aquaculture. Since this early period, many postsecondary institutions developed a menu of education and training options including programs at vocational-technical schools and community colleges. Numerous universities also invested in new aquaculture-related programs and permanent faculty as excitement intensified for the 'blue revolution'. Programs supporting aquaculture range widely across diverse fields of science and academic departments (fisheries, wildlife, aquatic sciences, forestry, veterinary medicine, animal science, economics, engineering, marine biology, food technology and more). These developments created increased student interest in formal education to fill jobs in the new field of aquaculture during the 1970s through the 1990s. Most early aquaculture-specific programs focused on freshwater culture environments followed by increasing interest in marine systems.

A nationwide survey of aquaculture extension educators in the U.S. conducted in 2003 by the U.S. Department of Agriculture (USDA) and the National Sea Grant Office revealed that the average age range among this community was 50-59 years old at that time (Jensen, et.al 2005). This group reflects other trained aquaculture professionals who joined the U.S. community during an earlier era of strong growth and optimistic forecasts for expansion. This was also a period when numerous U.S. institutions made significant investments in research, teaching and

extension, and expanded experimental infrastructures to realize the commercial potential of numerous aquatic species as new crops in rural inland and coastal communities advanced by pioneering discoveries. Higher education institutions need to prepare current and future generations to meet labor market demands that increasingly require the ability to adapt and adopt emerging technologies in order to actively participate in the global knowledge system (National Research Council, 2015). These investments helped train a new career generation dedicated to aquaculture science and development. This cohort of aquaculture professionals is now aging (average age range 61-70 years old today) and transitioning out of professional life in public and private sectors. New generations of aquaculture professionals are needed to replace the retiring 'boomers' and fill professional positions if institutions and businesses continue to support aquaculture education and industry development based on promising future growth. However, in response to failures to meet commercial development expectations and increasingly competitive extramural funding, some institutions with strong aquaculture programs in the past have forgone continued investment in favor of other emerging fields of science that are perceived to have greater potential return on investment. An aging workforce coupled with fewer educational opportunities for younger generations is clear cause for concern in any industry, including aquaculture. To advance sustainable, socially acceptable aquaculture development in diverse aquatic environments, one challenge is to connect student interest with future job opportunities in the public and private sectors.

In recent decades, there have been more job opportunities outside of the U.S., where aquaculture growth and demand for professionally trained individuals outpaced domestic industry expansion and new jobs. U.S. pioneering research on salmon, tilapia and shrimp aquaculture and worldwide technical assistance efforts helped stimulate early overseas development. The private sector has also provided a critical role through trained technical service teams. Over the years the U.S. has also trained many international students who have become a critical factor in developing the advancement of aquaculture in many countries.

This paper summarizes key findings from a national project conducted by the USDA National Institute of Food and Agriculture in collaboration with three professional organizations with interest and support for U.S. aquaculture, education, and student professional development: the United States Aquaculture Society (a chapter of the World Aquaculture Society); the Fish Culture Section of the American Fisheries Society; and the National Shellfisheries Association.

This project was undertaken as an inaugural attempt to document aquaculture-related instruction, teaching, and training at postsecondary institutions in the U.S. It represents an essential step toward assessing current status, future trends, and critical issues related to national workforce readiness to support aquaculture-related sciences, educational programs, sound policies, and long-term sustainable development. The approach was to solicit input from

postsecondary institutions across the U.S. that offer any level of teaching/instruction, including elective courses, subject matter specialization, diplomas, certificates or degrees related to aquaculture.

Methods

The concept for the project was initiated by USDA in 2007 and validated with respect to objectives and critical questions by an initial development group representing 25 postsecondary institutions. A project team was subsequently assembled with representatives from the three professional organizations appointed by the Boards of Directors of each. The project team was tasked with creating a database of institutions offering aquaculture-specific education/training programs, surveying this pool to assess various attributes of these programs and their status, and to interpret and report the resultant findings.

A major challenge was to identify postsecondary institutions in the U.S. that offer aquaculture-related instruction. The University of Connecticut developed an initial database of such institutions to gather information for its assessment of starting an aquaculture curriculum. Extensive efforts were also made at national conferences and informal meetings to seek assistance from the U.S. aquaculture community in identifying additional institutions and suggesting desired data to be generated during the course of the survey. An introductory letter to describe the project and solicit a point of contact was distributed to 139 institutions. Many were eliminated from the project because of a lack of response and likely no aquaculture training or programs. Ultimately, 115 postsecondary institutions with confirmed points of contact were identified for participation in the survey.

Another challenge was defining an aquaculture program, course or degree. Often, there is no "aquaculture" department or specific degree program, but rather many course topics that support aquaculture education or training. Some institutions offered a concentration, minor or major in aquaculture or aquaculture-specific or –supporting courses; these programs were included in the final analysis, but summer-only programs were not. The success of the project and quality of input for the questionnaire were dependent upon defining critical terms. The following definitions were adopted.

Postsecondary institutions – offer instructional programs that culminate in certificates for completion of programs (1-2 academic years); associate's degree; bachelor's degree; post-baccalaureate's certificate; master's degree; post-master's certificate; doctoral degree; post-doctoral certificate.

Instructional programs – combination of courses and experiences designed to prepare a student for advanced study, qualifications for an occupation/career or simply increase knowledge and understanding related to aquaculture.

