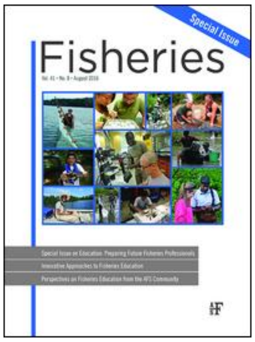

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Special Issue

Fisheries

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Special Issue on Education: Preparing Future Fisheries Professionals

Innovative Approaches to Fisheries Education

Perspectives on Fisheries Education from the AFS Community

Photo title: Future Fisheries Professionals in Action

1. 2014 AFS Hutton Scholar Eli Pease. Pease was mentored by Dana Ohman of the Massachusetts Division of Fisheries and Wildlife. Photo credit: MA DFW.
2. 2014 AFS Hutton Scholar Jennifer Zhao (left). Zhao was mentored by Chris Chambers of NOAA Fisheries Service. Photo credit: NOAA.
3. AFS Hutton Scholars. Photo credit: BLM.
4. 2014 AFS Hutton Scholar Kira Kirk and mentor Bob DiStefano, a resource scientist at the Missouri Department of Conservation. Photo credit: MDC.
5. Richard Pendleton (center; Winchester, VA) as a Virginia Tech undergraduate student, spent a summer in Ghana conducting fieldwork with international graduate students Yaw Ansah (left) and Gifty Anane-Taabeah (right) all of the Frimpong Lab. Photo credit: Emmanuel Frimpong.
6. Paige Crane of Blacksburg High School (AFS Hutton Scholar) examining a spawning male Bluehead Chub *Nocomis leptocephalus* with mentor Emmanuel Frimpong. Crane went on to enroll in the Virginia Tech Fish and Wildlife Conservation undergraduate program after her Hutton experience and is currently a rising senior. Photo credit: Emmanuel Frimpong.
7. 2014 AFS Hutton Scholar Lindsay Martinez. She spent her summer in the program working at the Montana Department Fish, Wildlife, and Parks fish hatchery at Giant Springs State Park. Photo credit: Montana FWP.
8. AFS Hutton Scholars. Photo credit: BLM.
9. The U.S. Forest Service's Eastern Regional Office has co-hosted AFS Hutton Scholars with Milwaukee's Discovery World Museum. In 2014, a high school senior from Bradley Tech in Milwaukee, Odell Chalmers, was selected as a Hutton Scholar. Chalmers worked at Discovery World as an assistant environmental educator and also spent time on a national forest in the Lakes States, sampling fish populations and learning how that information is used to manage fisheries, improving wetland and stream habitats, and monitoring water quality. Photo credit: USFS.
10. 2014 AFS Hutton Scholar Nathaniel Laughner who was mentored by Derek Aday at North Carolina State University. Photo credit: NCSU.
11. The Frimpong Lab at Virginia Tech offers training opportunities for graduate students and undergraduate technicians. In the foreground is Stephen Floyd, Jr. (grad student), and in the background is A. Dawn Mercer (Virginia Tech undergraduate and technician). Photo credit: Emmanuel Frimpong.

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433 William (Bill) Taylor, Captain Denny Grinold, and John Robertson, former chief of the Michigan Department of Natural Resources Fisheries Division, discuss lifelong learning on the stern. Photo credit: William Taylor.

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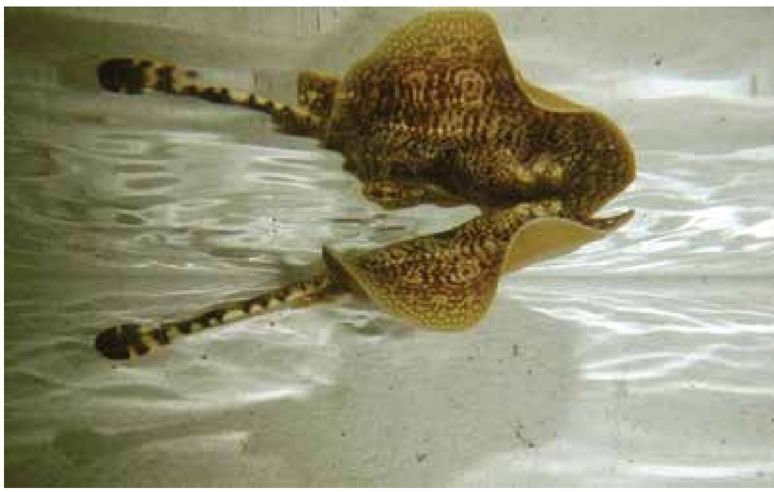

499 A juvenile Yellow Stingray *Urobatis jamaicensis*. Photo credit: Valentina Di Santo.

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The American Fisheries Society (AFS), founded in 1870, is the oldest and largest professional society representing fisheries scientists. The AFS promotes scientific research and enlightened management of aquatic resources for optimum use and enjoyment by the public. It also encourages comprehensive education of fisheries scientists and continuing on-the-job training.

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Preparing Future Fisheries Professionals

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In November 2012, AFS President John Boreman established the AFS Special Committee on Educational Requirements to help ensure that people entering the future workforce will be prepared to tackle issues facing fisheries (Boreman 2013). The major charge to this committee was to compare coursework expectations of fisheries employers with the fisheries degree coursework requirements of colleges and universities. The goal was to see whether there is alignment between the coursework employers want and schools offer. If there was not, then the committee would offer recommendations for improvement.

Several of the tasks needed to accomplish the committee charge have been completed. There is a list of North American colleges and universities currently offering undergraduate and graduate degrees in fisheries-related disciplines posted on the AFS Education Section website (education.fisheries.org/education-links/2015-revised-and-updated-master-list-of-fisheries-programs). This list has two main categories of schools. The first includes 131 schools with degrees that have the words "fisheries" or "aquaculture" in their titles or have other programs with a strong fisheries emphasis (e.g., many Canadian schools where fisheries courses are mainly within biology degree programs). The second category includes 214 schools with other related degrees (e.g., marine biology, aquatic biology, biological oceanography). Schools can appear in both categories if they offer different degrees. This list is intended to be dynamic as programs evolve and has been updated three times since its initial posting in December 2013.

A major task that the committee completed under the leadership of First Vice President Steve McMullin was a survey of employers who will be hiring graduates with degrees in fisheries-related disciplines over the next 5–10 years. The intent of this survey was to determine what coursework those graduates will be expected to have taken that would be most germane to their employment. The survey was conducted in the summer of 2013, was reported on at the AFS Governing Board 2015 Annual Meeting, and is the centerpiece article of this thematic issue (McMullin et al., this issue).

The committee also compared the coursework expectations from the employer survey with the educational requirements for AFS certification as an Associate Fisheries Professional (Kaemingk et al., this issue). The comparison results suggest that the AFS certification standards should increase emphasis on communications and statistics coursework compared to general biological or physical science coursework.

Another committee task was to compare the coursework expectations from the employer survey with the current educational requirements for the entry-level fish biologist job series of the U.S. Office of Personnel Management. Recommendations for better alignment within Essig (this issue) are intended to be forwarded to the U.S. Office of Personnel Management. Time did not allow a similar comparison for federal employment standards in Canada and Mexico.

A task that the committee did not fully complete and make recommendations on was a comparison of coursework expectations of fisheries employers with the fisheries degree coursework requirements of colleges and universities. Coursework requirements from 87 of the schools within the fisheries portion of the list of schools were analyzed. More than 56% of these schools required courses in fisheries science and management, limnology/aquatic ecology/marine ecology, and ichthyology. Courses in fisheries and aquatic sciences that were least often required were aquaculture, fish ecology, and population dynamics. More than 80% of the schools required courses in other biological sciences, physical sciences, mathematics, statistics, and communications that are needed for AFS professional certification. Human dimensions courses were required in 54% of the schools. Overall, 60% of the analyzed fisheries schools were found to have a suite of coursework that meets the AFS professional certification educational requirements.

This special issue of *Fisheries* represents the culmination of over three years of committee work. Now the focus should be on following up to effect change where needed.

This special issue of *Fisheries* represents the culmination of over three years of committee work. Now the focus should be on following up to effect change where needed. A new group called the Intersectional Committee on Education has formed organically through the leadership of the Education Section. The Intersectional Committee on Education plans to continue the effort by focusing on professional certification and college and university fisheries program accreditation. Their interest in the education topic is reinforced by the many AFS Sections who have contributed articles for this special issue. I am optimistic that such a diversity of AFS voices will lead to better paths to prepare future fisheries professionals.

I want to take this opportunity to thank past and present members of the committee for their persistence in completing most of their appointed tasks. These members and the AFS Units they represent are Craig Bonds (Fisheries Administration Section), Robin L. DeBruyne (Equal Opportunities Section), Troy Hartley (Socioeconomics Section 2012–2014), Mark A. Kaemingk (Student Subsection of the Education Section), Martha E. Mather (At-large member), Christopher Myrick (Education Section), Quinton E. Phelps (At-large

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COLUMN
POLICY

The Case for Interdisciplinary Fisheries Education

Thomas E. Bigford | AFS Policy Director

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Education is always a timely topic. In fact, I believe it is timeless. And reflecting AFS interests across so many fields, it's appropriate to build on the messages in this issue penned by leaders across AFS Units. Because this is the Policy Column, I'll share some thoughts that reach beyond the natural sciences that provide a solid base for so much of our collective work.

A degree or two in fisheries is certainly valuable, but a seminar on natural resource management, a course on economics or hydrology, or a mentoring relationship with a political scientist can add more power to those fisheries degrees.

These ideas have developed slowly since I was a freshly minted fisheries biology graduate from Michigan State University in 1974. At that time, biology was my universe, and that field offered satisfying solutions to all problems worth pondering. A master's in marine ecology from the University of Rhode Island did little to shift my intentions or alert me to my naiveté. I still envisioned myself as a fledgling Jules Verne soon to discover ocean features and critters. Academic knowledge reigned supreme and could solve all problems. I thought I could change the world unilaterally, or at least with my fellow natural scientists. Not quite! A poor job market sounded a colossal wake-up call. Nothing against the natural sciences that still enthrall me, but I learned there's so much more complexity in our fisheries fields.

A part-time research position at an Environmental Protection Agency laboratory opened my eyes to how natural science information was applied in a regulatory context, and how management experience fueled policy debates. I slowly realized that success for me meant expanding my graduate education well beyond biology and ecology. I applied to a marine affairs program that resembled an M.B.A. program for the oceans, and suddenly found myself embracing engineering, economics, political science, and law. The result has been a tremendously rewarding and pleasurable career now reaching into its fifth decade. I can still recite the scientific names of brachyuran crabs, but I also know about the intricacies of natural resource management. Most importantly, I can communicate with leaders in many disciplines. We can work together to solve problems. I treasure my education for that reason and so much more.

My point is to pursue opportunities to gain perspective and to understand how your primary interests relate to the more complex mix of society's woes. A degree or two in fisheries is certainly valuable, but a seminar on natural resource management, a course on economics or hydrology, or a mentoring relationship with a political scientist can add more power to those fisheries degrees.

There are many ways to broaden your education, to add value to your academic toils, and to prepare for success. Whether in a traditional setting on campus or something decidedly nontraditional, my experience is that there are lessons to learn everywhere. There are also opportunities galore to sharpen your skill set and to apply your expertise.

These opportunities begin early. The AFS Hutton Junior Fisheries Biology Program (hutton.fisheries.org) offers scholarships to high school students interested in fish and aquatic sciences. The National Oceanic and Atmospheric Administration grants Ernest F. Hollings Scholarships to promising undergraduates across all disciplines. After a successful launch in 2015, AFS is now hosting two rising college juniors as summer policy interns. The NOAA Sea

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To Evolve, or Not To Evolve?—That Is the Question

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KEY POINTS

- Formal and informal educational experiences and opportunities contribute to personal and professional development and growth.
- Mentors provide encouragement and guidance to their mentees as they pursue new experiences and opportunities.
- Professionals must learn how to evolve and adapt to a rapidly changing social, political, economic, and ecological environment.
- Melding knowledge, skill sets, experiences, and personalities will best prepare us for the future.

ROAD RACES AND REMINISCING

Just last month, I (M. J. G.) found myself on the course of the Fifth Third River Bank Run in downtown Grand Rapids, Michigan, dodging marathon runners, spectators, and police officers, as I attempted to maneuver myself from the outskirts of the city, through the marathon course, to the Amway Grand Plaza Hotel. It was there that I was planning to meet with my friend and former supervisor, Ralph Riley. Riley is an ecologist that I met 10 years ago. At that time, I was an outgoing and enthusiastic high school student, who was actively searching for opportunities and experiences that would help me learn more about and understand what I wanted to do professionally in the future. While in my guidance counselor's office one day, I happened upon an application for a program dedicated to exposing students to scientific field work and data collection and analysis through intensive, short-term research experiences. With support and encouragement from my high school biology teacher, I applied for and was fortunate to receive this once-in-a-lifetime opportunity through Earthwatch Institute's Student Challenge Awards Program (SCAP). I still remember the day I opened my program acceptance letter, for my Dad gifted me with a larger-than-life-size (a trophy size!) rainbow trout mylar balloon. Working alongside Riley and a team of five other high school students from all over the country, I traveled to the Puget Sound, where I was trained on the spot and quickly put to work gathering data and information about the ecology and geomorphology of salmon-bearing streams in the Pacific Northwest.

Since our first meeting in the SeaTac airport, I have maintained contact with Riley, one of my mentors, with whom I frequently discuss my interests and progress as an individual and a developing professional. In the last 10 years, my relationship with Riley and other mentors, along with a variety of my own opportunities and experiences, have allowed me to better define my interests, hone my skills, and successfully evolve as an individual and a developing professional, thus enabling me to contribute to the profession and to society in new and innovative ways. For example, over the course of this journey, I learned that one should not simply learn to learn, but instead strive to use what they learn to impact something or make a difference.

Molly J. Good working in a salmon-bearing stream in the Puget Sound as part of Earthwatch Institute's Student Challenge Awards Program in 2006. Photo credit: Ralph Riley.

Formal and informal education, along with the presence of good mentors, is paramount in readying developing professionals for success in a changing environment and an evolving profession.

Recognizing the need to adapt and the desire to improve myself, while at times scary, has increased my capacity to learn through new opportunities and experiences and, above all, inspired me to evolve or morph with the times and provide meaningful leadership in future challenges.

To us, formal and informal education along with the presence of good mentors, is paramount in readying developing professionals for success in a changing environment and an evolving profession. But, one cannot or may not be willing to take advantage of new experiences and opportunities alone, for they are often unfamiliar, uncomfortable, and anxietyproducing as the outcome is not always predictable. Great mentors, however, provide the necessary encouragement to pursue and the guidance to navigate through the uncertainties of change, enriching one's learning experiences. Through this process mentors also serve as a source of intellectual and personal support and a much-needed safety net in times of this uncertainty or misunderstanding.

FOR THE TIMES THEY ARE A-CHANGIN'

Just as we have evolved as developing professionals and engaged citizens in our community over our lives, so has the fisheries profession. To stay relevant and to help chart the path to a more sustainable future, one requires an understanding of the skills that one should experience and master in order to deal with a rapidly changing environment, in which emerging issues and threats to fisheries and aquatic ecosystem sustainability are inevitable. When these challenges arise, professionals should have the skills that allow them to feel secure, be confident, and function effectively in teams to address these changing needs meaningfully.

William (Bill) Taylor and Molly J. Good discussing the future. Photo credit: William Taylor.

Current and future professionals have a responsibility to continue their lifelong learning, and motivate others to learn, in order to adapt to the ever-evolving fisheries science and management profession.

In light of the challenges our fisheries resources and profession will face in the coming years, not to mention our own personal challenges that life provides each of us, fisheries professionals will need to work in interdisciplinary teams, which include not only fisheries-related scientists and managers, but also policymakers, legislators, and the public. All of these people will need to work together to mitigate and prevent damage to our fisheries resources in the future. Additionally, the profession will require new skills and disciplines that allow for the engagement of new types of individuals including more innovative and novel thinkers, strategists, problem solvers, politicians, and effective communicators to address future problems our fishery resources and society will face.

Whether or not all educational institutions are working to develop future professionals to be what the profession truly needs now and in the future may be debated. What cannot be debated, however, is that new knowledge and skills learned throughout one's lifetime are necessary if one is to make a continuing difference in the future sustainability of fisheries and aquatic ecosystems.

Thus, if we care about our future, then we must take advantage now of education, in whatever form it comes, for us to evolve to be impactful and successful in an ever-evolving profession. For example, the American Fisheries Society (AFS) is one organization that has provided opportunities for me (W.W. T.) to learn throughout my life. Over time, and with encouragement and support from my colleagues and mentors, I transitioned from being an active AFS member at the state and division to the national and international domains, eventually becoming the president of AFS. In these roles, not only did I learn more about fisheries and aquatic ecosystems, but I also learned hard life lessons about teamwork, inclusivity, leadership, communication, and the value that each and every individual brings to the team in solving problems at all levels of governance. I was able to seamlessly bring the unique set perspectives and skills I had acquired, often through the school of hard knocks, into my next role as an educator and administrator at Michigan State University (MSU). My involvement in AFS and other professional societies and community organizations facilitated my learning in ways that could not have been achieved through other means, and it has allowed me to, in return, provide mentoring to other developing professionals like Good.

Broadly speaking, the fisheries science and management profession appears to be evolving to consist of diverse professionals with wide-ranging knowledge bases, varied skillsets, and rich educational and life experiences. We hope that this evolution continues, for it brings together a variety of professionals of different ages, life history experiences, educational backgrounds, genders, and races to act toward the common goal of enhancing the status of fisheries and aquatic resources throughout the world. In reality, the fisheries science and management profession has evolved into a true mosaic of all segments of society including, most notably, students, educators, scientists, managers, academics, policymakers, law enforcement officers, legislators, and communicators, who must combine their knowledge, skillsets, and experiences to ensure sustainable and productive fisheries and aquatic ecosystems.

HERE'S WHAT YOU NEED TO SUCCEED

Current and future professionals have a responsibility to continue their lifelong learning, and motivate others to learn, in order to adapt to the ever-evolving fisheries science and management profession. This type of learning can be achieved by pursuing relevant educational opportunities and experiences, identifying and establishing mentor-mentee relationships, and participating in leadership and personal development trainings or workshops.

Relevant Educational Opportunities and Experiences

Formal and informal types of education can lead individuals to take advantage of opportunities and experiences that they would not discover elsewhere. For example, I (M. J. G.) was able to further my learning about forest ecology and salmon

William (Bill) Taylor, Captain Denny Grinold, and John Robertson, former chief of the Michigan Department of Natural Resources Fisheries Division, discuss lifelong learning on the stern before some Lake Michigan salmon fishing. Photo credit: William Taylor.

biology with the Earthwatch Institute through an opportunity I first heard about in my high school biology class. This educational experience not only introduced me to the sciences at a young, impressionable age, but it also helped me understand that a future career in this field was possible. Up until this point in my life, I simply knew that I enjoyed spending most of my childhood days up to my knees in muck, wrangling and observing frogs, newts, and fish—basically, anything I could get my hands on. How fortunate was I, at seventeen years old, to realize that I had found my lifelong passion?

Mentor-Mentee Relationships

It is impossible to take advantage of educational and life opportunities and experiences without the support and guidance from a great set of mentors. The best kind of mentor recognizes the strengths and the potential to evolve in his or her mentees and, thus, encourages his or her mentees to pursue new things. The best mentors not only allow but advocate for their mentees to continue their lifelong learning by identifying and engaging in new and exciting (although, at times, stress-inducing!) ventures with a goal to be impactful or make a difference in the profession and society. Great mentors also encourage their mentees to take on new challenges while still providing necessary guidance and support in unfamiliar or uncomfortable situations. Effective mentoring, though challenging, is worthwhile to all because it always works both ways; just as a mentee will learn from his or her mentor, a mentor will undoubtedly learn from his or her mentee as well.

Leadership Experience and Personal Development Training

Additionally, developing professionals in the fisheries science and management profession should actively seek out educational opportunities and experiences that bolster their leadership skills. Leadership skills take time to develop, and the best way to work on acquiring more leadership experience is by pursuing leadership positions or participating in other training or workshops. AFS, for example, offers many positions for developing professionals and current professionals that provide leadership experience, whether you wish to work as part of the AFS Student Subsection for a Chapter or for the Society. AFS also offers many opportunities to comfortably build one's skillsets and improve his or her personal and professional development. Over time, these types of educational

Effective mentoring, though challenging, is worthwhile to all because it always works both ways; just as a mentee will learn from his or her mentor, a mentor will undoubtedly learn from his or her mentee as well.

opportunities and experiences can lead to the growth of a network of people with diverse personalities, cultural backgrounds, and skillsets, which will be best equipped to handle changes in the environment and the profession.

DON'T SINK LIKE A STONE

As we have discussed in this article, it is up to us to meld our knowledge, skillsets, experiences, and personalities as we approach emerging issues and challenges that threaten the sustainability of fisheries and aquatic ecosystems not to mention our own self-worth. We must never stop learning, and we must acknowledge that, through lifelong learning, we will continue to evolve and adapt over our lifetimes. As the famous American singer-songwriter, Bob Dylan, would say, "If your time to you is worth savin', then you better start swimmin'." We are confident that—for us in the fisheries science and management profession—swimmin' is something we can and should continue to do, especially if we can do it better each and every day.

For more information about lessons regarding educational opportunities and experiences, mentor-mentee relationships, and effective leadership, please consider reading, *Future of Fisheries: Perspectives for Emerging Professionals* by W. W. Taylor, A. J. Lynch, and N. Leonard (2014). AFS

FEATURE

ARE WE PREPARING THE NEXT GENERATION OF FISHERIES PROFESSIONALS TO SUCCEED IN THEIR CAREERS?

A SURVEY OF AFS MEMBERS

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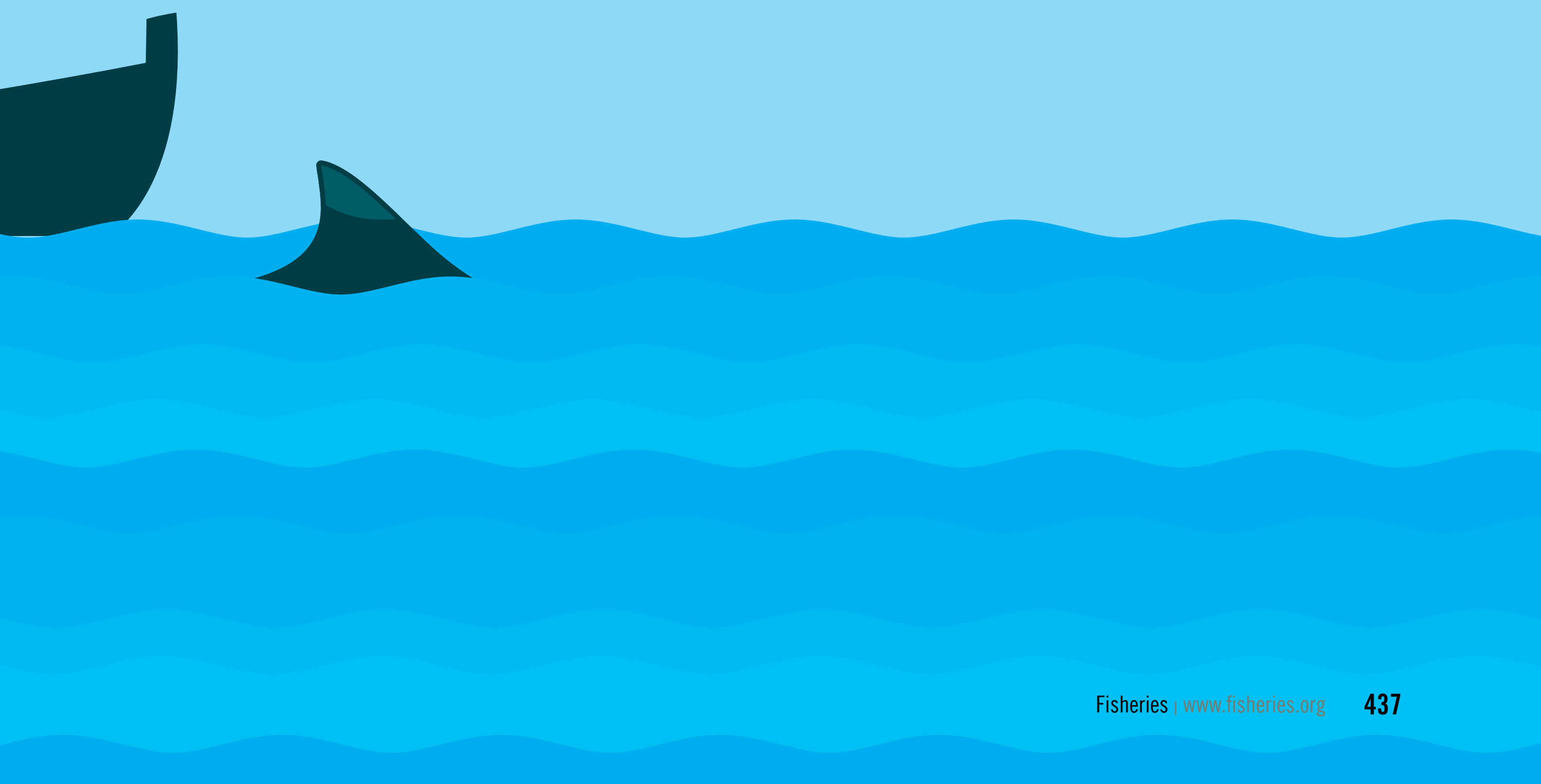

Natural resource professionals have frequently criticized universities for poorly preparing graduates to succeed in their jobs. We surveyed members of the American Fisheries Society to determine which job skills and knowledge of academic topics employers, students, and university faculty members deemed most important to early-career success of fisheries professionals. Respondents also rated proficiency of recently hired, entry-level professionals (employers) on how well their programs prepared them for career success (students and faculty) in those same job skills and academic topics. Critical thinking and written and oral communication skills topped the list of important skills and academic topics. Employers perceived recent entry-level hires to be less well-prepared to succeed in their careers than either university faculty or students. Entry-level hires with post-graduate degrees rated higher in proficiency for highly important skills and knowledge than those with bachelor's degrees. We conclude that although universities have the primary responsibility for developing critical thinking and basic communication skills of students, employers have equal or greater responsibility for enhancing skills of employees in teamwork, field techniques, and communicating with stakeholders. The American Fisheries Society can significantly contribute to the preparation of young fisheries professionals by providing opportunities for continuing education and networking with peers at professional conferences.

¿Estamos preparando a la siguiente generación de profesionales en pesquerías para que tengan éxito en sus carreras?: una encuesta a miembros de la AFS

Los profesionales de los recursos naturales, con frecuencia, han criticado a las universidades por la preparación deficiente de los graduados para tener éxito en sus trabajos. En este trabajo se encuestaron a miembros de la Sociedad Americana de Pesquerías para determinar qué conocimiento de tópicos académicos y habilidades laborales consideran los empleados, estudiantes y miembros de facultades universitarias como las más importantes en los profesionales de las pesquerías para tener éxito al inicio de sus carreras. Los encuestados también reconocieron las habilidades de los profesionistas regresados y contratados (empleados) o qué tan bien sus programas académicos los preparaban para tener éxito en sus carreras (estudiantes y facultad) en las mismas habilidades laborales y tópicos académicos. El pensamiento crítico y las habilidades de comunicación oral y escrita encabezaron la lista de habilidades y tópicos académicos importantes. Los empleadores percibieron a las contrataciones recientes como menos preparadas para tener éxito en sus carreras que los miembros de la facultad o los propios estudiantes. Los individuos recién contratados con posgrado fueron mejor calificados en cuanto a poseer el conocimiento y las habilidades más importantes que los titulados de licenciatura. Concluimos que si bien las universidades tienen la responsabilidad primordial de desarrollar el pensamiento crítico y las habilidades de comunicación en los estudiantes, los empleadores tienen la misma o mayor responsabilidad para fomentar las habilidades de sus trabajadores en lo referente a trabajo en equipo, técnicas de trabajo en campo, y comunicación con los involucrados en las pesquerías. La Sociedad Americana de Pesquerías puede contribuir significativamente a preparar a los jóvenes profesionistas de las pesquerías mediante el otorgamiento de oportunidades para continuar con su educación y el establecimiento de redes de contactos, durante conferencias, con pares y profesionales.

Préparons-nous la prochaine génération de professionnels de la pêche à réussir leur carrière?: Un sondage auprès des membres AFS

Les professionnels des ressources naturelles ont fréquemment critiqué les universités, car elles préparent mal les diplômés à réussir leur carrière. Nous avons interrogé les membres de l'American Fisheries Society pour déterminer quelles compétences professionnelles et quelles connaissances académiques les employeurs, étudiants et membres du corps professoral des universités jugent les plus importantes pour le succès des professionnels de la pêche au début de leur carrière. Les répondants ont également évalué l'aptitude des professionnels récemment entrés sur le marché du travail (employeurs) ou dans quelle mesure les programmes les ont préparés à réussir leur carrière (étudiants et professeurs) dans ces mêmes compétences professionnelles et sujets académiques. La pensée critique, les compétences en communication écrite et orale étaient en tête de la liste des compétences et des sujets académiques importants. Les employeurs ont perçu les professionnels récemment entrés sur le marché du travail moins bien préparés pour réussir dans leur carrière que les professeurs d'université ou les étudiants. Les employés au niveau d'entrée possédant des diplômes postuniversitaires étaient mieux notés dans la maîtrise des compétences et des connaissances très importantes que ceux ne possédant que des diplômes de baccalauréat. Nous concluons que, bien que les universités aient la responsabilité principale de développer la pensée critique et les compétences en communication de base des étudiants, les employeurs ont la responsabilité égale ou supérieure d'améliorer ces compétences dans le travail d'équipe, les techniques de terrain et la communication avec les parties prenantes. L'American Fisheries Society peut contribuer de manière significative à la préparation des jeunes professionnels de la pêche en offrant des possibilités de formation continue et de réseautage avec des pairs lors de conférences professionnelles.

INTRODUCTION

University programs that prepare students to enter the fisheries profession face a difficult task due to the complex and diverse nature of the field. Classmates in a single university program may become fisheries professionals but go into jobs with primary responsibilities in areas as diverse as fish ecology, population dynamics, population or habitat manipulation, water quality, human dimensions, economics, aquaculture, or numerous other specialty areas. Due to the complexity of the field, fisheries professionals (as well as other natural resource professionals) have debated the content of the "ideal" university curriculum for almost as long as the professions have existed (Leopold 1939).

Numerous symposia at professional conferences and publications in natural resource journals over the past 40 years have addressed the issue of how best to prepare students to become successful natural resource professionals. Several common themes that emerged from those symposia included discussions of the merits of broad and general undergraduate curricula versus more specialized curricula and frequent calls for more emphasis on communication skills. These themes are described in more detail below below.

First, the complexity and diversity of fisheries (and other natural resource fields) makes it impossible to adequately prepare students in basic sciences, humanities, communications, specific topics related to fisheries science and management, and critical job skills (e.g., ability to communicate effectively in writing and speaking, working in teams) during a four-year undergraduate program (Chapman 1979; Oglesby and Krueger 1989; Applegate 2009). Furthermore, employers frequently criticized universities for producing students they perceived as too narrowly focused on research questions and poorly prepared in basic skills needed by management-oriented employers (Donaldson 1979; Olmsted 1979; Cutler 1982).

Second, numerous authors suggested that undergraduate curricula should have a broad, interdisciplinary focus rather than a narrow, specialized focus (Hester 1979; Oglesby and Krueger 1989; Hard 1995), and that broad undergraduate programs should focus on developing critical thinking and problem-solving skills of students (Eastmond and Kadlec 1977; Donaldson 1979; Oglesby and Krueger 1989). Specialization should be left to graduate studies (Eipper 1973; Hester 1979). Bleich and Oehler (2000) suggested that more specialized undergraduate education leads to weaker, basic knowledge that hinders professional success of wildlife professionals.

Third, universal recognition of the importance of good written and oral communication skills in contributing to career success (for example, see Royce 1973; Stauffer and McMullin 2009; Blickley et al. 2012) has not resulted in desired proficiency in communication skills of students. Employers frequently cite communication skills of newly hired employees as their greatest deficiency (Cannon et al. 1996; Machnik et al. 2008; CNRS 2011; Sundberg et al. 2011; Sample et al. 2015).

Fourth, the broad category of people skills (e.g., interpersonal communication skills, working in teams, project management, human dimensions, policy processes) received almost as much attention as written and oral communication skills and, as with communication skills, nearly all authors believed that young professionals lacked well-developed people skills (Eastmond and Kadlec 1977; Hester 1979; Kelso and Murphy 1988; Crawford et al. 2011).

