The Future of Cooperative Fish and Wildlife Research

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The early fish and wildlife conservation profession and institution in the United States faced a number of fundamental challenges during the 1930s. Knowledge of basic principles as to limiting factors and management techniques, as well as a cadre of trained professionals to restore populations and habitats, was severely lacking (Leopold 1930). The Cooperative Fish and Wildlife Research Unit Program (CRU) is based upon an original model designed to fulfill these needs (Goforth 2006; Whalen and Thompson 2015). During the past 80 years, the profession and institution have evolved in response to changing scientific, environmental, social, political, and demographic factors (Jacobson et al. 2010; Organ et al. 2012; Organ and Batcheller 2010). This evolution has been necessary for maintaining relevancy, and some argue further transformative institutional changes are needed (Jacobson et al. 2010). How relevant is the CRU model to current and future needs of the conservation profession and institution? Should the CRU refocus in order to maintain relevancy or move towards an entirely different model? Herein, we offer perspectives on these questions and propose a vision for the future of the CRU.

Current Challenges, Emerging Needs

The 1973 North American Wildlife Policy (Allen 1973, 74) contained the statement, "The future of wildlife is tangled in the total complexity of man's relationship to nature." In the more than 40 years since this statement was written, that complexity has been magnified. Human population growth and high per capita rates of resource consumption, combined with economic globalization, have expanded the fish and wildlife conservation paradigm from restoration of populations and habitats to sustaining the functionality of landscapes and the ecosystems they contain (Worldwatch Institute 2014). Stressors operating at the landscape level include domestic energy production demands, water allocation issues, human-wildlife conflicts, land uses (e.g., grazing, crop production, human infrastructure development), international wildlife trade, invasive species, fish and wildlife diseases and zoonotics, and climate change. The role of science in informing public policy—a pillar of North American conservation (Organ et al. 2012)—has been perceived to have diminished greatly (Mahoney et al. 2008). The need to integrate human dimensions inquiry into ecological science, with comparable rigor, is essential for communicating science to policy makers and stakeholders (Organ et al. 2014). Purposeful application of decision-making tools to achieve more durable, transparent policy outcomes is needed as stakeholder demands become more contested (Riley et al. 2003; Williams et al. 2009). New and emerging scientific tools in areas such as conservation genomics and geospatial data analysis offer considerable potential for wildlife managers, but these new tools require specialized training and thoughtful integration into existing management and decision-making frameworks.

The significance of these issues is reflected in published and unpublished internal science planning and prioritization documents of the Association of Fish & Wildlife Agencies (AFWA), the U.S. Fish & Wildlife Service (USFWS), and the U.S. Geological Survey (USGS), representing three of the CRU's principal cooperators (Williams et al. 2013). Themes include the following:

- Landscape conservation science, planning and design (USFWS, USGS)
- Climate adaptation (AFWA, USFWS, USGS)
- Socioeconomic and cultural values (AFWA, USFWS)
- Science communication and delivery (USFWS, USGS)
- Monitoring (USFWS)
- Energy production and wildlife management (AFWA, USFWS, USGS)
- Emerging diseases/biosecurity (AFWA, USFWS, USGS)
- Ecosystem services (AFWA, USFWS, USGS)
- Advanced technologies (USGS)
- Ecological flows (USGS)
- Invasive species (AFWA, USFWS, USGS)

The American Fisheries Society (AFS) and The Wildlife Society, professional scientific societies that underpin institutional standards for science, education, and ethics, are concerned over the frequent lack of integration between science and management. This lack of integration is manifested in different ways, including gaps between the direction of science education and applied management expectations, which is a product of ineffective bi-directional dialogue between scientists and managers, as well as factors related to priorities at universities and priorities within agencies (Jacobson et al. 2010; McMullin et al. 2009).

Throughout the fish and wildlife conservation institution in the United States there is concern over the future workforce: Will there be appropriate training to meet emerging conservation challenges, and will the workforce reflect the diversity of the American public? Currently, 37.4 percent of Americans are nonwhite, Hispanic, or Latino according to U.S. Census data, but such Americans account for only 11.7 percent of hires during the last three years in government natural resources agencies (Taylor 2014). Recruitment and development of a highly skilled, diverse workforce is needed immediately as baby boomer retirements escalate (Hallerman et al. 2014).

