

Cooperative Fish and Wildlife Research Units Program—**2021** Year in Review

A photograph of two researchers in a stream. In the foreground, a woman with a braid, wearing a tan bucket hat, a red long-sleeved shirt, and blue gloves, is using forceps to handle a small fish on a white cloth. In the background, another person wearing a tan shirt, a red beanie, and sunglasses is observing. They are standing next to a grey equipment case. The background shows a rocky stream with autumn foliage.

Circular 1491

U.S. Department of the Interior
U.S. Geological Survey



Front cover. Kaitlyn Gahl, graduate student at Arizona Cooperative Fish and Wildlife Research Unit (sitting), and Elizabeth EbadiRad, undergraduate student at the University of Arizona, implant transmitter into smallmouth bass-redeye bass hybrid to identify habitat use and movement patterns of fish in Arizona.

Inside front cover. Fire monitoring during wildfires helps researchers understand the complex relationships among fuels, fire behavior, and fire effects.

Back cover. Tom Kwak (1958–2021), Unit Leader at the North Carolina Cooperative Fish and Wildlife Research Unit, and Ambar Torres Molinari, a master of science graduate student at the North Carolina Cooperative Fish and Wildlife Research Unit, in Puerto Rico.

A photograph of two elk wading through shallow water. The elk on the left is in the foreground, facing right, with its head lowered. The elk on the right is slightly behind and to the right, also facing right. Both animals have brown fur and antlers. Water splashes around their legs. The background is a blurred natural setting.

Cooperative Fish and Wildlife Research Units Program—2021 Year in Review

By Dawn E. Childs

Circular 1491

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Geological Survey, Reston, Virginia: 2022

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Suggested citation:

Childs, D.E., 2022, Cooperative Fish and Wildlife Research Units program—2021 year in review: U.S. Geological Survey Circular 1491, 25 p., <https://doi.org/10.3133/cir1491>.

ISSN 2330-5703 (online)

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Abbreviations

AFS	American Fisheries Society
AZGFD	Arizona Game and Fish Department
CRU	Cooperative Fish and Wildlife Research Units
CWD	chronic wasting disease
DDCSP	Doris Duke Conservation Scholars Program
DOI	U.S. Department of the Interior
ESA	Endangered Species Act
MDC	Missouri Department of Conservation
M.S.	master of science degree
NABat	North American Bat Monitoring Program
NYSDEC	New York State Department of Environmental Conservation
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
Ph.D.	doctor of philosophy degree
RWO	Research Work Order
SSA	Species Status Assessment
SWAP	State Wildlife Action Plan
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Leadership Message

The Cooperative Fish and Wildlife Research Units (CRU) program is pleased to provide you with our “2021 Year in Review” report. Inside you will find brief descriptions of just a few highlighted activities of unit scientists, students, and cooperators in support of our joint mission. Although space precludes us from highlighting every single activity from every unit and State, that in no way diminishes our appreciation of the excellent work that is conducted by each of our collaborators and partners and the value that this program places on each cooperative.

Fiscal year 2021 has been an exciting year at the CRU program. In September, we officially signed the Cooperative Agreement creating our first new Cooperative Fish and Wildlife Research Unit in 15 years at the University of Nevada, Reno. We appreciate the hard work of all our partners, including the U.S. Geological Survey (USGS); U.S. Fish and Wildlife Service (USFWS); University of Nevada, Reno; Nevada Department of Wildlife; and the Wildlife Management Institute, who helped bring this new unit into existence.

We also had the pleasure and privilege this year of welcoming many new scientists into our CRU program. We are excited about this influx of new talent. Our new team members look forward to working with our cooperators to address your most pressing scientific and technical assistance needs, while at the same time training the next generation of fisheries and wildlife scientists.

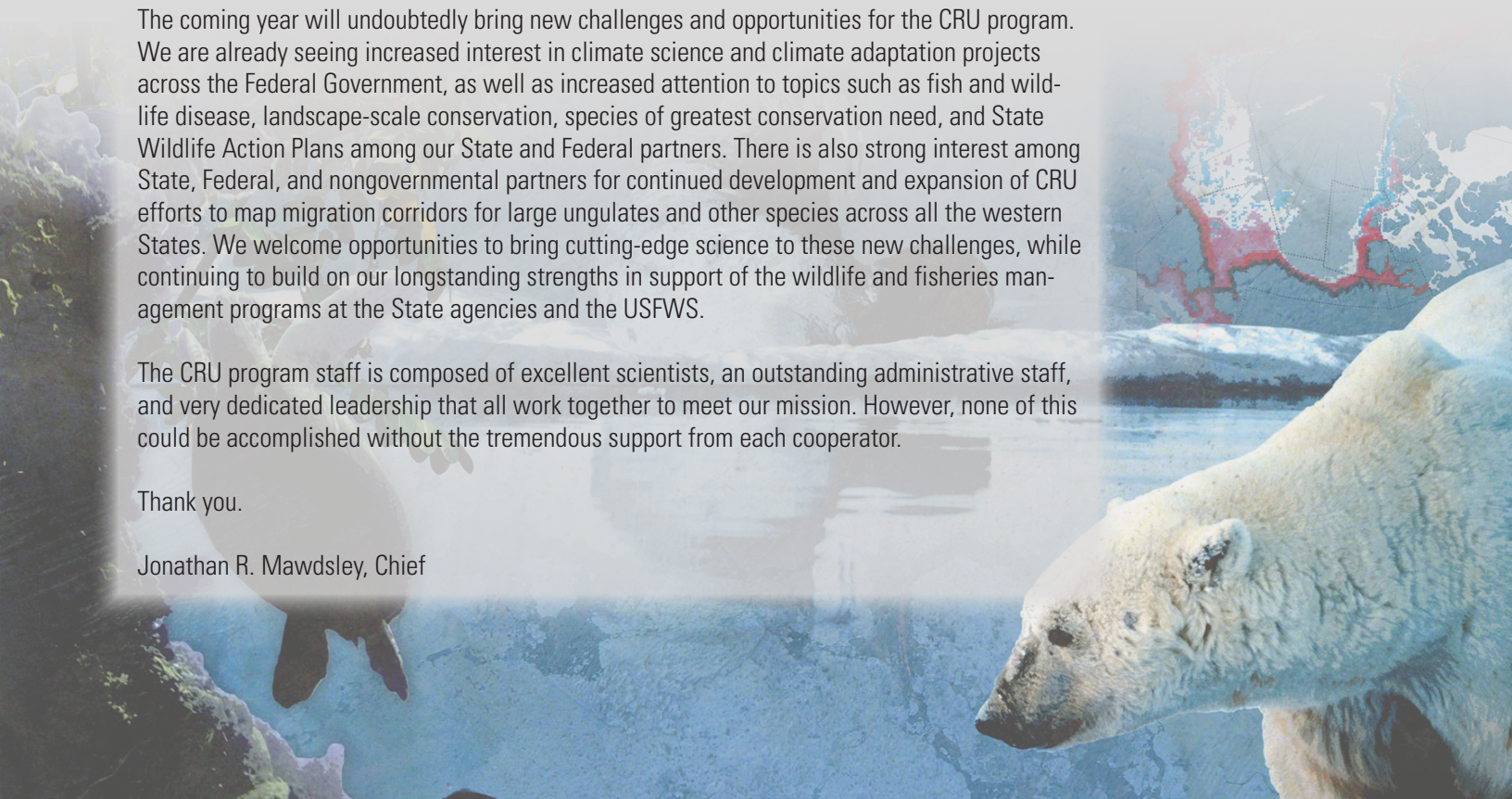
At the CRU program, we take our mission of helping to train new scientists and conservation leaders very seriously. I am especially pleased with the work of our Diversity, Equity, Inclusion, and Accessibility Committee and our entire management staff for implementing meaningful steps to increase diversity across our entire program. We continue to prioritize and support these efforts at all levels of our program.

The coming year will undoubtedly bring new challenges and opportunities for the CRU program. We are already seeing increased interest in climate science and climate adaptation projects across the Federal Government, as well as increased attention to topics such as fish and wildlife disease, landscape-scale conservation, species of greatest conservation need, and State Wildlife Action Plans among our State and Federal partners. There is also strong interest among State, Federal, and nongovernmental partners for continued development and expansion of CRU efforts to map migration corridors for large ungulates and other species across all the western States. We welcome opportunities to bring cutting-edge science to these new challenges, while continuing to build on our longstanding strengths in support of the wildlife and fisheries management programs at the State agencies and the USFWS.

The CRU program staff is composed of excellent scientists, an outstanding administrative staff, and very dedicated leadership that all work together to meet our mission. However, none of this could be accomplished without the tremendous support from each cooperator.

Thank you.

Jonathan R. Mawdsley, Chief





Special Appreciation

To the Wildlife Management Institute, a partner from the very beginning of the CRU program in 1935. We very much appreciate the Institute's leadership and staff for their ongoing support of the CRU program, and we look forward to many more years of productive collaboration and partnership together.

Northern spotted owl.

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Exciting News!

Welcome Cyndy Loftin to the CRU Program's Leadership Team

The CRU program selected Dr. Cyndy Loftin as the next CRU Unit Supervisor (East) to replace Mike Tome, who retired from the position in December 2021. Cyndy has a long and extensive association with the CRU program. She is currently the Unit Leader at the Maine Cooperative Fish and Wildlife Research Unit, a position she has held since 2011. Previously, she was the Assistant Unit Leader at the Maine Cooperative Fish and Wildlife Research Unit, being selected for that position in 1999. Cyndy's association with the CRU program began as a graduate student, as she was a CRU-program-affiliated student at both Auburn University and the University of Florida. Cyndy brings a wealth of experience in program leadership from her leadership positions at the Maine Cooperative Fish and Wildlife Research Unit and from having been a Fellow of Cohort 13 at the National Conservation Leadership Institute.

Nevada Becomes 39th State to Create Multiagency Cooperative Fish and Wildlife Research Unit

Congress must approve the creation of all new Cooperative Fish and Wildlife Research Units, and there must be resources in the program budget to support startup and ongoing costs (P. L. 86–686).

The newly formed Nevada Cooperative Fish and Wildlife Research Unit brings State and Federal wildlife-management resources together, providing a cooperative partnership that ensures resources are best serving Nevada's fish, wildlife, and wild places.