Fifth, authors frequently cited the lack of practical field skills among newly hired employees. Lack of experience in the field came up less frequently than the deficiencies in communication skills (Chapman 1979; Applegate 2009; Miller et al. 2009). Nevertheless, complaints about college graduates lacking field skills go back as far as Leopold's (1939:156) lament that "too few schools offer good instruction in the field operations of wildlife management and administration; too many offer indifferent training in wildlife science and research."

Finally, numerous authors suggested that employers should share in the responsibility of developing skills critical to career success of young professionals. Employers' contributions should focus on on-the-job training and support for continuing education (e.g., see Hester 1979; Kelso and Murphy 1988; McMullin et al. 2009).

As the first decade of the 21st century gave way to the second decade, this suite of concerns for the adequacy of university programs in preparing future natural resource professionals took on greater urgency as employers paid increasing attention to generational change in the workplace and workforce planning (McMullin 2005; Millenbah et al. 2011). Workforce planning involves more than supplying enough workers to replace those who retire; it also involves recruiting talented new employees and developing skills of existing employees so that they may move into positions of leadership vacated by retiring senior employees (Pynes 2004). Bieda (2011) attributed some of the persistently high unemployment in the United States workforce to a deficiency in the number of qualified workers to fill existing job openings.

Three major natural resource professional societies have addressed the adequacy of academic preparation of the next generation of natural resource professionals. A special committee of The Wildlife Society (TWS) assessed forces affecting university programs (McDonald et al. 2009) and reviewed university websites to determine that more than 400 universities in the United States offered wildlife, natural resource, or environmental science/management degrees (Wallace and Baydack 2009). The special committee also surveyed TWS members to assess perceptions of employers in the governmental, nongovernmental, and private sectors regarding the importance of various topics to the career success of entry-level hires, including how well-prepared recent entry-level hires were in those same topic areas (Stauffer and McMullin 2009). A few years later, the American Fisheries Society (AFS) followed a similar path when President John Boreman appointed the Special Committee on Educational Requirements and charged it with similar tasks, including assembling a list of North American colleges and universities offering degrees in fisheries and fisheries-related disciplines, conducting a survey of employers to determine what university coursework expectations they have for newly hired employees, and comparing university curricula with employer expectations for expertise of newly hired employees and with the U. S. Office of Personnel Management standards for entry into the federal 480 job series (Essig, this issue). In 2015, the Society of American Foresters devoted an entire issue of the *Journal of Forestry* to forestry education and employer expectations (Bullard 2015).

In this article, we present the results of a survey of AFS members conducted in response to the charge by AFS President Boreman and designed to address the following research questions:

1. What knowledge and job skills do students, university faculty members, and employers deem most important in contributing to early career success of entry-level hires?
2. Are students adequately prepared to succeed as fisheries professionals, and do students, faculty, and employers agree on how well students are prepared?
3. Does postgraduate education contribute significantly to perceptions of how well prepared students are to succeed as fisheries professionals?
4. What should be done to better prepare future fisheries professionals to succeed in their careers, and who should take primary responsibility to improve their preparation?

METHODS

During summer 2013, we invited all 9,214 members of the AFS listserv to participate in an online survey. Sampling from the AFS listserv membership allowed us to secure a broadly representative sample of employers, students, and university faculty in the fisheries profession, including adequate samples of employers in the federal, state, and nongovernmental organization (NGO) sectors, as well as private-sector employers (e.g., utility companies, consulting firms), university faculty, and students. We also hoped to receive enough responses from tribal/First Nation representatives to enable valid analyses.

We could not assign individual passwords, so two follow-up reminders were sent to all listserv members. Because we could not distinguish between respondents and nonrespondents in the listserv population, we relied upon comparison of key demographic characteristics of respondents and all AFS members to assess representativeness of the sample.

The first question of the survey asked the respondents to identify their employers (state/provincial agency, federal agency, tribal/First Nation entity, NGO, private-sector employer, university, student). University faculty members' and students' responses to the first question led them to unique sections of the survey that asked them to rate the importance to career success of 14 topics related to AFS academic requirements for certification as an Associate Fisheries Professional. Six topics in the survey related specifically to fisheries, four topics related to other biological sciences, and single items addressed each of the physical sciences, mathematics/statistics, communications, and human dimensions categories of the AFS professional certification framework. In addition to the certification-related academic topics, we asked respondents to rate the importance of seven other job-related skills to career success: written communication, oral communication, communicating to nontechnical audiences, critical thinking, working in teams, practical field skills, and a general assessment of technical knowledge of fisheries/aquatic sciences. We also asked students and university faculty to rate how well they thought their academic programs prepared them to succeed as fisheries professionals. We asked students to respond with respect to the degree sought (B.A./B.S., M.A./M.S., Ph.D.). University faculty at institutions with graduate programs answered two identical sets of questions: one for their undergraduate program and one for their graduate program. All nonacademic respondents answered a similar set of questions designed for employers. However, we asked employers to rate the perceived proficiency of recently hired entry-level employees (with the degree most commonly required of entry-level hires by their organization) in each of the certification topics and job-related skills. We compared perceptions of proficiency of recently hired B.S.-level graduates to perceived proficiency of M.S.-level graduates for state agency and NGO employers using a *t*-test. We compared perceived proficiency of recently hired B.S.-, M.S.-, and Ph.D.-level graduates in federal agencies and private-sector employers using analysis of variance, followed by a post-hoc Duncan's multiple range test.

All respondents answered questions near the end of the survey designed to assess the level of responsibility of universities, employers, and professional societies in developing knowledge and job skills of fisheries professionals. We also asked all respondents to rate perceived effectiveness of various strategies for developing knowledge and job skills (e.g., revising university curricula, continuing education, participating in AFS, revising the AFS Professional Certification Program).

RESULTS AND DISCUSSION

Response Rate and Respondent Characteristics

Sixteen percent of all listserv members ($n = 1,490$) responded to the survey. Although the low response rate raises the possibility of nonresponse bias, both the geographic distribution of respondents (Figure 1; χ^2 test, df = 1, $P = 0.32$), and the mix of students and working professionals in our sample closely matched the overall AFS membership. Students comprise 16.1% of AFS members and made up 15.5% ($n = 231$) of our sample. These comparisons suggest that our sample reasonably represented the members of AFS.

State, federal, and NGO employers hired entry-level professionals predominately at the master's degree level (Figure 2). Tribal/First Nation employers hired mostly at the bachelor's degree level. Only federal and private-sector employers hired a significant number of entry-level employees at the Ph.D. level. Although we report responses of NGO and tribal/First Nation employers, the reader should exercise caution in drawing conclusions about those employer groups due to small sample sizes.

Graduate students provided 87% of the student responses, and 70% of students responding attended public land grant universities. Seventy-four percent of students were enrolled in fisheries programs, combined fisheries and/or wildlife programs, or marine biology programs. The other 26% of students were enrolled in biology/zoology, environmental science, or conservation biology programs. University faculty responses closely resembled those of students, with 61% employed by public land grant universities and 56% housed in fisheries and/or wildlife departments.

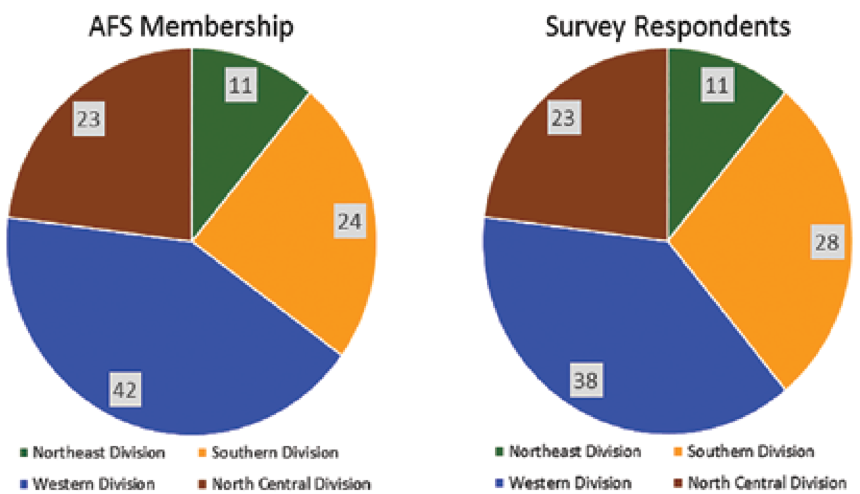

Figure 1. Percentage of AFS members in each of the four geographic Society-level Divisions and percentage of survey respondents in each of those Divisions.

Table 1. Mean ratings of the importance of job skills (A) and knowledge of academic topics addressed by the AFS certification program (B) in contributing to successful careers for entry-level professionals (biologists/scientists/managers) in the fisheries profession by undergraduate (UG), master's (MS), and Ph.D. students; university faculty (Faculty); and employers in state/provincial agencies (State), federal agencies (Fed), tribal/first nation organizations (Tribe), nongovernmental organizations (NGO), and the private sector (Private). Rating scale was 1 = not at all important to 10 = very important.

	Universities				Employers				
A. Skill/knowledge area	UG n = 30	MS n = 105	Ph.D. n = 88	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Effective written communication skills	9.1	9.2	9.0	9.2	9.0	9.2	8.4	9.3	9.1
Effective oral communication skills	9.4	9.3	9.0	9.2	9.0	9.1	8.6	9.2	9.0
Ability to communicate effectively with nontechnical audiences	9.2	9.1	8.8	8.9	8.9	8.5	8.1	9.1	8.4
Critical thinking skills	9.5	9.3	9.2	9.3	9.0	9.0	8.8	9.3	9.0
Working in teams	8.8	8.9	9.0	9.0	8.7	9.0	8.4	9.1	8.8
Practical field skills	9.1	9.0	8.5	8.6	8.5	8.1	8.4	7.4	8.5
Technical knowledge of fisheries/aquatic sciences	8.8	8.9	8.8	8.7	8.5	8.6	8.6	7.9	8.4
	Universities				**Employers**				
B. AFS certification area	UG n = 30	MS n = 105	Ph.D. n = 88	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Fisheries management	8.5	8.9	8.6	8.5	8.6	7.6	7.4	7.4	6.2
Fish ecology	8.8	8.9	8.9	8.8	8.1	8.3	8.3	7.8	7.7
Fisheries techniques	8.3	8.6	8.4	8.3	8.5	7.8	8.2	5.9	8.1
Aquaculture	7.0	5.9	5.8	5.4	5.1	4.4	5.7	4.5	3.7
Limnology/aquatic/marine ecology	8.0	7.5	7.9	7.8	6.6	6.8	6.0	5.9	6.9
Population dynamics	8.6	8.2	8.6	8.2	7.8	7.4	7.1	6.2	6.2
Conservation biology	8.4	7.6	8.0	7.6	6.6	7.8	6.8	7.8	6.3
Ichthyology	8.5	7.5	7.2	7.9	7.0	6.5	5.8	6.1	6.7
Aquatic entomology/invertebrate zoology	7.5	6.2	6.2	6.7	5.2	5.7	5.1	5.3	5.8
Other biological sciences	8.4	7.6	8.2	8.2	6.9	7.3	6.0	7.4	7.1
Physical sciences	7.2	6.6	7.0	7.2	5.7	6.2	5.5	5.5	6.1
Mathematics/statistics	8.2	8.5	8.6	8.4	7.5	7.3	6.6	6.5	7.2
Communications courses	8.4	8.6	8.9	9.0	8.7	8.4	7.5	8.3	8.6
Human dimensions/policy	7.5	7.5	7.9	7.5	7.5	7.0	5.8	7.4	6.6

Research Questions 1 and 2: What knowledge and skills contribute most to early career success, and how well prepared are students to succeed?

Overall, employers rated critical thinking skills and oral and written communication skills as the most important contributors to career success of entry-level employees. Communication courses and fisheries-specific topics rated highest in importance among academic topics, whereas aquaculture, aquatic entomology/invertebrate zoology, and physical sciences rated lowest in importance (Figure 3). Overall mean importance ratings for all job skills and academic topics, with the exception of aquaculture, exceeded the midpoint (5.5) of the 1–10 scale, suggesting that respondents considered all of those topics as at least moderately important. Differences in importance rankings of job skills and academic topics among students at every degree level, faculty members, and employers in every category were minor and generally consistent with the missions of employers (Table 1). For example, whereas all employers included communication courses and fish ecology among their five highest-rated academic topics, state agency employers rated fisheries management among their top five academic topics. Federal agency employers, which frequently deal with conservation of imperiled species, rated conservation biology among their five most important topics. Nongovernmental organizations ranked conservation biology and human dimensions/policy among their five most important topics.

Regardless of the level of education at which employers hire entry-level employees, what employers desire most includes the ability to think critically and to communicate effectively in

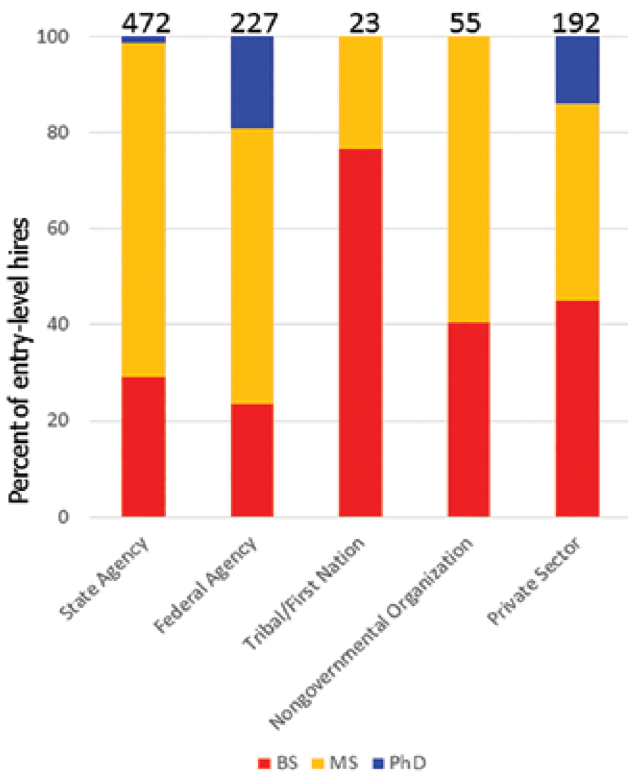

Figure 2. Percentage of entry-level hires with B.S., M.S., and Ph.D. degrees by employer. Numbers at the top of the bars are sample sizes for each employer type.

Table 2. Mean ratings by undergraduate students (UG) and university faculty (Faculty) of how well university undergraduate curricula prepare students in job skills (A) and academic topics addressed by the AFS certification program (B) and perceptions of employers in state/provincial agencies (State), federal agencies (Fed), tribal/first nation organizations (Tribe), nongovernmental organizations (NGO), and the private sector (Private) who hire primarily B.S.-level graduates of the proficiency of B.S. graduates as entry-level professionals (biologists/scientists/managers) in the fisheries profession. Rating scales were 1 = very poorly to 10 = very well (for students and faculty) and 1 = not at all proficient to 10 = very proficient (for employers).

	Universities		**Employers**				
A. Skill/knowledge area	UG n = 30	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Effective written communication skills	8.2	6.8	5.6	5.4	5.6	6.1	6.2
Effective oral communication skills	7.8	6.9	5.7	5.5	5.7	5.8	5.9
Ability to communicate effectively with nontechnical audiences	6.7	6.1	5.8	5.7	6.6	6.2	5.7
Critical thinking skills	8.2	6.8	5.7	5.4	6.1	6.2	6.2
Working in teams	7.4	7.2	7.1	6.5	6.4	7.2	7.0
Practical field skills	7.9	6.9	6.6	6.2	6.3	5.2	6.4
Technical knowledge of fisheries/aquatic sciences	8.1	7.1	6.3	6.4	5.6	4.9	6.3
	Universities		**Employers**				
B. AFS certification area	UG n = 30	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Fisheries management	7.6	6.9	5.4	5.2	4.8	4.1	4.6
Fish ecology	7.8	7.3	5.8	6.0	6.2	5.5	5.5
Fisheries techniques	7.1	6.6	5.9	6.2	6.0	4.3	5.1
Aquaculture	5.2	4.4	3.9	3.3	4.4	3.4	3.2
Limnology/aquatic/marine ecology	7.7	7.2	4.9	4.7	4.8	4.2	5.0
Population dynamics	7.8	7.0	4.5	4.5	5.0	3.4	4.0
Conservation biology	7.6	7.0	5.6	5.0	5.4	4.6	4.9
Ichthyology	8.5	7.0	5.5	5.2	4.7	4.3	4.8
Aquatic entomology/invertebrate zoology	7.3	6.0	3.8	4.5	4.6	4.1	4.5
Other biological sciences	9.0	8.0	6.2	5.6	5.7	5.4	6.3
Physical sciences	7.6	7.1	5.2	4.9	5.0	4.4	5.4
Mathematics/statistics	7.8	6.9	4.9	4.8	4.9	4.4	5.3
Communications courses	7.8	6.6	4.9	5.1	5.2	5.0	5.1
Human dimensions/policy	6.4	6.2	4.4	4.5	4.1	4.8	4.7

In addition to the desire for greater quantitative skills, employers desire graduates who understand and appreciate the social science, policy, and administrative aspects of fisheries conservation.

both writing and speaking. Although employers, university faculty, and students also identified fisheries-specific courses and quantitative courses as highly important, all employers rated all of the 14 academic topics and seven basic job skills (with few minor exceptions) as at least somewhat important. These findings are consistent with several of the themes found throughout the literature for at least 40 years, including the need for a broad, interdisciplinary undergraduate education that stresses critical thinking, problem-solving, and communication skills (e.g., Royce 1973; Donaldson 1979; Oglesby and Krueger 1989; Hard 1995; Stauffer and McMullin 2009).

Undergraduate students generally believed that their university curricula prepared them well to succeed in entry-level positions for all job skills and academic topics except aquaculture (Table 2). University faculty members also tended to rate their programs' undergraduate curricula as preparing students well to succeed in entry-level positions, with only aquaculture receiving a preparation rating less than 6.0 on the 10-point scale (4.4). However, faculty members rated every item lower than undergraduate students. Undergraduate students and faculty members differed most in perceptions of how well their curricula prepared students to succeed in entry-level jobs for ichthyology, critical thinking skills, and effective written communication skills.

Employers who hired entry-level employees primarily at the bachelor's degree level rated the proficiency of recently hired graduates substantially lower compared to both undergraduate students' and faculty members' ratings of how well their undergraduate programs prepared them to succeed in all job skills and academic topics (Table 2). Nongovernmental organization employers rated proficiency on all 14 academic topics below the midpoint of the 10-point scale and private-sector employers rated all but one of the items below the midpoint. All employer groups rated proficiency of recent entry-level hires below the midpoint on more than half of the 14 academic topics. Employers rated recent entry-level hires approximately two to three points lower than undergraduate students and one to two points lower than faculty members for critical thinking skills, effective written communication skills, effective oral communication skills, and technical knowledge of fisheries/aquatic sciences. Although job skills and academic topics that rated highest and lowest in importance tended to follow similar patterns for proficiency, the difference between importance and proficiency ratings differed notably for population dynamics, mathematics/statistics, and human dimensions/policy (Figure 4).

Respondents consistently rated proficiency (or in the case of

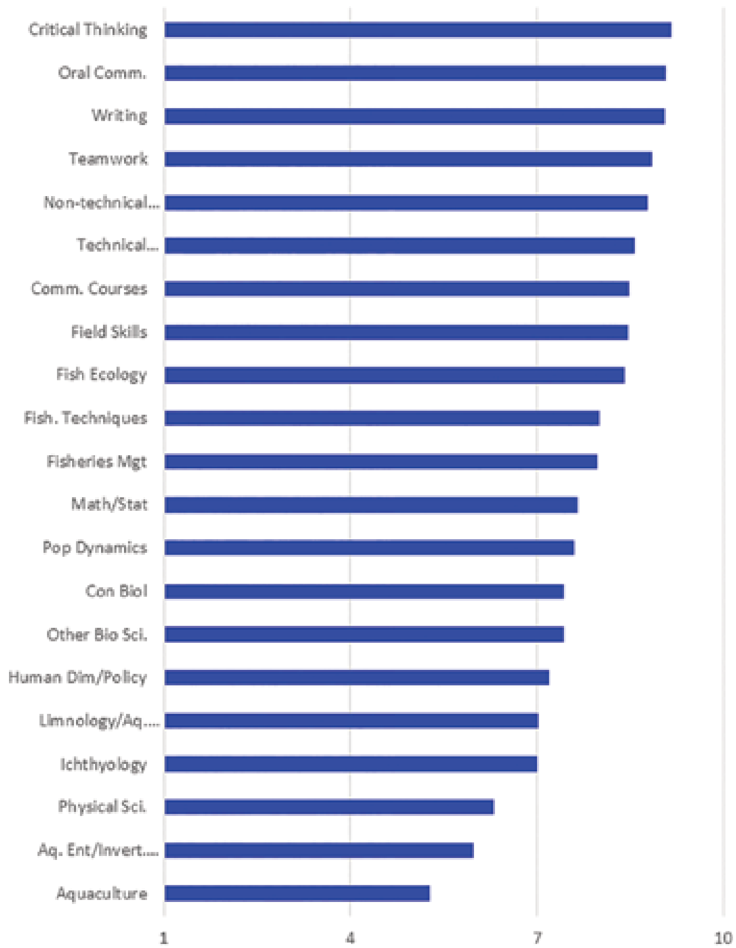

Figure 3. Overall ratings by all employers of the importance of job skills and academic topics to career success of entry-level hires.

faculty and students, preparation) lower on a 10-point scale than they did importance (also on a 10-point scale) of job skills and academic topics. Although the response scales are similar, they do not provide exact matches for comparisons. Nevertheless, the lower proficiency ratings (often by two or more points) suggest that employers do not feel that entry-level hires perform as well in basic job skills and academic topics as desired. Stauffer and McMullin (2009) found a similar pattern in responses of wildlife professionals. The greatest differences between importance and proficiency ratings occurred for the most important job skills: critical thinking, written communication, and oral communication.

Fisheries curricula will, and should, continue to include a substantial component of liberal arts, consistent with the recommendations found in several previously published papers (Hester 1979; Oglesby and Krueger 1989). Employer responses to this survey suggested that the central focus of fisheries curricula should be in fisheries-specific courses, communications, and mathematics/statistics. Employer responses mirror the recommendations found in previous papers that emphasized the need for greater quantitative skills among fisheries graduates (Hard 1995; USDOC and USDE 2008). The greatest disparities between employers' perceptions of importance and proficiency relative to academic topics occurred in the areas of population dynamics, mathematics/statistics, and human dimensions. Thus, in addition to the

The message to students should be clear: they should view a bachelor's degree as a stepping stone on the way to postgraduate education if they wish to maximize their chances of becoming a successful fisheries professional.

desire for greater quantitative skills, employers desire graduates who understand and appreciate the social science, policy, and administrative aspects of fisheries conservation. The need for increasing knowledge of human dimensions in natural resources has long been recognized (Cutler 1982; Kelso and Murphy 1988; Peek 1989; Decker and Enck 1996). Of course, all of these needs compete with the desire to maintain a "hands-on" educational experience so that natural resource graduates develop strong field skills as well as topical knowledge (Sample et al. 2015).

Research Question 3: Does postgraduate education contribute significantly to perceptions of how well prepared students are to succeed as fisheries professionals?

Master's students also felt that their programs prepared them well for entry-level positions, especially in the basic job skills, where their ratings exceeded those of undergraduate students on five of the seven skills (Table 3). In contrast, master's students rated their program preparation lower than undergraduate students on all but one of the academic topics.

University faculty rated their programs' preparation of graduate students (both master's and doctoral degrees) for entry-level positions similarly to the master's students' ratings for basic job skills (Table 3). In contrast to their lower ratings for undergraduate students, faculty members rated master's students' preparation higher than the students did for critical thinking skills, practical field skills, technical knowledge of fisheries/aquatic sciences, and 11 of the 14 academic topics (Table 3). Curiously, master's students rated their programs substantially lower than faculty members in preparing them for entry-level jobs in the academic topics of population dynamics and mathematics/statistics, both of which receive substantial emphasis in most graduate fisheries programs.

Employers who hired entry-level employees primarily at the master's degree level rated the proficiency of recently hired employees higher than employers that hired at the bachelor's degree level. State agency employers that hired entry-level professionals with master's degrees rated proficiency of those employees significantly higher ($P < 0.05$) for four of the seven basic job skills, and all five academic topics they rated as most important to early career success (communication courses, fisheries management, fisheries techniques, fish ecology, population dynamics) compared to state agency employers hiring bachelor's degree entry-level hires (Table 4).

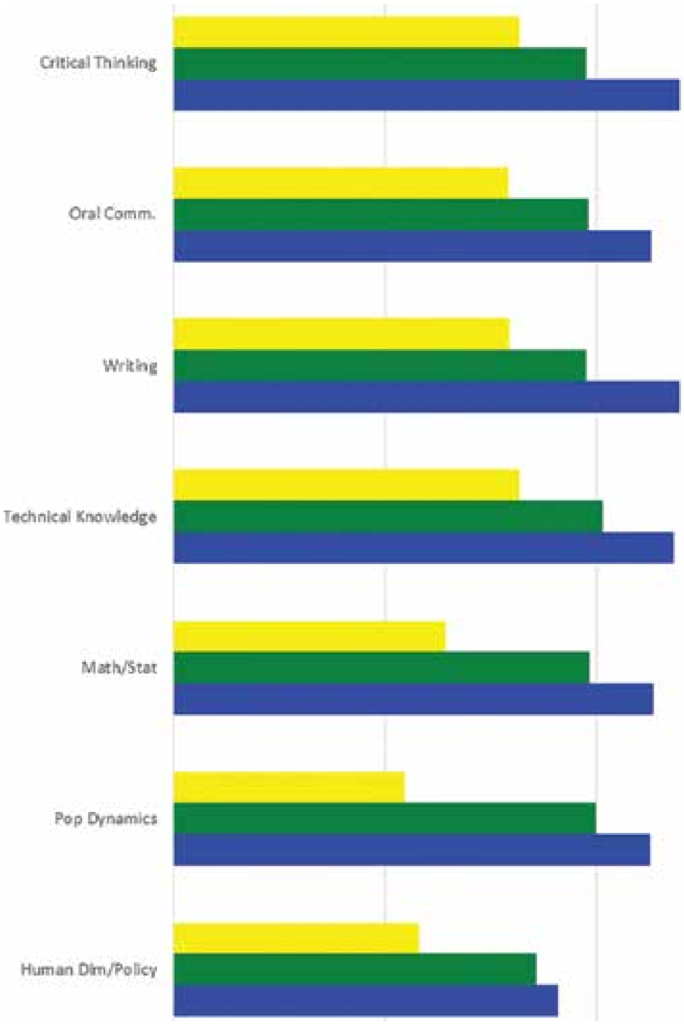

Figure 4. Comparison of employers' perceived proficiency of entry-level hires with B.S. degrees and the perceptions by university faculty and undergraduate students of how well their undergraduate curricula prepared them to succeed as entry-level professionals.

Federal employers also rated proficiency of entry-level employees with postgraduate degrees significantly higher than bachelor's degree entry-level hires ($P < 0.05$) for critical thinking, written communication, and oral communication skills (Table 5). Among the five academic topics federal employers rated as most important to early career success (communication courses, fish ecology, conservation biology, fisheries techniques, fisheries management), proficiency of entry-level hires with postgraduate degrees was rated higher only for fish ecology and conservation biology. Federal employer perceptions of the proficiency of entry-level employees with Ph.D. degrees did not differ greatly from perceived proficiency of master's students, with the exception of population dynamics and aquatic entomology/invertebrate zoology.

Although nongovernmental organization employers perceived large gains in proficiency among master's degree entry-level hires compared to employees with bachelor's degrees (range = 0.83 to 1.67; Table 3) in the five academic topics they deemed most important to career success (communications courses, fish ecology, fisheries management, conservation biology, human dimensions/policy), the differences did not differ significantly ($P > 0.05$), probably because of the small sample size of NGO respondents. Private-sector employers did not perceive significant gains in proficiency in the five academic topics they deemed most important to career success (communications courses, fish ecology, fisheries techniques, mathematics/statistics, other biological sciences) for any degree level ($P > 0.05$).

Increases in perceived proficiency for entry-level employees hired at the postgraduate level in state and federal agencies provide evidence of the value of advanced fisheries education and may help to explain why the largest employers of fisheries professionals hire the majority of their entry-level professionals at the postgraduate level (Kaemingk et al. 2013). The message to students should be clear: they should view a bachelor's degree as a stepping stone on the way to postgraduate education if they wish to maximize their chances of becoming a successful fisheries professional. Although some professional-level jobs are available to graduates with bachelor's degrees, more often, the bachelor's degree provides preparation for graduate school or technician-level jobs. Employers valued critical thinking and communication skills above all else in their entry-level employees, and postgraduate education clearly enhanced the perception of proficiency in those skill areas.

Research Question 4: What should be done to better prepare future fisheries professionals to succeed in their careers and who should take primary responsibility to improve their preparation?

Overall, respondents indicated that both universities and employers should have major roles in developing important job skills of entry-level professionals, with professional societies playing a lesser role (Table 6). Respondents suggested that universities had greater responsibility than employers or professional societies for developing critical thinking and written and oral communication skills of young professionals. In contrast, respondents suggested that employers had equal or slightly greater responsibility than universities for developing the ability to communicate effectively with nontechnical audiences, working in teams, and practical field skills.

Respondents rated experiential learning opportunities, such as internships and student participation in undergraduate research, as most effective in enhancing the knowledge, skills, and abilities of entry-level fisheries professionals (Figure 5). Continuing education workshops, revising university curricula, and involvement in AFS also rated high as effective strategies, whereas establishing university program accreditation rated slightly lower, and revision of the AFS professional certification criteria ranked lowest in effectiveness.

Most of the literature addressing how to adequately prepare students and young professionals to become highly effective natural resource professionals focuses on how universities can do a better job of educating students (e.g., Chapman 1979; Donaldson 1979; Kelso and Murphy 1988; Oglesby and Krueger 1989; Bullard 2015). We submit that the responsibility for meeting the challenge of preparing the next generation of fisheries professionals rests with the entire profession, not only with universities. The high ratings by respondents for both universities and employers (and, to a lesser extent, professional societies) to our question about who should be responsible for developing job skills suggests that the majority of AFS members agree with us. To

Table 3. Mean ratings by master's students (MS) and university faculty (Faculty) of how well university graduate curricula prepare students in job skills (A) and academic topic addressed by the AFS certification program (B) and perceptions of employers in state/provincial agencies (State), federal agencies (Fed), tribal/first nation organizations (Tribe), nongovernmental organizations (NGO), and the private sector (Private) who hire primarily MS-level graduates of the proficiency of MS graduates as entry-level professionals (biologists/scientists/managers) in the fisheries profession. Rating scales were 1 = very poorly to 10 = very well (for students and faculty) and 1 = not at all proficient to 10 = very proficient (for employers).

	Universities		**Employers**				
A. Skill/knowledge area	MS n = 105	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Effective written communication skills	8.3	8.2	6.5	6.6	7.8	6.8	6.0
Effective oral communication skills	8.2	8.2	6.5	6.6	8.0	6.6	5.9
Ability to communicate effectively with nontechnical audiences	7.5	7.0	6.1	6.1	7.3	6.7	5.5
Critical thinking skills	8.2	8.3	6.5	6.4	7.0	7.1	6.5
Working in teams	7.6	7.5	7.3	6.9	9.0	7.3	7.2
Practical field skills	7.5	7.9	7.0	6.8	7.0	6.3	6.4
Technical knowledge of fisheries/aquatic sciences	7.8	8.1	7.2	7.0	7.3	6.4	6.7
	Universities		**Employers**				
B. AFS certification area	MS n = 105	Faculty n = 184	State n = 472	Fed n = 227	Tribe n = 27	NGO n = 55	Private n = 192
Fisheries management	7.4	7.5	6.8	6.5	6.0	5.5	5.0
Fish ecology	7.6	8.0	6.9	6.9	7.5	6.3	6.2
Fisheries techniques	7.4	7.0	6.8	6.4	7.0	4.9	6.1
Aquaculture	4.3	4.9	4.1	4.2	5.0	3.5	3.4
Limnology/aquatic/marine ecology	6.0	7.3	5.4	5.5	7.0	5.2	5.4
Population dynamics	7.0	8.0	5.9	5.5	7.3	5.1	4.7
Conservation biology	6.7	7.5	6.1	6.2	7.5	6.2	5.3
Ichthyology	6.1	6.4	6.3	5.7	7.5	5.0	5.1
Aquatic entomology/invertebrate zoology	5.2	5.9	5.0	4.7	7.0	4.1	4.7
Other biological sciences	7.1	7.6	6.8	6.9	7.3	7.4	6.3
Physical sciences	5.7	6.5	5.6	5.5	6.3	5.6	5.5
Mathematics/statistics	7.2	8.0	6.1	5.9	5.8	5.6	5.8
Communications courses	7.2	7.1	5.7	5.8	6.8	6.3	5.4
Human dimensions/policy	6.3	6.2	4.7	5.2	4.0	6.4	4.4

effectively prepare the next generation of fisheries professionals, members of the profession should understand the unique challenges that students, university programs, and employers face and then collaborate to develop strategies to address those challenges.

