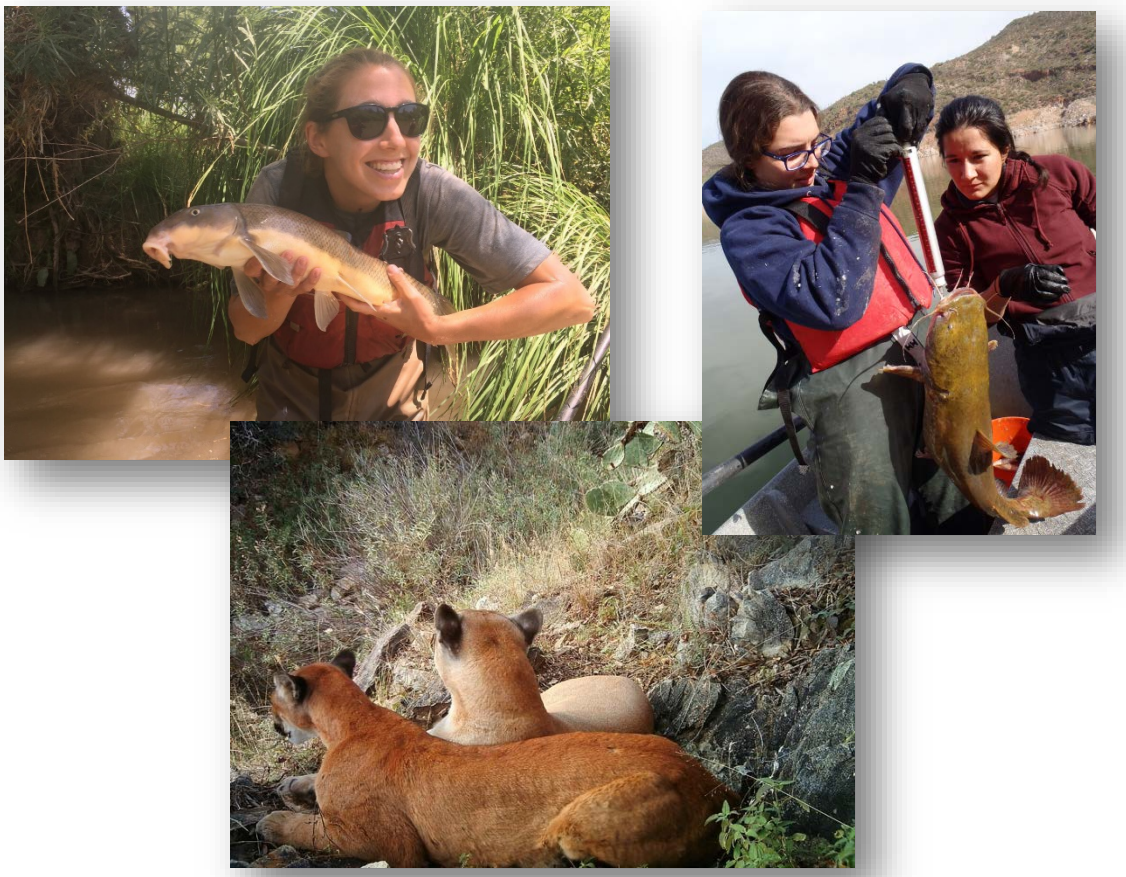
Arizona Cooperative Fish and Wildlife Research Unit – 2018 Annual Report



The Unit is a Cooperative Program of the following:

USGS science for a changing world

U.S. FISH & WILDLIFE SERVICE

THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE & LIFE SCIENCES
Natural Resources & the Environment

WILDLIFE MANAGEMENT INSTITUTE · WASHINGTON, D.C. ·

ARIZONA GAME & FISH

ANNUAL REPORT
2018

Arizona Cooperative Fish and Wildlife Research Unit
1064 E. Lowell St.
University of Arizona
Tucson, AZ 85721

The Unit is a Cooperative Program of the
U.S. Geological Survey
University of Arizona
Arizona Game and Fish Department
Wildlife Management Institute
U.S. Fish and Wildlife Service

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MISSION STATEMENT

These past years have been a time of great activity at the Arizona Cooperative Fish and Wildlife Research Unit. Many projects were conducted during 2017 and 2018. Our work currently encompasses a variety of terrestrial, genetics and aquatics research projects in both Arizona and across the United States.

We are excited to work closely with our cooperators: the University of Arizona, the Arizona Game and Fish Department, the U.S. Geological Survey, the Wildlife Management Institute, and the U.S. Fish and Wildlife Service to accomplish our mission: To provide excellence in graduate education; to conduct research and provide technical communication and cooperation among natural resource agencies and the University of Arizona; and to effectively communicate the results of research to further the cause of effective fisheries and wildlife management.