“Nevada is facing unprecedented environmental change. Native plant communities and their associated fish and wildlife species are challenged by invasive weeds, increased fire frequency and intensity, water quantity and quality, and development associated with a growing human population. Establishing a Cooperative Research Unit at the University of Nevada, Reno will significantly enhance the efforts of the University, the Nevada Department of Wildlife and other partners to address these natural resource management priorities.”

—Mridul Gautam, Vice President for Research and Innovation, University of Nevada, Reno

Cyndy Loftin canoes near shrubby cinquefoil and clayton's copper butterflies in Maine.

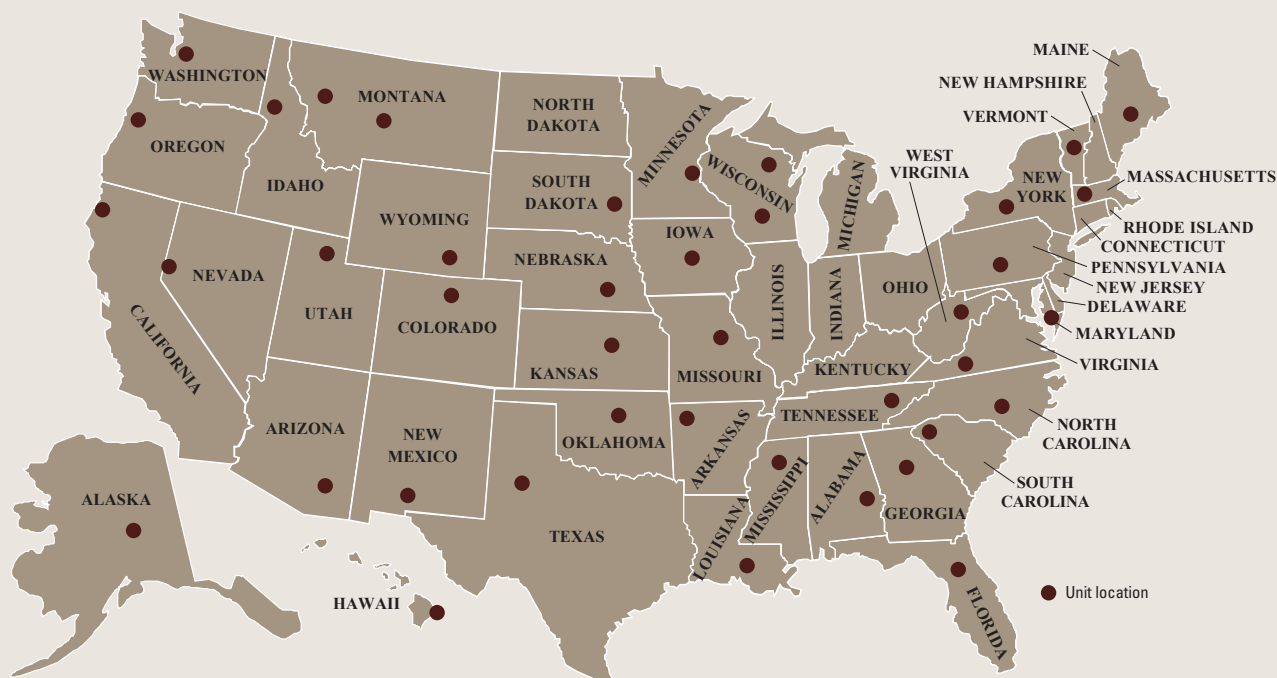
About

Established in 1935, the Cooperative Fish and Wildlife Research Units (CRU) program is a unique cooperative partnership among State fish and wildlife agencies, universities, the Wildlife Management Institute, the U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (USFWS). Designed to meet the scientific needs of natural resource management agencies and the necessity for trained professionals in the growing field of wildlife management, the program has grown from the original 9 wildlife-only units to a program that today includes 41 Cooperative Fish and Wildlife Research Units located on university campuses in 39 States.



Details about the program follow:

- If fully staffed, the CRU program would be served by 122 research scientists and a headquarters' administrative and management staff of 18.
- The research scientists hold faculty ranks at their universities and teach graduate-level courses.
- Research projects typically support graduate students and postdoctoral researchers.
- Some of the USGS's strongest links to Federal and State land and natural resource management agencies as mandated by the Cooperative Research and Training Units Act of 1960 are the partnerships that form each unit.

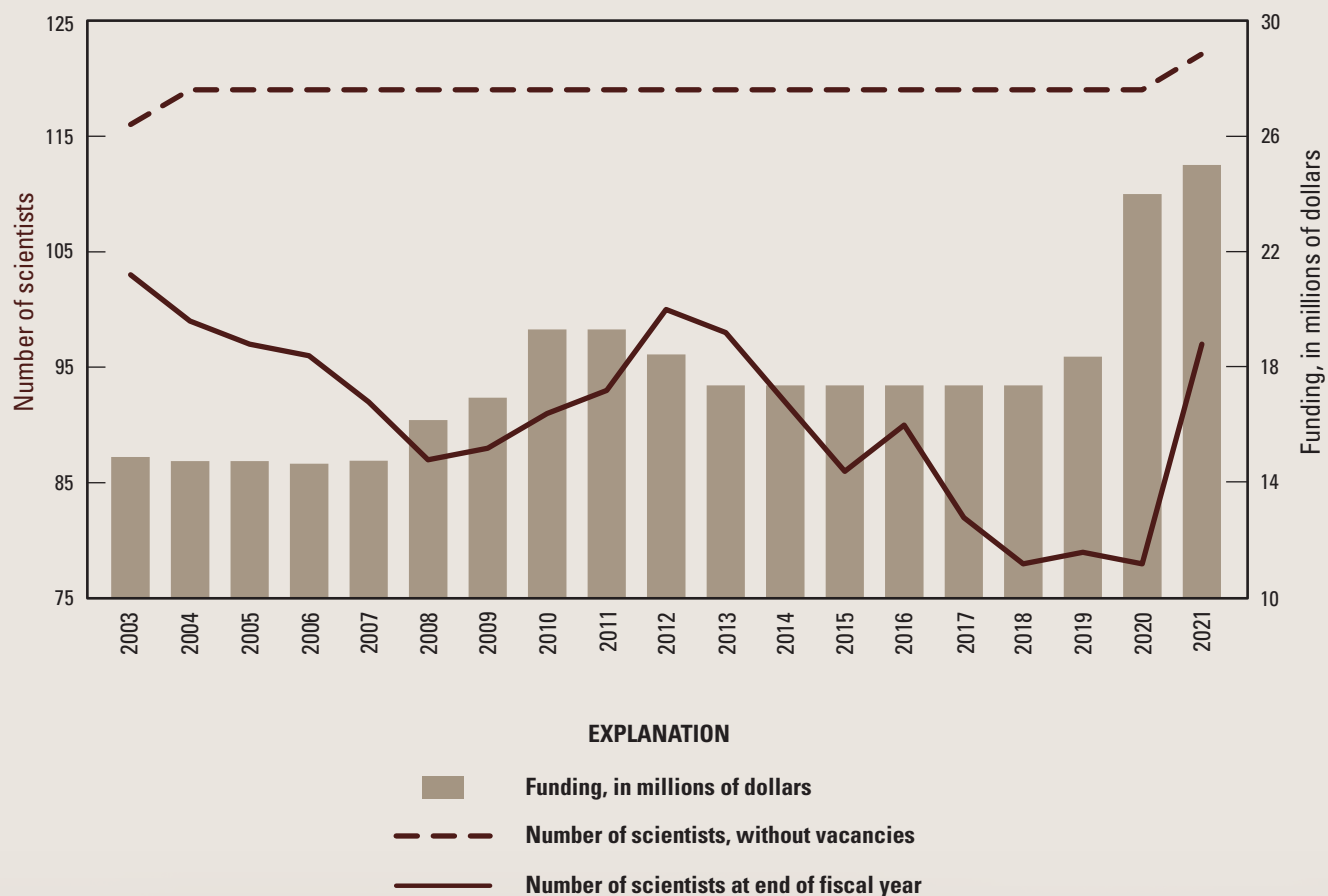


Locations of the 41 Cooperative Fish and Wildlife Research Units in fiscal year 2021.

Science Themes



Budget and Staffing



Graph showing budget and staffing data for the Cooperative Fish and Wildlife Research Units (CRU) program during fiscal years 2003–2021. The increase in congressional appropriations allows the CRU program to fill vacancies.



Greater scaup on the Arctic Coastal Plain.

Mission

The mission of the CRU program has three parts:

1. conduct research to deliver actionable science to cooperating agencies and organizations,
2. develop the natural resource conservation workforce of the future through graduate education, and
3. fulfill the training and technical assistance needs of cooperators.

Research Priorities

All research priorities are set locally in response to identified cooperators' applied science needs. Significant controls are in place to ensure projects align with the USGS mission and the priors including invasive carp and pythons; and several units (Wisconsin, Pennsylvania, Wyoming) have coordinated with the USGS National Wildlife Health Center on chronic wasting disease.

Project Selection

In keeping with the original legislation that created the CRU program (P.L. 86–686), the research priorities for a particular unit are set locally in consultation with Federal and State cooperators. Unit scientists and unit supervisors work with cooperators to help them identify their needs, and unit supervisors ensure that all research conducted is aligned with the USGS mission. Final approval for each project is made by CRU headquarters management (Chief or Deputy Chief) to ensure that projects meet the USGS mission and DOI priorities.

Project Controls

Research Work Orders (RWOs) are the mechanism through which host universities receive Federal financial support to conduct research as provided for in the 1978 amendment to P.L. 86–686. RWOs are an extension of the Cooperative Agreement establishing each unit. Funds from the USGS, other DOI bureaus, or other Federal agencies are obligated via Financial Assistance into an RWO and awarded to the University for a specific research project.

The Deputy Chief assures that the project meets the requirements for an RWO, including the following: (1) the project must be novel research; (2) the project must be

consistent with the mission of the USGS and DOI priorities; (3) the project must have an educational component; (4) the budget is complete and appropriate; and (5) no apparent conflicts of interest exist.

Regional Engagement and Coordination

CRU Headquarters staff and regional leadership participate in regular quarterly meetings between USGS Center Directors, USGS Regional Directors, and USGS Ecosystems Mission Area leadership. The CRU program's regional leadership regularly discuss points of shared interest with USGS Center Directors and other regional USGS staff.