What Can Students Do?

Today's university students face greater economic pressures to complete their education more quickly than previous generations of students. For example, the total cost of tuition, fees, and room and board at public institutions of higher education in the United States (where the majority of fisheries students get their education) increased by 40% between the 2001–2002 and 2011–2012 academic years (USDE 2013). During that same time period, the Consumer Price Index increased 27% (USBLS 2014). The cumulative student loan debt (in constant 2009 dollars) for graduates with bachelor's degrees in 2008 averaged US$24,700, 65% more than that of 1993 graduates (Woo and Soldner 2013). As a result of that economic pressure, many students seek to minimize their total expenses by taking summer classes in an effort to shorten their degree programs by one or more semesters. However, taking classes in summer often prevents students from gaining the experiential learning they could acquire through summer employment in the fisheries field. Students who wish to be competitive for jobs (or graduate school) in the fisheries field must balance their desire to complete their education quickly with the enhancement of their résumés that results from internships, undergraduate research, and other forms of experiential learning (Kaemingk et al. 2013).

Although most undergraduate curricula in fisheries and wildlife are so packed with university-mandated general education requirements and degree-specific requirements that little room is left for elective courses, results of our survey suggest that students would be wise to focus on communication-related courses for the few elective courses they can take. Similarly, graduate students (especially at the M.S. level) usually have few opportunities for elective courses beyond the degree-specific requirements (which often include multiple courses in quantitative subjects in addition to fish and wildlife courses). Graduate students also could benefit from more coursework in communications. In recognition of this need, numerous universities have developed graduate courses specifically addressing communication of science to nonscientific audiences (e.g., see Alan Alda Center for Communicating Science, www.centerforcommunicatingscience.org).

The Millennial generation (those born between 1981 and 1995) of students currently in college and entering the profession may be less patient with "paying their dues" to acquire knowledge and skills that normally come with more formal education and experience (Millenbah et al. 2011). Millennials also tend to overestimate their abilities. Sixty-nine percent of college freshmen responding to the Cooperative Institutional Research Program's Freshman Survey in 2012 rated themselves among the top 10% or above average in academic ability (Pryor et al. 2012). Curiously (and perhaps ominously, given the importance employers attach to communication skills), 46% of those same students rated themselves among the top 10% or above average in writing ability.

Superior academic performance (actually being a high achiever rather than perceiving it to be true), combined

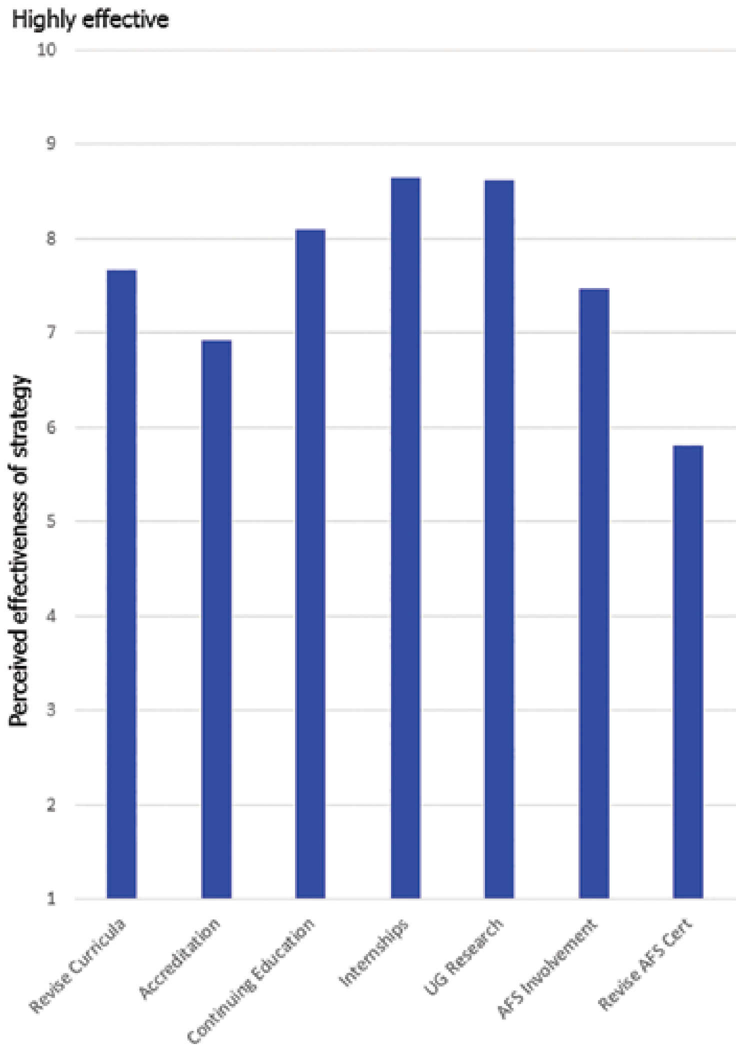

Figure 5. Perceived effectiveness of various strategies for enhancing the knowledge, skills, and abilities of entry-level fisheries professionals.

with practical experience gained through internships or undergraduate research, has always been key to opening the door to successful and rewarding careers in fisheries. Paying your dues through proven academic performance, practical experience, and postgraduate education is especially important in the highly competitive job market created by a backlog of graduates seeking jobs during the economic downturn that began in 2008–2009. Regardless of terminal degree, students and professionals at all levels in the fisheries profession should pursue lifelong learning. The knowledge and skills required of competent fisheries professionals change dramatically with time and technology, demanding continuous learning throughout one's career.

What Can Universities Do?

Universities face many challenges as they attempt to educate the next generation of fisheries professionals. Despite the rapidly rising cost of tuition, fisheries programs at many public universities have seen their budgets shrink as state governments have reduced their financial contributions to higher education. As the cost of a college education has shifted more to students and their families, pressure on universities to ensure that students can graduate in four years has intensified. For example, at the home institution of the lead author, today's students must complete 120 semester credits to earn a B.S. degree in fisheries conservation, 15 fewer credits than the degree required 20 years ago. The loss of an entire semester of courses increases the difficulty of simultaneously providing a broad undergraduate education and meeting the expectations of employers to produce competent fisheries professionals. Thus, university programs must choose between dropping liberal arts courses that broaden a student's perspective, science courses that may provide a broader foundation for fisheries education but may be less directly related to fisheries (for example, some physical sciences; see Gabelhouse 2010), or more directly related courses that emphasize hands-on, experiential learning but may be expensive to offer.

Universities cannot simply add more courses to address all of the skills and topics that employers cite as important to succeed as a professional. University-mandated general education requirements and basic science and mathematics courses that serve as prerequisites to fisheries-related courses often make up more than 80% of the total credits required to graduate. Adding required fisheries-related courses to the mix leaves little room for additional courses deemed important to career success. Applegate (2009) listed 68 university courses that he felt should be the minimum requirements to adequately prepare wildlife students for employment, more courses than most institutions require to earn B.S., M.S., and Ph.D. degrees. Instead, universities should employ pedagogical approaches that incorporate development of critical thinking, problem-solving, and communication skills across existing curricula. Fisheries educators today increasingly use case studies of real-world problems to force students to employ problem-solving techniques for interdisciplinary problems (Murphy et al. 2010). The case study approach, long a staple of teaching in business and law schools, forces fisheries students to integrate knowledge acquired (at least in theory) in previous courses, to work in teams, and to develop communication skills (Touval and Dietz 1994). Changing pedagogical approaches also requires university faculty to redirect some effort from research to the practice of teaching, something that many university promotion and tenure systems frequently do not reward (Nielsen 1987; Arlinghaus 2014).

What Can Employers Do?

Employers also must assume responsibility for continued development of their employees. Their responsibilities begin with having realistic expectations of entry-level employees at various levels of education; that is, not expecting an employee with a bachelor's degree to perform at the same level as an employee with a master's degree. Employers and universities should collaborate in the design and revision of fisheries curricula to ensure that graduates receive training in the topics of greatest importance to their future employers (CNRS 2011). Perhaps the most important responsibility of employers is to continue to invest in the development of their employees through continuing education and attendance at professional conferences.

The survey results indicated that employers should assume

Table 4. Comparison of perceived proficiency of recently hired entry-level employees in state agencies with bachelor's degrees and master's degrees (* $P < 0.05$, ** $P < 0.01$).

Skill/knowledge area	Bachelor degree entry-level hires (n = 104)	Master's degree entry-level hires (n = 247)	Master's degree hires – bachelor's degree hires
Effective written communication skills	5.6 (0.37)	6.5 (0.21)	0.9**
Effective oral communication skills	5.7 (0.36)	6.5 (0.20)	0.8**
Ability to communicate effectively with nontechnical audiences	5.8 (0.37)	6.1 (0.22)	0.3
Critical thinking skills	5.7 (0.37)	6.5 (0.21)	0.8**
Working in teams	7.1 (0.37)	7.3 (0.19)	0.2
Practical field skills	6.6 (0.41)	7.0 (0.22)	0.4
Technical knowledge of fisheries/ aquatic sciences	6.3 (0.37)	7.2 (0.2)	0.9**
Fisheries management	5.4 (0.4)	6.8 (0.24)	1.4**
Fish ecology	5.8 (0.38)	6.9 (0.20)	1.1**
Fisheries techniques	5.9 (0.37)	6.8 (0.23)	0.9**
Aquaculture	3.9 (0.44)	4.1 (0.26)	0.2
Limnology/aquatic/marine ecology	4.9 (0.4)	5.4 (0.25)	0.5*
Population dynamics	4.5 (0.43)	5.9 (0.26)	1.4**
Conservation biology	5.6 (0.43)	6.1 (0.26)	0.5
Ichthyology	5.5 (0.42)	6.4 (0.24)	0.9**
Aquatic entomology/invertebrate zoology	3.8 (0.41)	5.0 (0.26)	1.2**
Other biological sciences	6.2 (0.35)	6.8 (0.18)	0.6**
Physical sciences	5.2 (0.34)	5.6 (0.22)	0.4
Mathematics/statistics	4.9 (0.38)	6.1 (0.23)	1.2**
Communications courses	4.9 (0.37)	5.7 (0.22)	0.8**
Human dimensions/policy	4.4 (0.38)	4.7 (0.24)	0.3

Table 5. Comparison of perceived proficiency of recently hired entry-level employees in federal agencies with bachelor's degrees, master's degrees, and Ph.D. degrees (letters indicate significant ANOVA, $P < 0.05$, Duncan's post-hoc comparison).

Skill/knowledge area	Bachelor's degree entry-level hires (n = 39)	Master's degree entry-level hires (n = 94)	Ph.D. degree entry-level hires (n = 30)	Master's degree hires – bachelor's degree hires	Ph.D. degree hires – master's degree hires
Effective written communication skills	5.4^{a}	6.6^{b}	7.1^{b}	1.2	0.5
Effective oral communication skills	5.5^{a}	6.6^{b}	7.0^{b}	1.1	0.4
Ability to communicate effectively with nontechnical audiences	5.7^{a}	6.1^{a}	5.9^{a}	0.4	-0.2
Critical thinking skills	5.4^{a}	6.4^{b}	7.1^{b}	1.0	0.7
Working in teams	6.5^{a}	6.9^{a}	6.9^{a}	0.4	0.0
Practical field skills	6.2^{a}	6.8^{a}	6.8^{a}	0.6	0.0
Technical knowledge of fisheries/ aquatic sciences	6.4^{a}	7.0^{ab}	7.6^{b}	0.6	0.6
Fisheries management	5.2^{a}	6.5^{b}	6.0^{ab}	1.3	-0.5
Fish ecology	6.0^{a}	6.9^{b}	6.9^{b}	0.9	0.0
Fisheries techniques	6.2^{a}	6.4^{a}	6.1^{a}	0.2	-0.3
Aquaculture	3.3^{a}	4.2^{ab}	4.4^{b}	0.9	0.2
Limnology/aquatic/marine ecology	4.7^{a}	5.5^{ab}	6.3^{b}	0.8	0.8
Population dynamics	4.5^{a}	5.5^{b}	6.6^{c}	1.0	1.1
Conservation biology	5.0^{a}	6.2^{b}	6.5^{b}	1.2	0.3
Ichthyology	5.2^{a}	5.7^{a}	5.9^{a}	0.5	0.2
Aquatic entomology/invertebrate zoology	4.5^{a}	4.7^{a}	5.6^{b}	0.2	0.9
Other biological sciences	5.6^{a}	6.9^{b}	7.4^{b}	1.3	0.5
Physical sciences	4.9^{a}	5.5^{a}	5.6^{a}	0.6	0.01
Mathematics/statistics	4.8^{a}	5.9^{b}	6.4^{b}	1.1	0.5
Communications courses	5.1^{a}	5.8^{ab}	6.3^{b}	0.7	0.5
Human dimensions/policy	4.5^{a}	5.2^{a}	4.7^{a}	0.7	-0.5

Table 6. Perceived level of responsibility (1 = Low, 10 = High) of universities (U), employers (E), and professional societies (S) in developing knowledge and ability in various job skills (n = 1,490).

Job skill	U	E	S
Effective written communication skills	9.1	7.0	6.4
Effective oral communication skills	8.9	7.2	6.9
Ability to communicate effectively with nontechnical audiences	7.7	8.0	6.5
Critical thinking skills	9.0	7.0	5.6
Working in teams	7.7	8.2	5.4
Practical field skills	7.9	8.3	5.5
Technical knowledge of fisheries/aquatic sciences	8.9	7.5	7.1

much of the responsibility for developing employees' ability to communicate effectively with nontechnical audiences, to work effectively in teams, and to enhance field skills. In addition, employees will likely gain more knowledge and skills in some areas (e.g., supervision, leadership, working with stakeholders) through continuing education, after they have gained some job experience and can better relate to those topics. As budgets shrink, employers often cut back on opportunities for employees to travel and attend conferences and workshops. Unfortunately, shrinking budgets also frequently result in fewer vacant positions being filled and additional responsibilities being shifted to employees. Employees who are expected to do more with less need more continuing education and professional involvement, not less. Some employers hesitate to invest in employees for fear that their investment to improve the skills of employees will result in those employees seeking employment elsewhere. Employers should ask themselves, "What if we don't invest in our employees and they stay?"

What Can AFS Do?

The American Fisheries Society can play an important role in ensuring that the next generation of fisheries students enters the profession well- prepared. Although survey respondents did not attribute great responsibility to AFS for developing the knowledge and skills that employers seek in entry-level employees, the Society has primary responsibility for setting the standards of professionalism in fisheries. The criteria established by AFS for certification as a fisheries professional significantly influence the content of university fisheries curricula because most universities want their students to qualify for certification upon graduation. Although revision of the AFS certification program rated low among the strategies for improving the knowledge and skills of fisheries professionals, periodic revision of the certification criteria will ensure that the standards of professionalism in fisheries remain current. Recent examples of changing expectations of fisheries professionals reflected in revision of the certification program include increased emphasis on human dimensions and allowance of geographic information systems courses to fulfill the physical sciences requirement. Certification criteria probably cannot address the desire of employers for better critical thinking skills among entry-level hires, but increasing emphasis on communication skills could be addressed by certification. AFS should consider increasing offerings of continuing education courses at Society meetings at all levels that address the communication skills deemed so important by employers. Furthermore, AFS-sponsored continuing education workshops could help to address areas of knowledge frequently lacking in entry-level employees, such as human dimensions and quantitative skills. Accreditation of fisheries programs by AFS also rated low as a strategy for improving knowledge and skills of entry-level employees. Scalet and Adelman (1995) suggested that accreditation of university fisheries and wildlife programs would be redundant with the certification programs of both AFS and TWS and, furthermore, that attempts to establish accreditation would encounter substantial resistance from universities. The Society of American Foresters has taken a different path, emphasizing the value of accreditation of university forestry programs (Redelsheimer et al. 2015).

The American Fisheries Society can continue to play a major role in improving the knowledge and skills of fisheries professionals by promoting interaction and sharing of information through its meetings at Chapter, Division, and Society levels. Chapters play a particularly important role, because they provide more convenient and economical opportunities for fisheries professionals to meet and learn than Division or Annual Meetings of the Society. For many state agency employees who face severe restrictions on out-of-state travel, Chapter meetings may provide the only realistic possibility of involvement in the Society. The American Fisheries Society should continue to explore opportunities to expand the availability of continuing education workshops and content of conferences beyond those physically attending, but for fisheries professionals who are serious about upgrading their credentials and staying current in the profession, actual participation and the associated networking far surpasses virtual participation.

CONCLUSION

The challenge of adequately preparing the next generation of fisheries professionals faces the entire profession, not just universities. Universities play a critical role in building the foundation upon which professionalism is built, but employers, AFS, and the individual members of the profession all share in the responsibility to develop the next generation of fisheries professionals. To be effective, future fisheries professionals must think critically, employ excellent problem-solving skills, and communicate effectively with nontechnical audiences, specialists in other disciplines, and other fisheries professionals. Of course, they still must have a solid foundation of knowledge of fisheries and aquatic sciences, basic sciences, and mathematics. In most cases, graduates with bachelor's degrees will have only begun the process of becoming professionals. Postgraduate education will enhance the knowledge and skills that lead to success as a fisheries professional, but regardless of the number of degrees earned, professionals must embrace lifelong learning.

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FEATURE

Innovative Approaches to Fisheries Education and Outreach

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Fisheries pedagogy frequently uses outdated instructional models, even though newer approaches, such as multimodal and active instruction, may result in better educational outcomes. We discuss a variety of innovative instructional approaches for fisheries classes, including multimodal learning via music videos, student karaoke videos, and active learning via video observations of naturally behaving animals. Questionnaire responses from both undergraduate and graduate classes indicated that the various multimodal and active learning approaches generally improved students' attitudes toward class and studying; however, their impact on learning and retention is unknown. We also explore additional aspects of student-centered learning including e-portfolios, digital storytelling, and interactive, web-linked lab notebooks. Finally, viewing fisheries education in a broad sense, we describe experiences with a web-based information platform, www.troutnut.com, that serves as a stream ecology outreach site for both the scientific community and the public.

Enfoques innovadores para la educación y extensión de las pesquerías

La pedagogía de las pesquerías suele valerse de modelos de educación obsoletos, pese a que los nuevos enfoques, como la instrucción activa y multimodal, pueden producir mejores resultados educativos. Se discute una variedad de enfoques innovadores de instrucción para clases de pesquerías, incluyendo aprendizaje multimodal vía videos musicales, videos karaoke de estudiantes y aprendizaje activo vía observaciones en video de comportamiento animal natural. Las respuestas a los cuestionarios aplicados a graduados y no graduados indican que los varios enfoques multimodales de aprendizaje en general mejoraron la actitud de los estudiantes con respecto a las clases y a estudiar; sin embargo, su impacto en el aprendizaje y la retención se desconocen. También se exploraron distintos aspectos del aprendizaje centrado en el estudiante, incluyendo ePortafolios, narrativas digitales y cuadernos interactivos, conectados a la red, de notas de laboratorio. Finalmente, viendo a la educación de las pesquerías en un sentido amplio, se describen las experiencias de usar una plataforma informática en la red, www.troutnut.com, que sirve como un sitio de extensión de la ecología para la comunidad científica y el público en general.

Approches novatrices en matière d'éducation et de sensibilisation à la pêche

Les pêcheries utilisent fréquemment des modèles pédagogiques dépassés, même si des approches plus récentes existent, telles que l'enseignement multimodal et actif, et peuvent entraîner de meilleurs résultats scolaires. Nous discutons d'une variété d'approches pédagogiques novatrices pour les classes de pêche, y compris l'apprentissage multimodal via des vidéos musicales, des vidéos karaokés étudiant, et l'apprentissage actif par l'intermédiaire d'observations de vidéo d'animaux se comportant naturellement. Les réponses au questionnaire des deux classes de premier cycle et des cycles supérieurs ont indiqué que les diverses approches d'apprentissage multimodal et actif ont généralement amélioré les attitudes des étudiants envers la classe et l'étude ; cependant, leur impact sur l'apprentissage et la rétention en mémoire sont inconnus. Nous explorons également d'autres aspects de l'apprentissage centré sur l'étudiant, y compris le ePortfolio, la narration numérique, et les carnets de laboratoire interactives liés au Web. Enfin, en prenant l'éducation de la pêche au sens large, nous décrivons des expériences avec une plate-forme d'information sur le Web, www.troutnut.com, qui sert de site de diffusion de l'écologie pour la communauté scientifique et le public.

INTRODUCTION

Twenty years ago, one of us published an article in *Fisheries* entitled, "Pogo Was Right, Let's Change the Way We Teach Fisheries" (Orth 1995). The article focused on both philosophical and technical challenges in fisheries education, including narrow and overspecialized pedagogies and instructor-centered, rather than student-centered, instructional activities. In the intervening years, both the medium and perhaps the message have changed, and though we marvel at the march of progress, all marches necessitate occasional pauses for evaluation and reassessment. Despite the prescience of Orth's (1995) article, many of the same problems remain in fisheries education today; consequently, discussions of how new educational approaches may be incorporated in fisheries pedagogy are warranted.

In this article, we describe examples of highly effective approaches for fisheries education sensu lato, including active and multimodal instructional techniques, e-portfolios, and science-based web platforms. We focus on pedagogical methods that increase student engagement and improve attitudes toward class and assignments but also generally involve active learning, which has been shown to increase learning and retention (McKeachie et al. 1987; Prince 2004; Freeman et al. 2014). We do not examine the educational role of formal social media (e.g., listservers, chat rooms, Facebook, Snapchat, etc.) in fisheries, which is an extensive topic itself. Our main goal is to provide examples, for both current and future fisheries teachers and communicators, of techniques that improve student attitudes and consequently increase learning and retention. An additional goal is to describe experiences with a successful, science-based web platform for communication of scientific information.

NEW DEVELOPMENTS IN FISHERIES PEDAGOGY

Fisheries Education, the Status Quo Or?

For most of our (G. D. G., D. J. O.) teaching careers, we used fairly traditional instructional methods: standard lecture/lab presentations with a soupḉon of film to break the monotony. These pedagogical techniques represent "passive learning" because the students act as passive receivers rather than active participants. Educational research has a long history of evaluating modes of instruction, and the standard ranking of instructional approaches is Bloom's Taxonomy of knowledge acquisition (Krathwohl 2002; Krathwohl et al. 1964; Grossman and Richards, in press. Passive learning—that is, the standard "professor lectures, the students take notes and memorize information"—represents the lowest level of Bloom's Taxonomy, which then moves upwards through understanding, applying, analyzing, evaluating, and creating (Krathwohl 2002; Dresner et al. 2014). Consequently, if we teach using passive methods, we are employing the least effective technique for information transmission and learning. Obviously, teaching is an individual activity, and most fisheries/ichthyology professors do not remain stuck in passive mode; in fact, some laboratory activities may climb the learning hierarchy if true analysis and evaluation are called for in an exercise (Habron and Dann 2002). Nonetheless, in many cases, labs require a single outcome; consequently, opportunities for employing higher-level processes (i.e., original analysis, evaluation, and creation; Krathwohl 2002; Krathwohl et al. 1964) may be limited. Clearly, innovative methods that utilize higher-level approaches on the learning hierarchy are warranted if we are to improve fisheries education.

Great songs and great scientific papers are similar in that they communicate new information in an appealing and content-laden style, while engaging and maintaining listener/reader interest.

Multimodal Educational Approaches: The Use of Music

Innovative educational research has focused not only on the structure of instructional approaches but also on the sensory modes used in information transmission. For example, information communicated through multiple sensory modalities (speech/hearing and vision) results in greater retention and learning (Jewitt et al. 2001; Jaipal 2010; Arroio and de Souza 2012). Grossman's first foray into the arena of innovative science education involved the use of song, which has been underutilized as an instructional mode in university science classes (Crowther 2011; Crowther and Davis 2013; and references in Grossman and Watson 2015). Nevertheless, we all have childhood memories of the teaching songs used on television shows like *Sesame Street* and *School House Rock* and classroom songs that taught us the letters of the alphabet, colors, and hours of the day. Based on this model, Grossman hypothesized that the creation of songs containing ecological and evolutionary content might be a technique by which student engagement could be increased. Most contemporary college towns have a music scene, and anyone walking around a college campus cannot help but notice how many students are listening to music via mobile devices. The use of music and video for presentation and reinforcement of classroom material seemed perfect for students in a town (Athens, Georgia) where class attendance was frequently structured around which bands had played in local clubs the night before.

Specifically, Grossman became interested in innovative approaches to science education via the development of a new introductory course at the University of Georgia designed to teach non-science majors basic ecology, evolutionary biology, behavior, and regional natural history, including fish biology (Natural History of Georgia, Forest and Natural Resources [FANR] 1200). The course content was sufficiently rigorous to meet both the general education requirements for life sciences for most colleges and the environmental literacy requirement for all colleges/schools at the University of Georgia. A considerable challenge lay in introducing non-science students to sophisticated concepts, such as resource management, interspecific competition and the niche, animal behavior (schooling and foraging theory), and taxonomy, while maintaining a high level of student interest. Ensuring that business, political science, and art majors remained engaged in learning basic and advanced scientific and resource management concepts called for new techniques as well as a new mindset. No longer could Grossman count on the innate interest of the students toward the subject matter as is typical in fisheries classes, and with enrollments of over 140 students, strategies with broad appeal were required. The educational literature and seminars hosted by the University of Georgia Center for Teaching proved to be great resources for potential techniques, and these resources also showed that there was a dearth of information on the development, implementation, and evaluation of innovative pedagogical techniques for university-level biological sciences and natural resource management courses.

Around this time, Grossman took up the ukulele as a hobby, which coincidentally had become an instrument favored by college-aged youths due to its adoption by popular musicians, such as Eddie Vedder and Dave Matthews. Grossman had never written a song before, but great songs and great scientific papers are similar in that they communicate new information in an appealing and content-laden style, while engaging and maintaining listener/reader interest. So began Grossman's career as an ecological songwriter, buoyed by the fact that students like nothing more than seeing a professor behave in a goofy, non-professorial manner. Like many fisheries professionals, Grossman hadn't played an instrument since middle school, and his trepidation was palpable. He started with basic songs on speciation and natural selection. Given the musical tastes of 21st-century students, his first song was a rap, and a local musician was hired to write, record, and produce the music to which Grossman rapped his lyrics. One benefit of living in a university town is that talented musicians are not uncommon and typically will work for reasonable wages. The second song was a pop music song on natural selection for which Grossman wrote the lyrics and most of the music. Students responded positively to these songs, and questionnaire results indicated that they aided in studying and improved the class atmosphere (Grossman and Watson 2015). Although Grossman retained his day job, he forged onward in the production of scientific music videos. Over the course of the next two years, Grossman wrote and recorded 10 more music videos in various musical styles, on subjects ranging from foraging theory, to Brook Trout *Salvelinus fontinalis*, to Coastal Plain vegetation (see youtube.com/user/AssortedPieces), and these videos provide a ready-made resource for other instructors. Further classroom surveys (all conducted with institutional review board approval) demonstrated that the music videos improved student attitudes toward (1) class attendance, (2) instruction, and (3) studying, and the videos, which have been up on YouTube for time intervals of a few months to several years, were frequently viewed (range 124–1,499, as of May 5, 2016) by both students and non-students. This model of multimodal instruction clearly has a positive impact on student attitudes toward classes (Grossman and Watson 2015); however, its actual impact on learning and retention is unknown. The evaluation of learning impacts is difficult because true controls are problematical, interindividual variability is high, replication is expensive and logistically difficult, and students are frequently reluctant to participate in studies requiring extra work. Nonetheless, Grossman is currently attempting to evaluate the impacts of music videos on learning and retention.

Despite the success of the music video exercise, it is important to recognize that although multimodal instructional approaches are likely an improvement over basic passive instructional techniques, they remain low on Bloom's Taxonomy and basically represent an improved manner of passive instruction rather than active learning.

Although the task may seem daunting, making a music video is not particularly difficult, and all of the equipment one really needs is a cell phone and computer, given that most cell phones are now able to record high-definition video and reasonable sound. In addition, free video editing programs, such as Windows Movie Maker or Apple iMovie, are readily available and typically included in software packages installed in most new computers. More versatile programs are available for under US$150, and Grossman uses Power Director (no endorsement intended). In addition, professional-quality recording microphones may be purchased for as little as $75, although Grossman uses a Zoom Hn4 digital microphone, which is slightly more expensive but small and highly portable. As with video editing programs, free sound editing and mixing programs are available for Windows-based computers (e.g., Audacity), and Apple computers typically have Garage Band as freeware. Lest this all seem very intimidating, remember that nothing retains student interest better than a faculty member possibly making a public fool of themselves, so one need not be a rock star to succeed at using music video formats for science education.

This exercise takes students through all aspects of scientific research, including hypothesis generation, data analysis and summarization, and potentially even statistical analysis.

Student Karaoke Videos

To incorporate active learning into the music video exercise, Grossman created a karaoke music video assignment for all of his classes between Fall 2014 and Spring 2016, including (1) a first-year seminar course in natural history (First Year Odyssey [FYO] 2015, 2016), (2) an undergraduate non-science majors class in Natural History of Georgia (FANR 1200, 2015), (3) a graduate class in advanced fish ecology (Fisheries and Aquaculture [FISH] 8400, 2014), and (4) a graduate class in vertebrate diversity and conservation (Wildlife [WILD] 8680, 2015). In the FYO and graduate classes, the assignment was an individual assignment (although in 2015, FYO students could work with a partner), whereas in FANR 1200 the assignment was a group project with four students to a group. The assignment required students to make an original music video describing either an ecological/evolutionary process, a species, or a habitat. Students were allowed to use existing video and music (web sourced) but were required to write and sing or rap original lyrics. Video, music, and vocals were then all combined into an original music video. Videos, which counted between 15% and 40% of the total grade, were evaluated by Grossman for scientific accuracy, creativity, and technical quality. Student identities were then removed from the videos, and they were shown to the entire class during a lecture period. Analyses based on questionnaires and triangulation interviews for five classes (at least one of each listed above) demonstrated that the vast majority of students responded positively to all aspects of the exercise, and a mean of 79% (range, undergrad 75%–97%, grad 67%) responded that the karaoke video exercise aided in learning or synthesizing class material (unpublished data; see Grossman and Richards [in press] for 2014 data). A surprising result was that a mean of 22% of students (unpublished data; undergraduate only, range 17%–30%) preferred having an exam over the video exercise. Neither the student's level of musical experience nor rank in school had a significant effect on the frequency of positive or negative responses to questions about the karaoke video exercise for FANR 1200 and FISH 8400 in 2014 (Grossman and Richards, in press). That is, students with extensive musical experience did not express opinions on the exercise that differed significantly from students with minimal musical experience, nor did first-year students differ from fourth-year students in Grossman's 2014 classes (Grossman and Richards, in press). In addition, these factors did not affect students' favorite aspect of the video project (e.g., writing lyrics, video production, writing/obtaining music, etc.; Grossman and Richards, in press). Like any group project, students were concerned about equal participation, and Grossman required every student within a group to evaluate every other student. If two or more of the students in a group rated a student poorly, then that student's grade was discussed and reevaluated if necessary. Based on student responses, the karaoke active learning exercise was an instructional success (unpublished data; Grossman and Richards, in press).