Aquaculture-supporting – aquaculture is a multidisciplinary field that includes many diverse science disciplines and programs. Courses may support the science, production process, or business of aquaculture even if the course is not specifically about aquaculture.

The Department of Agricultural and Extension Education at Virginia Tech University developed and administered an online questionnaire (Qualtrics© software) to survey the institutions identified in the first phase of the project. Prior to distribution, the questionnaire was critically reviewed by survey instrument development specialists and beta-tested for functionality and accuracy. The project and questionnaire were also reviewed and approved by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech University.

For each identified postsecondary institution, a single contact was identified to receive and complete the questionnaire. All contributors voluntarily agreed by informed consent to participate in the project. The accuracy of input data and information was dependent on self-reporting by the designated contacts. Respondents were encouraged to use *best professional judgment* on how teaching and instructional programs contribute to, relate to, and support the field of aquaculture (private or public) that may include veterinary medicine, economics, environmental policy, food science, environmental sciences, engineering and more, as well as consulting with colleagues as needed.

Thirty-six queries comprised the questionnaire, corresponding to the following major sections: institutional profile; overall faculty profile; teaching/instruction; student training; and job placement prospects. To establish benchmark information with some forecasting insight, data were collected retrospectively for the year 2000, target year 2010, and prospectively for the year 2015. The online questionnaire was initially open for submissions in October 2011 and follow-up efforts continued through 2013 as more institutions were discovered and others required more time to collect and report the requested data.

Results

Eighty-eight of the 115 institutions surveyed responded to the questionnaire, yielding a response rate of 77%. Seventy-nine reported some level of training and education related to aquaculture and nine institutions reported no activity. The remaining 27 institutions that did not respond were presumed to have little-to-no instructional programs supporting aquaculture. The questionnaire was detailed and the accuracy of the information supplied depended upon

the institution having good records for the years selected in the project. Tracking and maintaining records of post-graduate employment, for example, requires dedicated resources, time, and effort. Not all institutions were equally able to provide this information. Much of the input depended on quantitative institutional knowledge that varied among institutions. Consequently, some of the input was semi-quantitative or more qualitative because of the lack of information, difficulty in defining terms, and the wide variety of instructional activities. Some institutions did not respond to all of the queries in the questionnaire.

Regarding initiation of an aquaculture-specific program (Figure 1), more than 20% of responding institutions reported never having had one; of those institutions that did have aquaculture programs, the majority of these were initiated in the 1970s. Relatively few programs were initiated in the current or previous decade. Regarding the highest degree/certification offered (Figure 2), a majority of responding institutions reported offering some type of degree, particularly at the graduate level; few institutions offered certifications only.

The number of aquaculture courses taught over the project years was relatively stable, ranging from 51 to 59 courses (Figure 3). There was considerable interest among institutions to broaden or modify existing aquaculture curricula with new courses for more diversified job opportunities in the aquatic sciences. Thirty-one institutions reported new courses including economics, engineering, genetics, aquaponics, business management, recirculation technology and online courses. Institutions are increasingly offering online courses for credit. This type of education is expected to continue expanding as students can be reached anywhere in the world and can take only courses of specific interest. For the baseline year 2010, institutions reported offering a variety of online courses related to aquaculture (Figure 4).

Responding institutions also provided information regarding trends in undergraduate and graduate enrollment and earned degrees/certificates in aquaculture programs over the project years for both U.S. and international students (Figure 5). Thirty-eight percent of responding institutions anticipated student enrollment in aquaculture programs to increase in 2015 while only 13% forecasted a decrease. Thirty-six percent anticipated no change in enrollment. There was no differentiation in the level of instruction. An interesting question related to the institutional cost of offering an undergraduate program in aquaculture and related budgetary issues. Of the 56 institutions that responded to this question, 11 reported that costs exceeded the demand for the program and nine expressed uncertainty. Only 10 institutions indicated that the institutional costs covered the demand for the undergraduate program. There was a strong indication (74% of institutions) that undergraduate students participated directly in research projects as a training component. Undergraduate student research provides another opportunity to develop the next generation of aquaculture scientists.

The enrollment trend for the U.S. students at the B.S. level increased 2.5 fold between the years 2000 and 2010 with a decline projected for 2015. There were few international students at this training level although a steady increase was reported over the period 2000 to 2015. At the M.S. level there was a 1.7 fold increase in U.S. students between 2000 and 2010 with a projected increase for 2015. International students were fewer but they had a steady increase from 2000 to 2015. At the Ph.D. level enrollment was unchanged for U.S. students between 2000 and 2010 but a 1.3 fold increase was projected for 2015. International Ph.D. student enrollment matched U.S. students in 2010 but no increase was projected for 2015. As a comparison, in the broad area of agriculture, agricultural operations and related sciences, the Food and Agricultural Education Information System (2013) reported undergraduate enrollment grew by 4% in 2012 and 28% since 2005, whereas the graduate enrollment grew by 1% in 2012 and 16% since 2005. For the natural resources and conservation programs, undergraduate enrollment increased by 1% in 2012 and 41% since 2005, however graduate enrollment in same areas decreased by 0.2% in 2012 but increased 13% since 2005. Aquaculture programs have experienced higher percentage increases in enrollment for both undergraduates and graduates over the project period, although total numbers are much lower.