The Chief of the CRU program maintains regular communications with USGS Center Directors and USGS Regional Directors on topics of mutual interest, including most recently the development of an interagency pollinator science partnership that engages regional staff, center scientists, as well as external partners (for example, the U.S. Fish and Wildlife Service, the U.S. Department of Agriculture, and the Smithsonian Institution) in research to inform pollinator conservation.

There are numerous examples of close collaboration on critically important research projects between CRU scientists and regional scientists. For example, the Washington Unit has been working with the USGS Alaska Science Center and others on projects modelling the demographics of polar bears; the Missouri Unit has worked with multiple USGS Ecosystems and Water Science Centers (Climate Adaptation Science Centers, Eastern Ecological Science Center, Northern Rocky Mountain Science Center, and Wisconsin Water Science Center) to investigate climate effects on North American fish populations; the Georgia, Florida, and Tennessee Units have been working with multiple USGS Science Centers (Great Lakes Science Center, Columbia Environmental Research Center, Wetlands and Aquatic Research Center) on invasive species issues including invasive carp and pythons; and several units (Wisconsin, Pennsylvania, Wyoming) have coordinated with the USGS National Wildlife Health Center on chronic wasting disease.

Productivity and Leveraging Resources

The CRU program model enables leveraging of all available resources such that every Federally allocated dollar is matched on about a 1:3 basis by State and host university contributions and grant funds. In fiscal year 2021, \$25 million was allocated Federally.

Despite the global pandemic, the CRU program remained highly productive, publishing more than 370 scientific papers in fiscal year 2021 and more than 400 in fiscal year 2020. Many courses were taught remotely owing to the pandemic, requiring reformatting of materials for that platform of delivery. This enabled the graduate education part of the CRU program's mission to continue to be met while most staff worked remotely.

Unit scientists publish in both free open-access journals and in journals requiring a fee to access. Below is a snapshot of the scientific journals that published results of CRU program research in fiscal year 2021.

- Biodiversity and Conservation
- Ecological Indicators
- Ecology and Evolution
- Ecosphere

- Fisheries Research
- Forest Ecology and Management
- Frontiers in Ecology and the Environment
- Global Ecology and Conservation
- Journal of Mammalogy
- Journal of Threatened Taxa
- Journal of Urban Ecology
- Journal of Wildlife Management
- Journal of Zoo and Aquarium Research
- North American Journal of Fisheries Management
- Science
- Science of the Total Environment

Publishing in journals by USGS scientists allows the research—including its scientific and practical contributions—to be disseminated to others in a particular field. This makes scientific researchers and practitioners with similar interests aware of new knowledge in their field, and it helps to advance knowledge and its application.




An adult female polar bear and her two cubs travel across the sea ice of the Arctic Ocean.

401

Presentations

376

Publications

67

Courses taught

49

Seminars

5

Workshops and short courses

Unit scientists garner
\$25 million to \$40 million
 in State and Federal research funding each year

Federal investment supports about
1,100 students and university staff members
 annually

Universities provide more than
\$20 million
 through in-kind support, tuition, and reduced overhead

Graduate Education To Develop the Conservation Workforce

One of the greatest legacies of the CRU program is the placement of students advised by unit scientists into jobs in natural resource agencies and organizations after graduation. A pillar of the program's mission is to develop the workforce of the future through graduate education. Alumni hold important leadership positions in nearly every State and Federal fish and wildlife management agency.

The CRU program educates more than 450 graduate students annually in natural resource management and conservation.

Graduate Student Spotlights

Students are advised by unit scientists and conduct applied research projects that directly address current natural resource concerns of the State and Federal cooperators. Students also receive cutting-edge academic training from university cooperators and develop expertise on the issues of State and Federal natural resource management and protection agencies. Students graduate from the experience uniquely prepared to be effective members of the natural resource workforce.

495

Active graduate students (318 M.S. and 177 Ph.D. students)

75

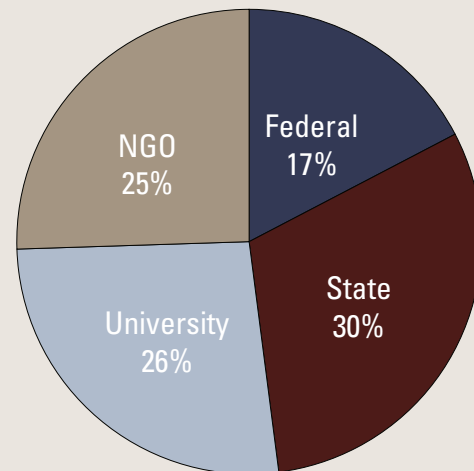
Postdoctoral researchers

66

Graduate degrees awarded (54 M.S. and 12 Ph.D. degrees)

57

Undergraduate students



Pie chart showing the types of professional positions obtained by recent graduates who participated in the Cooperative Fish and Wildlife Research Units program. Data are averaged for fiscal years 2012–2021. NGO, nongovernmental organization.

Nikola Rodriguez

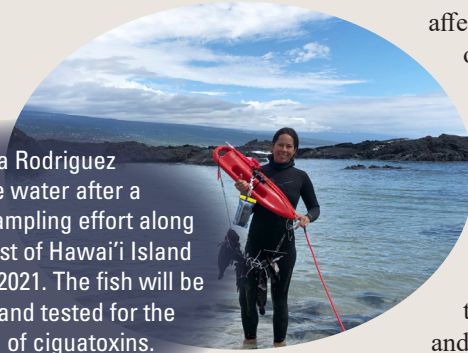
University of Hawai'i at Hilo
Hawai'i Cooperative Fishery
Research Unit

Research Project:

How factors related to climate change and overfishing affect the prevalence of ciguatera fish on Hawaiian coral reefs.

Nikola Rodriguez is an M.S. student with the Hawai'i Cooperative Fishery Research Unit and the Tropical Conservation Biology and Environmental Science graduate program at the University of Hawai'i at Hilo. She is studying how

Nikola Rodriguez exits the water after a successful sampling effort along the west coast of Hawai'i Island in September 2021. The fish will be processed and tested for the presence of ciguatoxins.



factors related to climate change and overfishing affect the prevalence of ciguatera fish on Hawaiian coral reefs. Ciguatera fish poisoning is caused by consumption of reef fishes containing toxins produced by dinoflagellates in the genus *Gambierdiscus*. *Gambierdiscus* attach to turf algae where herbivorous fishes incidentally consume it while grazing, and the toxins are biomagnified through the food chain. Climate change and alteration of reef fish assemblages through overfishing have the potential to affect the abundance of *Gambierdiscus*. The project results will help managers protect local communities from ciguatera fish poisoning and allow fishers to adapt their resource use patterns to changing reefs.

Kearstin Findley

University of Arkansas
Arkansas Cooperative Fish and Wildlife
Research Unit

Research Project: Conservation and ecology of the critically endangered, Arkansas endemic yellowcheek darter.

Kearstin Findley obtained a bachelor of science degree in ecology and evolution from Rockford University in her hometown of Rockford, Illinois. During her undergraduate studies, Kearstin was first exposed to working with freshwater fishes during a research experience at Ohio State University. This experience working with the USGS on

Kearstin Findley photographs a rosyside dace to quantify morphological differences among populations.



lake trout research led Kearstin to pursue her master of science degree at Southeastern Louisiana University. Kearstin's thesis was focused on using niche modeling to evaluate the distribution of imperiled freshwater fishes in Louisiana, and she used field surveys to ground truth the models she created. Kearstin's previous work and interests in freshwater fish conservation led her to pursue a doctor of philosophy degree at the University of Arkansas with the Arkansas Cooperative Fish and Wildlife Research Unit. Her dissertation research is focused on conservation and ecology of the critically endangered, Arkansas endemic yellowcheek darter. Kearstin's work is in collaboration with the USGS, U.S. Fish and Wildlife Service, Arkansas Game and Fish Commission, and the Arkansas Natural Heritage Commission.

Joshua Vine

University of Florida
Florida Cooperative Fish and Wildlife
Research Unit

Research Project: Gulf sturgeon monitoring in the Choctawhatchee River Basin, Florida.

Josh Vine is a Ph.D. student participating in a 4-year monitoring project of Gulf sturgeon populations, focusing on data collection from the Choctawhatchee River Basin. He received his bachelor of science and master of science degrees in wildlife and fisheries biology from Clemson University. Josh is tracking movement of juvenile Gulf sturgeon with acoustic telemetry, where

Graduate students track the movement of juvenile Gulf sturgeon with acoustic telemetry.



strategically placed stationary telemetry receivers detect fish with implanted sonic tags as they swim past. This passive technique is yielding tens of thousands of detections with minimal effort, and it enables Josh to monitor the spatial and temporal movement of the juveniles in the estuary and river. This research is part of a larger project done in conjunction with the National Oceanic and Atmospheric Administration (NOAA) and the USFWS in Panama City, Florida. The Choctawhatchee River is one of seven freshwater systems, stretching from the Pearl River in Louisiana to the Suwannee River in Florida, under examination in this multistate study. Assessing river-specific population trends with these data may inform restoration strategies.

Applied Research To Meet Cooperators' Science Needs

The CRU program is a leader in applied research to provide objective science for the management needs of cooperators and to inform decision making. The research priorities for each unit are identified locally in consultation with Federal and State cooperators.

In this report, we highlight just a few of the many management-oriented research projects conducted with our State, Federal, and university cooperators. Many more examples are available online. Each of these examples demonstrates the importance of this cooperative effort and the invaluable decision-based science that it can yield.

Section 1: Disease, Invasive Species, and Other Biological Threats

Biological threats and invasive species of plants, animals, and microorganisms pose significant risks to native species, ecosystems, and the health of humans, fish, and wildlife.

The economic, environmental, and health-related costs of invasive species exceed those of all other natural disasters combined. Biological invasions may affect the resilience of complex systems and can cause sudden and essentially irreversible changes.

Chronic Wasting Disease Management in the Midwest

Wildlife management agencies have historically applied a variety of disease control strategies to slow the spread of chronic wasting disease (CWD), but manipulation of harvest regulations has been the primary tool used to reduce density and presumably slow the spread of CWD. Despite the widespread use of harvest as a CWD management tool, it is difficult to measure the effects of harvest approaches within a single jurisdiction, and rigorous evaluations of how harvest regulations reduce CWD risk have not been conducted.