Active Learning via Analysis of Biological Videos

A challenge in improving fisheries education is the development of new active learning exercises that include analysis, synthesis, and creativity. Although not a new technique, Grossman has used a variety of video exercises of this type in FYO, FANR 1200, and WILD 8680, with generally favorable results. Today, many education specialists argue that "Video is the New Text!" (e.g., Talheimer 2015), and this approach certainly takes advantage of this trend. In FYO 2015 and WILD 8680, videos of birds at a feeder were used (shot from Grossman's house), and in FYO 2016 and FANR 1200, video of two male Gilt Darters *Percina evades*, shot by Dr. Todd Crail (www.youtube.com/watch?v=idijWE94EWY), fighting over a breeding location, and a group of Arctic Grayling *Thymallus arcticus* foraging were used, respectively. One exercise currently used by Grossman involves students watching up to 30 minutes of video of animals behaving and interacting naturally in a habitat (fishes, birds at a feeder, etc.), and then requiring students to define and quantify the observed intra- and interspecific behaviors as well as their consequences for both individuals and the population. Potential data for measurement include spatial orientation (random, regular, overdispersed), feeding behaviors (bite locations, foraging rates [bites per minute], fish size versus feeding location, spatial location versus foraging success), general behavior and interactions (sequence of species arrival; predictability of sequence arrival; behaviors used when individuals interact—e.g., approach, butt, lateral display, nip, flee, chase, etc—and how individual behavioral responses vary by species, size, or prior occupancy); behavioral time budgets (i.e., the amount and percentage of time devoted to feeding, searching, resting, etc.); and how these behaviors change temporally during the video. This exercise takes students through all aspects of scientific research, including hypothesis generation, data analysis and summarization, and potentially even statistical analysis. In FYO and WILD 8680, these exercises were very successful, with 87% (range 79%–100%) of students responding that the exercise helped them learn or synthesize material. However, in FANR 1200 (the first trial in this class and the largest class involved, with 90 students), many students responded negatively to the exercise, with 40% responding that the video helped them learn material and 63% preferring an exam in place of the exercise. Nonetheless, 55% of students also responded that having a chance to do scientific research was interesting. The FANR 1200 class is for non-science majors, and perhaps students were not given enough guidance or interaction with the instructor (although there was a classwork session as well as a teaching assistant for additional instruction). The FYO classes are also non-science major classes but much smaller (maximum enrollment 15 students); therefore, more interaction occurred between Grossman and his students. Or perhaps FANR 2015 contained a large number of unmotivated students, as can happen in courses that satisfy general education requirements. Nonetheless, the results illustrate the need to tailor the exercise to the particular class being taught. Although academic research on this phenomenon is not extensive for science students, now is the time for experimentation by both faculty and students.

LEARNING, NARRATIVE WRITING, AND DIGITAL RESOURCES

In this section, we describe a variety of new, technologically-based approaches to fisheries education, including the use of web-based science education. Orth has previously argued that the enemies of fisheries education were (1) narrow or overspecialized thinking and (2) the focus on specialized skills relevant to fisheries alone (Orth 1995). Orth (1995) advocated for contextual thinking and problem-solving approaches rather than passive receipt of knowledge from narrowly focused, overspecialized experts. Since that time, Orth has sought to place students at the center of educational activities, where they assume greater responsibility for demonstrating their competencies (e.g., Habron 2005).

ePortfolios

Anyone who teaches at the university level for any length of time will eventually engage in the wonderful activity of student "learning outcomes assessment." Although the history of assessment demonstrates mixed benefits for instructors, new approaches suggest that assessment will function best when it is embedded in how we teach, and hence becomes a form of continuous improvement (Maki 2015). These innovations include e-portfolios and digital storytelling as well as the techniques described previously. Widespread adoption of such authentic learning activities led to the formation of an international professional organization in 2009, the Association for Authentic Evidence-Based Learning (aaeebl.org), to advance *learning* with digital technologies (Bass 2014; Eynon et al. 2014). Modern digital technologies make it easy for students to capture original work in multiple digital formats, such as video and audio clips, and create an e-portfolio. Although e-portfolios are not a new pedagogy, our experience suggests that the tool only works when we ask the students to reflect, critique, and showcase their best works.

Orth's journey to student-centered learning moved him to lead a team of Virginia Tech faculty that developed a new first-year experiential course focused on problem solving, inquiry, and integration. In addition, Orth adopted a variety of nontraditional pedagogical approaches to fisheries education including (1) a portfolio approach for assessment of integrative knowledge, (2) resurrection of the lab notebook with links to photo-sharing websites, (3) digital storytelling where students reflect "on becoming an ichthyologist," and (4) first-person ethics approaches for teaching ethical decision making.

The first-year experiential class at Virginia Tech is called Invent the Sustainable Future and asks students to think deeply and use inquiry skills to answer the question, "How will *I* contribute to a sustainable future?" In this class, the students decide "what major, minor, internships, experiences, will *I* need to pursue" in order to "go confidently in the direction of my dreams." They write their own story on day 1 and revise and showcase their best work in an e-portfolio by the end of class. The inevitable question from students was, "What do *you* want *me* to put in the e-portfolio?" This comment exemplifies one of the negative aspects of passive instruction, where students focus on what the instructor wants rather than focusing on making assignments exercises in individual creativity. Nonetheless, it takes just one low grade from an inflexible instructor to reinforce the hierarchy in class, and tiresome as it may be, we likely should be more understanding when a student asks, "What do *you* want?" In Invent the Sustainable Future, students write frequent reflections about their learning in response to prompts related to learning outcomes. First-person reflective writing is new to these students, and teaching this writing genre is new for fisheries educators. After any class exercise is completed, it would make sense to ask students to respond to a prompt, "In what ways did this learning activity assist you in becoming a better fisheries student?"

Each student in the Invent the Sustainable Future class creates their own digital narrative using any number of broadly available tools, such as eP@VT, Weebly, Wix, Google Sites, or WordPress. These digital Web 2.0 skills are easily transferable to other learning settings, and at least some first-year students chose to write personal blogs to document learning experiences in subsequent internships. Scholars agree that "the process of reflection required by assembling an e-portfolio is central to its impact on learning" (Cambridge 2010:103). By encouraging creativity and control in what the student shares and how they reflect on their experiences, this pedagogy adheres to many principles of good instructional practice (Chickering and Gamson 2002). As Randy Bass writes, "The technology of e-portfolios, though enabling or inhibiting, is not the crux of the 'it' that makes e-portfolios effective. E-portfolios are at the heart of a set of pedagogies and practices that link learners to learning, curriculum to the co-curriculum, and courses and programs to institutional outcomes" (Bass 2014:35).

Orth became convinced of the value of reflection afforded by creating an e-portfolio only after he took the time to create his own teaching portfolio (tinyurl.com/DonsTeaching). Although Orth created the e-portfolio in order to demonstrate the technical aspects to his students, he learned from reflecting on his many teaching experiences. Virginia Tech was also one of 24 campuses in a Funds for the Improvement of Post-Secondary Education project focused on exploring e-portfolio strategies to advance student, instructor, and institutional learning. The project focused on the question, "What difference can e-portfolios make?" Very simply, across multiple campuses, the use of e-portfolios advanced student success, supported reflection and deep learning, and catalyzed learning-centered institutional change (Eynon et al. 2014).

Making Learning Personal

Orth also teaches ichthyology, an upper-division course taken by all fisheries majors and some wildlife conservation and biological sciences majors. In this class, students create a lab notebook, an age-old proven technique, to document their laboratory observations. Although many of us kept lab and field notebooks in the 1960s–1980s, this practice appears to have fallen out of favor in many undergraduate programs. Constantine Rafinesque, a French naturalist, in his 1820 treatise, *Ichthyologia Ohiensis*, wrote that "the art of seeing well, or noticing and distinguishing with accuracy the objects we perceive, is a high faculty of the mind, unfolded in a few individuals, and despised by those who can neither acquire it, nor appreciate its results" Rafinesque (1820:1). Observation and sketching skills can and must be taught and practiced by novice students when they observe unknown specimens. These teaching methods are both supported by neuroscience and widely used in other fields (Edwards 2012). In Orth's class, students are encouraged to record their thoughts as they examine specimens during lessons on anatomy, adaptation, species identification, and use of dichotomous keys. The lab notebook is a repository for the students' drawings, annotations, photographs, and reflective writing on how their observations relate to their existing knowledge. Adoption of these, or similar, web-based applications puts the student in charge of learning, allows for further student questioning or commenting, and potentially continues the learning community beyond the confines of an academic term.

This interaction via scientific information, commentary, and positive feedback helps foster a public understanding of the need for both science and esthetics in angling.

John Dewey wrote, "We do not learn from experience, we learn by reflecting on experience." Placing the student at the center of learning activities means that we must teach them to reflect on their experiences. In doing so, we as instructors are invited into their world, a world of dreams, difficulties, and confusion. The act of writing a personal narrative is not as simple as it would seem. Gibbs (1988) advocates the use of "What?," "So What?," and "Now What?," questioning stages to encourage genuine reflection, given that student responses to prompts typically result in a mere description of "What" and little more. For effective learning, students need to tell the "rest of the story."

Many press interviews begin with questions, such as "Tell me a story about…," and students are usually not prepared to tell the story. In the ichthyology class at Virginia Tech, Orth asks students to "create" a video story "On Becoming an Ichthyologist" about how they became better students of the study of fishes. Creation is one of the highest levels of Bloom's Taxonomy and represents active learning. These student stories rely on reflections from their lab notebooks along with notes about images and post-test reflections, and the exercise is a form of active multimodal learning. Students write a script that is approximately three minutes long, which is then recorded using Audacity, a high-quality free audio editor (audacity.sourceforge.net). One need not rely on computer software, though, because most smartphones have reasonable quality recording microphones. The students then use Movie Maker or iMovie to create the video story by combining audio files, images, video clips, and sound, just as we have described for the student karaoke videos used by Grossman. The final product is uploaded to YouTube and graded with a rubric similar to that for Grossman's karaoke video exercise, with a focus on creatively and accurately telling your story as well as technical proficiency. Although Orth has not evaluated these new pedagogical approaches statistically, he has noticed improved student attitudes and engagement in class activities, which has also been reflected in student evaluations (personal observation).

Digital Platforms as Outreach Resources: Troutnut.com

We have focused on both undergraduate and graduate education in previous sections; nonetheless, fisheries professionals also frequently interact with members of the general public. Certainly personal contact is a superb way to impart fisheries education to the public; however, web-based platforms have the advantage of being available 24 hours a day and are not limited by the physical separation of instructor and student. In 2003, Neuswanger created a fly-fishing entomology website (www.troutnut.com) that has grown into a comprehensive reference site for aquatic insect identification and life histories. The site also serves as a discussion forum where scientifically-minded fly anglers and angling-oriented scientists discuss their mutual passion. As of November 2015, the community has about 6,100 registered users, of whom 1,400 individuals have contributed 38,000 posts to the forum. Since March 2006 when tracking began, the site has served about 15 million page views to 3.2 million unique visitors from every country in the world except the Central African Republic, Western Sahara, and North Korea.

The website uses the advantages of digital media to build upon a tradition of printed books about fly-fishing, especially those describing the appearance and behavior of insect prey. Fly fishers commonly accept that trout feeding voraciously on a single abundant food source (such as a concentrated emergence of mayflies) will sometimes only strike an imitation that "matches the hatch" in key aspects of its appearance (e.g., size, shape, color) and behavior (e.g., drifting versus swimming or emerging versus egg-laying). Dedicated anglers and fly tiers may study their local insect species' appearance, life history timing, habitat, and behavior (emergence, mating, egg-laying), all to facilitate being at the right place, at the right time, with the right fly, presented in the right manner to catch difficult trout. Troutnut.com was born of the realization that this educational genre could greatly benefit from a centralized and interactive information resource using new technology.

Unconstrained by the limitations and expenses of the printed page and film photography, Neuswanger was free to assemble and publish an *Aquatic Insect Encyclopedia* of photos (currently 4,359 pictures of 1,022 specimens), combined with detailed notes on common species' life history and behavior. The forum section of the site is integrated with the *Encyclopedia* to enable participants to share insights or questions on the page for each taxon. These exchanges encourage readers to learn aquatic entomology via the practical application of scientific knowledge to angling success. This interaction via scientific information, commentary, and positive feedback helps foster a public understanding of the need for both science and esthetics in angling.

In addition to the taxon-specific discussions attached to the Aquatic Insect Library, conversations on the forum range from the amusing (topic title: "And then I hooked the friggin bat"), to fly fishing tactics ("fishing nymphs, then emergers, then low duns, then high duns"), to discussions on animal cognition ("educated fish?") and trout management ("trout stream improvement"). Web forums such as troutnut.com may be expected to occupy a lasting niche as meaningful vehicles for in-depth discussions among scientists, managers, and the general public.

However, digital forums also serve as mechanisms for scientists to engage in citizen science and educate the public. For example, an entomologist used the troutnut.com forum to recruit volunteers to contribute samples to a DNA barcode library for

North American mayflies (Ephemeroptera; Webb et al. 2012). Other taxonomic specialists have used the forum to explain the taxonomic criteria for reclassifications of photographed specimens and otherwise educate readers about insect identification. Educators ranging from agency public outreach personnel to professors designing college courses have used the *Aquatic Insect Encyclopedia* text and photographs, sometimes with input from forum members, to prepare instructional materials. Troutnut.com demonstrates how scientific information transmission and constructivist (learner-driven) knowledge (Habron 2005) may occur through interactions among scientists, managers, and the public.

CONCLUSION

In this article, we advocate the use of several relatively new approaches to fisheries education, as well as the use of digital platforms, to communicate science to the public and serve as mechanisms facilitating citizen science. It is our hope that further pedagogical innovation will result in fisheries having a "signature pedagogy" as described by Shulman (2005:52). Although there is nothing inherently wrong with passive educational approaches in fisheries, especially when employed by inspired teachers, we would encourage educators to avail themselves of active and multimodal learning methods, not only for their pedagogical advantages, but because of the clear benefits they evoke with respect to student engagement and attitudes toward classwork (Handelsman et al. 2007; Grossman and Watson 2015; Grossman and Richards, in press). Ultimately, it is likely that these techniques also result in an increase in learning and retention. The use of innovative techniques and technologies such as video, e-portfolios, and web-based platforms is a way to facilitate improved instruction in a time of decreasing support for public universities (Bowen 2012), which are the home of most fisheries programs in the United States and Canada.

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SPECIAL COMMITTEE ON EDUCATIONAL REQUIREMENTS

Examining the Relevancy and Utility of the American Fisheries Society Professional Certification Program to Prepare Future Fisheries Professionals

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INTRODUCTION

Fisheries science is a diverse field that requires individuals to be knowledgeable in many disciplines in addition to fisheries (e.g., economics, sociology, political science, chemistry; Kelso and Murphy 1988). This challenges students attempting to enter a career in fisheries, as well as academic institutions and eventual employers, to develop both depth and breadth of knowledge needed to succeed in the profession (Oglesby and Krueger 1989). The preparedness and competency of young professionals entering the workforce has long been a problem (Stauffer and McMullin 2009). Several constraints and ongoing challenges facing the profession have continued to magnify these issues over time (McMullin et al., this issue). These issues stem from the diversity of skills required or expected across employer groups (e.g., government agencies, private sectors, nongovernment organizations) and degree levels sought (B.Sc., M.Sc., Ph.D.), complexity of fisheries-related problems, and balancing a broad academic focus with specific training. Additionally, employers perceive that students lack well-developed critical thinking, communication, and statistical skills that are highly desired in any area of fisheries.

The American Fisheries Society's (AFS) mission of preparing and promoting the development of fisheries professionals has been addressed in many ways, including development of the AFS Professional Certification Program in 1963. This program provides minimum standards for which fisheries professionals are recognized across government, academic, and nongovernment entities. The certification program fosters greater recognition that fisheries professionals are well equipped and prepared to act on the public's behalf concerning fisheries-related issues. Two tiers of certification exist, with first-tier certification (Associate Fisheries Professional) contingent upon the completion of higher education courses in six broad subject areas. In this article, we focus on the first tier of certification, the basic education determined by AFS to be critical in preparing young professionals for a career in fisheries. The second-tier certification (Certified Fisheries Professional) expands upon academic requirements to include minimum professional experience and development standards; therefore, we do not evaluate this second-tier level of requirements.

In addition to the benefits of AFS professional certification (see Goldberg 2011; Long and Slaughter 2012; Essig 2016), certification serves as a standard for developing curricula across many university programs (Bonds et al. 2014). Thus, certification has widespread consequences relating to the coursework and training many young professionals receive prior to entering the workforce. To remain relevant, the certification program must be dynamic in delineating the skills and knowledge required to be effective in a fisheries-related profession. Thus, developing curricula to meet these needs is extremely challenging (i.e., broad vs. specialized or liberal arts vs. science-oriented classes; Oglesby and Krueger 1989; Bleich and Oehler 2000).

AFS is in a unique position to evaluate and address concerns involving preparedness and quality of newly hired young fisheries professionals. These concerns could be addressed and perhaps alleviated in part through the AFS certification program and a restructuring and revision of course curricula, among other avenues (see McMullin et al., this issue). However, first we must identify where, or whether, employers' needs and expectations diverge from the AFS certification requirements and, if so, identify potential options for AFS and the program to remain relevant. Three specific objectives are addressed and explored concerning this topic: (1) examine whether there is a misalignment with AFS certification course requirements and employer desired skills and knowledge; (2) identify where this misalignment occurs, if it exists; and (3) offer suggestions

Table 1. Major subject areas defined by the AFS Professional Certification Program, the number of semester credits or quarter hours required for Associate-level certification, and course examples for each subject area. Please see the AFS Professional Certification Program document for more details (fisheries.org/docs/wp/AFS-Professional-Certification-Program-description.pdf).

Subject area	Semester credits or quarter hours	Course examples
Mathematics/statistics	6 or 9	Courses pertaining to calculus and statistics
Human dimension	6 or 9	Human dimensions of natural resources, policy, planning, administration, law, ethics
Communication	9 or 13	Composition, technical writing, verbal communication
Fisheries/aquatic sciences	12 or 18	Fisheries science, limnology, oceanography, fisheries management, aquaculture
Physical sciences	15 or 23	Chemistry, physics, soils, geology, hydrology, earth science, astronomy, meteorology
Other biological courses	18 or 27	Biology, ecology, evolution, genetics, conservation biology, wildlife management

for how to remedy disconnects and potentially use the AFS certification program to better equip young professionals. Results presented here were part of a larger study that surveyed AFS members to address the importance of job skills and knowledge of recently hired fisheries professionals (see McMullin et al., this issue). A subset of that information is used here to compare AFS certification coursework requirements at the Associate Fisheries Professional level with employer-based desired job skills and knowledge necessary for an entry-level position.

METHODS

Survey respondents were asked to rate the importance of six academic study categories corresponding to those outlined in the Associate Fisheries Professional AFS certification program. Importance ratings for each academic study category were provided across degrees sought (B.A./B.Sc., M.A./M.Sc., Ph.D.). These results were compared to the number of credit or quarter hours necessary for certification (Table 1). Survey ratings (see McMullin et al., this issue) and the number of certification credit hours were converted to a ranking, therefore allowing direct comparisons between these two data sets. Certification credit hours were ranked across all six categories based on the total number of hours required within each category. This assumes that importance is positively related to the number of credit hours required. Survey ratings were ranked according to the mean importance rating of each of the six categories across entry-level hires at the B.Sc., M.Sc., and Ph.D. levels. A composite ranking was also tabulated that included all degrees, reflecting overall importance ratings within the profession for each academic study category. We compared importance rankings between the AFS certification program and the survey results using the Kendall's tau correlation test in R 3.2.3 (package = 'Kendall'; R Development Core Team 2015). Therefore, if importance rankings were similar between the AFS certification program and survey results (i.e., composite, B.Sc.-, M.Sc.-, and Ph.D.-level responses), we would expect a strong positive (correlation coefficient) and significant ($\alpha = 0.05$) relationship.

RESULTS AND DISCUSSION

The skills or specific knowledge desired by employers for newly hired fisheries professionals did not align with the AFS Professional Certification Program (Table 2). Composite (across all degrees) survey rankings were unrelated to the AFS certification program rankings (Kendall's tau = −0.28; $P = 0.56$). This misalignment is further reflected across B.Sc. (Kendall's tau = −0.41.; $P = 0.34$), M.Sc. (Kendall's tau = −0.41; $P = 0.34$), and Ph.D. (Kendall's tau = −0.28; $P = 0.56$) educational levels. The composite AFS membership survey results rated communication and mathematics/statistics (hereafter statistics) categories much higher than the AFS certification course requirements. Alternatively, the AFS certification program placed greater importance on the physical science category compared to the AFS survey composite results. Importance rankings were more similar for course categories relating to human dimensions, fisheries, and other biological disciplines (Table 2).

The six academic study areas had similar relative importance rankings at both B.Sc.- and M.Sc.-level hires but differed at the Ph.D. level (Table 2). Employers ranked statistics, human dimensions, and communication categories at the B.Sc. and M.Sc. level higher than what is reflected in the AFS certification program. In contrast, physical science and other biological disciplines were given a lower ranking than the AFS certification program. The Ph.D. and composite rankings of the six academic study areas were more similar to the AFS certification program rankings compared to B.Sc.- and M.Sc.-level rankings, although all were unrelated to the AFS certification program.

Major areas of concern include employers placing a higher emphasis on communication and statistical coursework and perhaps less emphasis on general coursework (see Gabelhouse 2010). These general biological or physical science courses contribute most of the non-aquatic credit hours to the certification process (Table 1) but were not rated as important as other subject areas according to the survey results. These findings were not especially surprising considering that most other biological or ecological disciplines have identified these areas to be extremely important as well (Burger and Leopold 2001; Kendall and Gould 2002; Millenbah and Wolter 2009). In addition, the physical sciences category acts as a "catch-all" category for non-biological and aquatic courses and is very diverse itself (e.g., chemistry, physics, hydrology, geographic information systems). The challenge remains to properly balance the broad focus of most academic programs while also delivering specific training in areas most important to future employers, such as statistics and written/verbal communication skills.

Importance rankings differed across individual degrees with respect to subject area. This seems intuitive given that most B.Sc.- and M.Sc.-level positions are management (and not research) focused, requiring different skills and knowledge. For example, human dimensions was ranked higher for B.Sc.- and M.Sc.-level positions compared to Ph.D.-level positions. Management biologists likely confront human dimension issues more frequently than positions that are more research oriented (e.g., academic, research biologist). Perceived performance in these subject areas was also higher for professionals with graduate degrees (M.Sc. and Ph.D.) compared to those with an undergraduate degree (McMullin et al., this issue). This

Table 2. Course categories and importance rankings (1 = most important; 6 = least important) according to the AFS Professional Certification Program and the AFS membership survey (see McMullin et al., this issue). A negative difference corresponds to a higher importance ranking in the survey compared to the certification process, whereas a positive difference reflects the opposite. Differences were calculated by subtracting the survey ranking from the certification ranking (i.e., the standard). Mathematics/statistics and human dimension categories require the same number of credit hours in the AFS certification program and thus were assigned a value of 5.5, representing the average ranking.

Category	Composite survey ranking	B.Sc. survey ranking	M.Sc. survey ranking	Ph.D. survey ranking	Certification ranking (AFS)	Composite difference	B.Sc. difference	M.Sc. difference	Ph.D. difference
Mathematics/statistics	2	3	2	2	5.5	−3.5	−2.5	−3.5	−3.5
Human dimension	4	2	3	4	5.5	−1.5	−3.5	−2.5	−1.5
Communication	1	1	1	1	4	−3	−3	−3	−3
Fisheries/aquatic sciences	5	5	5	5	3	2	2	2	2
Physical sciences	6	6	6	6	2	4	4	4	4
Other biological courses	3	4	4	3	1	2	3	3	2

further strengthens the utility and importance of pursuing the appropriate degree (and associated knowledge and skill sets) for obtaining the desired career within this diverse profession (Kaemingk et al. 2013). Currently, it appears that AFS certification program requirements align better for young professionals entering a fisheries career at the Ph.D. level rather than at the B.Sc. and M.Sc. levels, the education levels required for the vast majority of fisheries jobs.

The next step is to identify how best to reconcile this misalignment, if necessary. AFS has options available to encourage new fisheries professionals to bridge the identified gap through the AFS certification program. Options available are discussed in the following subsections.

Modify the AFS Certification Program Coursework Requirements

This approach would include requiring more statistical, communication, and human dimensions coursework and reducing the total number of credit hours in the physical and other biological science categories. Some of the general biological and physical science courses could be retained without a major sacrifice in the overall requirements, considering these categories comprise 50% of the current coursework (Table 1). For example, reducing the total biological science credit hours from 18 to 9 would still allow three courses (three credits each) to be offered without entirely compromising this subject area. This would free up credits for the aforementioned subject areas that were ranked higher in importance. The most difficult challenge would be allocating how many credits should be added within each category without compromising the broad academic focus and becoming too specialized in these areas (Oglesby and Krueger 1989), despite their perceived importance. This may not be feasible either because many smaller universities or liberal arts colleges do not have human dimension specialists to offer the additional courses required by this revision of the AFS certification program.

Another option could be to create separate “tracks” that would better accommodate both the broad nature of fisheries and the degree level sought. Although more complex than the first option, this would allow students the flexibility to seek a track that would better align with the needs of eventual employers. For example, students seeking private employment at the B.Sc. degree level could seek coursework that prepares them for this field as opposed to a one-size-fits-all AFS certification program (i.e., the current model). Alternatively, modifying the AFS certification program to more closely align with composite survey rankings would be a major improvement without a drastic loss in the preservation of individual degree differences.

Supplement or Create Flexibility in the AFS Certification Program Requirements

This option would consider implementing other requirements besides coursework or creating flexibility in the program to become certified, similar to the Certified Fisheries Professional level (i.e., second tier). For example, extending certification at this level beyond just coursework could bridge this gap and better prepare students for a career in fisheries (Kroll 2007). The deficiency in communication skills could be improved by giving professional talks or presenting posters at conferences, participating in local outreach events, or publishing popular articles—or some combination of these (Gabelhouse 2010). However, many of these activities are often completed at the graduate level where more specialized training occurs (Hard 1995). Concerns about the narrow focus or training stemming from option 1 (above) could be alleviated with this strategy, which would combine the broad academic focus with the additional requirements or experiences desired by employers.

The certification requirements at the associate level are quite stringent with respect to which courses are required and that these courses must be provided through an accredited university or college. It may be advantageous to build in some flexibility in how these requirements are met by providing opportunities through the use of work experience, continuing education courses, or other related avenues to count toward certification at this level. This may also encourage and provide options for those who did not meet the course requirements during their educational training (e.g., small liberal arts college) but are reluctant to enroll in university courses (to achieve certification) because of other constraints (e.g., time, money, job responsibilities).

The potential drawbacks of this option would be standardizing or evaluating these activities across applicants and selecting which activities should qualify toward certification, although adding presentations at state, regional, or national/international meetings could likely be incorporated with minimal difficulty. Additionally, current students already face several constraints to graduating in a timely manner and securing full-time employment (Bound et al. 2012); therefore, adding more requirements may not be the best option if certification is to be achieved upon completion of a bachelor’s degree.

Graduate-level experiences should provide ample opportunity to acquire any needed, missing, or additional AFS certification requirements.

Do Not Modify, Supplement, or Create Flexibility in the AFS Certification Program Requirements

The last option would be to refrain from revising or adding to the current AFS certification requirements. This would be the easiest option, but perhaps it would ignore a critical weakness in newly hired fisheries professionals that could be addressed in part through the AFS certification program. After all, the certification process provides many universities with an existing framework for curriculum development. Alternatively, one could argue that the number of courses required for communication, human dimensions, and statistics are currently adequate but reflect deeper issues unrelated to the number of classes within these categories (Oglesby and Krueger 1989). These areas are consistently addressed and regarded as deficient among newly hired professionals within ecology and natural resource disciplines and simply adding more coursework may not help (Kendall and Gould 2002; Millenbah and Wolter 2009) and may not be needed. Considering the broad nature of the fisheries profession, it may be difficult to find employees with an interest and skills relating to communication, human dimensions, and statistics while also performing highly in all other areas required to be effective professionals (e.g., fisheries knowledge, field skills, critical thinking; Johnson et al. 2001).

CONCLUSIONS

AFS should play an active role in identifying which skill sets and specific knowledge fisheries employer groups are seeking in order to remain relevant for new fisheries professionals, as well as for the university programs that use the AFS certification requirements when developing academic programs of study. This responsibility remains especially critical as AFS strongly promotes the development of fisheries professionals. Though most survey respondents generally placed greater responsibility on university programs and employers themselves (McMullin et al., this issue), AFS can and should remain active in this area. A particular finding worthy of further exploration within AFS is how the certification program appears to better match preparation of entry-level professionals at the Ph.D. level than at the B.Sc. and M.Sc. levels. One could argue that the focus should be on the B.Sc. and M.Sc. levels because they represent a disproportionate group of trained professionals within fisheries and AFS. Therefore, striving for equity across educational levels will remain important for long-term relevancy and utility of the AFS certification program. We can use information collected through the membership survey and consider all options to better prepare future fisheries professionals for a career in this highly diverse field. Important skills and knowledge identified in this survey are likely to change through time as fisheries and environment-related problems become more interdisciplinary in nature and complex (Lubchenco 1998). Given that the AFS certification program was last revised about 20 years ago (1997), it may be timely to consider revisiting the curriculum and making the appropriate changes. Any changes applied to the certification program should be evaluated and monitored to ensure that the certification process and overall benefits have been improved (Pegg et al. 1999). Thus, by taking a proactive approach we can continue to strive as a Society to set standards that improve the conservation and sustainability of fisheries and aquatic resources through the existing AFS certification program. Equipping young professionals to face these challenges and become highly effective within any fisheries-related job should remain a primary focus of AFS (Boreman 2012).

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SPECIAL COMMITTEE ON EDUCATIONAL REQUIREMENTS

U.S. Federal Fish Biologist Educational Requirements

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The United States Office of Personnel Management (OPM) sets standards for U.S. federal government jobs. Federal positions with similar occupational requirements are placed into categories within a General Schedule (GS) by OPM. Federal fisheries professionals work within many different job classifications, including fish and wildlife biologist, fish and wildlife administrator, statistician, oceanographer, and ecologist; however, the predominant one is fish biologist in the GS-482 series. The OPM occupational requirements include both formal education and work experience, but this article focuses on the educational requirements.

Basic educational requirements differ between fish biologist nonresearch and research positions (Table 1). Applicants for nonresearch positions must have a bachelor's degree in biological science with 6 semester hours in aquatic subjects and 12 semester hours in the animal sciences. It is also possible to have a combination of appropriate experience and education that includes at least 30 semester hours of courses equivalent to a biological science major. Applicants for research positions must have a bachelor's degree in biology, zoology, or biological oceanography that includes at least 30 semester hours in biological and aquatic sciences and 15 semester hours in the physical and mathematical sciences. These science educational requirements line up well with AFS professional certification educational requirements (Kaemingk et al., this issue).

Most federal positions include duties for which academic requirements in the technical subjects described above are clearly needed. For example, someone working on fisheries stock assessments would obviously need strong quantitative training. A fish culturist would need to have knowledge of cultural techniques plus fish health and genetics training. So even though a job applicant could meet the basic fish biologist academic requirements, he or she would not necessarily be successful in getting such a position.

The fish biologist basic educational requirements do not prescribe training for the "softer skills," such as communications, decision making, and critical thinking, that employers surveyed in 2014 placed a high value on for new hires (McMullin et al., this issue). There are at least two possible explanations for this. One might be simply that OPM assumes that these topics are covered within the general educational requirements for bachelor's degrees. All universities require written and oral communications courses, but schools employ a variety of academic approaches to provide training in the softer skills.

The other possible explanation for the softer skills not being prescribed in the fish biologist educational requirements has to do with the job application process. The softer skills are often specified within the duties and corresponding knowledge, skills, and abilities for positions. For example, a fish biologist who prepares biological opinions or environmental assessments would clearly need strong writing skills. A fish biologist who negotiates fish passage with dam owners would need to be a good critical thinker and problem solver. In addition to being obvious within the duties, these softer skills would also be part of the self-assessment questions that applicants rate themselves on. Finally, the softer skills could be drawn out during applicant interviews through behavioral-based questions.

The OPM should add the softer skills to fish biologist educational requirements to better reflect employer expectations. At a minimum, there should be 9 semester hours in communications to match AFS professional certification requirements. There should also be consideration of adding 6 semester hours in human dimensions coursework as per certification requirements. The OPM should also consider providing examples of general education courses that teach the softer skills similar to the list of appropriate courses for the various science categories (Table 1). Doing so would provide excellent guidance for students for completing their general education requirements while preparing for careers in fisheries.

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Table 1. Examples of subjects within required categories of coursework for the U.S. Federal Fish Biologist GS-482 job series.

Nonresearch positions		Research positions		
Aquatic subjects	Animal sciences	Fishery biology	Zoology	Physical and mathematical sciences
(6 semester hours)	(12 semester hours)	(6 semester hours)	(15 semester hours)	(15 semester hours)
Limnology	General zoology	Fishery biology	Invertebrate zoology	Chemistry
Ichthyology	Vertebrate zoology	Ichthyology	Comparative anatomy	Physics
Fishery biology	Comparative anatomy	Limnology	Histology	Mathematics
Aquatic botany	Physiology	Oceanography	Physiology	Statistics
Aquatic fauna	Entomology	Algology	Embryology	
Oceanography	Parasitology	Planktonology	Advanced vertebrate zoology	
Fish culture	Ecology	Marine ecology	Genetics	
	Cellular biology	Freshwater ecology	Entomology	
	Genetics	Invertebrate ecology	Parasitology	
	Fishery population dynamics			

Where Do We Go from Here? ICE Connects Employers and Educators to Bring Fisheries to the Next Level

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Though AFS and ICE do not prescribe that universities should seek to shape academic programs specifically to train students only for future employment, we do think that it is critical to the profession that education and employment are not viewed in isolation.