Scott Bonar

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CURRENT RESEARCH PROJECTS

AQUATIC

An Integrated Approach to Using YY Technology and Mechanical Control Methods for Invasive Fish Control

Project Partners: USBOR, USGS, UA
Project Duration: September 2017 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistants: Chad Teal

Nonnative fishes have substantial impacts on native fishes through competition and predation. Targeted means to remove nonnative fishes where they become pests is warranted. Advancing technology shows promise in manipulating the sex of fishes using hormones to produce Trojan sex chromosome carriers (i.e., YY males) that will spawn with existing fishes and over time, reduce, and even eliminate their populations. While YY males have been developed for several different species, efforts to develop YY males of some of the most damaging invasive fishes in the southwestern United States have not been established. We are examining the feasibility of producing Trojan sex chromosome carriers of a common, short-lived invasive nonnative species to the southwestern United States, the Red Shiner *Cyprinella lutrensis*. Further, we are examining the feasibility of the initial steps in production of Trojan sex chromosome carriers of a common long-lived invasive nonnative species to the southwestern United States, the green sunfish *Lepomis cyanellus*. We will also develop genetic sex identification markers that will be used to understand the sex determination systems of both species. Laboratory facilities were set up in 2018, genetic tests and initial rearing and treating of fishes with hormones has started. A dissertation and publications will result from this project. A Ph.D. student started on this project January, 2018.

Assessing Modified Prepositioned Areal Electrofishing Devices (PAEDs) for Surveying Fish Habitat Use in Desert Streams

Project Partners: USFWS, USGS, UA
Project Duration: June 2016 to December 2018
Principal Investigator: Scott Bonar
Graduate Research Assistants: Zach Nemec, Larissa Lee

Precise methods are often needed to characterize habitat use by fishes, especially for litigation and detailed habitat modelling. Pre-positioned areal electrofishing devices (PAEDs) have been developed to survey stream fishes and develop habitat suitability criteria. PAEDs, which consist of a shore-based generator and a submerged electrical grid, are less intrusive than other electrofishing methods and result in little to no fright bias, i.e., flight response, in fishes from the electrical stimuli. Standard practice allots eleven minutes post-implementation of the devices to allow fishes to recolonize the area. Thus, these low-cost apparatuses can sample distinct areas of stream reaches to assess the microhabitat of fishes. Challenges to using PAEDs include speed of deployment and difficulty of their transport to remote areas. Here we compare various forms of PAEDs to establish a technique for effective fish sampling at remote sites that considers fright bias, fish mortality, and the size of the electrical field. A digital multimeter and underwater videography were used to assess the electrical fields of various PAED designs and the fright bias induced by different techniques. We found that modified 8 PAEDs connected directly to a boat-mounted AC power source were sufficient for sampling desert fishes without inducing mortality or fright bias. Also, neither using two devices simultaneously nor using a 30-m extension cord affected voltage near the electrodes. This study demonstrated effective ways that PAEDs can be used to sample stream fishes in remote areas when collecting microhabitat parameters. Results were used to inform sampling conducted during the 2017 -2018 field seasons.

Relationship Between Native and Nonnative Fish Presence and Components of the Hydrograph in Streams of the Mogollon Rim Emphasis Area, Arizona

Project Partners: USFWS, USGS, UA
Project Duration: June 2016 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Larissa Lee

Streams of the southwestern United States contain some of the most unique and endangered fish species on the planet. Conserving these species requires knowledge of what physical and biological conditions enable them to live at a particular location. Our current knowledge is focused primarily on the need for adequate baseflow, and some on flood flow; however, information about the relative importance of various other parts of the hydrograph could improve our management decisions, especially because water interests want to harvest parts of the hydrograph outside of baseflow. The goal of this project is to identify relationships between select native and nonnative fish species presence with the five components of the hydrograph described above. Four streams in the Mogollon Rim region of Arizona were sampled during summer base flow conditions (May – October) of 2017 to collect information on fish distributions and habitat conditions. A 20-year dataset from fish sampling in the Verde River by the Arizona Game and Fish Department was used to examine temporal shifts in fish assemblages as they relate to streamflow. Streamflow data from USGS stream gages, the USGS StreamStats application, and the National Hydrography Dataset (NHD) provided metrics to characterize streamflow throughout the study sites. These metrics included estimates of 2-year flood flows, 10-year flood flows, 100-year flood flows, mean annual flows, mean channel velocity, stream power at mean flow, and stream power at 2-year flood flow. Relationships between streamflow characteristics and species assemblages varied by species. Certain native species, like Sonora Sucker, consistently demonstrated positive relationships with spatial flow characteristics across all four streams, demonstrating a preference for areas with higher velocities, flow, and power. Results for other species were more variable by stream, and differences often split the four study streams into similarities among Tonto Creek and the Verde River, the two larger systems dominated by nonnative species, as opposed to the Blue River and Eagle Creek, the two smaller systems dominated by nonnative species. Management strategies are optimized when tailored to specific species and streams. Field work and data analysis on this project concluded Fall 2018, and a thesis on this subject was completed in December, 2018. Results are now being prepared for publication.

The Role of Riparian Vegetation and Instream Habitat on Fish Communities in Intermediate-Sized Arizona Rivers

Project Partners: USFWS, USGS, UA
Project Duration: June 2016 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Zach Nemec

The native fish populations of the southwest United States are highly endangered and drastically declining due to multiple anthropogenic stressors. Physical habitat has been defined through habitat suitability criteria (HSC) for these vulnerable populations yet has been primarily limited to depth, flow, and substrate. The relationship between riparian vegetation and instream habitat on fish communities in the arid southwest United States is uncertain. The relationship needs to be assessed in order to implement management practices to conserve fish populations of interest. Four streams within central Arizona (Verde River, Blue River, San Francisco River, Tonto Creek) were selected based on high priority. Over 1,200 sites, throughout the streams, were sampled using pre-positioned electrofishing devices during the 2017 summer low-flow period to identify relationships among fish presence and riparian and instream habitat variables (overhead canopy, bank stability, bank vegetation type, grazing pressure, presence of undercut banks and overhanging vegetation, and percentage of aquatic vegetation and large woody debris) using both in-stream measurements and ArcGIS. Currently, logistic regression models are being constructed for these habitat variables on the presence of several fish species. This research will allow agencies in the arid southwestern United States to better manage riparian areas to benefit fish populations accordingly. Field work and data analysis are complete for this project, and results will be presented in a publication and a thesis (expected completion date January 2019).