Deer with chronic wasting disease.

Therefore, the researchers will examine the effects of harvest regulations on hunting and CWD dynamics.

Partners: Wisconsin Department of Natural Resources, Wisconsin Cooperative Wildlife Research Unit at the University of Wisconsin Madison.

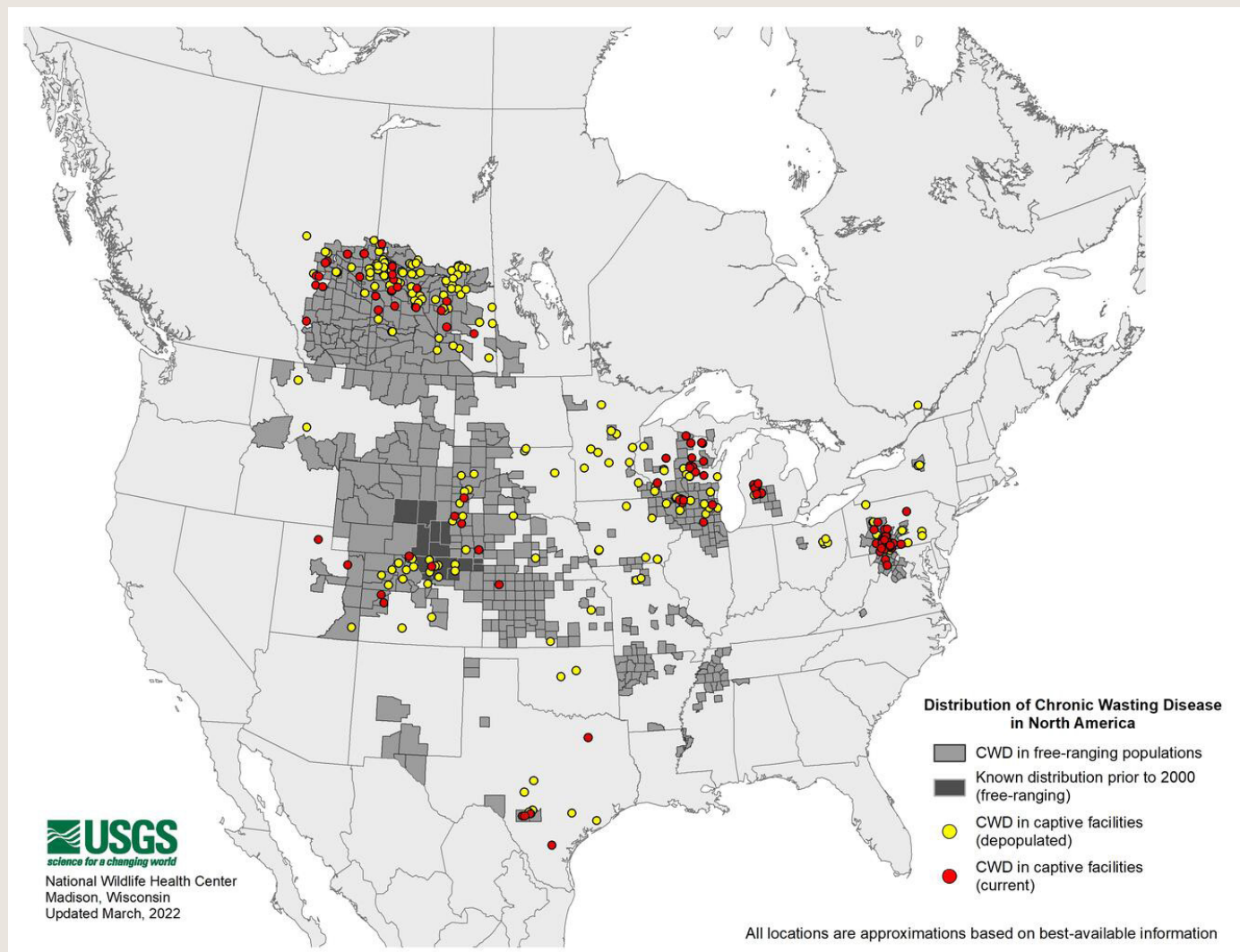
Issue: CWD is a fatal disease of deer, elk, and moose for which there is no treatment. CWD is increasing in prevalence in areas where the disease already is established. In heavily affected areas of Wyoming, Colorado, and Wisconsin, more than 40 percent of free-ranging cervids are infected.

Societal Impact: While there is not current evidence for CWD occurrence in humans, it does have potential population effects on deer, thus deer hunters.

Benefits to States: A critical examination of the effect of harvest regulations on hunting and CWD dynamics can be used to guide a regional application of adaptive management strategies for wildlife agencies so they may coordinate disease mitigation efforts.

Invasive Carp Throughout the Upper Mississippi River Basin

Like many invasive species, invasive carp have negative economic and ecological effects. Despite the lack of habitat for invasive carp within the Upper Mississippi River Basin, tributaries of the basin such as the Des Moines and Skunk Rivers



Distribution of chronic wasting disease in North America.

contain stretches of free-flowing sections where reproduction has been documented. Unit researchers are evaluating stock-recruitment trends present within the Upper Mississippi River (Des Moines, Skunk, and Iowa Rivers) where adult stock and recruits have been sampled. The objective is to also assess the accuracy of models that identify fish species based on the analysis of egg size and shape within the Upper Mississippi River Basin.

Partners: Iowa Department of Natural Resources, U.S. Fish and Wildlife Service, Iowa Cooperative Fish and Wildlife Research Unit at Iowa State University.

Issue: Invasive carp (bighead, black, grass, and silver) were imported to the United States from China in the mid-1960s to control nuisance algae, snails, and vegetation in aquaculture facilities in the southeastern United States.

Societal Impact: These invasive carp threaten local economies, contribute to dead zones and algae blooms, reduce recreational opportunities, and can be hazardous to boaters and anglers.

Benefits to States: Results can be used to inform management plans for these invasive species.



Silver carp.



Hibernating little brown bat.

Using Acoustic Data from the North American Bat Monitoring Program (NABat) to Evaluate Bats in White-Nose Syndrome-Free Areas

White-nose syndrome has led to substantial declines in populations of hibernating bats across North America. NABat was established to assess the ecological effects of these unprecedented declines, providing standardized monitoring protocols and a continental-scale collaborative framework to evaluate the status and distributions of bat species. Maps of distribution and status of bat populations to date can provide a baseline for evaluating further encroachment by white-nose syndrome and other threats.

Partners: National Park Service Upper Columbia Basin Network, numerous partners throughout the range of the North American Bat Monitoring Program (NABat, <https://www.nabatmonitoring.org/>), Colorado Cooperative Fish and Wildlife Research Unit at Colorado State University, USGS Fort Collins Science Center.

Issue: White-nose syndrome is an emergent disease of hibernating bats that has spread from the northeastern United States to the central United States at an alarming rate. Since the winter of 2007–8, more than six million insect-eating bats in at least 37 States and 7 Canadian Provinces have died from this devastating disease.

Societal Impact: USGS research indicates that bats likely save U.S. farmers billions of dollars each year in pest suppression simply by doing what they naturally do—eating insects. Bats, the only mammal capable of true flight, eat mind-boggling quantities of insects, including those that damage crops and forests (corn earworm moth, emerald ash borer beetle) and those that carry diseases (mosquitoes).

Benefits to States: Evaluating the survey methods and data can inform refinement of NABat. Federal and State agencies and other wildlife partners work together to help identify management actions that maximize bat persistence and reduce the spread of white-nose syndrome.

Section 2: Fire

We focus on priority ecosystems (such as the Arctic, coastal zones, wetlands, forests, deserts) and their response to both devastating natural events (including wildfires) and changing land management practices (such as fire control). Our scientists provide the information, data, and tools that resource managers need to manage priority ecosystems and their resources efficiently.

Boreal Aquatic Ecosystem Vulnerability to Fire and Climate Change

Research will combine detailed field experiments and measurements with an integrated suite of spatially and temporally explicit climate, terrestrial, and aquatic habitat models to better understand the effects of fire and climate change on aquatic communities in boreal ecosystems of interior Alaska.

Partners: Alaska Department of Fish and Game, Alaska Fire Science Consortium, U.S. Department of Defense, USFWS, Alaska Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks.

Issue: Fire size, frequency, and severity are increasing in Alaska. Interactions among fire, climate, permafrost, vegetation, and hydrologic and watershed processes are poorly understood, yet critical for conservation and management of boreal aquatic habitats in a changing environment.

Societal Impact: It costs an average of \$5 billion per year to respond to wildfires nationwide, and the net economic impact is about \$72 billion per year.

Benefits to States: Results could support a science decision making approach to refine management objectives, decision options, and management scenarios, to conduct cost-benefit analyses, and to create a web-based decision-support tool for State agencies.

Response by Female Lesser Prairie-Chickens to Patch-Burn Grazing

The lesser prairie-chicken is a declining species of prairie-grouse that requires a diversity of grassland plant species varying in composition and structure. Natural fire, which historically maintained these grasslands, has been removed from much of its range. Patch-burn grazing is a management strategy that reestablishes the fire-grazing interaction to a grassland system, increasing heterogeneity in vegetation structure and composition. Understanding the response of lesser prairie-chickens to a variety of grazing and prescribed fire practices, which are tools for managing landscapes to support the species, is important for conservation planning.

Partners: Kansas Department of Wildlife and Parks, Natural Resources Conservation Service Lesser Prairie-Chicken Initiative, Kansas Cooperative Fish and Wildlife Research Unit at Kansas State University.

Issue: The lesser prairie-chicken has been considered for listing as a threatened species under the Endangered Species Act (ESA). Lesser prairie-chickens are sensitive to disturbances on the landscape, especially grazing and fire. The occurrence of widespread, intensive wildfires is expanding the range of the lesser prairie-chicken.

Societal Impact: Landowners may use grazing and prescribed fire practices for management of lesser prairie-chicken populations.

Benefits to States: Development of conservation strategies by State and Federal agencies for lesser prairie-chickens would benefit from inclusion of grazing and prescribed fire practices that mimic ecological drivers of grassland systems.