Role of the CRU

Goforth (2006) and Whalen and Thompson (2015) provide concise historical and structural information on the CRU. They outline the strengths of the program via the collaborative framework, the applications of science to management, the development of natural resource leaders, and the role in bridging the science needs of state and federal agencies and NGOs with expanded university resources. By means of the CRU, a framework has been in place for decades to facilitate cooperation in tackling conservation challenges. This framework has shown itself to be robust to new developments in science as well as to new and emerging needs of natural resource managers. The role of the CRU in addressing contemporary and future needs has come into question though, and these concerns warrant attention.

Questions About The CRU

Despite the CRU's long-standing record of success (e.g., Goforth 2006, Whalen and Thompson 2015), concerns have been raised by some in the conservation community about the efficacy of the CRU model in addressing the challenges of the future. For example, these themes have occurred in recent years; counterpoints to those themes follow:

- *Is the CRU just a state-based program that cannot escape state boundaries and address larger issues at the landscape scale (i.e., a geography with boundaries defined by ecosystems as opposed to political or institutional units)?* Haukos et al. (2015) provide explicit evidence to the contrary with the multistate landscape scale research on the lesser prairie chicken (*Tympanuchus pallidicinctus*). Other examples include the eight-state Western Elk Research Collaborative and a multi-CRU effort in the eastern United States to facilitate scenario planning for climate change adaptation. The multistate, multi-agency effort is part of a broader transborder initiative that the CRU has invested in heavily. The CRUs as the focal point of a state, federal, university, nongovernmental organization (NGO) cooperative are quite capable and adept at working across borders and addressing landscape-scale science (Haukos et al. 2015).
- *Does the CRU have thematic limitations, and can it address the deeper, more fundamental scientific and theoretical, ecological, and methodological issues? Does it produce small-bore science that misses the big and important issues bedeviling us all?* Schreck et al. (2015) provide explicit examples of how one CRU's breadth and depth of expertise has been applied to develop methodological tools that have advanced science and how theoretical inquiry into vexing conservation issues such as endangered salmon stocks and old-growth forest have yielded science breakthroughs. The CRU has worked across large landscapes and hemispheres from the Arctic to southern California and across Russia, Asia, and Canada investigating relationships between air quality, water quality, and fisheries. This work ranged in extent from microscopic to macroscopic, from conservation genomics and under the skin physiology to population modeling (Schreck et al. 2015).
- *Is the CRU basically a federally subsidized technical assistance to the states?* The CRU is a cooperative, and each cooperator (e.g., states, NGOs) contributes to the benefit of all cooperators and stakeholders. The examples provided by Haukos et al. (2015) and Schreck et al. (2015) illustrate the benefits in species conservation, technical guidance, and workforce development derived by the federal government and other natural resource conservation entities in addition to the states from the CRU-directed conservation outcomes.
- *Does the CRU produce students at land grant universities who are not the big-picture thinkers we need to address the challenges of tomorrow, but who are instead trained to deal with the natural resource issues of the past?* The CRU produces students uniquely prepared to address the challenges of tomorrow by virtue of their association with and mentoring by scientists and practitioners alike. The CRU is training its students in advanced technology and preparing them to be future leaders through a variety of opportunities in current research and development areas

including studies in Adaptive Management and Structured Decision Making and training in recently evolving disciplines ranging from molecular biology to global climate change analysis (Whalen and Thompson 2015). Distance learning opportunities through the use of new web-based technologies are provided to the CRU students and afford them the ability to benefit even further from the greater CRU network.