The AFS Special Committee on Educational Requirements completed most of the tasks assigned by AFS Past President John Boreman in 2013. However, there was not sufficient time for the committee to address whether course requirements for employment in the federal sector and fisheries professional certification concurred with employer needs and expectations.

The Education Section chartered a new committee, the Intersectional Committee on Education (ICE), to pick up where the AFS Special Committee on Educational Requirements left off and address these important fisheries education–employment-related issues. The charge for ICE is threefold: (1) assess whether the current professional certification standards match with employer needs; (2) examine the need, feasibility, and best practices for academic program accreditation in fisheries; and (3) determine whether a need exists to develop standard screening and/or hiring operating procedures tied to the federal KSA (knowledge, skills, and abilities) application process so that employers know whether or not their best applicants made it through initial screening. To address this charge, ICE membership includes individuals representing a diverse array of AFS Committees and Sections with an interest in fisheries education and employment, such as the Professional Certification Committee (Wuellner), Fisheries Management Section (Phelps), Fisheries History Section (Jackson), Education Section (Sutton), Continuing Education Committee (Jolley), and an AFS member at-large (Reynolds). The intent behind the composition of ICE is broad Society-level representation and diversity, so any AFS Committee or Section not listed above but with an interest in serving this mission should contact ICE Chair Trent Sutton with a nomination and/or volunteers. The ICE will evaluate current professional certification requirements, federal KSA application requirements, and potential for academic accreditation of universities and colleges that offer fisheries degree programs. University programs seek to offer students educational opportunities that cultivate critical thinking and a solid foundation for applying learned skills and knowledge to future jobs. Though AFS and ICE do not prescribe that universities should seek to shape academic programs specifically to train students only for future employment, we do think that it is critical to the profession that education and employment are not viewed in isolation (Chapman 1979; Lackey 1979). Therefore, the principal goal of these evaluations is to assist employers to meet their needs for hiring well-educated and skillful fisheries scientists. The ICE will develop recommendations for (1) potential modifications to the certification guidelines for fisheries professionals, (2) strong KSAs that facilitate federal employers in identifying the best applicants for open positions, and (3) academic program accreditation. Although a final time frame for these recommendations has not been set yet, we anticipate that the completion of this evaluation to take place over the next one to two years.

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PERSPECTIVES

INTERNATIONAL FISHERIES SECTION

Preparing for International Research and Teaching

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Many international projects start from previous contacts made at conferences, during which a sense of common interest and personal trust is built.

Members of the International Fisheries Section of the American Fisheries Society are an extremely diverse group, representing many fisheries disciplines and nations. We have common interests in the biology, management, and conservation of fisheries on a global scale and promote the interaction of fisheries and aquatic science professionals worldwide. There are several steps to effectively work internationally, and we believe that some of the best preparations include learning another language; learning to appreciate the cultures where that language is spoken; participating in international research projects, workshops, and symposia; and remaining in contact with international colleagues via electronic media. Many international projects start from previous contacts made at conferences, during which a sense of common interest and personal trust is built (e.g., Hughes and Kaufmann 2014). Other opportunities may arise from consultancies and internationally funded projects obtained via a bidding process.

An international fisheries scientist should have an open mind to overcome language and cultural challenges. Although many fisheries scientists begin international work later in their careers, early career scientists can gain critical field and communication skills. Even if you have only rudimentary skills in another language, those skills help you break the ice and demonstrate an effort of taking part at a broader level when working abroad. An open mind and a large dose of tolerance for differences in writing skills, grammar, and technological expertise are needed to ensure that work plans, proposals, and reports are clear and goals are met.

English has become the universal language of science (Hughes et al. 2014), and if you are not a proficient English speaker, there are now many programs worldwide to assist you in improving your English-speaking skills. Acquisition of another language will assist in preparing you to learn new approaches and perspectives about fisheries and ichthyology.

Improving language skills will help you to understand and communicate about local or regional fish conservation issues and management efforts throughout the world. Those experiences, arising from a broader view of the world, will provide you with greater knowledge to aid you in finding answers to your questions.

Although language is a fundamental skill, more subtle matters include learning differences in cultural protocols, dress codes, acceptable work hours, and acceptability or unacceptability of gender equality (sometimes requiring a male or female colleague). To thrive in another country, one must be knowledgeable about diplomacy, local working protocols, and health and safety issues. International partnerships and time spent in another country can provide personal gains that go beyond the scientific exchange. Such immersion in another culture makes it possible to examine your worldview, including the science that you do, from another perspective. Before traveling to foreign lands to conduct research, it is helpful to find a mentor or colleague who can steer you through the cultural differences and help you avoid unwitting cultural mistakes that may hinder project goals. In addition, it is advisable to establish contact with people in your community who have had previous experience in the cultures where you plan to work. They will provide you with key information to better navigate a new culture. Adjusting to local food, religious schedules, and work ethics not only will help you be appreciated in host countries but will enrich your own experience. Moreover, fisheries is a very broad science, incorporating multiple biological, physical, and chemical disciplines, as well as socioeconomics, ecosystem services, and ecosystem science. Therefore, it is wise to have some understanding of those sciences—instead of a single simplistic fish or ichthyology focus (e.g., Cedarholm et al. 1999; Yeakley et al. 2016). Because many initial scientific visits are expensive and short, it is critically important that you be organized and clear about what you and your partners plan to produce out of an international relationship, in the medium or long term. If possible, the international relationship should be official, by means of an agreement between institutions or a grant or contract; such agreements can reduce many bureaucratic challenges and misunderstandings. Of course, it is helpful to develop those skills in science, collaboration, partnership, and organization in your homeland first, or by shadowing an experienced mentor, before venturing out internationally on your own.

Being involved internationally really means being respectful and having a desire to listen, learn, and share your experiences with others. The ability to provide a positive impact scientifically, as well as a positive impression from your home culture/nation, can be a powerful tool in building international relationships. It is critically important not to simply drop in, exploit others' knowledge, and depart forever (Hughes and Kaufmann 2014; Chapman et al. 2015). You must be willing to share data and knowledge; otherwise, we all will continue living in our own small bubbles, publishing only local research of little global importance. It is crucial to not treat any relationship as a mere data-gathering exercise but to work collaboratively and synergistically with the partner. Leave a legacy from your collaboration, in terms of either training, improved research techniques, or efficiencies in data collection and analysis. Well-developed collaborations are long lasting and mutually beneficial and, most of all, rewarding.

Being involved internationally really means being respectful and having a desire to listen, learn, and share your experiences with others.

To collaborate most effectively, one must develop skills at obtaining funding for foreign travel, research, and teaching. Funders increasingly realize that the benefits of collaboration and interchange are more valuable than just the scientific questions being addressed. This is particularly the case across markedly different regions and with respect to management of highly migratory species and the sustainability of fisheries for food security and livelihoods. Examples of funding options include the Academia Mexicana de Ciencias for U.S.–Mexico collaboration (www.amc.edu.mx); Australian Fisheries Research and Development Corporation (frdc.com.au); Fulbright Fund (catalog.cies.org); Japan Society for the Promotion of Science (www.jsps.go.jp/english); Marie Curie awards (ec.europa.eu/research/mariecurieactions/apply-now/how-to-apply/index_en.htm); Science without Borders for Brazilian graduate students, professors, and researchers (www.cienciasemfronteiras.gov.br/web/csf-eng; suspended for 2016); and the Small Research Grants and Sponsorships of the Fisheries Society of the British Isles (fsbi.org.uk). Once people are exposed to both local management and academic approaches to fisheries problem solving outside their home countries, they realize that there are solutions to similar problems in their home countries. There truly are local solutions to global problems that can be facilitated through international exchanges and collaborations. Solutions to global fisheries issues require global collaborations.

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Biological and Communication Skills Needed for Introduced Fish Biologists

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What skills and knowledge will a new graduate seeking employment need to work with introduced fishes? Clearly, success in introduced species management—similar to other disciplines in fisheries—requires a mixture of scientific and communication skills. However, specific abilities especially important to a biologist who manages introduced fishes should be highlighted. Unlike most other management strategies, stocking an introduced species can result in unintended and irreversible impacts, so particular care must be employed when stocking is considered. Furthermore, fish populations in areas outside of the introduced species management area might also be affected, usually negatively, if the introduced fish escapes. Therefore, rock-solid knowledge of basic aquatic ecology, including risk management; fish taxonomy (so the wrong fish species is not mistakenly stocked!); familiarity with human values of both the time and the place (which requires communication skills); and a strong understanding of human history are all important.

An effective introduced fish biologist is very conscious of human values, of both the time and place, and how these values can change.

Carrying capacity is an ecological concept important to all introduced (and other) fish biologists. Carrying capacity of a water body is defined as the amount of organisms that can be supported given a finite amount of resources available. When a new organism is stocked, something already in the water body—whether invertebrate, fish, or plant—usually has to decline to make room for the new species. This decline can be small and acceptable or drastic and damaging, depending on both biology and human values. For example, stocking catchable trout in a lake may impact plankton already there. However, if the trout are removed quickly by anglers, the trout do not have the opportunity to spawn or escape because no connecting streams exist, sportfishing opportunities are critically needed, the lake has been stocked with trout for years, and the few trout remaining die during the hot summer, the risk may be deemed acceptable for the value to society. Alternatively, if a new sunfish species is stocked that has a high likelihood to spawn and form persistent populations and is likely to eat sensitive and valued fish, invertebrate, and amphibian species, the stocking can be highly risky and unacceptable.

Strong communication and people skills are employed to choose whether or not to manage for—or eliminate—nonnative fish. An effective introduced fish biologist is very conscious of human values, of both the time and place, and how these values can change. A century (or less) ago, values of European settlers supported introducing a variety of fishes to North American waterbodies to improve fishing or forage. The thinking was something like this, "Could I clear out some of the 'trash fishes' (translate native suckers, cyprinids, etc.) and stock valuable fishes (translate Rainbow Trout *Oncorhynchus mykiss*, Common Carp *Cyprinus carpio*, Largemouth Bass *Micropterus salmoides*, Catfish *Ictalurus* spp.) that everyone is willing to catch and eat?" In the 21st century, human values are more nuanced. People see value in preserving the fishes that are native to streams and lakes—whether or not they can eat or angle for them—because these fishes are important parts of the ecosystem and our heritage, and are rare and unique. Furthermore, people better understand the unintended consequences of nonnative fish introductions. However, they also recognize that nonnative species continue to provide valuable sportfishing opportunities and are important as food, so their overall elimination would not be desirable. Often, waterbodies impacted extensively by humans (impoundments, urban waters) are favored as sites for managing nonnative fishes.

Similarly, evaluating the suitability of a specific site for nonnative vs. native species management also requires a mixture of biological and people skills. The modern fisheries biologist often has to balance two conflicting agendas: Do I manage a waterbody for the unique native species that it supports and that segment of the public who like having them there, or do I manage a waterbody for nonnative fish, which might provide the only valuable sportfishing opportunities to those who desperately need outdoor recreational opportunities? How many water bodies in my area should I manage primarily for native species versus the number that that I manage primarily for nonnative species? What types of water bodies should I manage for what types of fisheries? Making these choices is dependent on the values of the affected public and the biology of both the introduced species and the system.

Knowledge of history is also very important for the introduced fish biologist. North Americans are relatively recent to the practice of managing introduced species. A Greek biologist once told me, "We have been managing introduced species for thousands of years." I was in awe of their experience! Gigantic introduction—and control—programs have happened in various regions of the world for hundreds of years, involving Nile Perch *Lates niloticus* to Common Carp *Cyprinus carpio* to Pacific salmon *Oncorhynchus* spp. A savvy biologist would do well to learn from these events, understanding both their good and bad biological and human consequences.

Where can biologists get training in these important skills? Luckily, the American Fisheries Society provides important overviews (e.g., Fuller et al. 1999; Hubert and Quist 2010; Trushenski et al. 2014) of introduced fish biology and management considerations. Furthermore, simple web searches with introduced species and fisheries as key words reveal dozens of articles and books written on biological and social aspects of species introductions. Examples of communication skills important for fisheries professionals can be found in Bonar (2007), Jacobson (2009), and Bonar and Fraidenburg (2010). Finally, the history of nonnative species in fisheries is long and varied and can be found in many publications, including excellent North American overviews by Allard (1978) and Moffitt et al. (2010). Strong knowledge of potential effects of introduced species management, based on their history and biology, and success in interacting with the public, including evaluating their viewpoint, will serve a new (or experienced) biologist well.

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FISH CULTURE SECTION

National Assessment Sheds Light on Educational Needs for Aquaculture in the United States

Editor's Note: This article is a synopsis of an article published in the September 2015 issue of World Aquaculture *magazine. Visit www.was.org/magazine to access the full-length article.*

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INTRODUCTION

Education and training are fundamental to growing and maintaining a skilled workforce. Diverse, accessible educational opportunities are critical to the success and stability of the aquaculture industry. Ideally, aquaculture education and training blend many different sciences and technical fields germane to extensive or intensive rearing of aquatic organisms in inland, coastal, or offshore environments. Prior to the 1970s, there were few postsecondary institutions in the United States with aquaculture-specific programs (Figure 1). In response to growing enthusiasm for a "blue revolution" and the job opportunities aquaculture was expected to provide, numerous universities invested in new aquaculture-related programs, and student interest and enrollment grew through the 1990s. Graduates of these programs helped to build the U.S. aquaculture industry but are now nearing retirement. The average U.S. aquaculture extension educator, for example, is now in his or her 60s and 70s and transitioning out of professional life (Jensen et al. 2005). Although job opportunities outside of the United States have increased in recent years, new generations of aquaculture professionals are needed to replace retiring domestic aquaculture "baby boomers." Unfortunately, opportunities for education and training appear to be contracting, and even some historically strong aquaculture programs have been allowed to senesce.

An aging workforce, coupled with fewer educational opportunities for younger generations, is clear cause for concern

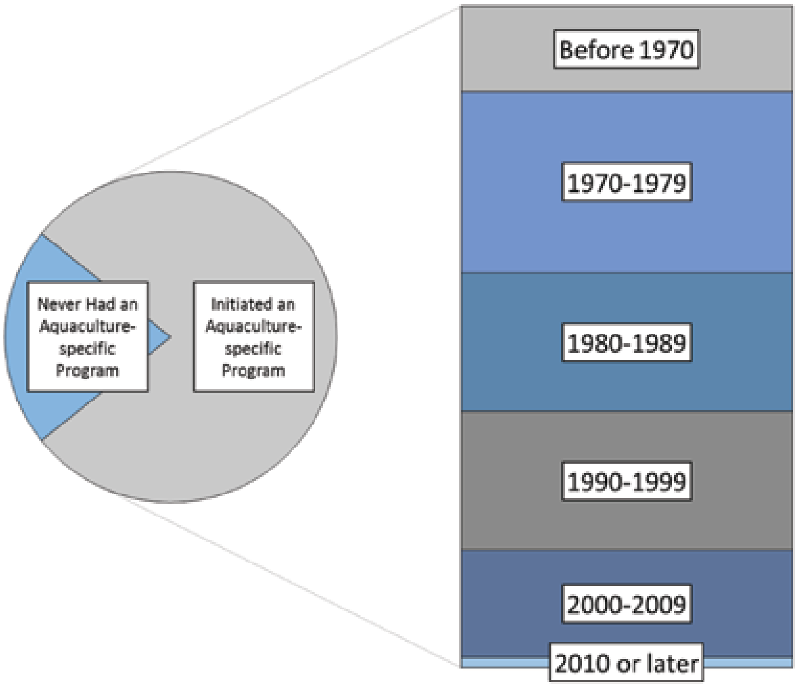

Figure 1. Relative number of the responding institutions (n = 79) that had or had not initiated aquaculture-specific undergraduate or graduate education/training programs and the decade of their initiation.

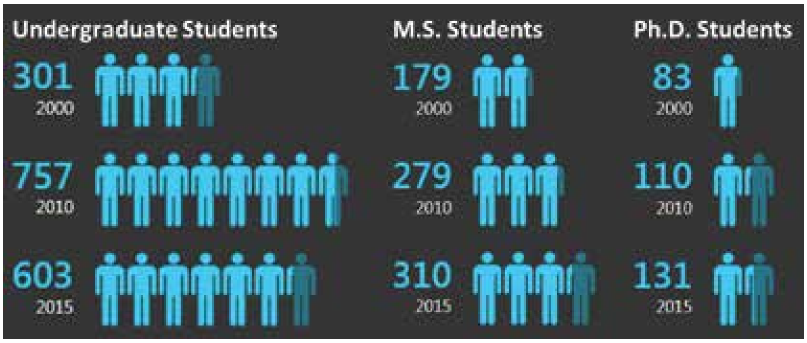

Figure 2. Number of students completing aquaculture-related degree/certification programs in 2000 (completed), 2010 (enrolled), and 2015 (projected). Each person icon represents 100 individuals, and both U.S. and international students are represented. Although international students only represent 3%–6% of undergraduate students, they represent 18%–25% of M.S. students and 35%–47% of Ph.D. students.

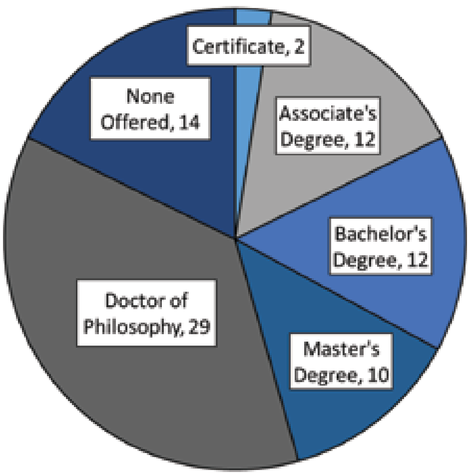

Figure 3. Relative number of responding institutions (n = 79) with aquaculture-specific education/training programs according to the highest certification/degree offered.

in any industry, including aquaculture. 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 among students to pursue aquaculture as a career. To address these issues, the U.S. Department of Agriculture National Institute of Food and Agriculture in collaboration with 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 conducted a national survey. The survey attempted to document aquaculture-related instruction, teaching, and training at postsecondary institutions in the United States. We solicited input from postsecondary institutions across the United States that offer any level of teaching/instruction, including elective courses, subject-matter specialization, diplomas, certificates, or degrees related to aquaculture (88 of 115 institutions responded with information about their programs). Here, we summarize key findings from the project.

RESULTS AND DISCUSSION

Some instructional programs contracted in response to slower growth in the domestic aquaculture industry and fewer job opportunities. In this context, the relatively stable enrollment from 2010 to 2015 may be considered "good news" (Figure 2); however, recruitment problems exist. Fewer international students enrolled in B.S. programs, but international enrollment in Ph.D. programs matched that of U.S. students. A considerable number of institutions still offer some level of instruction in aquaculture (Figure 3), though many are smaller institutions; the creation of new aquaculture programs virtually stopped after 2010 (Figure 1). Declining student interest in aquaculture could significantly affect future institutional capacity through a self-reinforcing feedback loop. Projected patterns of faculty retirement and contraction of aquaculture instructional programs will likely lead to further reductions in student interest and enrollment. A growing number of online course offerings may help to break this feedback loop (Figure 4); however, concerns regarding the ability of U.S. postsecondary institutions to prepare sufficient numbers of adequately trained aquaculture professionals appear warranted. Respondents suggested that employment prospects remain strong, particularly for those with advanced training in aquaculture (Figure 5), but whether an adequate number of students will be able to access the necessary education/training and seize these opportunities is unclear. Our findings reveal considerable interest in initiatives to "teach the teachers" innovative curriculum development techniques and teaching methods to help address this challenge and achieve improved learning outcomes.

CONCLUSIONS

Driven by market forces and public interest, aquaculture will continue to grow and innovate, but the trajectory of the domestic industry will depend upon the presence of a competent workforce to develop, regulate, and sustain what is now the world's most important source of seafood. The United States cannot afford to lose its critical human capital and instructional capacity that has matured since pioneering efforts in the 1960s–1970s. This first-ever assessment offers insights into the diversity and scope of aquaculture instruction at postsecondary institutions in the United States. The data and information can help to identify present needs and serve as a benchmark to monitor trends in future years. Over the past 10–15 years, there have been fewer job announcements specific to aquaculture, especially in the academic and government sectors. Interest among U.S. students to pursue aquaculture training appears stable; however, numerous institutions report challenges in recruiting U.S. students for advanced degree programs. Some institutions remain committed to aquaculture and are actively revamping existing programs and facilities, increasing capacity, and adding courses; others have seen their traditionally strong instructional programs waver or disappear. The ability to create and transfer knowledge is critical, if we are to capitalize on the diversity of animal science, including aquaculture, and improve national and global food security (NRC 2015). We encourage those in positions of influence to consider the future of U.S. aquaculture and the importance of maintaining needed instructional capacity at postsecondary institutions.

ACKNOWLEDGMENTS

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

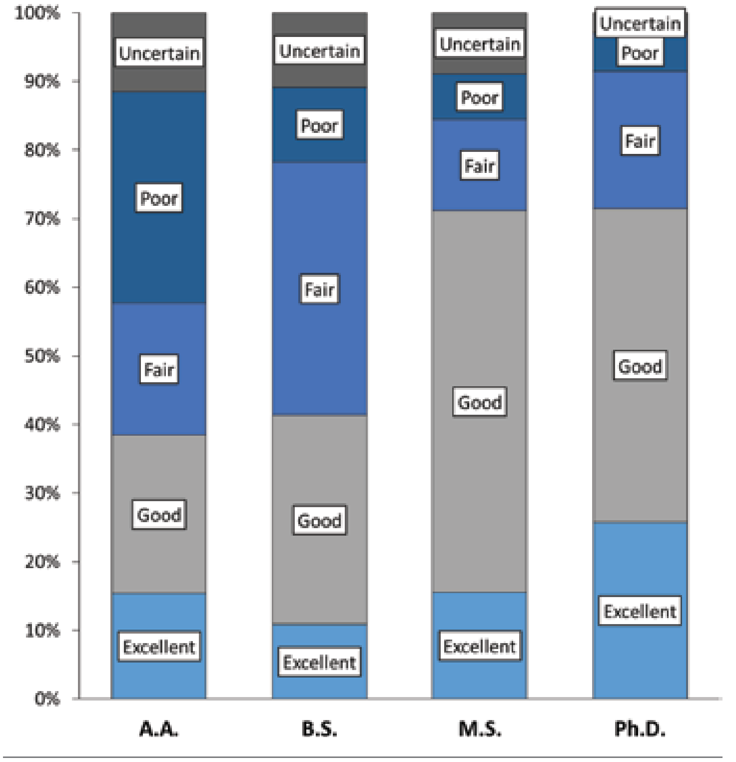

Figure 5. Prospects for job placement for students completing aquaculture-related degree programs in 2010.

EDUCATION SECTION

Are Universities Offering Fewer Fisheries Courses?

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Training of future fisheries professionals has been an issue of importance to the American Fisheries Society (AFS) as far back as 1918, when the Committee on University Courses in Fish Cultural Work was formed (AFS 1919). That committee's report included recommendations for full-term courses specific to the field of fisheries (e.g., ichthyology, limnology, principles and practices of fish culture) to complement more general courses in the sciences (AFS 1920). As societal priorities have changed, so too have the skill sets required of fisheries professionals, and the current issue of *Fisheries* includes the most recent assessment of employer priorities (McMullin et al., this issue). Across multiple disciplines in natural resources, concern has grown that university programs have moved away from offering specialized coursework toward more general courses as broad majors in the environmental sciences have replaced focused majors such as fisheries management (CNRS 2011).

We sought to assess the perceived trend in reduction of courses in fisheries offered by universities by surveying archived course catalogs at 18 institutions identified by Carlander (1970) as at the forefront of establishing specialized fisheries curricula. Though a complete report of our findings will be prepared for a future article in *Fisheries*, we provide here a brief summary of findings. The universities encompassed all AFS Divisions, ranging from two in the Northeastern Division to seven in the North Central Division. We assessed the number of courses offered relevant to training in inland fisheries careers (marine courses were not considered) and included only courses specific to fisheries (e.g., fish ecology but not animal ecology). We surveyed course offerings by decade, starting with catalogs from the early 2010s and moving back by 10-year increments. We were able to trace fisheries curricula from all 18 schools back to the early 2000s; 12 back to the 1990s, 6 to the 1980s, and 3 to the 1970s.

The number of offered courses in fisheries varied across universities and ranged from 5 to 25, averaging 12.1 in the most recent catalogs. Based on the universities we surveyed, the number of fisheries courses offered peaked in the 1990s (mean = 12.7), but we did not see a conspicuous decline in courses offered afterwards (2000s, mean = 12.3 courses; 2010s, mean = 12.1 courses). Similarly, the median number of fisheries courses offered peaked at 12.5 in the 1990s, remained at 12.5 in the 2000s, and was 11.5 in the 2010s. There was, however, wide variation among universities. Since the 1990s, the net change in number of fisheries courses offered by individual programs ranged from a loss of seven courses to a gain of seven, with six universities adding courses and four dropping them.

In terms of course offerings on topics identified by agencies as important (Gabelhouse 2010), we saw little evidence of change. Courses in fisheries management were offered by 100% of the universities surveyed in the 1990s and 89% in the 2010s. Fisheries techniques courses were offered by 25% in the 1990s and 33% in the 2010s. Courses in ichthyology were offered at 75% in the 1990s and 72% in the 2010s. Fish population dynamics courses were offered by 42% in the 1990s and 39% in the 2010s. Offerings of limnology courses did change, being offered by 92% of universities in the 1990s and declining to 72% in the 2010s. We also observed a decline in universities offering aquaculture classes, which were offered by 83% of surveyed universities in the 1990s and 67% in the 2010s.

Our survey did not uncover widespread declines in the number of inland fisheries courses offered by 18 universities with long-established programs. Though some schools had reduced course offerings, others increased. Similarly, we saw no strong trend in availability of courses in subject areas considered most important by employers. So why the widely held perception that today's university graduates are less prepared for entry-level positions in fisheries than in the past? Among specialized technical areas identified by employers as areas of deficiency in the survey by McMullin et al. (this issue), field techniques and population dynamics ranked highly. Though we did not see declines in the number of universities offering these classes, both were less commonly offered than other fisheries courses, being offered by less than 50% of the schools surveyed, perhaps contributing to why employers often find graduates lacking in these areas. Though availability of fisheries courses has changed little, it is possible that, within broader majors such as environmental sciences, fisheries courses are electives rather than core courses and fewer students are taking them. Our assessment was based on course titles and could not track changes in course content. If fisheries courses are now framed within the context of the wider environmental and ecological sciences, it is possible that there is less content directly related to applied fisheries. McMullin et al. (this issue) found that today's employers place a high priority on written and verbal communications and generally found recent hires deficient in these areas, a theme depressingly consistent with past surveys (Deason 1941). Our survey did not consider communications courses, but it seems clear that development of these skills should be a priority, with increased agency emphasis on outreach and public participation in decision making. It does not appear that perceived declines in preparedness of graduates for careers in fisheries can simply be attributed to widespread declines in specialized coursework available at universities but perhaps to changing emphasis on the skills needed in today's environment and an educational environment that is moving away from specialization.

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STUDENT SUBSECTION OF THE EDUCATION SECTION

Preparing the Next Generation of Fisheries Professionals: Insights from the Student Subsection of the Education Section

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INTRODUCTION

Various employment avenues exist within fisheries (e.g., early life history, geographic information sciences, habitat management, policy development, law enforcement), with new subdisciplines regularly materializing as the knowledge base changes. Currently, fisheries professionals in the academic, public, private, and tribal sectors are evaluating methods and curricula used to train fisheries students (McMullin et al., this issue). How is it possible, though, to ensure that students enter the fisheries profession with the skills and abilities to use technologies that have not been invented, address problems that society is unaware of, and succeed in subdisciplines that do not yet exist?

The Student Subsection of the Education Section (hereafter Subsection) of the American Fisheries Society (AFS) serves to facilitate interactions between fisheries professionals and students by providing member services aligned with the goals and mission of AFS. As leaders of the Subsection, we feel that by embracing a diverse array of educational opportunities, fisheries students of today can become successful professionals of tomorrow. Here we describe six action items that we believe can help enhance fisheries education and effectively prepare students for successful careers in fisheries.

DEVELOP MENTORING PROGRAMS

Mentoring has been shown to benefit mentees and mentors alike (Danielson 1999) and enable students to become successful fisheries professionals by providing real-world insights into the challenges of the profession (Taylor and Harrison 2016). Mentorship programs exist for early career scientists (e.g., AFS Emerging Leader Program) and high school students (e.g., Hutton Junior Fisheries Biology Program) but not for college students. A mentorship program assisting college students could provide assistance in coursework selection, instructor considerations, research projects support, or advice for securing internships from others besides their academic advisor. A mentoring program could be as simple as facilitating communication among undergraduates, graduate students, or young professionals. Students themselves could even seek these informal mentors. These mentorship programs would provide fisheries students and professionals opportunities to learn from and share their experiences with professionals.

CREATE NONTRADITIONAL WRITING ASSIGNMENTS

Writing fisheries manuscripts is often a formidable task (Eschmeyer 1990). Ample effort is required when writing a manuscript to ensure effective and accurate communication of one's thoughts and ideas, but many students dread writing assignments. Placing required course writing into different and new contexts may excite students to sharpen their writing skills. For example, writing assignments could be designed to enable students to translate scientific writing for nonscientific fisheries stakeholders through blogs, op-eds, or social media accounts. In addition, by mimicking the peer-review process in writing assignments, instructors could allow students to gain firsthand experience in preparing manuscripts, evaluating their scientific merit, and familiarity with journal submission guidelines.

Increasing student awareness of AFS certification and the requirements may enable students to experience greater success in seeking employment.

Students could even submit those manuscripts developed in class to journals to enhance their educational and professional development.

EMPHASIZE DISSEMINATION OF RESEARCH

Professors, instructors, and mentors should encourage current students to present their research, even small classroom projects, at local, regional, or national conferences. Students themselves should also seek opportunities to present their research to fisheries professionals, fisheries stakeholders, and the general public. By developing and delivering presentations, students will gain valuable experience in scientific communication that will benefit them throughout their careers. McMullin et al. (this issue) found that employers rated oral and written communication skills as one of the most important contributors to career success of entry-level employees.

FACILITATE INTERDISCIPLINARY COURSEWORK AND COLLABORATIONS

We encourage academic administrators to diversify fisheries curricula and interdepartmental collaboration with education, geography, human resources, mathematics, and other nontraditional fisheries disciplines. Atypical fisheries/aquatic science courses enable students to develop unique skill sets that help mold them into professionals. Working with researchers from other departments can expand a student's knowledge base. Benefits of such courses and collaborations might not be apparent initially, but they will ultimately allow students to cultivate skills for future success.

INCREASE INTERACTIONS WITH FISHERIES STAKEHOLDERS

We encourage professors and instructors to design classroom assignments and projects that involve real-world interactions with fisheries stakeholders. For example, students would benefit from evaluating the desires of lake associations and environmental organizations and designing research and management programs to fulfill them. Students would have the opportunity to develop and translate scientific information for fisheries stakeholders, a valuable skill for fisheries professionals.

INFORM STUDENTS OF AFS PROFESSIONAL CERTIFICATION REQUIREMENTS

AFS has offered professional certification since 1983 (Pegg et al. 1999), with continual updates to encompass major knowledge requirements for fisheries professionals, including aquatic biology, human dimensions, communication, and statistics (Essig 2016). However, new fisheries students, as well as fisheries students at smaller or nontraditional fisheries schools, may not be aware of the AFS Professional Certification Program. Increasing student awareness of AFS certification and its associated educational requirements may enable students to experience greater success in seeking employment. This may be particularly important at smaller or nontraditional fisheries schools where availability of undergraduate courses that align with AFS certification requirements is limited. Smaller universities and colleges should be encouraged to align programs in biology, environmental science, and other related disciplines to as many of the AFS certification standards as possible, alleviating difficulties of meeting certification requirements for students while ensuring that future fisheries professionals have the necessary skills for success in the fisheries profession.

CONCLUSION

A variety of approaches can be used to enhance fisheries education and prepare students for successful careers in the ever-changing fisheries profession. Mentoring programs, nontraditional writing assignments, scientific communication opportunities, interdisciplinary coursework, fisheries stakeholder engagement, and fisheries curricula that align with AFS certification standards promise to advance fisheries education. Ultimately, these strategies will enable students to enter the fisheries profession with the knowledge and skills required for personal and professional success.