Comparison of Densiometer and Inexpensive Hemispherical Photography to Assess Streamside Canopy

Project Partners: USFWS, USGS, UA
Project Duration: June 2016 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Zach Nemec

The spherical densiometer is a common field tool that measures the overstory density, commonly known as canopy cover, of forested areas. This tool has been used in several fish habitat studies, stream surveys, and sampling protocols when assessing coverage of riparian vegetation over streams. Although densiometers are very effective they cannot visually document an ever-changing canopy. Hemispherical photography is another tool that has been developed to evaluate the forest canopy. Photographs are taken in an upward direction using a wide-angle lens and post processed with image-analyzing software. However, hemispherical photography systems are typically expensive (~$2,000-$8,000), time consuming, and highly susceptible to damage when used in aquatic environments. The purpose of this study was to develop an inexpensive, fast, and rugged hemispherical photography system that can be used in aquatic ecosystems without fear of damage of equipment. We obtained paired densiometer readings and hemispherical photographs using GoPro Hero 4 action camera at sites in the Verde River in central Arizona. We post-processed the photos using two different image editing software programs. The inexpensive hemispherical photography method we developed provided cover measurements which were correlated ($r = 0.8546$, $P < 0.05$) with densitometer measurements, but could also provide a visual record of the overstory (different plant species, and amounts). Hemispherical photography, with further development, will be a useful addition or alternative to densitometer measurements for measuring stream canopy. Results are now being prepared for a thesis and a publication.

Habitat Suitability Criteria for Native Fishes in Intermediate-Sized Arizona Rivers

Project Partners: USFWS, USGS, UA
Project Duration: June 2016 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Zach Nemec

Endemic fishes of the arid southwestern United States have rapidly declined due to anthropogenic stressors. Identifying the habitat conditions needed by these species is critical for their successful management. Habitat suitability criteria are commonly used to conserve species of interest. Therefore, developing habitat suitability criteria for native fish species across multiple rivers permits better understanding of how different environments are occupied under various circumstances. Over 1,200 sites were sampled using pre-positioned electrofishing devices during the 2017 summer low-flow period to identify relationships among fish presence and habitat variables (depth, velocity, and substrate class). We developed stream-specific and generalized criteria for Longfin Dace *Agosia chrysogaster*, Speckled Dace *Rhinichthys osculus*, and Desert Sucker *Pantosteus clarki*, in central Arizona streams (Eagle Creek, Blue River, Tonto Creek). Because of low number of sites containing native fishes, stream specific criteria could not be developed for the Verde River for all species, Eagle Creek for Sonora Sucker; and Tonto Creek for Speckled Dace. Furthermore, there were not enough sites occupied by Roundtail Chub *Gila Robusta*, Loach Minnow *Rhinichthys cobitis*, or Spikedace *Meda fulgida*, in any of the study streams to develop stream-specific or generalized HSC. Optimal (central 50% of range used) and suitable (central 95% of range used) ranges within each habitat variable were calculated for each stream, based on the occurrence of each species. In general, Longfin Dace occupied depths of 9.00 – 54.75 cm (14.25 – 27.25 cm) velocities of 0.00 – 0.63 m/sec (0.11 – 0.31 m/sec), and substrate (modified Wentworth scale) of 0.5 – 4.3 (2.1 – 3.3). Speckled Dace occupied depths of 8.25 – 74.00 cm (17.00 – 34.25 cm) velocities of 0.00 – 0.74 m/sec (0.16 – 0.43 m/sec), and substrate of 0.0 – 4.5 (2.2 – 3.6). Desert Sucker occupied depths of 9.00 – 45.00 cm (15.25 – 25.00 cm) velocities of 0.09 – 0.72 m/sec (0.21 – 0.44 m/sec), and substrate of 1.0 – 4.6 (2.5 – 3.7). Only 13-53% of generalized habitat suitability criteria transferred to the various streams. Therefore, criteria are most accurate when developed for the stream of interest. Field work and data analysis for this project was completed fall 2018, and a thesis (expected completion January 2019) and a publication are currently being written.

Habitat Suitability Criteria for Non-Native Fishes in Intermediate-Sized Arizona Rivers

Project Partners:	USFWS, USGS, UA
Project Duration:	June 2016 to Present
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Larissa Lee

Nonnative fishes were stocked into Arizona streams, starting over 100 years ago, and are currently found in most streams of the state. Commonly, species introduced to Arizona are able to outcompete or predate on native Arizona stream fishes, and fish communities are entirely dominated by nonnatives. However, in some areas, nonnatives have not been able to outcompete native fishes, and both live together. Knowledge of the habitat used by selected nonnative fishes in Arizona streams is important for predicting where they might persist and how habitat might be managed to reduce their numbers or discourage their establishment when desired. We sampled four Arizona streams containing a variety of habitats and documented habitat used by nonnative fishes. Furthermore, we developed habitat suitability curves for the seven nonnative aquatic species based on this use. Nonnative species were generally selecting similar habitats to that of their native range. Depth, temperature, velocity, and substrate all showed significant relationships, but results varied by species. Native species management and augmentation programs in these Arizona streams have typically relied on stocking of native species, fish barriers to impede the spread of nonnatives, and chemical and mechanical control to eliminate pest species. Understanding nonnative species populations and habitat use provides managers with additional information that can help them to better structure habitat in stream systems to benefit native species over nonnative species. Field work and data analysis on this project was completed in the fall, 2018. A thesis was completed on this work in December 2018, and results are now being prepared for publication.