- *Has the CRU become a program that is increasingly out of touch with mainstream ecological science as emphasized in universities in the U.S.?* To the contrary, being embedded in major universities in 38 states allows the CRU scientists to be in the vanguard of mainstream ecological science. In particular, the CRU scientists have been in the forefront of adopting new scientific advancements including conservation genomics and landscape-scale geospatial data analysis, which are revolutionizing all aspects of ecological science. In recent years, the proportion of postdoctoral associates enrolled by the CRU has increased and these associates are on the cutting-edge of mainstream ecological science.
- *Has the gap between natural resource issues and the curricular focus of universities that is growing ever larger degraded the capacity and relevance of the CRU at an increasing rate?* The CRU plays an essential role in maintaining connection between the management community and universities. Students and faculty have greater awareness of natural resource issues by virtue of the CRU scientists embedded into faculty. The technical assistance role of the CRU scientists serves to keep natural resource managers abreast of university science advances (Whalen and Thompson 2015). Relevance of natural resource issues in university curricula is vastly expanded by the CRU relative to most typical faculty because of focus on actionable agency-sponsored science. Many, if not most, Unit projects have coprincipal investigators from state and federal agencies who interact with students, often on a daily basis.
- *Is the CRU model, as a jointly funded enterprise where the federal government is responsible for staffing, old, inflexible, and no longer relevant to today's world?* The CRU staffing model, although developed 80 years ago, comports squarely with the current desires of Congress as expressed in appropriations language, where cost-sharing between federal agencies, states, and the private sector is preferred (e.g., 114 STAT. 2762A–118 PUBLIC LAW 106, 2000) (Goforth 2006; Whalen and Thompson 2015). Federal dollars invested in scientist salaries are leveraged to generate funding well in excess of that investment.

A Vision for the Present and Future of the CRU

The CRU has evolved considerably over the course of its history and trained scores of practitioners and scientists currently active in federal and state agencies, NGOs, and universities (Whalen and Thompson 2015). To ensure the CRU continues to provide the science that supports natural resource decision-making and develops the next generations of natural resource leaders, a number of initiatives are proposed.

Networks of Expertise

Whalen and Thompson (2015) described the geographic diversity of the CRU, with Units at 40 university campuses in 38 states, all with direct access to the faculty and resources of those institutions. Schreck et al. (2015) illustrated the applied science breadth that an individual Unit can encompass to meet a diverse array of cooperator science needs. Haukos et al. (2015) demonstrated how several individual Units can collaborate and be the catalyst that engages multiple partners, including USGS Science Centers, Landscape Conservation Cooperatives, state fish and wildlife agencies, U.S. Department of Agriculture, USFWS field stations, universities, and NGOs in addressing large-landscape, complex natural resource science needs.

The CRU will identify thematic networks of expertise that can be mustered to address technical science problems ranging from development of advanced technologies to collaboration on studies that will benefit from the experimental power of having multiple study sites formed around a common experimental design. The nucleus of these networks of expertise will be the CRU scientists who share expertise in particular technical disciplines. Such thematic networks of expertise could mirror the science themes listed above, as well as incorporating disciplinary areas such as:

- Population demography and modeling
- Conservation genetics and genomics
- Human dimensions
- Fish and wildlife health (including conservation medicine)
- Landscape ecology
- Climate science
- Invasive species
- Spatial ecology
- Quantitative science
- Restoration ecology
- Urban fish and wildlife ecology
- Ecosystem services
- Habitat and population monitoring
- Toxicology

The CRU will enable these networks of expertise with enhanced communication tools, funding support, and collaboration with professional scientific societies. These networks will be catalogued and distributed to cooperators and utilized in transboundary research development and implementation. The incentive for cooperators will be a greater return on their investment in a single CRU by virtue of access to a larger network. Cooperator engagement with any given network will be fundamental to ensuring the collaboration has an applied focus and can enhance outcomes by virtue of management feedback within an adaptive management framework.

Landscape Science

The CRU is in a unique position to facilitate scientific inquiry at landscape scales because the on-the-ground science they conduct at the behest of cooperators generates interest from beyond the traditional cooperator network. The CRU is not established to advocate for any particular science agenda; it serves to facilitate the needs of others and provide science solutions to their challenges—a neutral, trusted partner. The CRU will be better able to fulfill this role with technical and administrative improvements (see Conclusions) that will provide for a nimble complementary role with other efforts, such as Landscape Conservation Cooperatives (LCCs), and bring the strength of the CRU in identifying science solutions to the forefront. Each Unit is a cooperative science endeavor among state, federal, university, and nongovernmental cooperators. Units host regular cooperator meetings to discuss science needs and achieve consensus on research that the Unit will pursue. The USGS is a participant in all cooperator meetings as, to a lesser degree, are the USFWS and the Wildlife Management Institute (WMI). USGS can identify science needs brought forth by state cooperators that align with needs of other states, as can the states through their regional associations or AFWA. USFWS can bring regional and national perspectives, as well as science needs identified by LCCs. WMI has facilitated multiagency collaboration for decades and is instrumental in brokering the science needs of LCCs. The cooperator model that is in place has the capacity to identify and catalyze investigation and application of landscape science. Haukos et al. (2015) described how effectively this model can work in practice, where individual needs of several states overlapped with those of federal natural resource agencies and multiple CRUs responded. With the development of networks of expertise, the CRUs can be engaged as needed to tackle particular science aspects.