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FISHERIES ADMINISTRATION SECTION

Preparing the Next Generation of Fisheries Professionals

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Fisheries administrators need well-rounded knowledge of the fisheries sciences and current issues. Successful administrators are generally visionary people. They must think strategically when solving problems or setting organizational goals. Fisheries administrators serve as facilitators, collaborators, skilled communicators, and leaders of people. These leaders must be able to embrace change and lead their staffs through times of uncertainty; times that are becoming all too common in our profession today. Being a fisheries administrator means that sometimes you will have to make very difficult and challenging decisions in order to achieve the greater good for an organization, its stakeholders, or employees.

A broad-based, interdisciplinary undergraduate program would be a good start for any student desiring a career as a fisheries administrator. Gaining early exposure to a variety of fisheries disciplines and natural resources fields, or the problems faced in natural resource management, would help expand one's outlook beyond just fish biology. Advanced degree programs (such as a M.S. or Ph.D.) would provide additional opportunities to enhance a student's critical thinking and communication skills, especially through the completion of a graduate research project and thesis or dissertation. Advanced degree programs may also offer the opportunity to study aspects of leadership or natural resource policy-related areas, such as human dimensions of natural resources, political science, social science, and public administration. Knowledge of these areas is important in a career in fisheries administration.

Fisheries administrator positions are not entry-level jobs. The required skills are obtained by working with a wide diversity of agency staff and stakeholders. These positions typically require years of supervisory or project management experience. Employers have primary responsibility for nurturing and training the future generation of fisheries administrators. Some agencies have created managerial career tracks that eventually lead to these top-level administrative positions. Many agencies have found it necessary to offer these opportunities to provide for their own successional planning. Others provide employees with opportunities to participate in intensive leadership training or development courses offered by other entities (e.g., courses offered by other agencies or the National Conservation Leadership Institute). Involvement in leadership roles of AFS Subunits such as Chapters, Sections, or Committees at all levels of AFS provides excellent opportunities to develop leadership skills for any student or young professional interested in a career in fisheries administration. AFS

FISHERIES MANAGEMENT SECTION

Preparing Future Fisheries Professionals to Make Good Decisions

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Future fisheries professionals will face decision-making challenges in an increasingly complex field of fisheries management. Though fisheries students are well trained in the use of the scientific method to understand the natural world, they are rarely exposed to structured decision making (SDM) as part of an undergraduate or graduate education. Specifically, SDM encourages users (e.g., students, managers) to think critically and communicate the problem and then identify specific, measurable objectives as they relate to the problem. Next, users must think critically and creatively about management alternatives that can be used to meet the objectives—there must be more than one alternative or there is no decision to be made. Lastly, the management alternatives are evaluated with regard to how likely they are to succeed in terms of multiple, possibly completing, objectives, such as how stakeholder groups value outcomes of management actions versus monetary cost. We believe that exposure to SDM and its elements is an important part of preparing future fisheries professional to meet the challenges they may face. These challenges include reduced budgets, the growth of potentially competing natural resource interest groups, and stakeholder desire to be involved in management decisions affecting public trust resources, just to name a few.

Reduced financial resources continue to affect fisheries agencies, resulting in hiring freezes, layoffs, and reduced operating budgets. The likely consequence of reduced resources is that future fisheries professionals will need to prioritize what sampling and monitoring can be conducted given resource constraints. This challenge raises difficult questions to answer, such as "How does a manager make a decision about sampling one system versus another?"; "What are the consequences of reducing sampling efforts?"; or "How much sampling is needed?" Statistical power analysis can partially help with these questions but is generally indirectly related to attaining management objectives. To illustrate, suppose that a fishery manager has identified four habitat restoration alternatives that potentially meet management objectives. It turns out that the best restoration alternative depends on how many fish are currently in the system and the population mortality rate. Ideally, the manager could estimate fish abundance and mortality and select the best decision given those values. However, the likely case is that the manager does not have resources to estimate population size and mortality rate and must decide which is most important to estimate and what level of effort is necessary. If the restoration decision is framed using SDM, the manager can use tools such as sensitivity analysis, calculate the value of sampling information to address this question, and provide a way to prioritize the allocation of resources to collect data that will directly inform the decision.

Stakeholders have been scrutinizing fisheries management and providing commentary and feedback on fisheries management through online outlets and litigation. This will likely continue given the growth of nongovernmental organizations with natural resource interests (McMullin and Pert 2010). In extreme cases, conservation groups have successfully sued fisheries agencies over policies that they believe are adversely affecting fisheries resources. For example, in 2012, four conservation groups sued fisheries agencies associated with fish stocking in the Elwha River, Washington (Cassandra 2014). The outcome was that a federal judge ordered the agencies to consider alternative stocking actions that included stocking fewer fish. This outcome highlights an important element in the SDM process: multiple alternatives must be evaluated.

Stakeholder and natural resource interest groups also believe that they should be able to participate in a transparent decision-making process. In well-organized instances, stakeholder interest groups can wield influence, resulting in management agencies creating independent science advisory panels to serve as a neutral party evaluating management programs. For example, management of the Missouri River has been subject to scrutiny from an independent science advisory panel assisting the Missouri River Recovery Implementation Committee, a stakeholder group representing stakeholder interests (i.e., states, tribes, local, federal). A common recommendation from scientific advisory panels is the adoption of an SDM or adaptive management (AM) approach—adaptive management is a special case of SDM where recurring management actions are used with monitoring to reduce uncertainty in understanding of the system dynamics (Conroy and Peterson 2013). Initiating an SDM or AM process can be challenging because it requires facilitators who are knowledgeable of the process and significant training of participants during the process to be successful. Exposing future fisheries professionals to SDM and AM as part of university training can potentially provide a foundation that will facilitate successful SDM and AM processes in the future.

Despite publication of several papers that demonstrate the utility of decision analysis (e.g., Lackey 1974, 1998; Powers et al. 1975; Bain 1987; Peterson and Evans 2003), we have yet to realize widespread student exposure to the topic. An SDM approach has been identified as a way to integrate natural resource research, management, and monitoring (Conroy and Peterson 2009), which seems like a natural fit for university natural resource programs. In fact, the School of Natural Resources at the University of Nebraska has embraced the integrative and interdisciplinary nature of SDM by incorporating elements of SDM and AM within the curriculum to prepare students to face the complex future of natural resource management and decision making (Powell et al. 2011). At a smaller scale, M.E.C. (first author) exposes students to SDM and AM in an undergraduate fisheries management class through case studies that effectively use SDM or AM, such as Peterson and Evans (2003) for SDM or Tyre et al. (2011) and Smith et al. (2013) for AM. The learning objectives for these case studies are to have the students be able to identify the major elements of a decision analysis and understand that decisions can be made even if uncertainty exists. J.T.P. (second author) provides graduate-level instruction in quantitative decision making in natural resources where students learn SDM and AM elements in detail sufficient to perform decision analysis once they enter the field. Exposing and equipping future fisheries professionals with the background in decision analysis will provide the necessary context and understanding to face increasingly complex natural resource management challenges and complements many of the qualities desired by employers (e.g., communication, human dimensions, problem-solving; McMullin et al., this issue).

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If I Knew Then What I Know Now: Advice for Fisheries Students from Recent Fisheries Graduates

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University students today must prepare for careers in the context of rapid environmental and economic change. In this issue, McMullin et al. (2016) offer helpful advice for fisheries students on how to prepare for success based on three perspectives: potential employers, professors, and students. All three are valuable, but a critical perspective is missing from this narrative: that of recent fisheries graduates who are currently employed. Those who have successfully navigated the path from graduation to employment have recent experience applying components of their fisheries education and can provide insight for current students hoping to follow similar paths.

Employers in fisheries ranked all possible job skills and academic topics areas as "important" in contributing to successful careers (McMullin et al., this issue). However, students should recognize that fulfilling every expectation on prospective employers' "wish lists" may not be in their personal best interest. For an employer, having a deep pool of highly qualified applicants is ideal, and there is no downside to students spending as much time as needed to develop these myriad skills. However, time spent preparing for a fisheries career comes at a cost to students, both directly (e.g., tuition) and as lost opportunity costs (e.g., forgoing employment; Complete College America 2014). Fisheries students also should understand that they are likely to enter a highly competitive job market saturated with qualified individuals. For instance, the number of Ph.D.s awarded in ecology increased by 77% from 2003 to 2010, though the number of jobs available has not kept pace (Hansen et al. 2014).

I interviewed seven young professionals with advanced degrees in fisheries or related fields to document the knowledge and skills that contributed most to their early career success, learn where and how they obtained those skills, and gather recommendations for fisheries students on how best to prioritize their time. Though these interviewees do not constitute a random sample, their experiences and career paths are diverse. Of the seven interviewees, three had M.S./M.A. degrees, three had both M.S.s and Ph.D.s, and one had only a Ph.D. Three were employed by state agencies, one by a federal agency, two in academia (one at a primarily teaching institution and one at a research institution), and one left fisheries to work for the Ford Motor Company.

Interviewees offered a range of valuable advice for students (Box 1). Although these professionals hold diverse positions within and outside of fisheries, collectively they identified common themes regarding the importance of different types of experiences in preparing them for their careers (Table 1). Most valued their undergraduate education for providing a broad foundation of basic knowledge and allowing them to explore different subjects to identify the areas of greatest personal interest. From the perspective of these young professionals, graduate school was the place to develop both specific technical skills and high-level skills such as problem solving (Table 1).

Consistent with McMullin et al. (this issue), all interviewees believed that experiences outside the classroom were critical to their success. Field experiences were important for honing problem-solving, critical thinking, and personnel management skills, in addition to hands-on experience with fisheries and ecological techniques. Even for a career outside of fisheries, research experiences were valued for developing collaboration skills and cross-disciplinary tools (e.g., database management). Many interviewees believed that being exposed to a wide range of experiences helped them to be more adaptable in their career choices and, indeed, more well-rounded people in general. Everyone recommended seeking out diverse experiences outside of the classroom and disciplinary boundaries.

Regardless of their training, all interviewees agreed that a certain level of on-the-job learning was required in order to succeed in their current positions, consistent with the findings of McMullin et al. (this issue). Most interviewees thought that this learning was best achieved via "jumping right in" as opposed to formal institutional training. Skills learned on the job included facilitation, grant writing, negotiation, and certain fisheries or ecological techniques and principles. These skills were specific to the individual, suggesting that current students should consult

Table 1. Responses from interviews of seven young professionals with fisheries degrees regarding the value of training and experience obtained from four sources in preparing them for success in their current careers.

Undergraduate	Graduate	Field/research experience	On-the-job training
Broad scope of basic knowledge	Specialized training	Designing projects	Workshops and conferences
Discovering interesting areas	Statistics and programming	Independent thinking	Formal training is often not that useful
Field courses	Population dynamics	Problem solving	Delving into your job is the best training
Lay foundation of critical skills	Managing people	Field experience	
Basic statistics, math	Thinking like a scientist, problem-solving	Database management	
Scientific writing	Seminars and discussion groups	Collaboration	
Public speaking			

Box 1: Advice from Recent Fisheries Graduates to Fisheries Students

"Take as much math, statistics, and writing as you possibly can. Read as much as you can."

"Don't be afraid to ask questions, even if you think it will make you look dumb!"

"Get out of your comfort zone. It will help you be more creative in the field, understand other perspectives, and increase your critical thinking."

"Most important, get involved ASAP; experience is key in this field."

"As was told to me at some point in the last decade—'there is no such thing as a work–life balance. It's just life.' I've kept that in mind. … I think a healthy perspective on work is important, which I've been able to maintain (so far)."

"Don't just think of yourself as a fisheries professional … think of yourself as a professional that works on fish[eries]. Learn everything you can about your project/study system/etc. but also seek training in disciplines that are widely applicable."

with those who currently hold the jobs that students hope to get after graduating to understand what needed skills they might not be developing (see also Rombenso et al. 2015).

A broad base of experience and knowledge is important (Dunmall and Cooke, this issue), and focusing on broadly applicable skills is particularly wise in a competitive job market. Based on the perspectives of recent fisheries graduates, limited time in school would be best spent honing communication and critical thinking skills, focusing on technical skills that are applicable across a range of disciplines (e.g., statistics, programming, database management), and gaining experience outside the classroom. Employers in fisheries place a high value on broadly applicable skills such as communication and problem solving (McMullin et al., this issue). However, students see themselves as more competent in these critical skills than do employers (McMullin et al., this issue), suggesting that students must seek additional training and experience in these areas in order to meet employers' expectations. These experiences may come at the cost of a fisheries-specific course or two, knowledge of which is also rated as important by prospective employers (McMullin et al., this issue). However, fisheries principles and techniques may be more easily self-taught or learned on the job than high-level communication and critical thinking skills. Fisheries students should be encouraged to remain open to a variety of careers either within or outside of fisheries, and to tailor their training to make them competitive across a range of disciplines.

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The Next Generation of Fisheries Professionals—Understanding Generations

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The feature article, "Are We Preparing the Next Generation of Fisheries Professionals to Succeed in their Careers?: A Survey of AFS Members," addresses the issue of career preparedness of entry-level professionals. However, there is a responsibility by employers to assimilate the skills of new hires into the current workforce. Accordingly, existing generational differences need to be recognized and considered. Although every employee is a unique individual, she or he also is a product of her or his generation. Each generation differs in how they behave within the work environment and how they view success.

The four generations currently in our workforce are traditionals (born before 1945), baby boomers (1946–1964), Generation X (1965–1980), and millennials (after 1980). Traditionals are loyal and value leadership and tenure. Baby boomers value education and believe that dedicated, hard work is the path to career advancement. Gen Xers value independence, equality, and work–life balance and believe in career progression through work products, not through tenure. Millennials thrive in teams, prefer one-on-one mentoring and advice, and are comfortable and adept with new and emerging technologies. They have and will continue to reengineer the modern workplace. Employers and new hires may lack insight into these differences, but better comprehension of these traits could help employers and new employees become more adaptable and foster the success of entry-level hires.

Many agencies offer training in adapting to a multigenerational workforce. Numerous venues exist to provide generational education (e.g., incorporation into leadership training, web-based offerings, or workshops). As the Continuing Education Committee evolves over the next few years, we will engage multiple levels of AFS to address and support, not only this topic, but other ways in which we can equip the next generation of fisheries professionals with the skills to be successful.

Narrow or Broad: Diverse Academic Pathways to a Career in Fisheries Science and Management

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The most successful graduates are those who have combined their broad or narrow fundamental knowledge base with diverse experiences to achieve a well-rounded and comprehensive background.

Preparing students to succeed in fisheries-related jobs in a rapidly changing, globally connected environment is challenging (Boreman 2013). Adaptability in a graduate is an asset that stems from having a broad academic base, yet specialization is both necessary and rewarded in science. Depending on the degree program offered, institutions of higher learning may channel students into broad programs (e.g., biology, environmental science) or specialized fisheries programs. This initially sets students on different pathways toward the same goal of gaining employment in fisheries. Fundamentally, however, employers naturally seek the most knowledgeable and most experienced candidates that can also communicate effectively. Therefore, regardless of the broad or specialized approach, formal academic settings may provide the necessary foundation and can certainly promote skill development. Experience, however, is also critical and is often gained by seeking out additional opportunities external to formal academic programming (McMullin et al., this issue). The most successful graduates are those who have combined their broad or narrow fundamental knowledge base with diverse experiences to achieve a well-rounded and comprehensive background.

The pressure to specialize is rooted in the ease of dividing science into fields and the depth of knowledge required to become competent and compete successfully within those divisions (Casadevall and Fang 2014). Specialization is generally a measure of success in science because it is reflective of the amount of information available in a particular field. The specialized approach is common in institutions of higher learning in the United States, and such specialization is rewarded through the requirement of specific courses as prerequisites for employment eligibility or professional designation (i.e., the American Fisheries Society Professional Certification Program). Researchers associate their scientific identity with their specialization (Casadevall and Fang 2014), and students may seek to carve out a very specific niche as a viable strategy to be competitive for an equally specific job. Through this process, specialists also gain a sense of community, which facilitates networking and thus collaboration. Indeed, specialization is pervasive and even inherent to science.

There are, however, disadvantages to specialization. Specialists risk having lower adaptability and being compartmentalized or isolated. In a fluctuating economy and competitive job market, specialists may have difficulty finding employment within their niche or adapting to shifting political priorities. In addition, multidisciplinary collaborations in a specialized environment could mean collaborations among subfields of science, rather than being integrative or across disciplines, which may result in losing valuable insights due to restricted perspectives. Indeed, the risk of specializing is becoming too focused (Casadevall and Fang 2014), and thus being maladapted for varying environments.

A broader approach to a career in fisheries allows for the integration of information from multiple perspectives but at a cost of the knowledge being less in-depth. This broader approach is more common in Canadian universities because named fisheries programs at the undergraduate level frequently have been replaced by integrative programs such as natural resource management, environmental sciences, and conservation biology. Although there are instructors with deep expertise in "fisheries" at many institutions, specialized fisheries programs are uncommon. This broad approach rewards facilitation of adaptability, which promotes employment survival, and development of a wider collaborative network, which leads to transdisciplinary opportunities for research.

There is a cost to such breadth. Graduates often lack some aspects of core training or requisite depth of knowledge in fundamental topics such as quantitative stock assessment and systematics, despite obvious needs (Whitehead 1990; Cotterill 1995), or are missing important fisheries-specific courses such as ichthyology or fisheries techniques (McMullin et al., this issue). In addition, the erosion of laboratory courses with hands-on training in the field (especially at field stations; Eisner 1982; Hodder 2009) and the reduced resourcing of field stations makes it difficult for professors to provide practical skill development in university settings. College polytechnical programs continue to exist where there is a focus on skill development, but it means that students may have to opt for both college and university programs to learn the practical skills and the theory. Although broad training is useful, this should not be at a cost of having graduates who truly do not understand the fundamentals of fish biology, stock assessment, and management.

Pragmatically, gaining a fundamental science degree, whether specialized or more general, should only be viewed as a step toward becoming a fisheries professional (McMullin et al., this issue). To be successful, graduates also need practical experiences in communication, decoding policies, writing proposals, preparing and managing budgets, managing people, developing safety plans, adhering to ethics, resolving conflicts, and working in collaborative team environments, among many other things. They must also know about legal instruments such as workplace safety and labor laws, transport of dangerous goods, safe boating, animal care, collaborative agreements, and intellectual property. These topics related to professional practice are generally not taught in either the specialized degree or generalized academic programs. Gaining practical experience, however, as an entry-level employee, as a co-op student, through a mentorship program (e.g., the AFS Hutton Junior Fisheries Biology Program), by volunteering, or by generally seeking experiences outside of a known skillset can help to fill those voids.

Regardless of the narrow or broad academic approach to a career in fisheries, those graduates who seek out diverse experiences will be the ones most employable. A variety of experiences will provide depth of knowledge in certain topics to those with a broad degree (i.e., biology) and a wider breadth of knowledge to those with a specialized degree (i.e., fisheries management). Thus, there is ultimately no prescribed approach for a successful career in fisheries science and management. The best-prepared graduates will be those who have combined knowledge with experience to become generalized specialists.

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FISHERIES INFORMATION AND TECHNOLOGY SECTION

The Fisheries Information and Technology Section and the Organization of Fish and Wildlife Information Managers Guide to Swimming in the Ocean of Information

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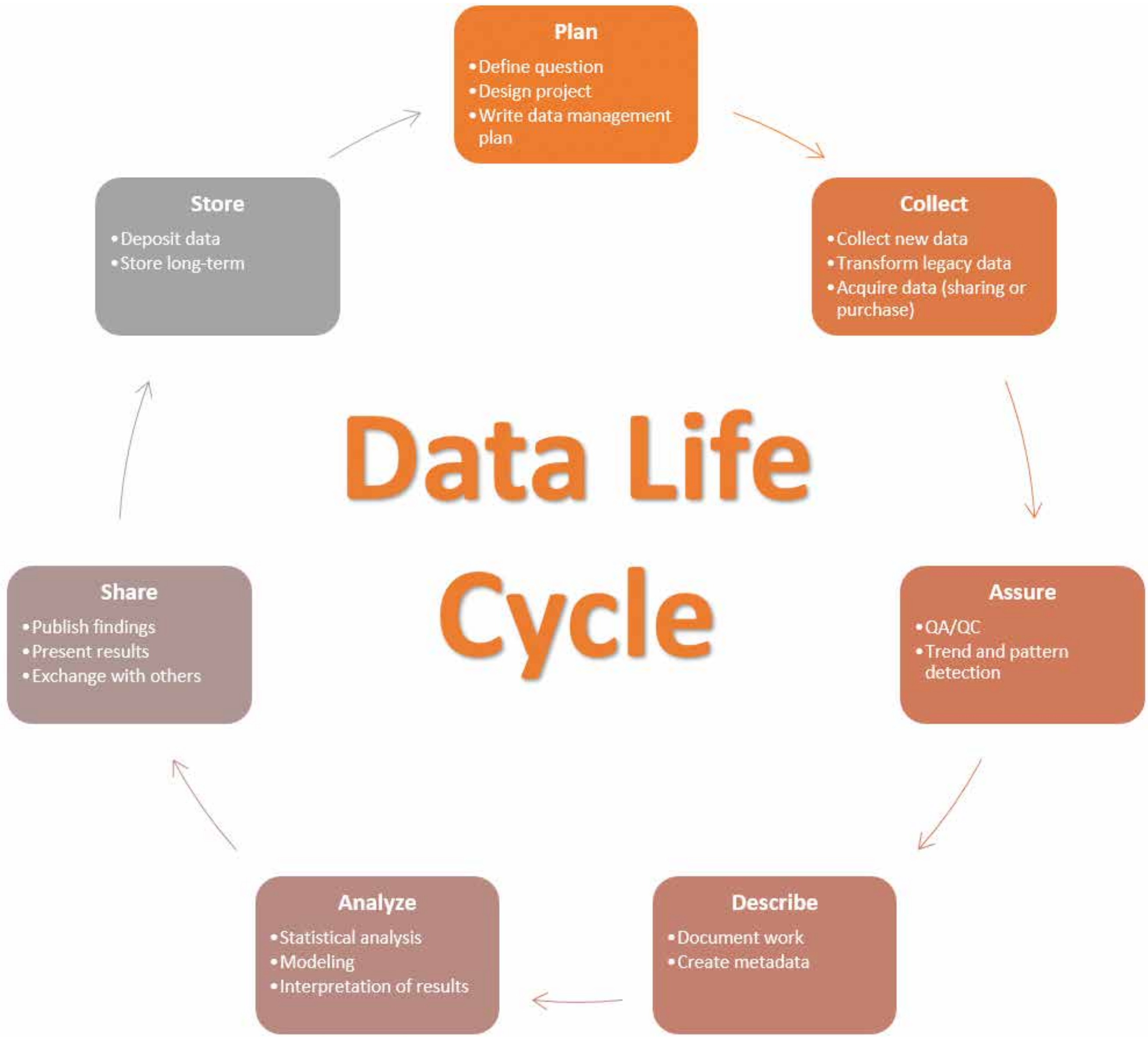
The volume of data available for fisheries management and research is growing exponentially, and fisheries professionals need to grow with it. We live in the Information Age, a time when humanity presumably has instant access to the sum total of all human knowledge, distributed freely across the Internet and accessible on any smartphone. Data are the building blocks of information or, rather, the raw material that can be synthesized into information; information can consequently be viewed as the raw material of knowledge (Zins 2007). In the words of Sir Francis Bacon, "knowledge is power", the power to successfully study, assess, analyze, manage, and conserve the natural resources with which we as fisheries professionals have been entrusted is dependent upon on our ability to handle data throughout its life cycle (plan, collect, assure, describe, analyze, share, store; Figure 1). Fisheries programs have traditionally focused on only a few aspects of this cycle, training practitioners to collect and analyze data to create meaningful information and then use that information to build a knowledge base. In order to prepare the next generation of fisheries professionals, we (Fisheries Information and Technology Section and the Organization of Fish and Wildlife Information Managers) believe that future professionals must strive to achieve greater proficiency in all components of the cycle.

Many universities provide a statistics course in experimental design and analysis. Coauthor Jeff Kopaska attended an agricultural university with predefined notions about



The data life cycle provides the whole story for fisheries professionals and is the key for the next generation to ensure that they are familiar with data management.

experimental units (e.g., field test plots, plant and animal treatment units). One lecture was dedicated to "the mechanics of organizing and summarizing numbers from experiments." The sum total of his educational experience in data management went something like this: computers are great at handling data; numbers from experiments should be logically organized into arrays, with rows representing distinct experimental units and columns listing the identifying codes and responses measured; arrays so organized and stored in computer files represent the places where data analysis, summarization, and interpretation begin; and attention to detail and accuracy at this level usually reaps rewards as the work proceeds. To a knowledgeable reader, all of that is about as insightful as calling the *Mona Lisa* an interesting painting of some woman or intimating that Babe Ruth was just some baseball player. Though it is true, it doesn't quite tell the whole story. The data life cycle provides the whole story for fisheries professionals and is the key for the next generation to ensure that they are familiar with data management.

Through discussions with coworkers and colleagues at AFS meetings, we have found that fisheries professionals are rarely given the opportunity to explore the concept of data management, let alone hone their skills. Wilson et al. (2014) citing Hannay et al. (2009) and Prabhu et al. (2011) said, "…recent studies have found that scientists typically spend 30% or more of their time developing software (programming). However, 90% or more of them are primarily self-taught, and therefore lack exposure to basic software development practices…" and then documented a number of high-profile retractions of scientific papers due to programming errors. This is an issue because fisheries professionals collect and must work with copious amounts of data. Some of the basic parameters collected in various specialties include species names, fish lengths and weights, gears, age-estimating structures, landings, disposition, genetic materials, marks or tags, grades, markets,

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modes, and water quality and quantity. Intricate studies may collect more detailed data, and long-term studies can have years of information, requiring a deeper understanding of statistics to deal with such massive amounts of data. Studies involving a broader spatial or temporal scale (e.g., geographic information systems or climate change modeling) require data management orders of magnitude greater than a fish community survey. Regardless of the type of study or volume of data, the skills and tools to plan, assure, and describe (Figure 1) data will:

- make data collection and analysis more efficient;
- ensure that data are complete, accurate, and reliable;
- meet funding agency requirements and protect the investment in the research;
- reduce misuse or unauthorized use;
- minimize the risk of data loss;
- expand the utility of data by enabling others to use it in future; and
- ensure research integrity and replicability.

Coauthor Keith Hurley, fisheries data manager for Nebraska Game and Parks, has teamed with fisheries professors at the University of Nebraska to promote data skills. He conducts an annual one-day seminar to expose students to basic data concepts such as:

- data management life cycle,
- data management planning,
- data security and sharing,
- data validation and verification,
- quality assurance and quality control,
- types of data tools,
- choosing the right tool for the job,
- conceptualizing a data schema,
- designing a relational database structure, and
- creating a database.

This type of training opens a new world of data management techniques and possibilities to students and provides a foundation for building competency in data handling. The creation of a mechanism for the inclusion of only good data, and the corresponding reduction of bad data, eliminates a plethora of potential data analysis land mines. Increasing the speed and efficiency of bringing data into the analysis phase will benefit these professionals throughout their careers. This instruction, even if only for one day, can provide career-long benefits in data management as well as a greater appreciation for data nuances.

Sharing and storing, the final two pieces of the data life cycle (Figure 1), are as vital as collection and go hand-in-hand with each other. Fisheries professionals have plenty of training in the scientific method, yet very little of that focuses on the sharing of results and data. Nowadays, simply publishing journal articles is not enough. It is important to communicate our findings both professionally and publicly—this is required in all areas of fisheries and requires popular writing and creative communication skills (Gabelhouse 2010). Numerous comments and citations by McMullin et al. (this issue) identify the importance of these enhanced communication skills. Furthermore, many peer-reviewed professional publishing outlets now require the publication of raw data sets in addition to the analyzed results of a study. If data are not stored and described properly, they can't easily be made accessible to others; sharing is the key to replicability and to allowing others to build upon our work.

Fortunately, those individuals in the next generation of fisheries professionals will have had a lifetime of exposure to technology and social media and should be well-prepared to utilize the new mechanisms of sharing science with the public (Millenbah et al. 2011). Technology-based forums like "The Fisheries Blog" (thefisheriesblog.com) demonstrate how quality science can be broadly disseminated to both fisheries professionals and society at large. Technological advances drive how communication happens, so providing our future fisheries professionals with the skills to effectively communicate research findings, both professionally and publicly, is vital to the future of fisheries. Without broad public support, developed through engagement and transparent communication with the public, our field will struggle to remain relevant.

The new generation of fisheries professionals needs the skills to create data management plans that effectively collect, assure, describe, analyze, and store information and the ability to share the information and results. Data are an essential part of fisheries, and only those individuals and agencies capable of successfully sharing and managing them will be able to answer the new questions and challenges the future holds. The Fisheries Information and Technology Section and Organization of Fish and Wildlife Information Managers feel that future fisheries professionals must be prepared to meet the Information Age head on, well versed in the data management and communication skills necessary to be good stewards of those natural resources with which we are entrusted.

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NOAA's Teacher in the Laboratory Program–Northwest Fisheries Science Center

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INTRODUCTION

In 1990, the National Oceanic and Atmospheric Administration (NOAA) implemented the NOAA Teacher at Sea Program (TAS) to place competitively selected teachers on NOAA research vessels (McMahon and Hammond 2010). The goal of the program is to increase teachers' awareness of ocean-related research through hands-on experience, thereby stimulating the development of relevant, real-world NOAA-related science studies for students. Since its inception, teachers from all 50 states have participated in TAS, bringing NOAA-related science back to their classrooms (Figure 1). In 2010, TAS expanded to include a similar shore-based program called Teacher in the Laboratory (TIL), which allows teachers to spend part of their summer working with scientists in NOAA research laboratories around the country. Research topics covered by TIL have ranged from field studies of green turtles *Chelonia mydas* to krill culture to fish genetics (Table 1).

We developed a TIL program at the NOAA Northwest Fisheries Science Center (NWFSC) that emphasizes collecting and analyzing population genetic data of English Sole *Parophrys vetulus* within the Salish Sea, an estuarine ecosystem that includes the Strait of Georgia, Puget Sound, and the Strait of Juan de Fuca. This species was chosen because it represents one of the dominant members, by biomass, of the demersal fish group in the Salish Sea, and it is used extensively in NWFSC studies of eco-toxicity of the marine ecosystem (Johnson et al. 2008). We train teachers to gather population genetic data for DNA microsatellite loci of English Sole and to apply their findings to a current marine science issue. For two to three weeks during the summer, scientists mentor teachers at the center's Mukilteo Research Station in Mukilteo, Washington. During the following academic year, the teachers spend several weeks teaching a population genetics unit to their high school classes. During this time, students collect, interpret, and apply genotypic data to a mini population genetic survey.

The Mukilteo Research Station is an ideal setting for this program. It is a small research facility located on Puget Sound, where teachers, in the course of their training, are exposed to a variety of in-house research programs, including the use of fish and invertebrate culture for eco-toxicity, life history, and aquaculture investigations. Moreover, use of this field station in the summer helps to ensure that the TIL laboratory and classroom work does not interfere with other agency research at the main NWFSC research laboratory in Seattle.

The purpose of training teachers in population genetics is to give teachers the necessary skills and experience to collect their own genetic data from individual specimens. After training, TIL participants are able to:

- extract DNA from tissue samples and prepare it for analysis,
- amplify specific DNA microsatellite loci via polymerase chain reaction (PCR),

Figure 1. Number of teachers by state on NOAA research cruises 1990–2015. See NOAA (2016a).

Table 1. Examples of NOAA Teacher in the Laboratory programs 2010 to 2014.

Research topic	Laboratory	Location
Green turtle biology	Southwest Fisheries Science Center	La Jolla, CA
Boundary layer climatology	Earth Systems Research Laboratory	Erie, CO
Krill culture	Alaska Fisheries Science Center	Juneau, AK
Water quality	Chesapeake Bay Laboratory	Oxford, MD
Juvenile fish	Southeast Fisheries Science Center	Miami, FL
Fish population genetics	Northwest Fisheries Science Center	Seattle, WA

- load and operate an automated genetic analyzer,
- interpret and score individual fish genotypes, and
- apply basic descriptive statistics to evaluate patterns of variation within and among collections.

These skills are developed and practiced in the summer course and then applied in the classroom using curricula developed specifically for this work by us (J. B. and G. W.; Table 2). Student participation hinges on the fact that many classrooms today have access to common biotechnology tools, such as centrifuges, incubators, micropipettes, and a theromocycler, to amplify segments of DNA via PCR. Thus, using this equipment, a class can conduct a basic population genetic program using microsatellite markers.