Habitat Suitability Criteria for Zuni Bluehead Sucker *Catostomus discobolus yarrowi* and Navajo Nation Genetic Subunit Bluehead Sucker *Catostomusdiscobolus*

Project Partners:	USFWS, NFWS
Project Duration:	May 2013 to Present
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Roy Ulibarri

Desert fishes are some of the most endangered in the United States. Many species exist for which the critical habitat needs are poorly known. The Zuni Bluehead Sucker *Catostomus discobolus yarrowi* is one example, an imperiled fish recently listed as endangered under the U.S. Endangered Species Act of 1973. Based on the proposed listing rule the majority of Zuni Bluehead Sucker populations are located in streams on the Navajo Nation in Arizona. Additionally, new genetic information raises the possibility that Bluehead Suckers *Catostomus discobolus* on the Navajo Nation may be a distinct genetic unit closely related to the Zuni Bluehead Sucker. We examined adult selection of microhabitat conditions (i.e., water velocity, substrate size, over-head cover, water depth, instream cover and mesohabitat conditions (i.e., pool, run riffle), and compared environmental characteristics of occupied sites were compared to those of all available sites to identify habitat that was suitable and preferred for each target species compared where fish were present to what was available in the stream in both high and low flow conditions. We used electrofishing, seining, and snorkeling to evaluate fish occupancy in six streams containing our target species. Zuni Bluehead Suckers and Navajo Nation Genetic Subunit Bluehead Suckers occupied similar environmental characteristic ranges; low velocity pools, over sand, silt, and pebble substrate, at water temperatures ranging from 2-21°C, and a wide range of instream and overhead cover. Suggestions for managing habitat for the target species include constructing livestock exclusion fences around sections of stream to reduce bank erosion, managers should maintain and construct more instream cover, include promoting overhead cover (e.g. maintaining large trees bordering streams), and more pools. A thesis on this work was completed January 2016 and results are now being prepared for publication.

Comparing Established Snorkeling Techniques to eDNA Sampling Techniques in Streams with Zuni Bluehead Sucker *Catostomus discobolus yarrowi* and Navajo Nation Genetic Subunit Bluehead Sucker *Catostomus discobolus*

Project Partners:	USFWS, NFWS, USGS
Project Duration:	May 2013 to January 2017
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Roy Ulibarri

Advances in technology have allowed development of DNA based methods to detect and monitor aquatic species. This new method of species monitoring in aquatic environments is referred to as environmental DNA (eDNA), and has typically been used to detect invasive species in aquatic environments through water samples. This study focuses on comparing eDNA methodology to a traditional fish sampling technique (snorkel surveys) to allow researchers and managers to compare fish abundance estimates to eDNA concentrations from water samples. Our study site included three streams on the Navajo Nation in northern Arizona and northern New Mexico containing Navajo Nation genetic subunit of the Bluehead Sucker *Catostomus discobolus* and the Zuni Bluehead Sucker *Catostomus discobolus yarrowi*. To sample, we first divided entire wetted area of streams into 100-m consecutive reaches. We systematically selected 10 of those reaches for snorkel surveys. Water samples were taken every ten meters within the 100-m reach. Samples were collected at the downstream starting point of each reach, and continued upstream 5-8 meters ahead of the snorkeler. All water samples were sent to the USGS-Upper Midwest Environmental Sciences Center in Lacrosse, Wisconsin for eDNA processing. We were able to positively detect both species with eDNA sampling techniques in two out of three streams, and snorkeling in all three streams. We found a relationship between number of fish observed in each stream and positive detections, however, this relationship was not strong. Snorkel surveys detected fish in all streams even when numbers were low, eDNA samples only had seven to ten percent positive detection when fish numbers were higher. We found no environmental characteristics (i.e., water velocity, substrate size, over-head cover, water depth, instream cover and mesohabitat conditions (i.e., pool, run riffle) to be significant predictors for positive eDNA detection. According to results of this study, traditional snorkeling techniques are recommended over the type of eDNA techniques employed here when identifying presence of rare species in small streams. To improve eDNA sampling, the amount of water collected and tested should be increased. Additionally, filtering water on site may improve eDNA techniques for detecting fish. Future research should focus on standardizing eDNA sampling to provide a widely operational sampling tool. A thesis on this work was finished January, 2016 and results were published in 2017, in the *North American Journal of Fisheries Management.*

AFS Standard Fish Sampling Techniques and Environmental DNA (eDNA) for Characterizing Fish Relative Abundance, Biomass, and Species Composition in a Large Reservoir

Project Partners:	AZGFD, UA, USGS, USGS Upper Midwest Environmental Sciences Center
Project Duration:	September 2013 to March 2017
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Christina Perez