An interesting issue driven by changes in industry development, budgetary pressures, and changing program directions at some institutions is whether aquaculture positions vacated in the future might be replaced in the same subject area (Figure 6). Vacated positions are usually refilled in subject areas that are determined by administrators of colleges who take into account budgetary, state priority and long-term sustainable program considerations. Organized and vocal constituents can also influence new hire faculty subject areas. In many cases the decision is based on available funding support.

Most institutions (n = 42) indicated no future plans to add a new aquaculture program by 2015, but some (n = 15) responded that new aquaculture programs were in development and would be added. Of these, 26% were planning to add new Ph.D. degree programs or certificates, new courses, or an online M.S. program; these figures demonstrate continued support for aquaculture education/training at these institutions. Regarding attrition, a majority of responding institutions (n = 54) indicated no plans to eliminate their existing aquaculture programs, though a small number (n = 3) indicated closure was likely. Collectively, these findings suggest maintaining the overall *status quo* with respect to aquaculture education/training programs.

Respondents were also asked to estimate job placement prospects for the year 2010 (Figure 7). Some uncertainty was reported, but prospects were generally considered most favorable for those earning graduate degrees.

Other miscellaneous findings included 72% of institutions reported no faculty exchange programs with other aquaculture institutions and only 16% of institutions reported having high success with extramural funding during 2000-2010 that is critical to recruit and train graduate students. University faculty requires extramural grant funds to support research projects and stipends for post-graduate students and some to cover partial salary. Overhead funds from extramural grants are used to fund general departmental or program costs, including new equipment and facility operations.

Sixty percent of institutions include formal mentoring or internship as a training component. Finally, 59 institutions expressed interest in professional development sessions at national aquaculture conferences. The topics of greatest interest were curriculum development and innovations in teaching methods.

Discussion

Although not revealed in the data because of the limited time span over the period 2000 to 2015, there is considerable anecdotal evidence that suggests previous trends in student enrollment and new jobs have slowed or reversed in the most-recent decade (2000-2010). U.S. student interest and support by some institutions began to change during this period, with some historically strong programs scaling back and others being terminated. The number of institutions starting new aquaculture programs declined during 2000-2009. After 2010, investment in new aquaculture programs practically ended. More recently, however, interest in the marine sciences and marine aquaculture has increased as popular topics at several institutions.

It is perhaps expected that some aquaculture instructional programs would contract in response to slower growth in the domestic industry and fewer job opportunities. Recruitment of U.S. students is becoming more challenging at some institutions, even with attractive stipends. In some science fields it is has been difficult to hire people experienced with aquatic species or systems, and more specifically aquaculture. Individuals with backgrounds in animal sciences, fisheries or general aquatic sciences enter job pools often without aquaculture-specific training but acquire skills and knowledge via on-the-job learning.

There are many institutions in the U.S. that still offer some level of instruction in aquaculture and many are smaller institutions. There was a wide diversity of departments and program affiliations with aquaculture that include: fisheries and wildlife sciences; aquaculture; aquatic resources management; aquatic sciences; marine science; natural resources; animal science; zoology; biology; water resources; mariculture; biological systems and engineering; and

environmental sciences. This diversity of affiliations characterizes the breadth of multiple sciences and the many disciplines that contribute to aquaculture education.

There is concern about the size and readiness of the aquaculture workforce poised to take over the aquaculture industry in the future, as well as the desire amongst students to pursue aquaculture as a career. The project did not include a quantitative assessment whether or not the current number of students and their expertise are sufficient to meet projected academic and employment demands. The results show that U.S. students dominate the training at the undergraduate level. Although U.S. students still represent the majority of students enrolled in graduate training programs, the demographics shift to reflect greater interest among international students in M.S. and Ph.D. degree programs. There were no data collected regarding the ratio of male and female students at various aquaculture education levels.

The U.S. has numerous world-class research and education institutions and continues to draw international students from around the globe to specialize in various areas of science supporting aquaculture. During the 1970s and 1980s in particular the high caliber of training and recognized education in aquaculture attracted many students worldwide who were supported by their national governments or U.S. foreign assistance programs. This worldwide training role contributed to aquaculture advances in many countries as the global aquaculture community increased with more national training capacities.

The national landscape of aquaculture continues to evolve with increasingly complex socio-political forces, impacts from global level factors, and changing consumer demographics and product preferences. As a country, we face a critical juncture for aquaculture: in the current challenging economic environment, will incentives be created to foster investment in commercial growth as well as workforce readiness? Although not a specific questionnaire topic, anecdotal evidence suggests some research infrastructures are aging and need upgrading to reflect current industry standards as well as to adequately train undergraduate and graduate students for industry employment and conduct applied research. Aquaculture research infrastructures are often very specialized and are not multi-purpose for non-aquaculture uses. They require regular maintenance and repair for optimum operation.

There are several federal extramural programs that fund postsecondary programs to create innovative curricula, new learning tools and technologies, and student professional development. In addition to research and extension activities, education is one of the core mission areas in USDA National Institute of Food and Agriculture (NIFA). The federal agency now offers a Fellows Program for pre- and post-doctoral students interested in agriculture, including aquaculture. NIFA and the National Oceanic and Atmospheric Administration's Sea Grant Office also have supported farmer-training programs and on-farm learning experiences.

The National Science Foundation also has a host of programs to support student development and postsecondary educational programs.