In addition to technical training, important biological concepts are emphasized during the summer course. Through reading current literature and seminars with NWFSC staff, we expose teachers to the significant questions underpinning the basic biological tenant that a species is composed of genetically identifiable populations or stocks. Information on population-level variability forms the basis of many conservation and management actions, many of which are under NOAA's purview as the primary federal agency charged with management and stewardship of living marine resources.

Discussions of these biological concepts are anchored to current NOAA research, including life history variability; restoration of salmon, marine fishes, and invertebrates; ocean acidification and shelled organisms; and marine protected areas. Teachers become acquainted with the notion that a species' response to environmental change may vary from population to population. Thus, they develop an understanding of the importance of genetic population delimitation to marine stewardship, conservation management, and monitoring.

During the course of discussions, we evaluate and, when necessary, refine relevant class curricula for conservation genetic issues of the Salish Sea (Table 2). We note significant milestones in genetic research, including the idea that species are composed of distinct population segments, a basic concept pioneered for Pacific salmon at NWFSC in the 1990s that is central to species conservation under the Endangered Species Act.

A key aspect of the TIL program is that participating teachers enable students to contribute to a *real* science project (see Box 1). During academic year 2013–2014, 300 students in six high school classrooms in the Puget Sound area collected data for alleles from two highly polymorphic microsatellite loci for English Sole. Using tissue samples from fin clips, students in each classroom isolated DNA from about 48 fish and used PCR to generate copies of the portions of DNA containing the alleles being studied. These PCR products were sent to the Mukilteo Laboratory for analysis on an automated genetic analyzer that produced unscored electropherograms, which are plots of DNA fragments that are separated by size through electrophoresis and that correspond to alleles (see multimedia link in NWFSC 2016). These unscored electropherograms were returned to the classrooms from which samples were obtained, and the allele values were determined by the students in a process called genotyping (see Figure 2). The students completed lessons on calculating allele frequencies, examining allele frequency diversity between populations, and calculating genetic distance trees. Because each classroom had a unique collection of fish to be genotyped, we encouraged inter-classroom comparisons via e-mail or Skype so that students could discover and describe population-level variations.

The final step of the process is to verify and add data obtained from the students to a baseline we are maintaining. Once this baseline is expanded to a 15-locus data set by NOAA scientists, we will conduct a final population structure analysis. When completed, this will be the first comprehensive population genetic survey of English Sole, an important flatfish species in the Salish Sea.

Table 2. Titles of study lessons focused on population genetic studies of English Sole using microsatellite markers.

Lesson 1. The Sole Purpose
Lesson 2. Your Conservation Ethic (Supplements: Callicott essay and vocabulary)
Lesson 3. Microsatellite DNA Sequences (Supplement: How to Use GenBank—An Open Access Sequence Database)
Lesson 4. Scoring Microsatellite Data (see Figure 2)
Lesson 5. Measures of Variability in Population Genetics (Supplement: Diversity tables)
Lesson 6. Calculating Genetic Distance
Lesson 7. Constructing a Phylogenetic Tree (see NOAA 2016b)

THE FUTURE: BEYOND ENGLISH SOLE

Population genetics studies are an important component of ecosystem management. Our goal is to understand the Salish Sea ecosystem more completely by studying the genetics of multiple species, covering multiple habitats and taxonomic groups. For several decades, federal, state, academic, and tribal laboratories have collected genetic information for economically important species like Pacific salmon *Oncorhynchus* spp. and rockfish *Sebastes* spp., as well as charismatic species like killer whales *Orcinus orca*. However, there is a paucity of genetic data for a large number of other ecologically important organisms including forage fish such as Pacific Herring *Clupea pallasii*, Surf Smelt *Hypomesus pretiosus*, and Pacific Sandlance

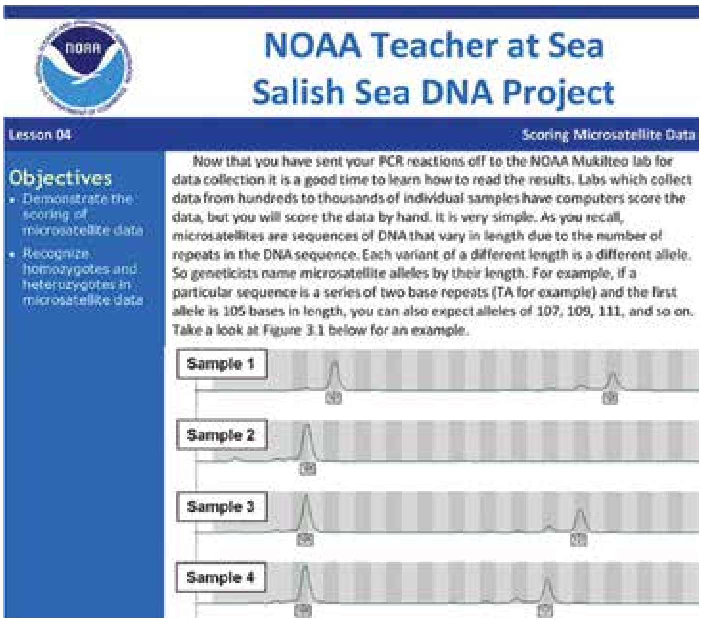

Figure 2. Cover sheet (in part) for Study Lesson 4: Scoring Microsatellite data on an Electropherogram.

Box 1: Students Crave Real-World Science Research Projects

High school students crave authentic, meaningful experiences. “Cook book” science is convenient for the teacher and teaches skills to the younger learners, but high school students are savvy, and want to do work that is REAL. The Teacher in the Laboratory project provides all of this by involving students in science research projects that are current, have a clear purpose, and one in which student data can be submitted and used by NOAA scientists. Getting students excited about real-world projects with real-world issues is the best teaching practice and the best for turning kids into scientists and engaged citizens.

—J. Duncan-Taylor, Pt. Angeles High School, Pt. Angeles, WA,
M. Wolski, Arlington High School, Arlington, WA (High school teachers from 2010 TIL)

Ammodytes hexapterus; plants, such as eel grass *Zostera marina*; and flatfish, such as English Sole. These marine species ultimately support salmon, rockfish, and killer whales in the Salish Sea but are under studied in this regard. Though including all these organisms is an ambitious goal, we have been able to expand our reach through the TIL program.

We are also exploring the possibility of including other abundant or interesting organisms in our genetic studies. For example, spot prawn *Pandalus platyceros*, Shiner Surfperch *Cymatogaster aggregata*, and the dogwhelk *Nucella lamellose* all have larvae with limited dispersal, making them candidates for increased likelihood of population differentiation. Our expectation is that obtaining genetic data of stock structure of multiple species will improve our ability to:

- monitor species and their constituent populations in marine habitats,
- model ecosystem dynamics, and
- predict effects of climate change and other human-induced effects.

By sharing these ideas and data collection experiences with teachers and their students, we believe that we can enhance progress in these areas and increase public involvement in the stewardship of marine resources.

Finally, we introduce teachers to the concept of integrating genetic and photographic surveys. A comprehensive digital inventory of phenotypes will capture how marine life looks now, providing a frequently overlooked source of intraspecific diversity (Figure 3). Comparing and matching phenotypic variability with genetic variability may lead to a better understanding of such natural phenomena as local adaptation and life history variability (Winans et al. 2003). Processing digital inventories via multivariate morphological analyses is another potential project for students at the high school or college undergraduate level.

The NOAA TIL program at NWFSC enables teachers to connect with NOAA scientists and thus connect their classroom curricula to real-world applications using fauna or flora in their own backyard. Involving students in real and relevant scientific research enhances their engagement in the ocean sciences and provides examples of how learning can be linked to future career options. Programs like NOAA’s TAS and TIL highlight the importance of the ocean, the diversity of marine animal and plant life, our close relationships with these organisms, and how phenotypic and genetic diversity of marine organisms in many key habitats remains largely unexplored.

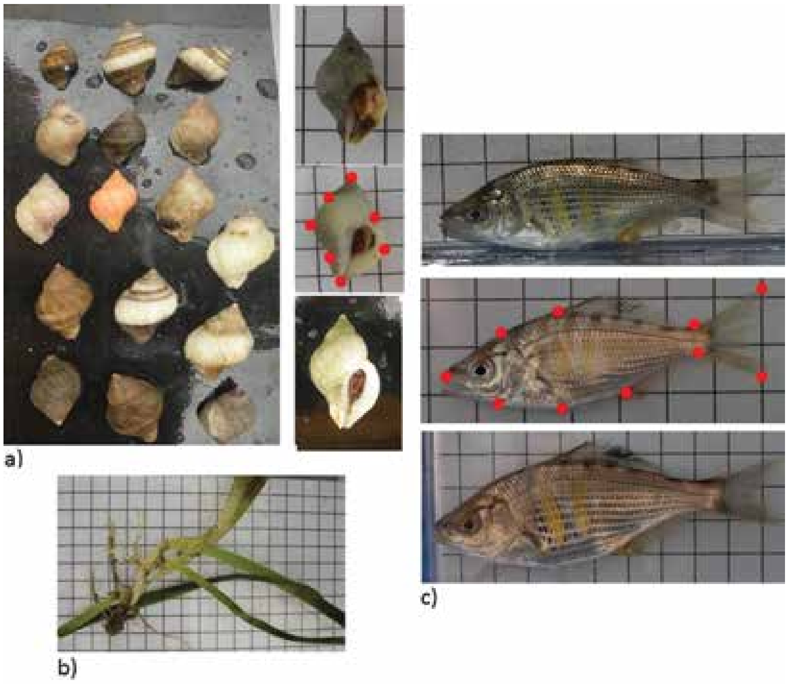

Figure 3. Examples of photographic entries for phenotypic inventories of whelk *Nucella lamellosa* (a), eelgrass *Zostera marinus* (b), and Shiner Surfperch *Cymatogaster aggregata* (c) photographed on a 1-cm grid. Points along an animal outline are morphological landmarks that are digitized and used for capturing and analyzing body shape dimensions.

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ESSAY

Consultants' Role in Fisheries (Is There Really a Dark Side?)

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There are many job opportunities and positions in fisheries, including academia, state/provincial/tribal/federal governments, nonprofit organizations, and for-profit consulting firms. Although we have seen an increase in fisheries consultants within the American Fisheries Society (AFS; along with decreases in public employment opportunities), this remains a career path that is unknown to many and poorly understood by most. Many of us in the early stages of our careers felt that we had moved to the "dark side" when we took our first consulting job. However, that perception has changed, at least among us, and most consultants are increasingly regarded as respected scientists. Though some consultants are still rightly regarded as "hired guns" and bias analyses in favor of the corporations they work for, the same can be said for some government and academic scientists who may be pressured to only provide results that follow a particular policy or perspective of their employers (e.g., Wood 2013; Aviv 2014; Union of Concerned Scientists 2015). Definitely more important than being a consultant, a government employee, or an academic researcher is being a good scientist; poor science and/or unethical practices within any sector can be disastrous to one's reputation as well as that of his or her employer.

We all have had different experiences as consultants, and none of us considered consulting as our first job choice. Examples of how we adapted and thrived in these positions include the following:

At an unexpected point in my time as a federal employee, I was approached by a large engineering company with whom I was collaborating and offered an opportunity as a staff scientist. Though the position was small in the scheme of the large company, I was offered exposure to a wealth of aquatic project experiences (e.g., wetland development, hydropower relicensing, recreational fishery enhancement, mine site reclamation) spanning an array of issues (e.g., mitigations, rehabilitations, effective reservoir management). Prior to that position offer, I didn't really think of myself as working for the right side or the wrong side of the resource. I had met and worked with smart, dedicated, and equally ambitious (even aggressive) folks across industries, but the offer got me thinking about how I was currently viewed and wished to be perceived by other scientists.

—Doug Bradley

For my first job after graduate school, I worked for an environmental consulting company that specializes in environmental permitting and impact assessment for the energy sector (primarily the pipeline industry). Initially, I wrestled with feeling out of place and like a sell-out in some ways (weren't these oil and gas companies supposed to be the bad guys?). But I quickly came to realize that consulting is actually important work, since consultants are one of the main intermediaries between big business interests and valuable public resources. Corporations look to consultants to advise them on the most environmentally and socioeconomically friendly ways to complete a project, and that is a powerful role.

—Danielle Reich

Whereas my tenure with the federal government was intellectually challenging and rewarding, I soon realized that my employer did not always share my interest in how we should go about protecting water quality and the aquatic organisms that depend on it. So, in 1999, I left my secure position and started an environmental *consulting firm—MacDonald Environmental Sciences Ltd (MESL). My goal with MESL was to provide a vehicle that enabled me to work on projects that mattered and to have the autonomy to deliver scientific results unfettered by economic or political interests.*

—Don MacDonald

During the 20 years that I have been a consultant, I was never directed to produce a particular result desired by my funding source and I often was able to conduct independent research. In fact, some of my scientific papers resulted from those projects (e.g., Oliveira et al. 2004, 2009). In other words, "lesser scientific work" resulting from consulting projects may produce good scientific publications. Perhaps because I was able to develop scientifically sound work as a consultant, I have found that most of my academic and agency peers classify consultants such as me based on their scientific and technical products rather than their employers.

—Joao Oliveira

The Brazilian academic scientific community generally views consultants with suspicion, because consultants help resolve the environmental issues of the companies that hired them, creating apparent or real conflicts of interest. In addition, the companies, focusing on profits and least costs, do not always invest in the highest quality consultants. In my particular case, my parallel research activities, research articles, book chapters, and books buffer such impressions (e.g., Alves 2007; Alves and Pompeu 2010; Callisto et al. 2014a; Di Dario et al. 2015). Another way of demonstrating my professional independence and competence is to be an active member of scientific societies and to present my research for peer scrutiny at scientific society meetings.

—Carlos Alves

Through my AFS and Society for Freshwater Science contacts, I learned that I often had greater freedom to fund, conduct, present and publish my research, and travel than many of my agency and academic colleagues. During my 30 years of employment as an onsite contractor, I was never constrained regarding what I could publish or where, and I was encouraged to develop independent research projects (including some with other funding sources) as long as they fit under the general mantle of the larger research program (e.g., Spence et al. 1996).

—Bob Hughes

I started my career working with state government. My first job as a consultant was working with the U.S. Environmental Protection Agency Headquarters. I was not a consultant for industry; rather, I was working for the "good guys." Later, I was able to take the knowledge that I had learned from my state experiences and my federal government consulting and provide that insight to the regulated community, those often thought of as the "bad guys." I found that the regulated community was interested in developing economically sound and practical ways to be in compliance with state and federal requirements so that they can go about the business of doing what they do as efficiently as possible. Often it is lost that compliance with environmental regulations does not contribute to the bottom line of a company. Usually it is my job to find economically achievable ways for an industry to be in compliance.

—J. Fred Heitman

Early in my consulting career I quickly learned that there really isn't a dark side to consulting work, regardless of what side of the table you sit on. I have worked for a range of clients including industry, government, and nonprofit agencies. The ability to work with a variety of clients requires maintaining a sound scientific focus in all cases. My first concern is always for the resource, it has to be. My role is more like a mediator—providing the scientific expertise to clients and in compliance with the regulations. I do not advocate for any of my clients; I advocate for the resource and hope that what I do provides sustainable fisheries for the future. The diversity of projects in consulting is exciting and every day brings new challenges.

—Margaret Murphy

Membership in AFS has been an essential resource in each of our successes. AFS provides an important environment for information sharing, networking, and professional development.

Working in consulting has helped us develop invaluable business, management, and stakeholder engagement skills in addition to our technical skills. Whereas some clients limit the amount of work that can be published in scientific journals, much of the work can be presented at state, national, and international meetings (e.g., Hughes 2001, 2009, 2014; Heitman et al. 2008; Murphy et al. 2011, 2013; Heitman and Upp 2012; Santos et al. 2013; Oliveira et al. 2014). Other clients welcome and expect publications; for example, Bob Hughes' consulting work with the U.S. Environmental Protection Agency resulted in publications related to ecoregion testing (e.g., Larsen et al. 1986; Hughes et al. 1987; Peterson et al. 1996), developing and testing multimetric indices of biological condition (e.g., Whittier et al. 2007; Meador et al. 2008; Stoddard et al. 2008), and conducting multistate or national aquatic resource assessments (e.g., McCormick et al. 2001; Peterson et al. 2007; Pont et al. 2009; Kaufmann et al. 2014). That work, in turn, led to subsequent collaborative research with colleagues in Europe (Oliveira et al. 2009; Segurado et al. 2011; Gardner et al. 2013), South America (Ibañez et al. 2009; Callisto et al. 2014b; Buss et al. 2015), and Asia (Chen et al. 2014; Li et al. 2014; Qin et al. 2014).

Membership in AFS has been an essential resource in each of our successes. AFS provides an important environment for information sharing, networking, and professional development. Perhaps more important, AFS provides avenues for building and maintaining lifeling friendships and for helping us through the challenges that we encounter in the consulting field. In addition, many of our leadership skills were honed and developed by serving at all levels of AFS. We all need to embrace the diverse array of expertise within AFS and take advantage of the wide range of perspectives we all bring to the table. Finally, the AFS professional certification program has been very important to consultants and provides an added level of scientific credibility when needed. Maintaining these credentials requires continued participation within the fisheries discipline, including publishing, volunteer service, and continuing education.

A career path in environmental consulting is a solid choice. If you like a range of projects and interacting with other scientists and engineers, it might be the way to go. For those still in college or graduate school trying to determine their career path, we would recommend courses in humanities and business as well as the more specialized science classes. Keeping an open mind and maintaining strong data analysis skills will ensure that the science comes first; we can all help clients solve problems—if we have a good understanding of the problem first.

Consultants often are paid more than state or federal biologists. But there is a trade-off with an increased risk of losing your job when all projects are completed. Unlike other positions, consulting is a for-profit industry and overhead hours decrease corporate profits. Consultants also travel a lot—locally, nationally, and/or internationally. For those who enjoy traveling, it is a great opportunity to explore other regions and learn about a wide array of fisheries issues. You also interact with scientists from around the world, further increasing your network and opportunities to learn from others.

The pressure to support and win big contracts and work on many disparate projects at once, producing quality results under tight schedules, can be very stressful, but it is never boring. It is important to balance those pressures and make sure that you can still provide quality, unbiased work. Larger, complex projects often require teamwork (internal and external) for success and survival. At most companies, it is recognized that external partnerships can create a broad-based, more scientifically credible perspective on challenging and controversial projects (e.g., mining, large transportation, energy development).

Now, more than ever, fisheries and environmental professionals who care about the resource need to work together to ensure that the right information is available to decision makers and to make sure that the information is used to make good decisions—ones that benefit society as a whole, not just special interest groups. We need to avoid becoming an advocate for our clients—the resource will suffer if we deliberately act to mislead or misinform the public. Regardless of the pressures from our employers and clients, we need to make sure that we work for the best science. We all share the same enthusiasm and concern for fish, fisheries, and aquatic resources—whether we are academicians, government employees, tribal biologists, nongovernmental organization scientists, or consultants. AFS will continue to provide the support to all of us to ensure that we all do our best work, and that our leaders and the public understand the need for this high-quality work.

None of us regret our careers in consulting. The diversity of projects we all work on keeps our work challenging and thought-provoking. Our projects have included protected species issues, recreational fishery enhancement, marine spatial planning, environmental impact assessment, reclamation, long-term monitoring, habitat restoration, natural resource damage assessment, wetland delineation, permitting, modeling, risk assessment, stormwater management, permit application and compliance, and fish and aquatic animal tissue sampling. If you are someone who thrives on variety and novel challenges, consider a potential career in consulting. You will be surprised and rewarded by where it leads you.

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HUTTON SPOTLIGHT

U.S. Fish and Wildlife Service's Alabama Field Office Hutton Scholars: Where Are They Now?

Denise Rowell

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Benjamin Franklin once said "Tell me, and I forget. Teach me, and I may remember. Involve me, and I learn."

At the U.S. Fish and Wildlife Service's Alabama Field Office (AFO), we take Franklin's philosophy to heart. Since 2009, AFO has been hosting young students to help achieve their dreams of conserving natural resources. Through the American Fisheries Society's Hutton Junior Fisheries Biology Program, AFO biologists have mentored four high school students to help set them on a path to a career in biology.

The Hutton Program is an eight-week mentoring opportunity that allows high school students to intern with fisheries professionals. In addition, the students also receive a $4,000 scholarship. High school seniors and juniors are eligible, and the scholar is selected from a pool of candidates.

Once a scholar is selected, he or she is paired with a mentor. Although Andy Ford and Jennifer Grunewald are the lead AFO mentors, most of the staff plays a role in guiding the scholar. Even AFO's trusted partners have turned into dedicated mentors. Biologists with the Alabama Department of Conservation and Natural Resources have also taken Hutton Scholars under their wing.

Hutton Scholar Garrett Lloyd. Photo credit: USFWS.

2009 Hutton Scholar Garrett Lloyd

Garrett Lloyd of Fairhope was AFO's first official Hutton Scholar in 2009. Lloyd was selected by the American Fisheries Society from a pool of applicants to spend the summer at our office under the mentorship of fishery biologist Andy Ford. "I knew right away that Lloyd would be an asset to our office. He was ready to hit the ground running and get his hands dirty," said Ford.

With a jam-packed summer, Lloyd had plenty of opportunities to go out in the field and do the work of a professional biologist. Along with his mentor and various other biologists, Lloyd participated in mussel surveys, gopher tortoise relocations, sea turtle nest patrols, red-bellied turtle fencing, and stream fish sampling, just to name a few. "The project that I enjoyed most was mollusk sampling in the Alabama River tributary; searching for mussels and aquatic snail populations," explained Lloyd.

For mentor Andy Ford, the experience was just as rewarding. "Lloyd was attentive, enthusiastic, and easy to work with. I wanted to make sure he could experience many different aspects of conservation," said Ford. "When you work in conservation, you need to network and develop partnerships to successfully do your job. During the summer that Lloyd was here, we worked with multiple agencies and groups, which exposed him to more experiences and opportunities."

Lloyd said his mentor was an excellent example of someone who truly loves his work. "It was apparent from the beginning that Ford had dedicated many hours of work to plan, so I could get a well-rounded learning experience," said Lloyd. "He made sure I was well-prepared prior to each field assignment, and gave me generous exposure to other organizations involved with fisheries science."

Thanks to his connections through the Hutton Program and continued mentoring by Ford, doors of opportunity opened and Lloyd received a summer job with the Alabama Department of Conservation and Natural Resources in 2012. During the previous summer, Lloyd had an opportunity to work with and meet Dave Armstrong, District V fisheries supervisor, and that connection translated into a new job opportunity. A year later, and because of the previous opportunity, he got a job working for the Weeks Bay Foundation, a non-profit organization dedicated to conservation.

While still attending Troy University, and most likely because of the impressive resume he built before graduation, Lloyd was hired by the Natural Resources Conservation Services as a Pathways Intern. The Pathways Program is a federal program that selects college students and employs them within specific agencies. This opportunity led to full-time employment after graduation from Troy University in 2015 with a degree in ecology and field biology, and is currently where Lloyd is employed.

Lloyd is forever grateful for the time he spent as a Hutton Scholar. He says the opportunity catapulted him into a career in conservation. "Just like every organism has a unique niche, we as people have a niche in how we contribute to our world," said Lloyd. "If you feel you have a calling in biology, the Hutton Program will help you and your passion and elevate you to new levels."

Below is a list of other Hutton Scholars who spent the summer with AFO. How are they doing now?

2010 Hutton Scholar David Bernasconi

Since finishing the program, Bernasconi received a bachelor's degree from Louisiana State University in natural resource ecology and management with a concentration in wildlife ecology. While in school, he was an alligator research technician and conducted his own bald eagle migration project. After that, Bernasconi worked as an avian technician in the mountains of Borneo in Malaysia. He was also a volunteer research assistant at the Danau Girang Field Center, also in Malaysia, where he helped to track and trap clouded leopards, sun bears, and other species. In the summer of 2015, Bernasconi was a bald eagle technician for the North Carolina Resources Commission. Currently, he is looking for graduate school opportunities, and eventually wants to earn his Ph.D.

"This program holds a special place in my heart as it gave me a huge leg up in the eyes of my undergrad professors and early employers. I am still in contact with my mentors today and they have been extremely important friends and professional resources."

Hutton Scholar David Bernasconi. Photo credit: USFWS.

Hutton Scholar Katie Dankovic. Photo credit: USFWS.

2013 Hutton Scholar Katie Dankovic

Dankovic is attending the University of South Alabama, where she is majoring in biology with a concentration in marine sciences. She joined a team of biology majors, working on various projects overseen by her herpetology professor. One project entailed finding populations of the bahaman anole *Anolis sagrei*, a highly invasive species in both Mobile and Baldwin counties. Dankovic is also working on a database for evidence of cancerous tumors in reptiles, specifically turtles, in various zoos and aquariums. She plans to spend the summer with the Dauphin Island Sea Lab, where she'll study sharks, rays, and marine conservation biology. Dankovic graduates in December 2016.

"Before I participated in the Hutton Program, I wasn't exactly sure that I wanted to major in Biology in college. But after participating in the program for the summer, I went into college very confident that I could major in Biology and enjoy it. The Hutton Program gave me some much needed confidence in myself to succeed."

2015 Hutton Scholar Dionna Walker

Fresh from her internship, Walker is just getting started! She's a freshman at the University of Alabama-Birmingham, double majoring in biology and international studies, in addition to minoring in environmental studies. Since her college career is just beginning, she spends most of her time studying. Walker is in the Science and Technology Specialized Honors Program, which is designed to help undergraduate students get involved in research and complete a thesis project. She hopes to begin lab work and start on her project by fall of next year.

"I had a great time working at the Alabama Field Office. I feel like I learned a lot and got to know some amazing people. My favorite part of the internship was the fieldwork. It was interesting, engaging and gave me a chance to get my hands dirty and get to know a lot of people in a different way than I would have just in the office."

Hutton Scholar Dionna Walker. Photo credit: USFWS.

For updates on AFO Hutton Scholars, please visit the Alabama Field Office Facebook page: www. facebook.com/usfwsalabama.

NEWS

World Fisheries Congress Wrap-up

Beth Beard
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The 7th World Fisheries Congress in Busan, South Korea, was "one of those meetings you can tell is going well just by the buzz in the hallways," as Felicity Huntingford, former president of the World Council of Fisheries Societies, put it in her toast at the gala dinner. With 10 keynote speakers, 36 oral presentation sessions in 12 concurrent slots, and hundreds of posters, there was a lot for more than 1,000 attendees to buzz about. Much of the convention center area of the city was decorated in congress banners and the Opening Ceremony was reported in Korean television news.

The meeting kicked off with AFS Past President (1990–1991) Larry Nielsen's retrospective on the first World Fisheries Congress in Athens in 1992, making this the silver anniversary of the congress. He talked about the hurdles of organizing an international conference in the pre-Internet era and reviewed the predictions and assertions of those first congress speakers and whether they were realized almost 25 years later. Most of predictions were right on target, except for perhaps an underestimation of how much aquaculture would grow.

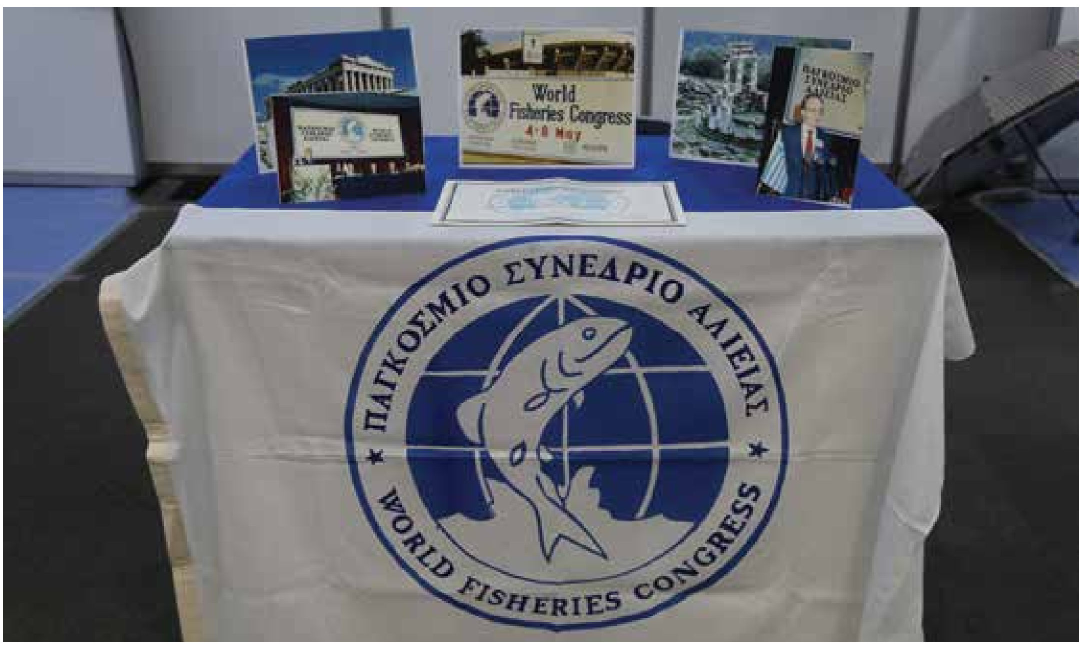
The Opening Ceremony included a traditional drum performance, followed by welcome remarks from the mayor of Busan and the Korean Minister of Oceans and Fisheries, along with a video message from Korean President Park Geun-hye. Much of the ceremony focused on a major announcement about a proposal to found a "World Fisheries University" at Pukyong National University in Busan, potentially under the auspices of the Food and Agriculture Organization of the United Nations (FAO). The university would focus on fisheries management capacity building through training for students from developing countries, and the Korean government has proposed to fund the program at US$100 million over the first 10 years.

Besides Nielsen, other AFS members giving keynote talks were Terry Quinn of the University of Alaska Fairbanks, Kenneth Rose of Louisiana State University, Mary Fabrizio of the Virginia Institute of Marine Science (AFS Past President 2007–2008), and Ray Hilborn of the University of Washington. Among the talks by other keynote speakers, one of the most fascinating was Goro Yoshizaki's story of his lab's quest to produce Bluefin Tuna gametes from mackerel parents and the many technological and biological hurdles involved.

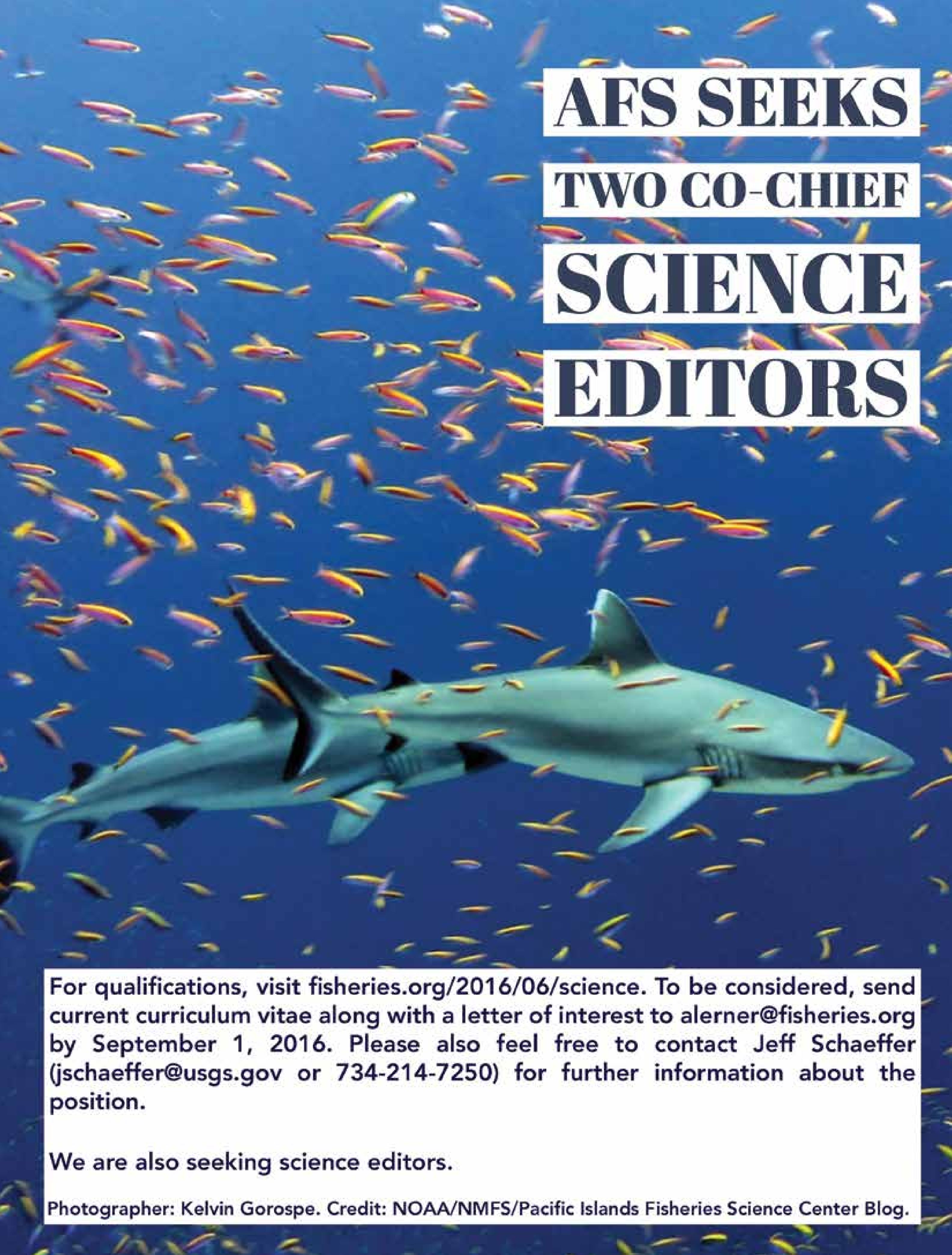
The concurrent sessions were presented entirely in English. Several sessions were organized by AFS members, including sessions on climate change and inland fisheries, standardized sampling for freshwater fishes, and advancements in stock assessment.