Building the Workforce of the Future: The Unit Brand

Developing the next generation of natural resource conservation professionals through graduate and postdoctoral education is one of the three legs of the CRU's mission. The CRU model that requires research to be sanctioned by cooperating agencies and organizations ensures that students will be engaged in research that has real-world management application. The needs of cooperating agencies are varied and range from traditional population and habitat management to landscape ecology and human dimensions, as well as application of advanced technologies such as unmanned aerial systems, conservation genomics, stable isotopes, and Bayesian analytics, to name a few. The diversity of the CRU research portfolio, based on the diverse needs of cooperators, will provide a cadre of skilled entry-level professionals whose skills range from traditional techniques to new and emerging technologies. However, a proactive approach to identify future scientific and technical skills that will be needed should be implemented in order to ensure that agencies are prepared to meet emerging challenges.

Ensuring that the future workforce will represent the diversity of the American people—an important component of societal relevance—will require additional efforts (Hallerman et al. 2014). As noted in the demographic data cited above, recent hires are not representative of U.S. population as a whole. The CRU can be a catalyst for increasing workforce diversity—indeed, the CRU has received numerous diversity awards in recent years, but it may have to expand upon its efforts beyond traditional recruitment approaches to increase its impact. Fortunately, an existing initiative in which the CRU is engaged—the Doris Duke Conservation Scholars Program (Duke Program)—shows promise. The Duke Program recruits undergraduate students from underrepresented societal segments through a competitive process at universities with Units. Currently, five universities and Units participate. These students are mentored by the CRU graduate students and faculty and work as technicians on Unit research projects. The students benefit by receiving hands-on training in research and orientation towards natural resource agency operations.

A similar effort is being developed through collaboration between USGS and USFWS where undergraduate technicians from underrepresented societal segments will assist graduate students in Units' applied research on national wildlife refuges. This effort and the Duke Program can establish a pathway for students to go on to pursue graduate education or enter the workforce after undergraduate training. As such, these programs can serve as pathways for both future scientists and resource managers.

A greater challenge is encouraging students from diverse backgrounds to pursue natural resource education in the first place. The AFS Hutton Program is an innovative effort that targets students in high school through an eight-week paid internship program with a fisheries professional mentor. Currently, the Hutton Program is not directly linked with incentives or programmatic connections that would support their continued involvement in collegiate natural resource education. Hutton, the Duke program, and the USFWS/CRU initiative could be expanded and greater linkages could be built so that these pathways become highways for developing a skilled workforce in natural resources.

Bridging Science and Management

Management and science should not represent a customer/client relationship in natural resources conservation. The relationship is most beneficial when collaborative and interactive and when it fosters learning that reduces uncertainty in how agencies fulfill their public trust responsibilities. The CRU is well positioned to facilitate such a relationship—in fact, its origins 80 years ago were based on this premise (Gofoth 2006; Whalen and Thompson 2015). Fruitful engagement is best fostered through ongoing relationships among managers and researchers where the initial focus is on conservation issues and challenges. The coupling of on-the-ground practical knowledge of managers with scientific design expertise of researchers can lead to identification of products needed to address these conservation issues and challenges. Some products could be in the form of research projects and science deliverables. Others could be technical assistance, such as training in emerging science tools or how to apply and interpret new science. The CRUs are particularly well positioned to help state wildlife management agencies and partners capitalize on the best aspects and applications of new and emerging technologies. Throughout, the skills and training necessary to address emergent needs should be articulated by cooperators, and the CRU should incorporate them into education to prepare the future workforce.