Graduate level training usually involves a stipend or student assistantship to defray the high cost of post-graduate education. Much of the Ph.D. and post-doctoral training requires a stipend that is often included in federal research grant awards. With the decline of extramural funding for aquaculture and increasing competitiveness (8-15% success rate) for funding, these student support dollars are harder to obtain and can influence the number of U.S. graduate students likely to study aquaculture. Faculty with active and well-funded research programs with stipends offers more graduate education opportunities. At NIFA, the primary extramural granting agency in USDA, the average annual investment in aquaculture science research for the years 2003-2012 was $18.653M second only to dairy production and surpassing beef, poultry and swine (National Research Council, 2015). Providing adequate support for graduate and postgraduate research is a key element in meeting future hiring needs. A declining condition of student interest in aquaculture education and training could significantly impact future faculty capacity, particularly given the projected pattern of faculty retirement.

Conclusions

This first-ever assessment offers insights on the diversity and scope of aquaculture instruction at postsecondary institutions in the U.S. The data and information can help to identify present needs and serve as a benchmark to monitor trends in future years. Since about the year 2000 there have been fewer job announcements specific to aquaculture, especially in the academic and government sectors. Some long-standing programs at major universities have scaled back or eliminated formal aquaculture graduate degree programs. The interest by U.S. students to pursue aquaculture training shows a promising trend in undergraduate and postgraduate programs, however, numerous institutions report challenges in recruiting U.S. students for advanced degree training even with attractive stipends. The findings suggest a stable trend of U.S. and foreign students over the period 2000 to 2015. The fact that numerous institutions are revamping their aquaculture programs and adding courses indicates continued support. Hopefully, as more aging professionals leave public and private sectors the pipeline of replacements is not lost. Job placement responses for the year 2010 suggest similar prospects between excellent-good and fair-poor for A.A. and B.S. degrees but higher placement prospects for M.S. and Ph.D. students.

There appears to be more attention and expansion in marine aquaculture with increasing interest by students to this sector as new marine species are under investigation and new technologies evolve in challenging marine environments. Recently the National Agricultural Statistic Service (2014) reported in their Census of Aquaculture that the number of aquaculture farms decreased by 28% nationwide between 2005 and 2013 and farm gates sales reached

$1.37 billion in 2013. That was only a modest increase over this period when adjusted for inflation. The U.S. continues to lag behind other regions of the world when compared to higher global rankings in earlier decades. The competition in the globalized seafood market is strong and access to suitable open marine sites remains challenging to shellfish and finfish businesses in many areas. There should be more societal pressures and supportive policies to expand domestic production for food security and developing models of sustainability. Aquaculture will continue to be influenced by trade globalization, increased urbanization and expected growth in other global factors, including projected population growth.

There are many opportunities for instruction at different levels including summer training programs and industry sponsored training and internship activities. Over the years since the 1970s, the United States has trained many students who have made immeasurable contributions to advancing sustainable aquaculture development domestically and globally. The offering of online courses is increasing to reach more students. Each of the three contributing aquaculture professional organizations has active student professional development activities and strongly supports the premise that today's students represent the future of aquaculture.

As aquaculture becomes more science- and technology-focused and information-rich, education and training will become more specialized with new research tools and instrumentation to support a more intensified, diverse and sophisticated sector. Most attention is directed to research and extension programs that are active collaborators with industry sectors. However instruction and training are the foundations for these programs in addition to sound industry development, good governance frameworks, and much more. Successful business models will be driven by competitive, fast-changing technologies and continuing innovative practices. Stricter environmental regulations and new water policies will stimulate new pioneering systems and development directions that will depend on training a competent workforce to develop, regulate, sustain and expand this important farmed aquatic food sector both domestically and globally. The U.S. cannot afford to lose its critical human capital from education and training or lose critical competencies required to support long-term sustainable aquaculture development that has evolved over several career generations since pioneering efforts in the 1960s-1970s. Significant research and development, and training are essential so current productivity can be adequately enhanced to meet increased future demands of technological changes. Education and training are the mainstays to transfer knowledge, skills and attitudes in research. They are critical to capitalizing on the diversity of animal (aquaculture) science research needed to improve national and global food security (National Research Council, 2015).

Research in the biological sciences has undergone a major transformation in the last 10-15 years from three powerful innovations: 1) recombinant DNA technology; 2) new instrumentation; and 3) the digital revolution (The National Academies, 2003). These new tools have expanded discovery in new areas creating a stronger scientific base for aquaculture development. They have also created new niches of research and specialized expertise. Underfunding animal (aquaculture) research has long lasting consequences, including a decline in faculty, post-doctoral and graduate student positions, loss or consolidation of aquaculture supporting departments, and lagging of improvement/enhancement of other essential infrastructure that is critical to new innovations to address challenges (National Research Council, 2015).

Curriculum development and new learning tools and practices are continuously evolving for more effective learning outcomes. The research and extension communities are often well represented at aquaculture conferences. The education community can take advantage of the same conferences to share expertise and knowledge for the betterment of instruction and student learning. The project findings revealed considerable interest for more special or technical sessions that focus on new curriculum development and innovative teaching methods.