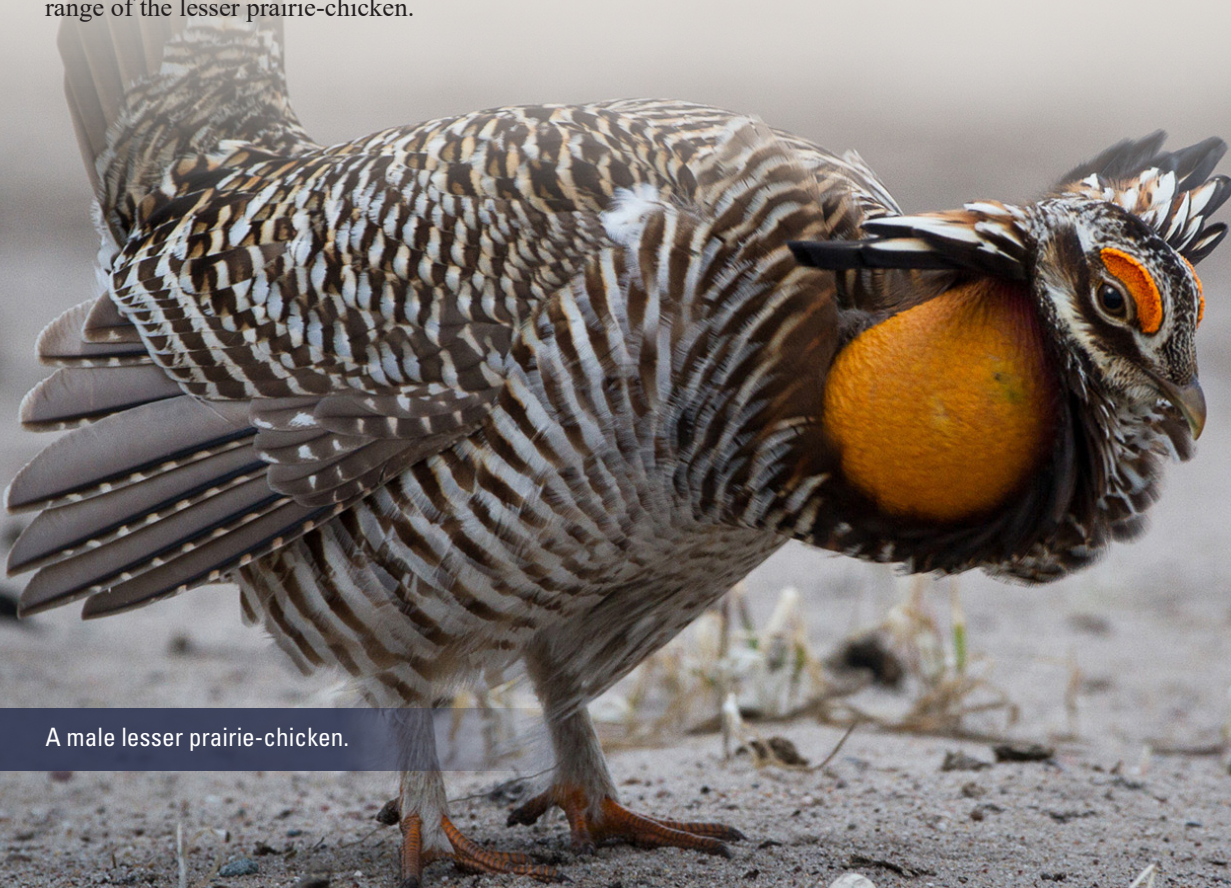
Ground Squirrels and Forest Restoration in Idaho

Idaho Cooperative Fish and Wildlife Research Unit at the University of Idaho

Northern Idaho ground squirrels are listed as threatened and have a very small range in central Idaho. Ground squirrels hibernate for approximately 8 months per year. Research suggests that recovery efforts for northern Idaho ground squirrels should include protection and management for the full range of habitat conditions throughout summer and winter. More broadly, researchers emphasize the need to identify and protect habitat during all seasons because habitat requirements can differ substantially during different periods in an animal's annual cycle and effective conservation will require management of year-round habitat needs.

Partners: U.S. Department of Agriculture Forest Service, U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, Idaho Cooperative Fish and Wildlife Research Unit at the University of Idaho.

Issue: Fire suppression over the past century has caused widespread changes to the distribution and composition of coniferous (trees that bear their seeds in cones) forests in the western United States.



A male lesser prairie-chicken.

Societal Impact: Forest management actions that reduce fire risk benefit society by protecting life and property, as well as ensuring that those actions are compatible with endangered species recovery efforts.

Benefits to States: The results will help land management agencies implement forest management practices that benefit an ESA-listed species such as the threatened northern Idaho ground squirrel. Recovery and delisting will help reduce ESA-imposed restrictions on activities within the species range, which will assist agencies in accomplishing their conservation objectives.

Section 3: Climate

The effects of projected climate trends on humans, fish and wildlife populations, and habitats are a major concern. Unit scientists work with cooperators to better understand potential implications and to reduce uncertainty so that managers can better evaluate future scenarios and management options.

Wyoming Migration Initiative

The Wyoming Migration Initiative was created with the broad goals of understanding and conserving ungulate migration routes through migration research, developing conservation tools, and sharing information through public outreach and education. Current research is focused on mapping

undocumented corridors and studying the benefits and challenges of long-distance migration.

Partners: Wyoming Game and Fish Department, Wyoming Cooperative Fish and Wildlife Research Unit at the University of Wyoming, other State and Federal agency partners, conservation groups.

Issue: Migratory species and the corridors they travel face new and ongoing threats, and their conservation is constrained by an incomplete understanding of migration ecology and by misconceptions among public stakeholders. Understanding the ability of different species to accommodate changing conditions is a critical component of identifying which species are most vulnerable to climate change and can ultimately inform the prioritization of conservation efforts.

Societal Impact: Wyoming's ungulate migrations, like the vast landscapes on which they take place, are a vital part of the State's cultural heritage. However, migration corridors are facing new and ongoing threats, and their conservation is constrained by a still-incomplete understanding of migration ecology and by misconceptions among public stakeholders.

Benefits to States: Creating a powerful archive of corridor data and tools to analyze those data can inform on-the-ground conservation and policy. Outreach and education programs continue to tell the story of migration to a broad audience, focusing on "live" tracking of migrations, compelling new videos, storytelling, and resources for K–12 instructors.



Matt Kauffman, Unit Leader at the Wyoming Cooperative Fish and Wildlife Research Unit, second from left, works with Wyoming Game and Fish Department and University of Wyoming collaborators to release an elk fitted with a global positioning system tracking collar.

Managing Coastal Wetlands for Wildlife and Sustainability in the Face of Sea-Level Rise

Coastal marshes are critical habitat for a wide variety of wildlife and fisheries species. To keep up with sea-level rise, marsh growth rates must exceed decomposition rates. Common marsh management practices, such as fire, flooding, and drawdowns, affect decomposition and accretion and have led to elevation declines of several feet in many waterfowl management units. The purpose of this project is to study the effects of selected management practices on marsh growth rates and decomposition processes in waterfowl management units at the J.D. Murphree Wildlife Management Area near Port Arthur, Texas.

Partners: Texas Parks and Wildlife Department, Louisiana Cooperative Fish and Wildlife Research Unit at Louisiana State University.

Issue: Marsh loss in ecosystems is common along the Gulf coast and may increase with sea-level rise. Coastal marshes are critical habitat for a wide variety of wildlife and fisheries species.

Societal Impact: Wetlands are valuable to humans for flood protection, shoreline erosion control, recreation, and water quality improvement, and they provide important habitat for fish and wildlife.

Benefits to States: This research could be used to develop waterfowl management practices that benefit waterfowl and allow marshes to adjust to increasing sea levels.

Conservation Planning for Amphibians in a Changing Landscape

Amphibians are a bellwether of environmental change. Maintaining year-long habitat connectivity can be critical to their persistence in both undeveloped and developed landscapes. Understanding relationships between their distributions, habitat conditions, wetland landscape context, and how amphibians adapt to changing environments can reveal how human-caused alterations in landscape composition and arrangement may affect amphibian populations. This information can be used to develop conservation planning guidance that contributes to long-term persistence of amphibian populations.

Partners: University of Maine, Clark University, Maine Department of Inland Fisheries and Wildlife, Tennessee State University, Clemson University, Maine Cooperative Fish and Wildlife Research Unit at the University of Maine.

Issue: Worldwide declines in amphibians are attributed to disease, collection, and loss of habitat. Landscape change potentially affects population connectivity by disrupting movements across the landscape and reducing access to quality habitat.

Societal Impact: Amphibians provide important linkages between terrestrial and aquatic systems, providing food for numerous wildlife species in diverse ecosystems, while also

contributing to control of insect agricultural pests and pests that transmit diseases to humans.

Benefits to States: Consideration of the vulnerability of quality amphibian habitat to mid-21st century land use and climate change can increase effectiveness of conservation planning for amphibian populations. This research characterizes how threats to amphibians, including disease, climate change, exposure to contaminants, invasive species, and habitat loss, are impacting populations and are working with other agencies to avert further losses.

Section 4: Species of Greatest Conservation Need

State Wildlife Action Plans (SWAPs, <https://www1.usgs.gov/csas/swap/>), are required by Congress to obtain funding under the State Wildlife Grants Program. SWAPs contain a list of species of greatest conservation need and identify the information needs, threats, and conservation actions pertinent to them. CRU scientists work with State cooperators to develop the science needed to inform conservation actions.

Species Status Assessment for the Eastern Black Rail To Support an Endangered Species Listing Decision

Unit researchers assisted with development of the Species Status Assessment (SSA) framework to support USFWS decision making processes under the ESA and applied the framework to the determination of the eastern black rail as a threatened species. Listing decisions are an important step in conservation of rare, declining, or at-risk species, but listing and protecting species that do not require protections uses limited resources unnecessarily. Our work on eastern black rails determined that the species has exhibited steep declines and range contractions in recent decades, is currently rare, and we predicted that it will continue to decline and likely go extinct in the coming decades. As a result of this work, the USFWS decided to list the species as threatened thus providing the species with the protection it needs to prevent extinction.

Partners: Florida Wildlife Conservation Commission, South Carolina Department of Natural Resources, Florida Cooperative Fish and Wildlife Research Unit at the University of Florida, Alabama Cooperative Fish and Wildlife Research Unit at Auburn University, USFWS.