Recently, examination of deoxyribiose nucleic acids in water samples (environmental DNA or eDNA) has shown promise for identifying fish species present in water bodies. In water, eDNA is the result of bodily secretions such as mucus, gametes, and feces. We investigated whether eDNA can be effective for characterizing fish relative abundance, biomass, and species composition in large (>200 ha) waterbodies. We compared fish relative abundance, biomass, and species composition measured through eDNA methods and established American Fisheries Society (AFS) standard sampling methods in Theodore Roosevelt Lake (Lake Roosevelt), an 8,698 ha reservoir in the Tonto National Forest, Arizona. We compared Largemouth Bass *Micropterus salmoides* and Gizzard Shad *Dorosoma cepedianum* catch at electrofishing and gill netting sites with their eDNA in water samples collected at those same sites. We found no relationship between relative abundance and biomass of these fish captured by established methods and their DNA copies at individual sites or by lake section. However, we observed that eDNA reflected relative proportions of Largemouth Bass and Gizzard Shad in total catch composition for the reservoir. Furthermore, we identified seasonal differences in catch of fish species utilizing all three methods. Catch by electrofishing, gillnetting, and number of eDNA copies were higher in Spring than Fall for both species. Our study suggests eDNA collections will not be useful for in-lake comparisons in a large, mixed reservoir such as Lake Roosevelt. However, they may be useful for characterizing relative abundance and biomass in an overall lake. A thesis was finished on this work in May, 2016 and an article was published in 2017 in the *North American Journal of Fisheries Management*.

Use of Ultrasonic Imaging to Evaluate Egg Maturation of Humpback Chub *Gila cypha* in Grand Canyon

Project Partners: USGS
Project Duration: June 2013 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Morgan Brizendine

Humpback Chub *Gila cypha* are endangered cyprinids endemic to the Colorado River drainage and are adapted to live in fast currents of warm, turbid water. Although nine known aggregations of Humpback Chub currently exist in the main-stem Colorado River in the Grand Canyon, little is known about their reproduction. We hypothesized that recruitment of juvenile Humpback Chub in Grand Canyon was limited because hypolimnetic water releases from Glen Canyon Dam create water temperature conditions that are too cold for female Humpback Chub to develop mature eggs for spawning. Our goal was to use ultrasonic imaging, a non-lethal method, to evaluate reproductive condition of female Humpback Chub in Grand Canyon to determine if water temperature limits egg development in female Humpback Chub. We documented egg development in female fish from the main-stem Colorado River, Little Colorado River, Havasu Creek, and Shinumo Creek. Egg development in Humpback Chub varies by location and time of year. Potentially ripe female fish were found at all sample locations and dates except at Shinumo Creek in 2013 and 2014. Potentially ripe females were also detected in every main-stem aggregation except for Pumpkin Springs and in two locations outside of established aggregations. Our findings indicate that female Humpback Chub are able to produce eggs throughout the main-stem Colorado River and that internal egg development and egg production likely do not limit Humpback Chub recruitment in Grand Canyon. However, if female fish experience the environmental triggers they need to spawn remains unknown. Furthermore, if these fish do spawn, the degree that their spawned eggs survive and develop in the cold water temperatures currently present within much of the Colorado River in Grand Canyon remains unknown. A thesis on this work was completed in May 2016, and results are being prepared for publication in the *North American Journal of Fisheries Management*.

Can Ultrasonic Imaging Be Used in Remote Field Environments? A Case Study in Grand Canyon

Project Partners: USGS
Project Duration: June 2013 to November 2018
Principal Investigator: Scott Bonar
Graduate Research Assistant: Morgan Brizendine

Ultrasonic imaging, also called ultrasound, is an effective, non-lethal method used to determine sex and maturity of a variety of freshwater, anadromous, and marine fishes. However, most previous studies have been performed in laboratory environments. We developed a standardized method for ultrasonically scanning endangered Humpback Chub *Gila cypha* in remote locations within Grand Canyon, Arizona, USA. This method minimized stress to individual fish and took less than 1 min to perform. We were able to identify female fish with eggs based on two jpeg images and one 10 s video clip collected in the field. We also used ImageJ®, a National Institute of Health image processing program, to develop a brightness index to evaluate the maturity of eggs in female fish. We collected ultrasonic scans of captive, ripe Humpback Chub held at the Southwestern Native Aquatic Resources and Recovery Center (SNARRC) to determine that female fish were potentially ripe when a subsample of their eggs exhibited a brightness value within the 32-44 range. Although we were able to estimate egg maturity, we were not able to estimate egg mass of female fish. We successfully scanned 751 Humpback Chub in the field and collected jpeg images and video clips for each fish. Fisheries managers can use this noninvasive technique in remote or rugged field locations to collect vital information about the reproductive status of fishes that cannot be killed. A thesis on this work was completed in May, 2016, and results were published in the *North American Journal of Fisheries Management* in 2018.