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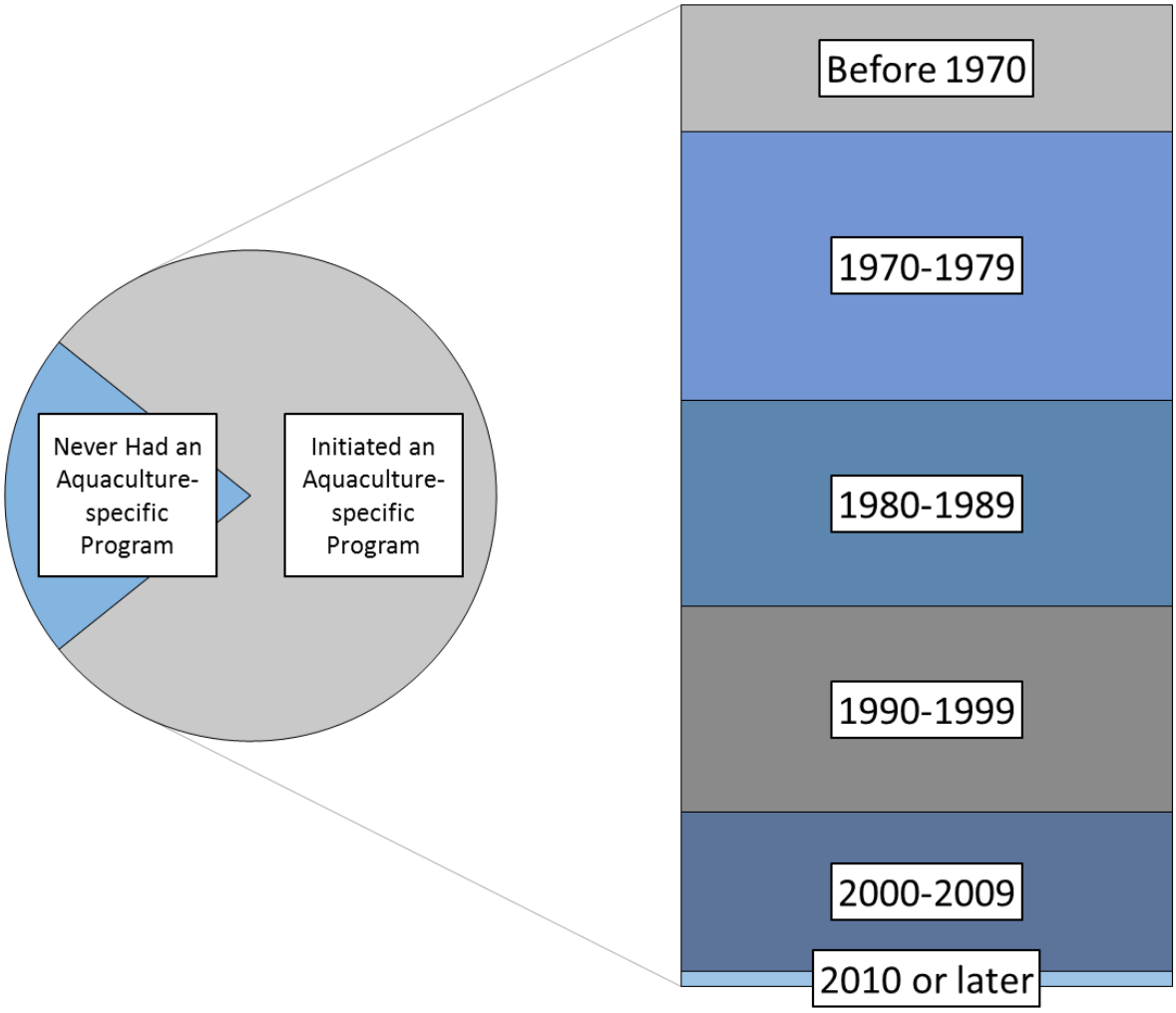

Figure 1. Relative number of the responding institutions (n = 79) that had or had not initiated aquaculture-specific undergraduate or graduate education/training programs and, the decade of their initiation.