Issue: Sea-level rise and changes in precipitation patterns owing to climate change are likely to eliminate black rail habitat, which indicates that wetlands overall are at risk from these large systemic forces.

Societal Impact: Listing the eastern black rail as threatened opens opportunities and resources for protecting wetland habitats and mitigating the effects of climate change in these sensitive wetland ecosystems.

Benefits to States: The black rail is a sentinel species for coastal and interior wetlands, meaning that its status is an early indicator of the health of these important ecosystems.

Research, Education, and Training in the Proper Application of Species Distribution and Habitat Models to the Management and Conservation of Plant and Animal Species

Modeling animal movement through landscapes is a key component to understanding population ecology, how populations can be managed, how human actions impact the population, and how the population could respond to anthropogenic change factors such as climate and urbanization. This research is relevant to species of concern in the United States.

Partners: Association of Fish and Wildlife Agencies, Utah Division of Wildlife Resources, USFWS National Conservation Training Center, Utah State University, Utah Cooperative Fish and Wildlife Research Unit at Utah State University.

Issue: Many (not all) species distribution models do not provide adequate spatial resolution.

Societal Impact: Species distribution models can simulate the Earth's climate system. The output from these modeling efforts can be used to understand and predict changes in natural systems, and the implications of these changes on wildlife, land, and water management decisions.

Benefits to States: Species distribution modeling is integral to State Wildlife Action Plans and management agencies such as the Bureau of Land Management, National Park Service, and U.S. Department of Agriculture Forest Service. States and the USFWS, along with land management agencies, have both data and a need for species distribution models (SDMs). Training and education are key components and relies heavily on partnerships. The Association of Fish and Wildlife Agencies (AFWA) provides scientific information to States: they are engaged in updating existing or creating new distribution models of species of specific concern. The

USFWS has significant roles in transferring science to cooperators, especially States, through established means such as the National Conservation Training Center.

Recovery of Salmon and Steelhead in the Columbia River

Recovery goals of Chinook salmon have not been achieved despite substantial efforts. There is a need to better understand the effects of various threats and ecosystem drivers on population dynamics. Three factors are of particularly high interest: (1) the effect of the quality of freshwater habitats used for egg incubation and juvenile rearing, (2) the effect of broad-scale ocean conditions on marine survival, and (3) the effect of predation by marine mammals. The goal of this project is the development of an integrated population modeling framework for spring-summer Chinook salmon, built by combining count and mark-recapture data, and designed to evaluate the effects of management and threats on the fish.

Partners: University of Washington, NOAA Fisheries Northwest Fisheries Science Center, Washington Department of Fish and Wildlife, Yakama Nation, Washington Cooperative Fish and Wildlife Research Unit at the University of Washington.

Issue: Much of the historical abundance and diversity of Chinook salmon and steelhead trout have been lost owing to logging, dams, weather, and overfishing in the Columbia River Basin.

Societal Impact: Estimated benefits from some fisheries exceeds hundreds of thousands of dollars per day.

Benefits to States: The resulting population model will facilitate evaluation of the benefits of past habitat restoration actions, support decisions about future actions, and provide an assessment of population viability.



Chinook salmon.


Technical Assistance to Cooperators

Technical assistance to cooperators is an integral part of the mission of the CRU program, and both State and Federal cooperators rely on the scientific and technical expertise of unit personnel. CRU program scientists and graduate students use their expertise in natural resource management, experimental design, data analysis, and leadership to assist partners. Below are just a few examples of this important part of the CRU program's mission.

- The USFWS appointed the Alabama Cooperative Fish and Wildlife Research Unit as a member of the Apalachicola-Chattahoochee-Flint Adaptive Management Technical Team to provide technical expertise on adaptive management implementation for five threatened and endangered species in the Apalachicola-

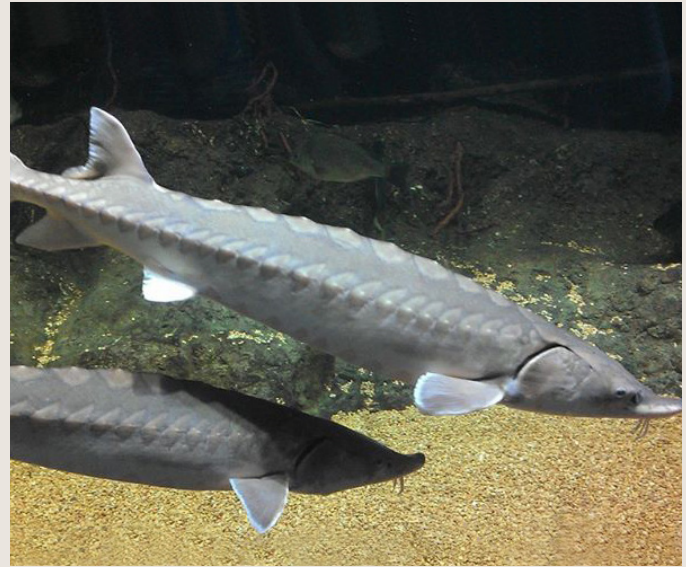
Chattahoochee-Flint Basin, including the fat threeridge, Chipola slabshell, purple bankclimber, and oval pigtoe freshwater mussels, as well as Atlantic sturgeon.

- The Arkansas Game and Fish Commission is working with the Arkansas Cooperative Fish and Wildlife Research Unit on avian monitoring data collection at various Wildlife Management Areas in Arkansas.
- The Wyoming Cooperative Fish and Wildlife Research Unit is working with State wildlife agencies and conservation partners in the 11 western States to share technology and data related to the mapping of migration corridors for large ungulate species (mule deer, elk, and pronghorn). These data are helping to inform conservation and management strategies for these species.



Two elk test and develop their abilities.

- Managers at the Sutter Bypass in California’s Central Valley are working with the California Cooperative Fish and Wildlife Research Unit on an anadromous fish passage project using structured decision making.
- The Oregon Department of Fish and Wildlife, U.S. Department of Agriculture Forest Service, and Bureau of Land Management are collaborating with the Oregon Cooperative Fish and Wildlife Research Unit on estimating the abundance and distribution of endangered Umpqua chub.
- The Tennessee Cooperative Fishery Research Unit is working with partners to improve estimates of total inland fish capture to support the Food and Agriculture Organization of the United Nations.
- The West Virginia Division of Natural Resources and USGS biologists are working with the West Virginia Cooperative Fish and Wildlife Research Unit to assess potential effects of supersaturation of oxygen on fish kills.



Atlantic sturgeon.

Diversity, Equity, Inclusion, and Accessibility

The CRU program supports White House Executive Orders 14035, 13985, 13988, 14020. CRU leadership established a Diversity, Equity, Inclusion, and Accessibility Committee in fiscal year 2020 to develop strategic goals, tactics, and define measures of success. These efforts emphasize the importance of recruitment, retention, and reactivation of a diverse science workforce. The examples below demonstrate our commitment to diversity, equity, inclusion, and accessibility.

Ambar Torres Molinari and Clayton Lynch

North Carolina Cooperative Fish and Wildlife Research Unit

Location: North Carolina State University

Ambar Torres Molinari is an M.S. student at the North Carolina Cooperative Fish and Wildlife Research Unit, advised by Unit Leader Tom Kwak (1958–2021). Ambar is Puerto Rican, English is her second language, and coming to graduate school at the North Carolina Unit was her first residential venture away from her island home. She is researching American eel biology and ecology in Puerto Rico rivers for her thesis. Her study includes dissecting eels to identify sex, parasites, and other anomalies.

Ambar produced an instructional video (<https://www.youtube.com/watch?v=OPImEwgyFLU>) with the help of research technician Clayton Lynch, who joined her for field sampling in Puerto Rico. Clayton is Native American, a member of the Haliwa-Saponi tribe in North Carolina. The video is targeted at middle- and high-school students, as a substitute for in-person learning during the coronavirus pandemic, for



Ambar Torres Molinari is a current master of science graduate student at the North Carolina Cooperative Fish and Wildlife Research Unit. She is researching American eel biology and ecology in Puerto Rico rivers for her thesis research.



Clayton Lynch, research technician at the North Carolina Cooperative Fish and Wildlife Research Unit, with a common snook in Puerto Rico.

a popular North Carolina State Museum of Natural Sciences environmental educational program. Ambar and Clayton bring cultural diversity, novel ideas, and talent to the CRU program. The benefits to the program, students, and science are mutual and valuable.

Doris Duke Conservation Scholars Program Collaborative

The Doris Duke Conservation Scholars Program (DDCSP) Collaborative is a 2-year undergraduate conservation, diversity, equity, and inclusion field program. The Arizona, Florida, Idaho, and Massachusetts Units are members of the collaborative. The students attend leadership training, work with scientists and graduate students on research projects, and are mentored by current CRU program graduate students and Federal scientists. These “Doris Duke Scholars” participate in paid summer internships with local, State, Federal, and Tribal agencies, or nongovernmental organizations.

Phoenix Aguilar McFarlane

Idaho Cooperative Fish and Wildlife Research Unit

Location: University of Idaho

Phoenix Aguilar McFarlane is a sophomore majoring in environmental science at the University of Idaho College of Natural Resources. She entered the DDCSP with a can-do attitude and a passion for volunteering in community service

and sustainability projects. Through the DDCSP, Phoenix gained a broad array of professional skills in the wildlife field. During her first summer with the DDCSP, she worked with a field crew and a graduate student mentor in Bear, Idaho, studying the northern Idaho ground squirrel, a threatened mammalian species endemic to only two counties in the State. She researched whether food preferences of northern Idaho ground squirrels were based on availability or nutrient quality within their environment, and she presented her poster at the annual Ecological Society of America conference. This past summer, she completed an internship at the Hatfield Marine Science Center at Oregon State University as an Oregon Sea Grant Summer Scholar. This academic year, Phoenix serves as a College of Natural Resources Student Ambassador engaging current, incoming, and prospective students to the college and all it has to offer. Phoenix was also elected President of the Conservation and Environment Club at the University of Idaho and plays an instrumental role connecting fellow students to environmental conservation through service and learning.