Habitat Suitability Criteria for Apache Trout

Project Partners:	USFWS, AZGFD
Project Duration:	August 2011 to January 2017
Principal Investigator:	Scott Bonar
Research Assistant:	Sally Petre

In the past 60 years, native fish species endemic to the southwestern United States have declined in abundance and range, resulting in the federal listing of the majority of these species (70%) under the Endangered Species Act (ESA). Apache trout, *Oncorhynchus apache*, a salmonid endemic to the White Mountains of east-central Arizona, is listed as threatened under the ESA. Major reasons for the decline and listed status of Apache trout include overfishing, drought, negative species interactions (non-native salmonids and crayfish) and habitat degradation. In order to maintain and successfully manage populations, managers need to know the parameters for suitable Apache trout habitat so that fish are stocked in areas with the highest survival and reproduction probabilities. This study was designed to develop habitat suitability criteria for Apache trout that will give managers the information to make informed decisions about recovery stream selection and barrier placement. Also, comparing habitat suitability criteria for other species (non-native salmonids or crayfish) to that of Apache trout will aid in understanding habitat usage and potential problem areas among species. We sampled three Apache trout streams, the West Fork of the Black River and East and West Forks of the Little Colorado River, to identify where fish were located (occupied vs. unoccupied) and measured habitat parameters (flow in ft/sec, depth, substrate, instream cover, overhead cover and temperature) at these occupied locations and unoccupied locations. These data were analyzed to determine quantitative habitat parameters suitable or preferred by Apache trout. Apache trout are likely to be found in areas with instream cover such as large woody debris (fallen logs/log jams), overhanging banks or aquatic vegetation, deep areas such as pools, and are limited in their range by suitable temperatures. A thesis was completed on this work, and results were published in 2017 in the *Transactions of the American Fisheries Society*.

Habitat Suitability Criteria for Northern Crayfish

Project Partners:	USFWS, AZGFD
Project Duration:	August 2011 to Present
Principal Investigator:	Scott Bonar
Research Assistant:	Sally Petre

A concern with the survival and persistence of native species is the introduction of non-native species. In the Southwest, especially in Arizona, a growing concern is the introduction of the non-native virile or northern crayfish *Orconectes virilis*. Virile crayfish not only negatively affect native threatened and endangered fish populations but also other vertebrates (Sonoran mud turtles *Kinosternon sonoriense*, leopard frogs, *Rana chiricahuensis*, and narrow-headed garter snake *Thamnophi rufipunctatus*), macroinvertebrates, and aquatic plants. Effective or efficient control methodologies for crayfish have proven elusive; however, reducing the amount of habitat for crayfish might give promise. Thus, determining which habitat parameters are optimal for crayfish and more importantly, which parameters are unsuitable for crayfish is critical. We are developing habitat suitability criteria for northern crayfish then identifying and assessing overlap in habitat criteria for other managed aquatic species (Apache trout, *Oncorhynchus giliae apache*, brown trout *Salmo trutta*, or rainbow trout, *O. mykiss*) that may give habitat advantages to desired species. We sampled crayfish in the West Fork of the Black River every 5 meters moving upstream using a quadrat sampler. This enabled us to determine occupied and unoccupied locations and measure habitat parameters of each location. Apache Trout occupied areas with colder water and more instream and overhead cover than Virile Crayfish. My findings suggest that, to suppress Virile Crayfish populations and increase Apache Trout populations, managers must: (1) reduce stream warming, (2) increase water velocity, (3) trap crayfish after floods, and (4) provide instream cover for Apache Trout. Understanding life history characteristics and habitat preferences of each species is critical to the management of species assemblages. This work was provided in a thesis and is now being formatted for journal publication.

Environmental Conditions Utilized by Endangered Moapa Dace While Spawning

Project Partners: USFWS
Project Duration: October 2011 to Present
Principal Investigator: Scott Bonar
Graduate Research Assistant: Jack Ruggirello

Moapa Dace *Moapa coriacea* is an endangered cyprinid endemic to the Warm Springs area of Clark County in southeastern Nevada. Moapa Dace were federally listed as endangered because of their limited range, low abundance, and competition with introduced species. Spawning by Moapa Dace has never been documented; consequently, the environmental conditions they require for this critical aspect of their life history are unknown. Knowledge of Moapa Dace spawning ecology would provide vital data for managers to manage habitat and to identify factors that induce spawning in captivity. Twelve underwater cameras were deployed in the uppermost reach of Plummer Stream to attempt to capture Moapa Dace spawning activity. Camera sites were selected systematically and represented a variety of conditions available. I quantified the available environment by dividing the field of view in front of each camera into a grid and estimating size and embeddedness of substrate, depth, stream velocity, and cover categories in each cell of every grid. Video was recorded from March through May 2012 and then watched to identify grids over which spawning occurred and their associated characteristics. From over 4,000 10-min video clips selected for analysis, 13 spawning events were identified. Moapa Dace displayed behaviors consistent with broadcasting cyprinids. For spawning, Moapa Dace selected depths ranging from 30-34 cm, water velocities from 0.11-0.17 m/sec, cobble substrate, and instream overhead cover. I could not find that they selected for any category of embeddedness or cover (i.e. open water, instream velocity shelter, instream overhead cover, or above stream overhead cover). This information will further the understanding of Moapa Dace spawning ecology in the wild. Moreover, replicating these conditions in captivity will aid in initial efforts to breed Moapa Dace in captivity. This work was prepared for a thesis, and a peer-reviewed final report was published in December 2015. This work is currently being prepared for publication.