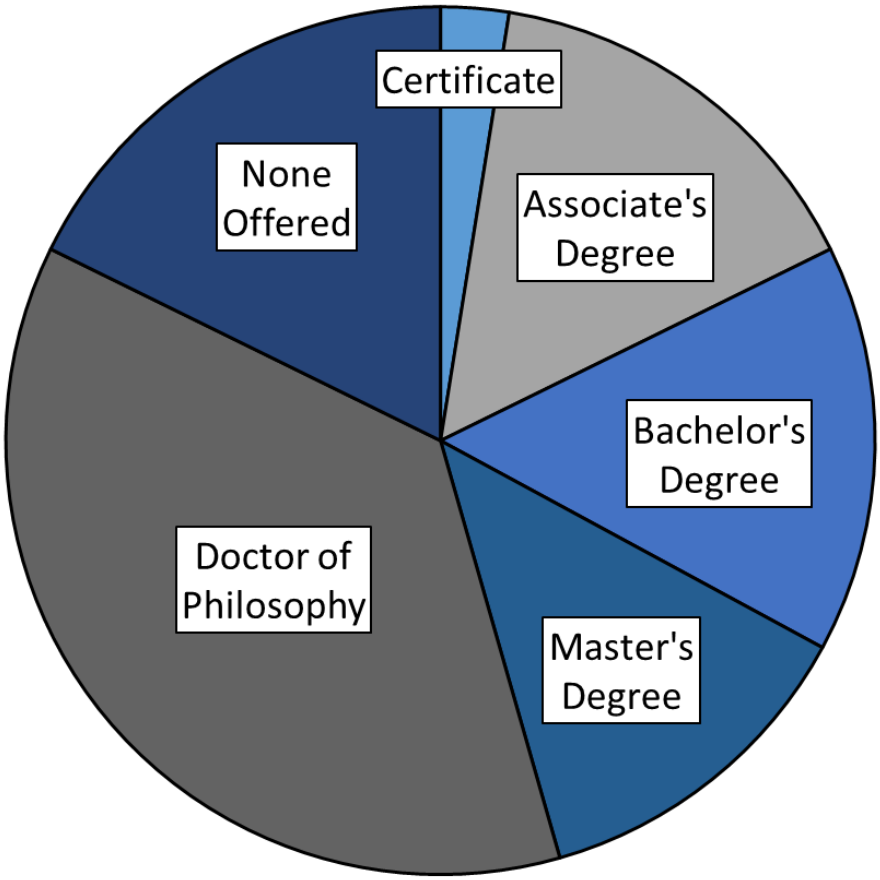

Figure 2. Relative number of responding institutions (n = 79) with aquaculture-specific education/training programs according to the highest certification/degree offered.

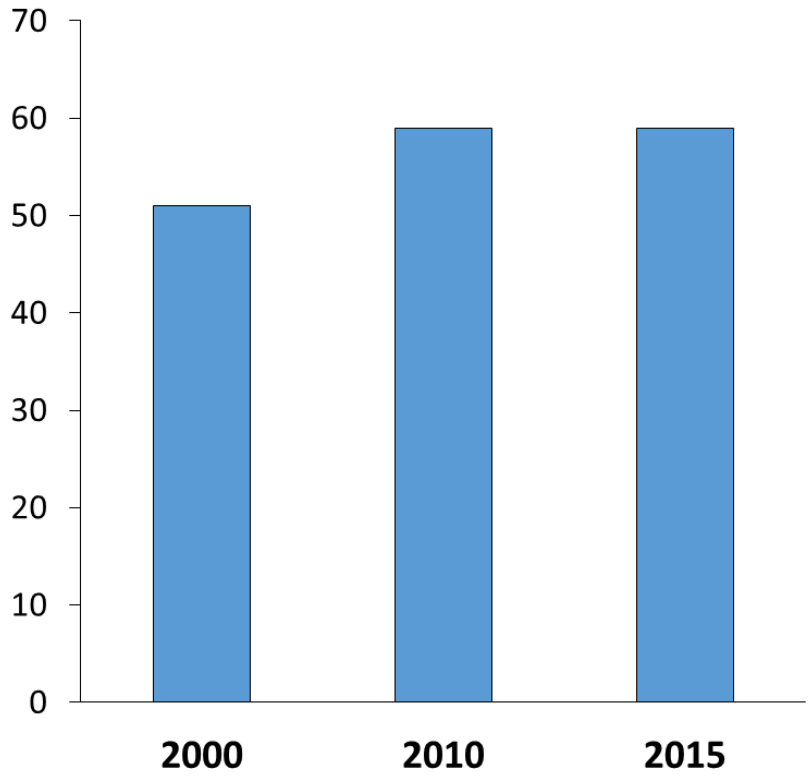

Figure 3. Number of aquaculture-specific courses taught in 2000 (completed), 2010 (completed, in progress, or planned), and 2015 (projected).