Collaboration to Support Native American Graduate Students in Wildlife Biology

Montana Cooperative Wildlife Research Unit

Location: University of Montana

The University of Montana is one of seven universities in the United States that are part of the Sloan Indigenous



Phoenix Aguilar McFarlane, graduate student with the Idaho Cooperative Fish and Wildlife Research Unit at the University of Idaho, researches the food preferences of the northern Idaho ground squirrel.

Graduate Partnership. The purpose of the Sloan Indigenous Graduate Partnership is to expand university initiatives to recruit, train, and graduate American Indian and Alaska Native students in science, technology, engineering, and mathematics (STEM) graduate programs.

The Wildlife Biology Program at University of Montana is committed to enhancing diversity through partnerships with American Indian Tribes and other partners to expand graduate education opportunities. In 2019, the University of Montana admitted three new American Indian students into its graduate program.

- **Sattie Whitefoot Fisher from the Confederated Tribes and Bands of the Yakama Nation**

- **Plan:** Initiate a conversation with the Yakama Tribe to identify a graduate project that would simultaneously meet species conservation needs of the USFWS, Yakama Tribe, and potentially the Washington Department of Fish and Wildlife.
- **Research Focus:** Changing migration and movements of wild horses, deer, elk.
- **Location:** USFWS Region 1, Pacific (DOI Columbia-Pacific Northwest Region).

- **Xavier Lovato from Cochiti and Santo Domingo Pueblo**

- **Plan:** Collaborate with the New Mexico Department of Game and Fish, U.S. Department of Agriculture Forest Service, and other potential partners to identify a project that would meet Federal, Tribal, and (or) State species conservation needs.

- **Research Focus:** Mexican spotted owl (this project also has a comparative component with northern spotted owls in USFWS Region 1).

- **Location:** USFWS Region 2, Southwest (DOI Lower Colorado Basin, Upper Colorado Basin, and Arkansas-Rio Grande-Texas-Gulf Regions).

- **Kenneth Edmo from the Confederated Salish and Kootenai Tribes of the Flathead Reservation**

- **Plan:** Work with the Confederated Salish-Kootenai Tribal Wildlife Management Program to identify a project in Montana that would meet USFWS species conservation priorities.
- **Research Focus:** Human conflict and human safety related to grizzly bears.
- **Location:** USFWS Region 6, Mountain-Prairie (DOI Missouri Basin, Upper Colorado Basin, and Lower Colorado Basin Regions).

Project Benefits:

- This experience may lead to careers in natural resources.
- The students may return to their communities to help manage natural resources.
- This project strengthens research and partnerships with local Tribes.

Stories From the Field

Standardizing Sampling of North American Fish Populations

Arizona Cooperative Fish and Wildlife Research Unit

Location: University of Arizona

Arizona Cooperative Fish and Wildlife Research Unit M.S. students Joshua Grant and Steven Ingram, in collaboration with the Arizona Game and Fish Department (AZGFD), are calibrating gear and testing new fish sampling techniques (hydroacoustics and electrofishing boat operation) in western canyon-bound reservoirs. This research compares current AZGFD sampling protocols with American Fisheries Society (AFS) standard methods; facilitates AZGFD's adoption of AFS standard sampling techniques they are not already using; and will help inform the next edition of the AFS' "Standard Methods for Sampling North American Freshwater Fishes" (AFS Standard Methods), a sampling guide used by fisheries biologists across North America. Standardization of fisheries

sampling across North America has many positive benefits. These include the ability to measure large-scale effects of climate change and increasing water demand; larger sample sizes to test effects of regulations, habitat improvements or other management techniques; reliable means to check for species presence; easier communication among fisheries professionals and the public; and simpler data sharing across State and Provincial boundaries. With these and other needs increasing, reasons for wide-scale standardization are more compelling than ever. The AZGFD has consistently supported this multiagency effort from the beginning. The AZGFD, along with nine other sponsors, helped support development of the first edition of AFS Standard Methods, released in 2009, which is widely used in the United States and elsewhere. Since then, State agencies and others have aggressively requested an update to include new methods, gears, data, and expanded web-based tools to support data analysis and comparison. Additionally, the AZGFD, as part of the Association of Fish and Wildlife Agencies, strongly supported the development of a second edition of AFS Standard Methods. To date, more than 400 biologists from the United States, Canada, and Mexico have been involved in this project,

along with many Cooperative Fish and Wildlife Research Units. This collaboration is resulting in advances in fisheries management that extend far beyond the boundaries of Arizona. **Julie Meka Carter, Aquatic Wildlife Branch Chief, and Andy Clark, Statewide Sportfish Program Supervisor, Arizona Game and Fish Department**

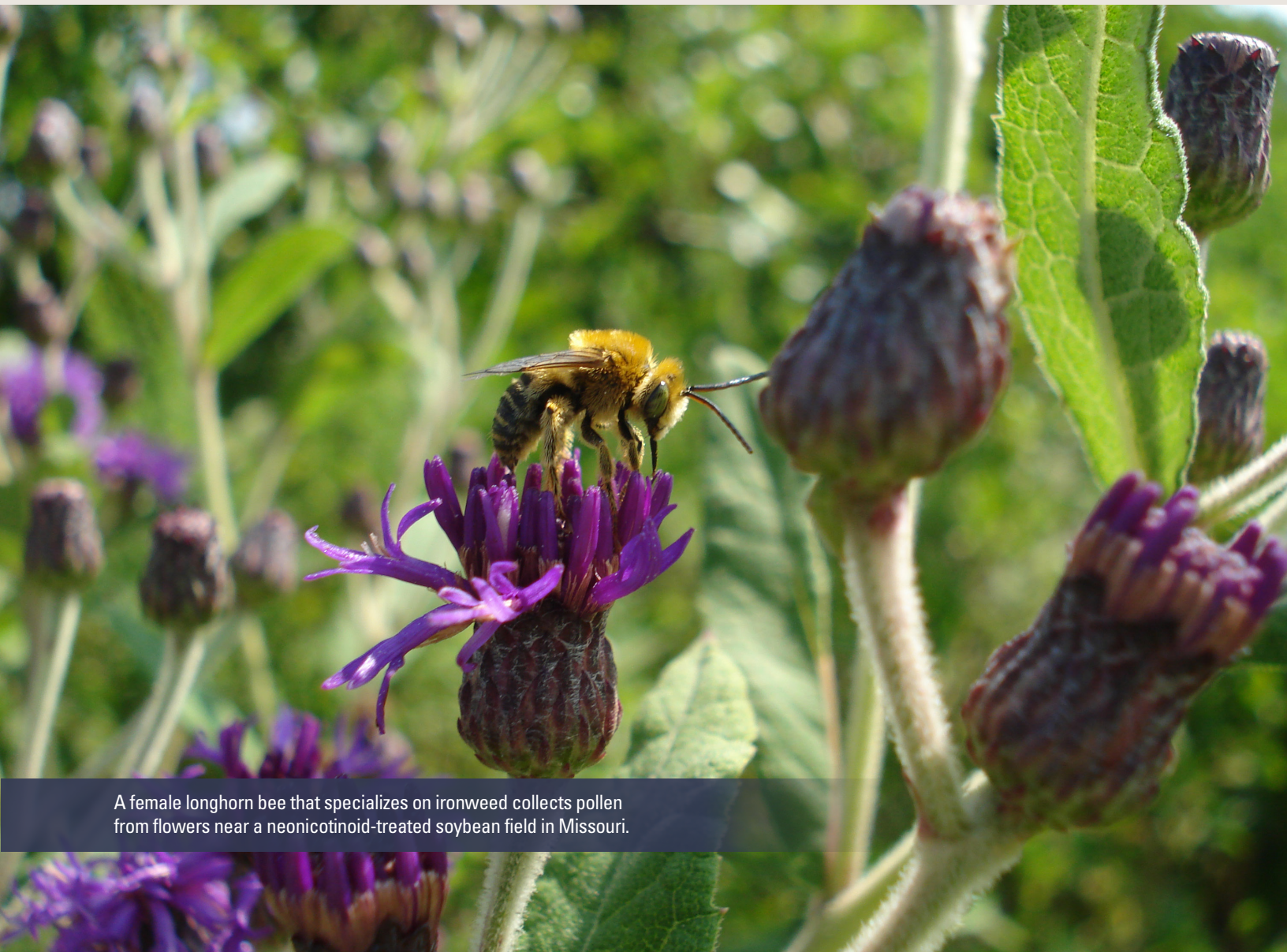
Neonicotinoid Use on Missouri Public Lands: To Be or Not To Be?

Missouri Cooperative Fish and Wildlife Research Unit

Location: University of Missouri Columbia

Neonicotinoids are systemic, chemical insecticides widely used as preplanting treatments on crop seeds to control insect agricultural pests. Neonicotinoids are a controversial class of insecticides given their ability to be acutely toxic to nontarget insects as well as insect pests. Across the midwestern United States, thousands of hectares of public land are

cultivated annually for production of agricultural crops, food plots, and cover for wildlife. Many of these public lands have historically used neonicotinoid seed treatments on crops such as corn, soybean, and sunflowers. Because of their relatively long half-lives in soil, high water solubility, and the potential for exposure to nontarget insects, a priority information need of the Missouri Department of Conservation (MDC) was determining if these chemicals persisted in concentrations detrimental to insect communities on public conservation areas. During 2016–2020, the Missouri Cooperative Fish and Wildlife Research Unit, in collaboration with the MDC, quantified neonicotinoid concentrations in soils (fields and margins), vegetation (field crop and margin flowers), and wetlands on public lands to evaluate the effects of annual neonicotinoid seed-treatment use on native bees and aquatic macroinvertebrate communities. Anson Main (postdoctoral research associate at the Missouri Unit) and advisors Lisa Webb (Missouri Unit) and Keith Goyne (professor, University of Missouri) found widespread and persistent presence of neonicotinoids in soils of agricultural fields and field margins on public lands, with some measured concentrations exceeding those known



A female longhorn bee that specializes on ironweed collects pollen from flowers near a neonicotinoid-treated soybean field in Missouri.