Captive Rearing and Propagation of Critically Endangered Moapa Dace

Project Partners: USFWS
Project Duration: October 2011 to November 2018
Principal Investigator: Scott Bonar
Graduate Research Assistant: Jack Ruggirello

Moapa Dace *Moapa coriacea* is a critically endangered cyprinid endemic to the Warm Springs area of Clark County, Nevada. Moapa Dace were federally listed as endangered because of their limited range, low abundance, and competition with introduced species. Prior to this work, Moapa Dace had never been successfully held in captivity for any length of time. In an effort to develop a protocol for rearing and propagating Moapa Dace in captivity, 40 fish were collected in February 2013, and an additional group of 30 fish were collected in January 2014. We were able to successfully transport and rear Moapa Dace employing slow acclimation and aggressive prophylactic treatment; feeding adults with a combination of live and frozen invertebrates and commercially available pelleted foods; and providing an artificial stream environment to them. To attempt to spawn Moapa Dace, we applied 14 different treatments, including introduction of different types of cover and different sized substrates; manipulations of photoperiod, water chemistry, and temperature; and application of hormone baths and injections. Moapa Dace were successfully propagated in one treatment left ongoing for over three months. This treatment occurred in an artificial stream and incorporated 14 broodstock from the second capture period, an additional submersible pump to direct an increased velocity along gravel and cobble substrate, and a variety of substrate sizes and artificial plants. To successfully rear and captively propagate Moapa Dace, biologists should take great care with acclimating Moapa Dace, and provide an environment similar to that experienced by fish in the wild, incorporating stream conditions and minimal human disturbance. This work was prepared for a thesis, and a peer-reviewed final report was published in December 2015. This work was published in 2018 in the journal *Copeia*.

Habitat Variables Associated with Stream Temperature Resiliency in the White Mountains of Arizona with Implications for Apache Trout Distribution in Response to Climate Change

Project Partners:	AZGFD
Project Duration:	January 2010 to Present
Principal Investigator:	Scott Bonar
Research Assistant:	Joy Price

The distribution of Apache trout, *Oncorhynchus apache*, a threatened species endemic to eastern Arizona, and that of other Southwestern coldwater species may be compressed due to increased stream temperatures associated with climate change. Knowledge of habitat conditions which best buffer stream temperatures against increase and fluctuation may help preserve current Apache trout distribution. Our goal is to use a stream temperature model, ground-truthed with field data from various streams in Eastern Arizona, to predict how increases in air temperature may affect temperatures of streams containing Apache trout. We used the Stream Segment Temperature Model (SSTEMP) to predict the effects of stream habitat variables on water temperatures, and how planned management activities will affect stream temperatures. SSTEMP uses the time of year, location of study, and meteorological data to compute the solar radiation available at a specific point on the surface of the Earth. It reduces the estimate by accounting for topography and riparian vegetation on-site that can block radiation in order to predict downstream temperatures. We used the model to determine how different management actions: regulating groundwater withdraws, planting riparian vegetation, and altering stream channel shape, can moderate water temperature increases. We found that discharge had the greatest effect on regulating stream temperature, regardless of the amount of riparian shade. Streams with greater discharge exhibited lower downstream temperatures than streams with less discharge even when the streams with low discharge had a higher density of riparian vegetation. However, planting vegetation can increase the longitudinal distance it takes for a stream to heat to a certain point. We found that conifers commonly found in the area shade the streams far better than the native deciduous trees such as alders and willows. Furthermore, decreasing the width of the stream also had a cooling effect on the streams we modeled. A comprehensive understanding of which parameters most affect stream temperature is needed both to manage existing populations of Apache trout, and to help identify suitable stocking locations. A thesis has been completed on this work, and the final draft of results are now being prepared for publication.

In re: Aravaipa Canyon Wilderness Area (W1-11-3342), in the General Adjudication of All Rights to Use Water in the Gila River System and Source, Ariz. Sup. Ct., Case Nos. W1-W4. Aravaipa Canyon Wilderness Area FRWR CLAIMS: Protection of Fish Resources

Project Partners:	U.S. Department of Justice.
Project Duration:	September 2013 to December 2018
Principal Investigators:	Scott Bonar, Norman Mercado Silva

On request by the Environment and Natural Resources Division of the Department of Justice, in the adjudication of water rights in the case of In re: Aravaipa Canyon Wilderness Area (W1-11-3342), in the General Adjudication of All Rights to Use Water in the Gila River System and Source, Ariz. Sup. Ct., Case Nos. W1-W4, we report hydrological requirements for native fish in Aravaipa Canyon, Arizona. The fisheries requirements were derived from existing literature, aided by the authors' experience studying fish communities in Arizona, Nevada, California, Eastern Washington, and Mexican deserts. We compiled numerous studies from peer-reviewed and "grey" (e.g., agency reports) literature to help determine habitat requirements for each native fish species in Aravaipa Creek throughout their ontology. Further, we analyzed existing literature to document effects of altered hydrographs on long term viability of fish communities. This information shows that fishes of the Aravaipa fish community use a variety of habitats in the creek and all parts of the natural hydrograph are important to various species and life stages. Unaltered flow conditions are especially important for desert fishes that have evolved under the natural hydrographs of desert streams. All native species require habitats and stream conditions that result from floods in early spring. These floods are key trigger events that 1) signal native species the start of their growing and reproductive seasons, 2) create habitat heterogeneity that favors the appearance of food resources and nesting habitats for these species, and 3) aid in providing the main channel with nutrients derived from inundated areas, that will be used by all components of the in-stream foodwebs, including native fishes. Maintenance of low flows during the dry season are key to the reproductive success of numerous native species, as most larval fish require 1) areas with low water velocities and fine sediments, 2) areas with warm temperatures relative to the rest of the channel in which to grow, 3) areas where algal growth provides them with food resources and coverage, and 4) cover from terrestrial and aquatic predators. The periodic flooding typical of desert streams during early spring and the monsoon season is important for displacing non-native fish predators and competitors and depressing their populations. Native fishes are adapted to flash flooding characteristic of desert streams. Those nonnative fishes typically stocked into Southwestern streams have been introduced from habitats outside the desert (e.g. lakes and backwaters of large river systems) that are characteristically more stable and do not experience the degree of flash flooding present in desert systems. Modifying the natural hydrograph will result in the disappearance of the flow conditions required by native species to survive in the long term. We conclude that long term viability of valuable native Aravaipa Creek fishes requires that the natural hydrograph is maintained unaltered. A report was prepared for this work, and in 2015 Scott Bonar prepared for trial, appeared in a court deposition, and appeared as an expert witness on a trial regarding the matter in Phoenix. The trial concluded, and final written arguments were presented to the court in February, 2016. In December 2018 the court reached a decision, protecting aspects of baseflow, but allowing some extraction of flood flows.