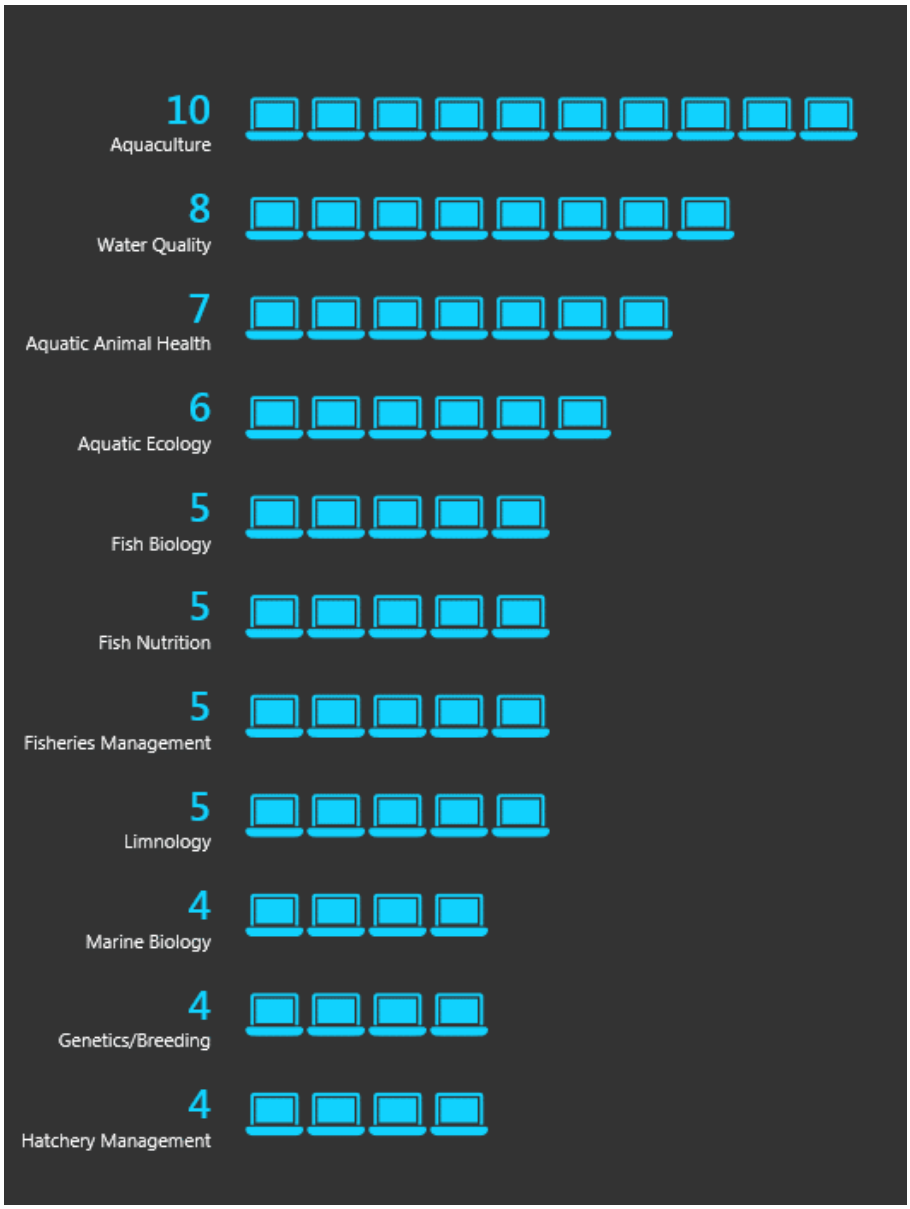

Figure 4. Number of institutions reporting online courses in subjects related to aquaculture in 2010. Each computer icon represents an institution.

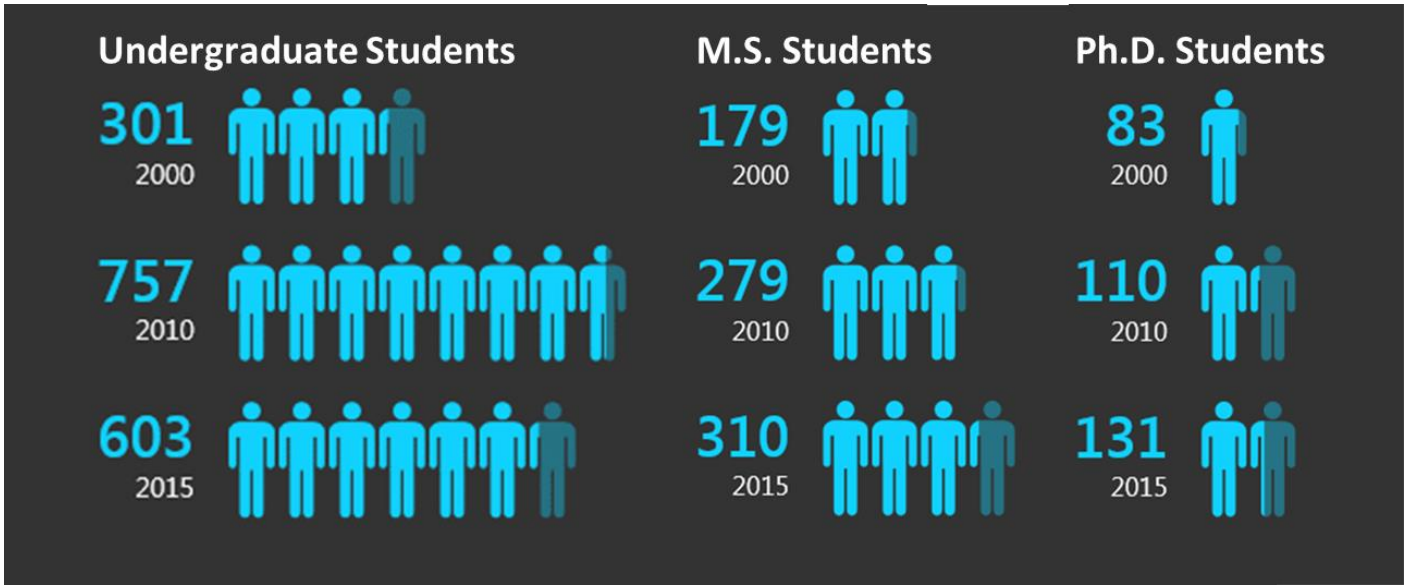

Figure 5. Number of students completing aquaculture-related degree/certification programs in 2000 (completed), 2010 (enrolled), and 2015 (projected). Each person icon represents 100 individuals, and both U.S. and international students are represented. Although international students only represent 3-6% of undergraduate students, they represent 18-25% of M.S. graduate students and 35-47% of Ph.D. graduate students.