to have sublethal effects on ground-nesting bees. The experimental study provides evidence over two seasons that annual use of neonicotinoid seed treatments can result in reduced abundance and richness of ground-nesting bees living in or near agricultural fields. In a concurrent project, Kyle Kuechle (M.S. student) found widespread and persistent presence of neonicotinoids in water and sediments of public wetlands across Missouri. Mean aquatic neonicotinoid concentrations met or exceeded the chronic exposure threshold for aquatic life established by the U.S. Environmental Protection Agency for 75 percent of sampling events. The outcomes of these collaborative research projects contributed toward a decision by MDC to phase out use of neonicotinoid seed treatments on all lands owned or managed by the MDC. **Joel Porath, Wildlife Section Chief, Missouri Department of Conservation**

Fisheries Management in Lake Ontario

New York Cooperative Fish and Wildlife Research Unit

Location: Cornell University

Great Lakes fisheries generate substantial revenues and livelihoods and contribute to the cultural identity of lake

communities. However, the long-term sustainability of these fisheries requires that managers regularly evaluate stocking and harvest strategies in response to shifting ecological, environmental, and social factors. The New York State Department of Environmental Conservation (NYSDEC) and the New York Cooperative Fish and Wildlife Research Unit are collaborating to develop cutting-edge quantitative tools to help inform fisheries management in Lake Ontario. Chinook salmon is the most popular recreational fishery in Lake Ontario and contributes to the \$2 billion recreational fishing industry in New York; however, the continued success of this fishery is dependent on the availability of a key prey fish population, alewife. In collaboration with NYSDEC and other United States and Canadian regional partners, Kimberly Fitzpatrick (Ph.D. student) and Dr. Suresh Sethi (Assistant Unit Leader) designed a multispecies stock assessment model to jointly estimate the population dynamics of Chinook salmon and alewife in Lake Ontario. By including both predator and prey dynamics, this novel modeling framework provides an assessment of both the status of the fishery and the risk of future population instability. This stock assessment is generating information for joint United States–Canada management of this hallmark Great Lakes fishery. **Chris Legard, Lake Ontario Unit Leader, New York State Department of Environmental Conservation**



Juvenile Chinook salmon.

Awards

Unit Scientists

Clarence W. Watson Award

Southern Division of the American Fisheries Society, the Southeastern Section of The Wildlife Society, and the Southeastern Association of Fish and Wildlife Agencies

Leandro “Steve” Miranda, Mississippi Unit

Driver to Distinction

University of Missouri College of Agriculture, Food and Natural Resources

Craig Paukert, Missouri Unit

John Pearce Memorial Award

Northeast Section of The Wildlife Society

Duane R. Diefenbach, Pennsylvania Unit

Wings Up Research Achievement

Tennessee Tech University

Amanda Rosenberger, Tennessee Unit

Graduate Students and Postdoctoral Researchers

Small Grant Award

Arizona/New Mexico American Fisheries Society

Chris Jenny, Arizona Unit

Fishery Worker of the Year

Oregon American Fisheries Society

Christina Murphy, Maine Unit

Outstanding Teaching Assistant

University of Georgia

Abhishek Kumar, Massachusetts Unit

Best Student Paper (Oral Presentation)

American Fisheries Society Annual Meeting

Aaron L. Coons, Tennessee Unit



Leandro “Steve” Miranda, Mississippi Cooperative Fish and Wildlife Research Unit, receiving the Clarence W. Watson Award. From left to right: Larry Pugh, Mississippi Department of Wildlife, Fisheries and Parks; Miranda; Curtis Hopkins, Southeastern Association of Fish and Wildlife Agencies.

Acknowledgments

The CRU program is a unique cooperative partnership among State fish and wildlife agencies, universities, the Wildlife Management Institute, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. The cooperating universities and State fish and wildlife agencies are listed below.

Alabama

Auburn University
Alabama Department of Conservation and Natural Resources

Alaska

University of Alaska Fairbanks
Alaska Department of Fish and Game

Arizona

University of Arizona
Arizona Game and Fish Commission

Arkansas

University of Arkansas
Arkansas Game and Fish Commission

California

Humboldt State University
California Department of Fish and Wildlife

Colorado

Colorado State University
Colorado Parks and Wildlife

Florida

University of Florida
Florida Fish and Wildlife Conservation Commission

Georgia

University of Georgia
Georgia Department of Natural Resources

Hawai‘i—Fishery

University of Hawai‘i
Hawai‘i Department of Land and Natural Resources

Idaho

University of Idaho
Idaho Department of Fish and Game

Iowa

Iowa State University
Iowa Department of Natural Resources

Kansas

Kansas State University
Kansas Department of Wildlife, Parks and Tourism

Louisiana

Louisiana State University
Louisiana Department of Wildlife and Fisheries

Maine

University of Maine
Maine Department of Inland Fisheries and Wildlife

Maryland

University of Maryland, Eastern Shore
Maryland Department of Natural Resources

Massachusetts

University of Massachusetts
Massachusetts Division of Fisheries and Wildlife
Massachusetts Division of Marine Fisheries

Minnesota

University of Minnesota
Minnesota Department of Natural Resources

Mississippi

Mississippi State University
Mississippi Department of Wildlife, Fisheries, and Parks

Missouri

University of Missouri Columbia
Missouri Department of Conservation

Montana—Fishery

Montana State University
Montana Department of Fish, Wildlife, and Parks

Montana—Wildlife

University of Montana
Montana Department of Fish, Wildlife and Parks

Nebraska

University of Nebraska Lincoln
Nebraska Game and Parks Commission

Nevada

University of Nevada, Reno
Nevada Department of Wildlife

New Mexico

New Mexico State University
New Mexico Department of Game and Fish

New York

Cornell University
New York State Department of Environmental
Conservation

North Carolina

North Carolina State University
North Carolina Wildlife Resources Commission

Oklahoma

Oklahoma State University
Oklahoma Department of Wildlife Conservation

Oregon

Oregon State University
Oregon Department of Fish and Wildlife

Pennsylvania

Pennsylvania State University
Pennsylvania Fish and Boat Commission
Pennsylvania Game Commission

South Carolina

Clemson University
South Carolina Department of Natural Resources

South Dakota

South Dakota State University
South Dakota Department of Game, Fish, and Parks

Tennessee—Fishery

Tennessee Tech University
Tennessee Wildlife Resources Agency

Texas

Texas Tech University
Texas Parks and Wildlife Department

Utah

Utah State University
Utah Division of Wildlife Resources

Vermont

University of Vermont
Vermont Fish and Wildlife Department

Virginia

Virginia Polytechnic Institute and State University
Virginia Department of Game and Inland Fisheries

Washington

Washington State University
University of Washington
Washington State Department of Ecology
Washington Department of Fish and Wildlife
Washington State Department of Natural Resources

West Virginia

West Virginia University
West Virginia Division of Natural Resources

Wisconsin—Fishery

University of Wisconsin Stevens Point
Wisconsin Department of Natural Resources

Wisconsin—Wildlife

University of Wisconsin Madison
Wisconsin Department of Natural Resources

Wyoming

University of Wyoming
Wyoming Game and Fish Commission

Photograph Credits

All photographs featured in this publication were taken by the U.S. Geological Survey except those for which credits are indicated in the list below.

Front cover, Graduate students implanting a transmitter into smallmouth bass-redeye bass.

Front inside cover, Researchers monitoring a wildfire.

p. i, Two bull elk fighting in a lake.

p. iii. A Pacific chorus frog.

p. v, A USGS climate change collage.

p. vi, Northern spotted owl by Emily Brouwer, Mount Rainier National Park.

p. 1, Cyndy Loftin canoeing in Maine.

p. 3, Animal collages.

p. 4, Greater scaup on the Arctic Coastal Plain.

p. 6, A female polar bear and two cubs walking across an Alaska glacier.

p. 8, Nikola Rodriguez sampling fish in Hawai'i.

p. 8, Kearstin Findley photographing a rosieside dace.

p. 8, Graduate students tracking Gulf sturgeon with acoustic telemetry.

p. 9, Deer with chronic wasting disease by Terry Kreeger, Wyoming Game and Fish and Chronic Wasting Disease Alliance.

p. 10, Chronic wasting disease distribution map of North America.

p. 11, Silver carp jumping out of the water by Ryan Hagerty, USFWS.

p. 12, A hibernating little brown bat by Ann Froschauer, USFWS.

p. 13, A male lesser prairie-chicken.

p. 14, Elk fitted with a global positioning system tracking collar.

p. 16, A chinook salmon by Michael Humling, USFWS.

p. 17, Two elk jumping.

p. 18, Atlantic sturgeon swimming by NOAA Fisheries.

p. 18, Ambar Torres Molinari holding an American eel in Puerto Rico.

p. 19, Clayton Lynch holding a common snook in Puerto Rico.

p. 19, Phoenix Aguilar McFarlane releasing a northern Idaho ground squirrel.

p. 20, A female longhorn bee.

p. 22, Juvenile Chinook salmon.

p. 23, Leandro "Steve" Miranda, receiving the Clarence W. Watson Award by Ian Munn, Mississippi State University, used with permission.

Back cover, Tom Kwak (1958–2021) and Ambar Torres Molinari by Michelle Ann Jewell, North Carolina State University, used with permission.

For more information about this report, contact:

Cooperative Fish and Wildlife Research Units Program

U.S. Geological Survey

12201 Sunrise Valley Drive, Mail Stop 303

Reston, VA 20192

Telephone: 703–648–4260

<https://www1.usgs.gov/coopunits/>



Jonathan Mawdsley

Chief, Cooperative Fish and Wildlife Research Units

jmawdsley@usgs.gov

John Thompson

Deputy Chief, Cooperative Fish and Wildlife Research Units

jthompson@usgs.gov

Cyndy Loftin

Unit Supervisor (East), Cooperative Fish and Wildlife Research Units

cyndy_loftin@usgs.gov

James (Barry) Grand

Unit Supervisor (South), Cooperative Fish and Wildlife Research Units

barry_grand@usgs.gov

Kevin Whalen

Unit Supervisor (West), Cooperative Fish and Wildlife Research Units

kwhalen@usgs.gov

Don Dennerline

Senior Program Biologist, Cooperative Fish and Wildlife Research Units

ddennerline@usgs.gov

Dawn Childs

Information Specialist, Cooperative Fish and Wildlife Research Units

dchilds@usgs.gov

Shana Coulby

Administrative Officer, Cooperative Fish and Wildlife Research Units

scoulby@usgs.gov

Publishing support provided by the Reston Publishing Service Center

Layout and Design by Ethan Whitecotton