Collaboration among researchers and managers should not end with a final report or a workshop. Ongoing engagement is essential in ensuring that science as delivered can yield desired outcomes. To foster this process, the CRU has developed capacity in decision-tool science. Adaptive management provides for a rigorous, iterative framework that facilitates learning by researchers and managers from management interventions, and adapting management accordingly, with systems modeling and scientific monitoring (Williams et al. 2009). This feedback loop ultimately can reduce uncertainty and ensure that resources are directed most efficiently and effectively.

Application of science to natural resources management can be contentious, particularly if there are opposing stakeholder interests. The CRU has developed capacity to train students in, as well as deliver, Structured Decision Making (SDM) processes. When stakes are high and transparency is essential, SDM is a valuable tool. The CRU is helping to develop a workforce with adaptive management and SDM capability so that agencies that hire the CRU students will have internal capacity.

Cooperating agencies have fundamental monitoring needs ranging from impact of harvest rates on species viability to population status of lesser-known species. Coupling of needs across cooperators can yield efficiencies and leverage resources to the benefit of all. For example, a state may need information on a species' population status as part of their State Wildlife Action Plan (SWAP), and that same species could either be a surrogate species for a LCC or a rare species under the umbrella of a surrogate species. A monitoring effort as part of a Master of Science project not only could inform the SWAP; it also could test the efficacy of the surrogate in representing the landscape needs of a priority species. The CRUs are positioned well to leverage such projects.

Conclusions

We began this paper with two questions: How relevant is the CRU model to current and future needs of the conservation profession and institution? And should the CRU refocus in order to maintain relevancy or move towards an entirely different model? We believe the CRU model, rather than being a relic of the past, was, at its inception 80 years ago, a harbinger of the future. It established a vital framework for federal, state, and nongovernmental collaboration in development of applied science to achieve conservation outcomes. The model is robust in relation to new advances in science and technology, while continuing to deliver the best of traditional fish and wildlife science and scientific training to the broader management community. Efforts in recent years (e.g., Haukos et al. 2015) have demonstrated that the model is not constrained by geography or organizations and functions effectively across political borders and large landscapes. A USFWS partner described one such multi-Unit endeavor as follows: "Any effort to collect data in a similar manner across multiple projects to first answer smaller localized questions, but then use this same information at a larger scale to get a landscape perspective, is resulting in information that will ultimately inform future management across multiple spatial scales" (Clay Nichols, USFWS, Arlington, TX, personal communication, February 24, 2015). This statement speaks to the essence of the CRU model: grass roots science and management that collectively informs landscape-level conservation.

Rather than recasting the model, efforts can focus on further enabling transboundary landscape work. This effort may involve modifications to the cooperative agreements for each Unit as they become renewed in order to facilitate a broader cooperator network. Modifications can be designed to allow greater cooperation and sharing of resources among other science practitioners and collaboratives such as USGS Climate Science Centers, USGS Ecosystem Mission Area Science Centers, USFWS Fishery Centers, LCCs, and Joint Ventures. Cooperators could dedicate funds to be used to incentivize transboundary work. In addition to annual cooperator meetings, periodic "brainstorming" sessions where cooperators and others can discuss issues and challenges and forecast future challenges and science needs would be productive. Ideally, there would be forums where these discussions would occur in a regional context (e.g., LCCs, AFWA regional associations, USFWS project leader meetings). Currently, the CRU is engaged in such discussions with a range of partners including traditional cooperators and other conservation organizations (e.g., Wildlife Conservation Society).

The CRU is the brainchild of the legendary J.N. "Ding" Darling. Darling, in reminiscing on the uncertain beginnings of the CRU, noted that the Unit program "has produced an amazing volume of original information on wildlife problems and has developed scores of new techniques in wildlife management while training literally thousands of young people for professional careers in wildlife work" (Lendt 1979, 80). Indeed, since the year 2001 alone, more than 2,500 students have graduated from the Unit program, with most going on to careers with state, federal, and private conservation institutions. The CRU model has stood the test of time and is well positioned to continue serving the evolving needs of the conservation institution.

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