The meeting culminated on Friday with the presentation of the International Fisheries Science Prize to Ray Hilborn, who then gave the final keynote presentation on how fisheries stocks vary around the world and how much of that is due to fisheries management. The Closing Ceremony featured the WFC flag being turned over to the Australian Society for Fish Biology, which will be hosting the 8th World Fisheries Congress in Adelaide (wfc2020.com), October 11–15, 2020. AFS member Doug Beard will soon be concluding his term as president of the World Council of Fisheries Society, but Donna Parrish, previously co-chair of the WFC Program Committee, was elected as co-vice-president of the council.

Many thanks to our hosts at the Korean Society of Fisheries and Aquatic Science for their warm hospitality and an informative, well-organized meeting in dynamic Busan. AFS



Artifacts on display from the First World Fisheries Congress in Athens, 1992.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We are also seeking science editors.
Photographer: Kelvin Gorospe. Credit: NOAA/NMFS/Pacific Islands Fisheries Science Center Blog.

What Not to Miss at the 2016 KC Annual Meeting

6 Questions with Program Co-Chairs Quinton E. Phelps and Sara Tripp

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1. Why should you attend Kansas City?

The 2016 146th AFS Annual Meeting offers a chance to hear science from experts around the world, enhance your job skills with hands-on Continuing Education Workshops, see the latest technology in the Trade Show, and network with colleagues old and new. Overall, we will have 40 symposia, plus the Student Best Papers and Posters Session, around 20 contributed sessions, and nearly 750 oral presentations and 110 poster presentations. Plus, this year's hotel and conference center are all under one roof at the Sheraton Kansas City at the Crown Center, giving you more free time to see presentations, meet with collaborators, and explore the city. And Kansas City's affordable, central location combined with its thriving arts culture, nightlife, and stunning natural resources, means that there is something for everyone to enjoy in August 2016!

2. Why should students and early career scientists attend?

The decision to go with a theme this year "Fisheries Conservation and Management: Making Connections and Building Partnerships" was chosen by our AFS President Ron Essig because he really wanted to stress the importance of developing collaborations among our profession. You should attend for:

- Opportunities to build those relationships with other professionals
- Symposia focused on career development:
    - Hatchery Fish Biologist...A Career for the Future
    - Preparing Fisheries Professionals with Depth and Breadth (T-Shaped Professionals)
- Free Continuing Education Courses:
    - Leadership at All Levels in AFS
    - Scientific Publishing and Communication

3. What will be the largest fisheries issues addressed at the meeting?

We believe that there will be more than one major public issue at this meeting. Habitat, humans, fish, and their interactions are the top topics at this meeting, not to mention the advancements that have been made in fisheries research, management, and communication. Currently, a diversity of challenges are being faced by fisheries managers, scientists, and stakeholders. The following symposia will have the greatest number of presenters: (1) Cooperative Fisheries Research in Marine and Freshwater Systems: From Policy to Practice-Monday, (2) An Examination into Influencing the Future of Angling Participation to Sustain Conservation Support, (3) Managing Centrarchid Fisheries in Rivers and Streams, (4) Release and Discard Mortality Estimation: Lessons from Freshwater and Saltwater Environments, (5) Reservoir Fisheries Habitat Restoration: Innovative Techniques to Restore Habitat in our Nation's Impoundments, and (6) Documented and Documenting the Effects of Climate Change on Inland Fish and Fisheries. There will also be several general sessions that will be well attended: (1) Freshwater Fisheries Management, (2) Movement and Aquatic Organism Passage, and (3) Salmonids.

4. What will be the biggest local newsmakers as far as symposia goes?

Now that is an interesting question. Which topic makes the news will likely be dependent on the fact that we are in the heart of the Midwest on the Missouri River and emerging topics that are of importance to that readership group. In the Kansas City area, Pallid Sturgeon *Scaphirhynchus albus* and other big river related research (e.g., invasive Asian carp, trophy Blue Catfish *Ictalurus furcatus*, floodplain connectivity) are always great news items.

5. What do you think will be the most unique symposium and why?

There are two symposia related to drought and climate change that will certainly be distinctive. These are both certainly hot topics in the fisheries world right now. The information garnered will bring to light new perspectives on topics we don't frequently discuss but that impact our success at managing our fisheries resources. Another symposium entitled "Applications of Methods and Techniques and Collaborations in Managing and Conserving Large River Basin Fishery Resources and Environment" will also be unique in terms of international flare. This symposium is a continuation of previous symposia that has built on a partnership between Chinese and North American scientists as it relates to issues facing big river resources. We also believe that the symposium "Fisheries Science in 140 Characters: The Role of Social Media in Our Science" will be unique.

6. What topics do you think attendees will be talking about the most after the final door closes in Kansas City?

From a technical standpoint, we think that many of the topics covered at the meeting will generate a lot of discussion both during and post meeting. At this point, we really don't know what that topic will be—but are certain that attendees will remember Kanas City. From a meeting location standpoint, they'll be talking about how great it was to explore Kansas City and the surrounding area and trying to discover everything that makes Kansas City unique. That being said, I am certain most folks will remember the hospitality they will feel in Kansas City…and certainly will not forget how delicious that slab of ribs or pulled pork sandwich goes with that wonderful local Kansas City Brew. AFS

In Memoriam

Otto F. Fajen
1927–2016

Otto F. Fajen, retired fisheries research biologist of the Missouri Department of Conservation, passed away Monday April 25, 2016, at the Boone Hospital Center in Columbia, Missouri.

Fajen began his career with the Missouri Department of Conservation in 1959 after obtaining bachelor's and master's degrees in fisheries and wildlife from the University of Missouri–Columbia.

He spent his entire career working on streams, conducting numerous research projects on stream dynamics and fish populations. He was a nationally recognized Smallmouth Bass *Micropterus dolomieu* expert. His early research on this species provided the scientific basis for a statewide 12-inch length limit on bass. Two of his papers on bass in streams and rivers were published in *Black Bass Biology and Management*.

Fajen had an impressive understanding of stream functions and fluvial processes. His pioneering work on streams and stream fish populations provided a scientific basis for the development of important programs to improve Missouri's streams and fisheries, including rehabilitation of habitat, length limits on bass, supplementing black bass fisheries in appropriate stream systems and the establishment of a Streams Unit in the Fisheries Division of the Missouri Department of Conservation, which included the creation of voluntary, citizen-driven stream teams. He also developed a stream habitat assessment plan to evaluate stream habitat conditions and assess the potential impacts of stream alteration projects.

Fajen's knowledge of stream functions and habitat enabled him to work effectively with agency personnel and private landowners as well. One example of his ability occurred in the mid-1980s when a contractor graded two miles of Hinkson Creek, a fifth-order stream near Columbia, Missouri, while installing a new sewer line. This resulted in near total elimination of pools and deepwater habitat within the graded area. Fajen contacted personnel from regulating agencies and determined that the contractor was in violation of 404 regulations.

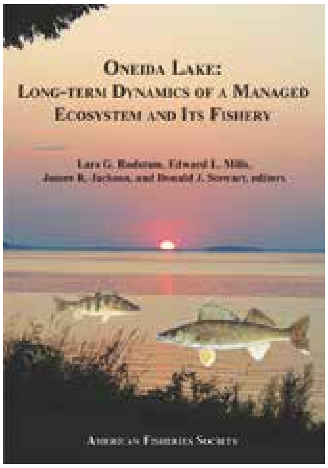
Fajen believed that the most habitat could be provided by restoring the riffles. The challenge was that no one had any experience in this type of restoration. The contractor reestablished the pool-riffle sequences; restored pools to previous depths; and restored aquatic habitat to near former levels. Fajen's knowledge about what to do and how to do it resulted in the restoration of this destroyed habitat.

Fajen received several awards for his contributions to the protection and management of stream systems. The Missouri Chapter of the American Fisheries Society awarded him a Letter of Recognition in 1989 and the Award of Excellence in 1992. In 1996, he was inducted into the National Fisheries Hall of Excellence by the Fisheries Management Section of the American Fisheries Society for his lifetime of dedicated work supporting streams and fishing.

Fajen was an avid naturalist and owned several local properties well known to local bird, wildlife, fish, and water plant experts. After retirement, he continued to be active in conservation and worked to restore water quality of coal strip-mine lakes on his property and on nearby acidity-affected creeks in central Missouri.

Fajen is survived by his wife Ann, daughter Ava and husband Scott Christianson, and son Otto J. Fajen and wife Lisa and their five children. A celebration of his life and work was held May 27, 2016, at the Unitarian Universalist Church of Columbia, Missouri. Memorials are suggested to The Nature Conservancy.

—Compiled by Joe G. Dillard



Oneida Lake: Long-Term Dynamics of a Managed Ecosystem and Its Fishery

Lars G. Rudstam, Edward L. Mills, James R. Jackson, and Donald J. Stewart (editors). American Fisheries Society, Bethesda, MD. 2016. 541 pages. US$79.00 (softcover or pdf download).

Reviewed by: Edward D. Houde

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This edited book tells the story of a large lake ecosystem and research conducted on it over several decades. Its 24 chapters and 61 contributing authors present a comprehensive treatment, documenting successive changes since the 1960s. In the early years, research conducted at the Cornell University Biological Field Station (CBFS), was focused on the dynamics of a fishery dependent on the coupled dynamics of Walleye predators and Yellow Perch prey. A goal of the science was to develop management recommendations to support the productive and valuable recreational fishery. This part of the Oneida Lake story evolves from the enduring insights, accomplishments, and contributions of John Forney, first director of the CBFS (1956–1992). The book, fittingly, is dedicated to him.

Ecosystems change and Oneida Lake is no exception. Reductions in phosphorus inputs (1970s) and invasions by White Perch *Morone americana* (1960s), zebra *Dreissena polymorpha* and quagga *D. rostiformis bugensis* mussels (1990s), and ongoing climate change have impacted the lake and broadened the scope of science on its problems that have included a wide range of limnological research since the 1980s under CBFS Directors Edward Mills and, most recently, Lars Rudstam. A "simple" fishery management scheme proposed by Forney, which relied on annually assigned, minimum size limits on Walleye *Sander vitreus*, referred to as "Forney's algorithm" in the book, became less effective after the 1980s. Much of the book is a synthesis of the decades of data documenting changes and leading to predictions and forecasts of the ecosystem's trajectory. The massive amounts of data supporting contributions in this book are archived and available to all (Chapter 1).

The first six chapters of the book (Parts I and II) largely serve as an introduction to the Oneida Lake ecosystem and its history of successive changes, especially those since the late 20th century. The interesting history of the CBFS (Chapter 2) is followed by readable and engaging chapters that describe the lake, the history of fish and fisheries on the lake back to the 18th century, the people who fished, and the science aimed at understanding and managing fisheries. Atlantic Salmon *Salmo salar* and American Eel *Anguilla rostrata* disappeared from Oneida Lake long ago. White Perch invaded and thrived in the 1950s–1960s. The history of species losses and ongoing introductions of invasive species and range extensions (Chapter 6) demonstrate the lake's ability to absorb changes while remaining resilient and productive. Stressors and factors emerging successively since the 1950s are documented—these include (1) eutrophication and disappearance of the mayfly *Hexagenia* as a dominant benthic invertebrate; (2) the range extension and establishment of White Perch in the lake; (3) the reductions in phosphorus inputs and a trend toward oligotrophication; (4) introduction of invasive, filter-feeding zebra and quagga mussels; and (5) accelerating climate change. Readers will be disappointed to not find a clear, detailed, map of the lake, its watershed, tributaries, canal systems, and surrounding towns.

Part III consists of 13 chapters, each written as a typical journal paper. Topics include nutrient and plankton dynamics, submerged aquatic vegetation, hydrodynamics, and trophic-level analysis. The chapters on zebra mussel invasion in the early 1990s and its impact (Chapters 9 and Chapter 18) describe the "benthification" of the lake and associated changes, including probable effects on fish community ecology. The reestablishment of submerged vegetation, associated with increased water clarity after zebra mussel establishment, is well documented (Chapter 10) and similar to outcomes in other ecosystems invaded by this mussel. Chapters on plankton indicate recent declines in phytoplankton biomass (Chapter 8) but no clear change in dynamics of key zooplankters (*Daphnia* spp.; Chapter 12) that are prey for young of Walleye and Yellow Perch *Perca flavescens*.

For fisheries scientists, key chapters in Part III are those on the Walleye and Yellow Perch population trends, recruitment variability, and predator–prey relationships (Chapters 15–17). The analyses and bioenergetics modeling that quantify Walleye predation on Yellow Perch (Chapter 15) should be instructive and useful for scientists addressing similar questions in other systems. Chapter 16, in my view, is the single most important chapter in the book. It critically addresses recruitment variability in Walleye and Yellow Perch and the trends over time, with analysis of change and causality. The paper's benchmark is the important paper by Forney (1980) that synthesized the topic years ago and strongly influenced management strategies for Walleye and Yellow Perch fisheries in Oneida Lake and beyond. The new analysis indicates that the length-based management strategy proposed by Forney for the closely coupled predator–prey pair may no longer apply in the evolved Oneida Lake with its decoupled Walleye–Yellow Perch dynamics.

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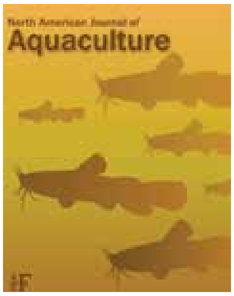

Journal Highlights

NORTH AMERICAN JOURNAL OF AQUACULTURE

Volume 78, Number 2, April 2016

Effect of Taurine Supplementation on Growth Response and Body Composition of Largemouth Bass. *Catherine A. Frederick, Shawn D. Coyle, Robert M. Durborow, Leigh Anne Bright, and James H. Tidwell*. 78:107–112.

Implementation and Enforcement of Best Management Practices for Florida Ornamental Aquaculture with an Emphasis on Nonnative Species. *Quenton M. Tuckett, Jared L. Ritch, Katelyn M. Lawson, and Jeffrey E. Hill*. 78:113–124.

Low-Intensity, Stocker-Based Channel Catfish Culture. *Bartholomew W. Green, Carole R. Engle, Rebecca Lochmann, and Harold Phillips.* 78:125–135.

[Communication] Effects of Family, Feeding Frequency, and Alternate Food Type on Body Size and Survival of Hatchery-Produced and Wild-Caught Lake Sturgeon Larvae. *John M. Bauman, Brittany M. Woodward, Edward A. Baker, Terence L. Marsh, and Kim T. Scribner*. 78:136–144.

[Technical Note] Survival of Hatchery Raised Red Drum Exposed to Abrupt Salinity Increases—Simulating Bay Stockings. *Dusty L. McDonald, Paul D. Cason, Britt W. Bumguardner, and Joseph R. Tomasso.* 78:145–147.

[Technical Note] Mark Retention of Calcein in Cisco and Bloater. *M. A. Chalupnicki, G. E. Mackey, K. Nash, R. Chiavelli, J. H. Johnson, T. Kehler, and N. Ringler*. 78:148–153.

Can Application of Commercial Microbial Products Improve Fish Growth and Water Quality in Freshwater Polyculture? *Jin-yu Tang, Yang-xin Dai, You-ming Li, Jian-guang Qin, and Yan Wang.* 78:154–160.

Artificial Rearing of Endemic Red-tailed Barb *Hypselobarbus kurali*: A First Report. *Sherly E. Williams, P. Vijayalekshmi, Allen Benziger, Razeena Karim, and Vishnu Nair*. 78:161–167.

Effects of Different Corn Starch Levels on Growth, Protein Input, and Feed Utilization of Juvenile Hybrid Grouper (male *Epinephelus lanceolatus* × female *E. fuscoguttatus*). *Yuan Luo, Xiaoyi Wu, Weifeng Li, Shuntian Jiang, Senda Lu, and Mingjuan Wu*. 78:168–173.

[Communication] Survival and Physiological Responses of Juvenile Red Drum Exposed to Hypersalinity and Elevated Temperatures. *Erica M. Molina, Delbert M. Gatlin III, and Joseph R. Tomasso Jr.* 78:174–177.

A Review of Carbohydrate Nutrition and Metabolism in Crustaceans. *Xiaodan Wang, Erchao Li, and Liqiao Chen*. 78:178–187.

Continued from page 431

member), Trent Sutton (Education Subcommittee of the Board of Professional Certification), and James R. Triplett (Socioeconomics Section 2014–2016). A particular debt of gratitude is extended to Steve McMullin, who spearheaded the employer survey effort and graciously agreed to take over for me as chair of the committee when I became president-elect.

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McMullin, S. L., V. DiCenzo, R. Essig, C. Bonds, R. L. DeBruyne, M. Kaemingk, M. E. Mather, C. Myrick, Q. E. Phelps, T. Sutton, and J. R. Tripplett. 2016. Are we preparing the next generation of fisheries professionals to succeed in their careers? A survey of AFS members. Fishers 41(8):436–449. AFS

Continued from page 432

Grant John A. Knauss Marine Policy Fellowships and Coastal Management Fellowships offer opportunities for graduate students to branch into other fields. All are paid positions that will strengthen a resume and affirm potential career directions. Those few and many more opportunities await your Internet search.

Internships, fellowships, postdocs, special academic projects, and other creative ideas are important to budding fisheries professionals. Each offers the prospects of greater perspective as everyone from pending graduates to mid-career employees considers their academic and professional options. These positions offer ecologists the opportunity to dabble in policy, for aquatic policy experts to learn about physiology, and for Ph.D. engineers to go to law school. We need all of those opportunities. We need fisheries professionals with training across those disciplines. We need all of the above in a steady talent pipeline.

The depth and breadth needed for a successful career reflect a commitment to continuing education. Formally, that means completing coursework on specific topics but avoiding the tendency to pursue a narrow course of study. Informally, professionals can expand their expertise by joining AFS Sections “outside” your primary field or by attending events that stretch your knowledge base. Many of us maintain memberships in multiple societies, scientific and otherwise, extending well beyond fish and aquatic resources.

The future is yours. The opportunities are limitless. Create your own internship or task to suite your needs and ambitions. Go for it! And enjoy your never-ending education.

Note: The opinions expressed herein are those of the author alone. Comments are invited at tbigford@fisheries.org. AFS

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Two chapters in Part IV present quantitative models of Walleye and Yellow Perch population dynamics, demonstrating that individual-based models (Chapter 20) and matrix models (Chapter 21) can simulate variability in abundances and have utility to understand long-term changes. A comparative analysis of recent fish community trends in Oneida Lake with trends in three embayments of the Great Lakes (Chapter 23) indicated similarities but also differences. The final chapter (Chapter 24) summarizes the book’s content and forecasts and speculates on the future of Oneida Lake’s fisheries, concluding that climate change will inevitably lead to shifts in community structure, with Largemouth Bass *Micropterus salmoides* and Smallmouth Bass *M. dolomieu* increasing in dominance while percids decline.

The book need not be read in its entirety to appreciate the Oneida Lake ecosystem. Fishery scientists, managers, and limnologists will benefit from reading selected chapters. Students will be interested in chapters on the history of an evolving lake ecosystem and will learn about the evolution and conduct of large, collaborative research programs.

I was pleased to have the opportunity to review this book. Fifty-three years ago, I began my graduate research on Oneida Lake at the CBFS. I was John Forney’s first graduate student. Forney was a role model, teaching by example and instilling in me lessons that served me throughout my career. I add my accolades to those offered by Noble et al. in the book’s dedication to John Forney. I can heartily recommend the book for its science, its history, and its recognition of Forney’s contributions to understanding Oneida Lake and factors that regulate fish population abundance.

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Forney, J. L. 1980. Evolution of a management strategy for the Walleye in Oneida Lake, New York. New York Fish and Game Journal 27:105–141. AFS

CALENDAR

To submit upcoming events for inclusion on the AFS website calendar, send event name, dates, city, state/province, web address, and contact information to sharrison@fisheries.org. (If space is available, events will also be printed in *Fisheries* magazine.) More events listed at www.fisheries.org

August 21–25, 2016

146th Annual Meeting of the American Fisheries Society | Kansas City, Missouri | 2016.fisheries.org

August 24–25, 2016

3rd Annual International Conference on Fisheries and Aquaculture | Sri Lanka | aquaconference.com/2016

September 5–8, 2016

Australian Society for Fish Biology Conference | Hobart, Tasmania

September 14–17, 2016

6th International Billfish Symposium | Dania Beach, Florida | bfsymposium.org

October 2–6, 2016

The World of Trout: 1st International Congress | Bozeman, Montana | troutcongress.org

November 10–12, 2016

2nd International Congress on Applied Ichthyology and Aquatic Environment | Mesolonghi, Greece | hydromedit2014.apae.uth.gr

December 6–7, 2016

Flatfish Biology Conference | Westbrook, Connecticut | nefsc.noaa.gov/nefsc/Milford/flatfishbiologyworkshop.html

December 10–15, 2016

Restore America's Estuaries and The Coastal Society: 2016 Summit: Our Coasts, Our Future, Our Choice | New Orleans, Louisiana | estuaries.org/Summit

June 26–28, 2017

European Inland Fisheries and Aquaculture Advisory Commission Symposium | Olsztyn, Poland | eifaac2017.infish.com.pl

February 5–8, 2017

77th Midwest Fish & Wildlife Conference | Lincoln, Nebraska | www.midwestfw.org

November 19–24, 2017

5th Biennial Symposium of the International Society for River Science | Hamilton, New Zealand | isrs2017.com


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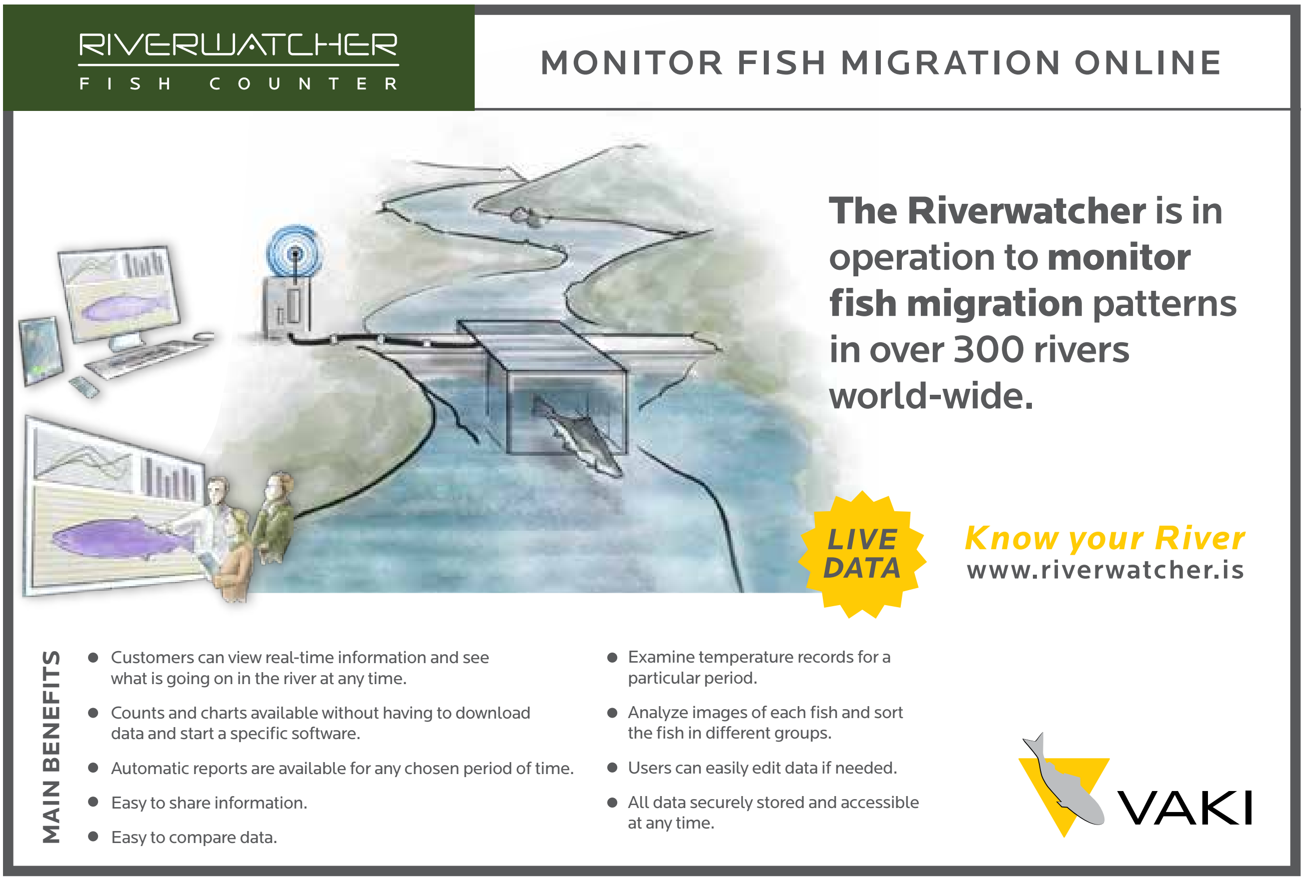
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VAKI

Back Page Photo Series:

Reflector An Interview with Valentina Di Santo

Interview by Natalie Sopinka | AFS Contributing Writer

Photographer: Valentina Di Santo (vdisanto@fas.harvard.edu, www.valentinadisanto.com), Harvard University

Location: Calabash Caye, Turneffe Atoll, Belize

I'm a postdoctoral fellow in George Lauder's lab at Harvard University. My research aims to elucidate the strategies employed by marine fishes to cope with fluctuations and challenges in their environment. I'm interested in understanding the degree of interindividual variation and local adaptation in aerobic performance of fishes exposed to climate change stressors, specifically ocean acidification, warming, and hypoxia. I study a diverse group of fishes, but I have focused mainly on elasmobranchs, in particular batoids (skates and stingrays). I am currently measuring locomotor performance of skates by integrating their energetics with kinematics and fluid dynamics.

Am I seeing double? How many batoids are in this photograph?

Just one! This is a juvenile Yellow Stingray *Urobatis jamaicensis*, which is generally found on sandy and seagrass bottoms of shallow waters and coral reefs in the western Atlantic Ocean.

Where was this photo taken?

This photo was taken at the University of Belize Marine Field Station, at Calabash Caye, Turneffe Atoll. I was co-teaching a field course on coral reef dynamics through the Boston University Marine Program. I was snorkeling right off the dock with a group of students and found this juvenile Yellow Stingray swimming close to the surface.

What is your connection to the batoid in this photo?

At the time this photograph was taken, I was a Ph.D. student at Boston University with a growing interest in using fish swimming performance to predict migration potential under changing climatic conditions. Stingrays and skates have largely expanded pectoral fins that form a disc. These uniquely shaped fins generate propulsive waves of bending from anterior to posterior. Stingrays and skates are good maneuverers but not very fast, unlike the migratory eagle, manta, and cownose rays, which use an oscillatory locomotor mode (Lauder and Di Santo 2015). When I joined Lauder's lab as a postdoc, I started to combine 3D kinematics and bioenergetic analyses to characterize the undulatory locomotion of batoids.

What role do batoids play in the ecosystem?

Batoids have important and complex effects on marine ecosystems. Batoids are mesopredators, meaning that they are both prey and predators. As mesopredators, batoids control benthic prey populations through predation and are predated upon by sharks.

What are the predicted effects of climate change on these benthic creatures?

At the moment it is difficult to make predictions on batoids as a whole because there are only a handful of studies in which the effects of climatic stressors have been examined on these fishes. Elasmobranchs mature slowly (an average of about 10 years but varies with species), so they are particularly susceptible to rapid, directional changes in the environment. If they cannot adapt or acclimate to new conditions, the only viable alternative is to relocate to more favorable areas. Efficient locomotion may therefore ensure resilience in batoids. However, the ability to undertake large-scale migrations raises serious concerns for benthic and oviparous species that also tend to be philopatric. Skates, for example, are relatively smaller than other large-scale migrators (e.g., some larger pelagic sharks and stingrays), and size correlates with the ability to maintain wide geographic ranges. In addition, female skates lay eggs on the seafloor and embryos are stuck inside egg cases for a prolonged period of time (about 5 to 12 months), so adults have to restrict their ranges to suitable spawning areas (i.e., they are highly philopatric). As a consequence, many skate species do not exhibit long-range migrations and often do not recolonize even nearby areas where other populations have been extirpated. More work needs to be done to understand whether skates also spatially restrict their movements because they are inefficient swimmers. In fact, if these benthic elasmobranchs are not capable of adjusting their physiology or relocating because of limited locomotor capacity, climate change is expected to cause widespread extinctions.

How is your research addressing climate change-mediated impacts on batoids?

In the past few years I have quantified the physiological responses of embryonic and juvenile Little Skates *Leucoraja erinacea*, a temperate species living in the northwestern Atlantic Ocean, to ocean acidification, warming, and hypoxia. I try to answer fundamental questions in conservation physiology. Can skates developmentally acclimatize to climatic stressors? Is there any significant interindividual variation in the response to climatic stressors? Does body size play a role in determining which populations of skates will be more or less resilient to climatic stressors? And, finally, if acclimation or adaptation to a new environment is unlikely, do skates have the capacity to sustain a large-scale migration and relocate?

To answer these questions I quantify metabolic performance of fishes throughout embryonic development and in juveniles while they are swimming, digesting, or reacting to an external stimuli (such as an attack from a predator). In particular, I look at body size, oxygen consumption, and fin and body kinematics to determine whether and how fishes increase locomotor efficiency when faced with perturbations in their environment. I found that skates are very sensitive to warming and hypoxia, and acidification exacerbates the effect of warming on their aerobic scope (i.e., the amount of energy they have to be active; Di Santo 2015, 2016). Little Skates also show morphological and physiological differences between latitudinally separated populations (Gulf of Maine, 43°N, 68°W, and Georges Bank, 41°N, 67°W). Smaller skates from the Georges Bank are less sensitive to acidification when compared to larger conspecifics from the Gulf of Maine, possibly because they grow slower and therefore have more energy available to cope with environmental stressors. Another hypothesis is that skates from the Georges Bank are somewhat "pre-adapted" to fluctuating pH levels, as a result of frequent upwelling in the area (Di Santo 2016). When it comes to swimming, Little Skates are very efficient metabolically (using less energy per unit of time and mass than any other elasmobranch ever tested) but cannot move very far distances because their cost of transport (energy per kilometer per unit of mass) is much higher (Di Santo and Kenaley 2016) and it is only surpassed by very active species, like the Mako Shark *Isurus oxyrinchus*. Cost of transport is higher in smaller fishes because they require more energy (and time) to cover a given distance. These results support field studies that show limited geographic ranges in smaller benthic species, such as skates, when compared to larger elasmobranchs. The good news is that there appears to be intraspecific variation in physiological responses to climate change stressors; this variation suggests that there is the potential for adaptation in this species.

How does one measure aerobic performance of embryonic batoids?

Skate embryos are constantly moving inside the egg case. To ensure that clean, oxygenated water is circulated inside the egg case, embryos whip their tail (see a video here: youtu.be/eziPYb1INA0). This is an important but energetically expensive behavior that is affected by climatic stressors (Di Santo 2015; Di Santo et al. 2016). I place the embryos (~5 g) inside a tiny (<0.5 L) respirometer and measure oxygen consumption as they are whipping their tails. To calculate an embryo's aerobic scope, I subtract the resting metabolic rate (measured in anesthetized embryos) from the metabolic rate when the embryo is whipping its tail. The metabolic rates of skate embryos can double from resting state while whipping their tail at the average temperature they are currently experiencing in nature. However, energetic costs of circulating water inside the egg case can triple at acidification and warming levels expected by the end of the century.

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