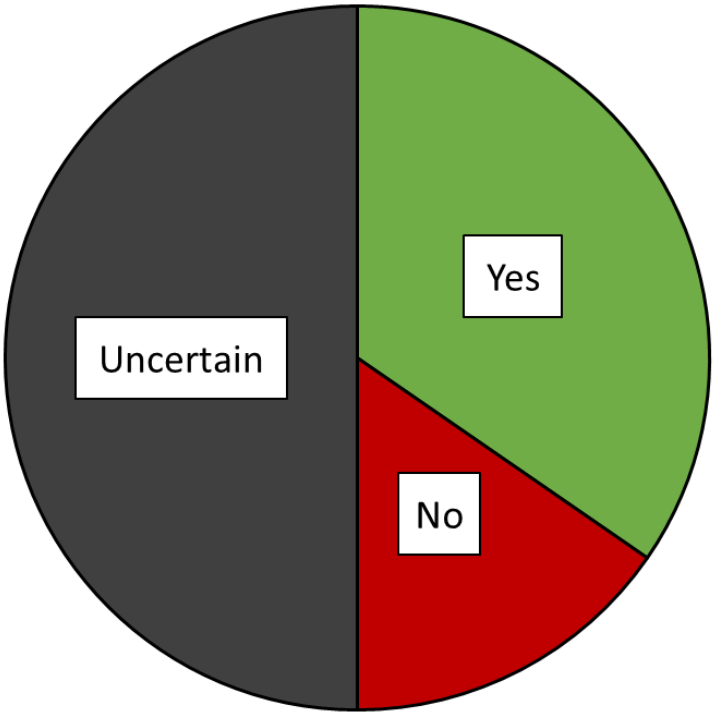

Figure 6. Likelihood of filling future vacated aquaculture positions.

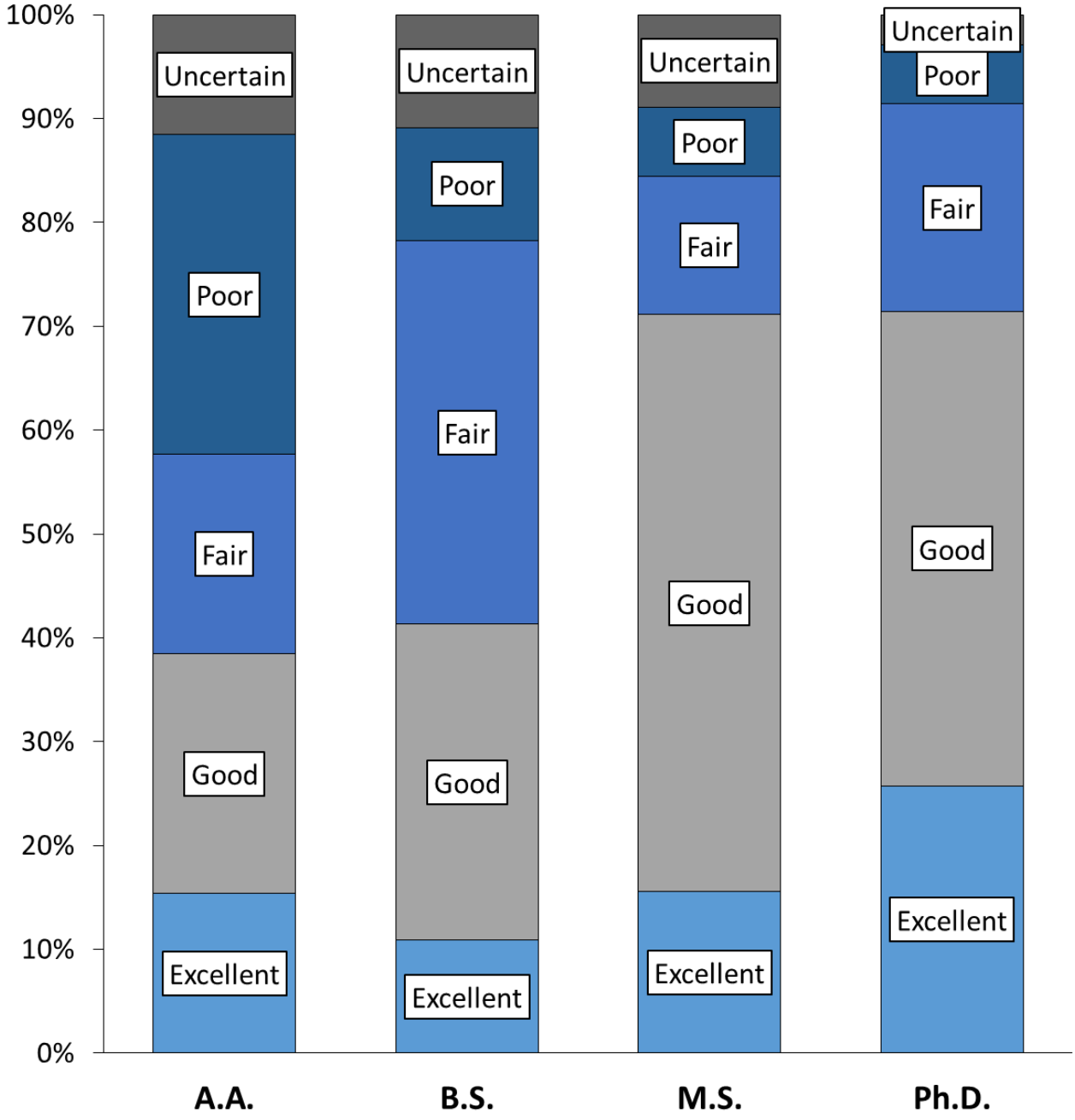

Figure 7. Prospects for job placement for students completing aquaculture-related degree programs in 2010.