Standard Methods for Sampling North American Freshwater Fishes

Project Partners:	USGS, Association of Fish and Wildlife Agencies, American Fisheries Society, USFWS, AZGFD, NPS, BLM, BOR, National Fish and Wildlife Foundation
Project Duration:	September 2004 to Present
Principal Investigators:	Scott Bonar (lead editor), Wayne Hubert (coeditor, University of Wyoming), David Willis (coeditor, South Dakota State University), and about 50 authors from the US, Canada and Mexico. In total 284 biologists and managers from 107 agencies, universities and private industries contributed to the book as authors, reviewers or sponsors. Editors for the 2nd Edition are Scott Bonar (lead editor), Norman Mercado Silva (Universidad Autónoma del Estado de Morelos, Mexico), and Kevin Pope (Nebraska Cooperative Fish and Wildlife Research Unit).

Standardization in industry, medicine and science has led to great advances. However, despite its benefits, freshwater fish sampling was generally unstandardized, or at most standardized locally. Standardization across large regions allows for measurement of large-scale effects of climate or geography on fish populations; larger sample sizes to evaluate management techniques, reliable means to document rare species; easier communication; and simpler data sharing. With increased interaction among fisheries professionals worldwide, reasons for wide-scale standardization were more compelling than ever. The Fish Management Section of the American Fisheries Society in collaboration with the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, U.S. Bureau of Land Management, National Park Service, USGS Cooperative Research Units Program, National Fish and Wildlife Foundation, AFS Education and Computer User's Sections, and Arizona Game and Fish Department developed standard sampling methods for North America. This was the largest such project in the history of fisheries science. Almost 50 United States, Canadian and Mexican fish sampling experts authored a book on the subject. These methods were reviewed by 54 representatives from 33 North American agencies and by biologists from six European and one African country. Final drafts were reviewed by an additional 36 sampling experts. In total 284 biologists from 107 agencies and organizations contributed as authors, reviewers, data providers and sponsors. *Standard Methods for Sampling North American Freshwater Fishes*, was published in 2009, and described standard methods to sample fish in specific environments so population indices can be more easily compared across regions and time. Environments include ponds, reservoirs, natural lakes, streams and rivers containing cold and warmwater fishes. This book provides rangewide and regional averages; calculated from over 4000 data sets from 42 states and provinces; of size structure, CPUE, growth, and condition for common fishes collected using methods discussed. Biologists can use these data to determine if fish from their waterbody are below, above, or at average for an index. These procedures will be useful to those hoping to benefit from standard sampling programs in their regions. Since publication, these methods are being increasingly adopted across North America. Three symposiums at the North American meeting of the American Fisheries Society have been held; and numerous presentations on the techniques throughout the United States, Mexico and Canada have been given. Furthermore, keynotes have also been invited and presented in the United Kingdom, South Korea and the Czech Republic discussing the techniques. Publications concerning this work since 2016 have been published in *Fisheries*, *Reviews in Fish Biology and Fisheries*, and *Freshwater, Fish and the Future: Proceedings of the Global Cross-Sectoral Conference at FAO, United Nations, Rome*. Now a 2nd edition is underway with unanimous support from the Fisheries Management Section of the American Fisheries Society. The Association of Fish and Wildlife Agencies also is funding the 2nd edition. Currently surveys of biologists across North America are being conducted to identify needed updates to the 2009 edition. Other collaborators on this edition are being sought, and publication date is slated at 2020-2021.

Fisheriesstandardsampling.org: A Simple Web-Accessible Tool to Compare Standard Fish Sampling Data

Project Partners:	USGS, NBII and Coop Unit Program; NPS, USFS, American Fisheries Society, UA, University of Guadalajara
Project Duration:	January 2010 to Present
Principal Investigators:	Scott Bonar, Norman Mercado-Silva
Lead Programmers:	Matt Rahr, Toby Torrey, and Averil Cate

Recently, the American Fisheries Society developed standard methods to sample freshwater fish populations, publishing them in 2009 in the book "*Standard Methods for Sampling North American Freshwater Fishes*". This project involved 284 scientists from 107 different organizations across Canada, Mexico and the United States. Data collected using standard methods gives biologists the ability to compare data across regions or time. An on-line web-accessible database program to compare fish growth, condition, length-frequency, and catch per unit effort data collected using AFS standard methods was developed. Development of this database is a collaborative effort among AFS, the US Geological Survey, the National Park Service, the U.S. Forest Service, the University of Arizona, the University of Guadalajara, and a variety of other contributors. The database (1) provides on-line summaries of more than 4000 data sets of condition, length-frequency, CPUE and growth indices of common freshwater fishes, collected using standard gears from 42 states and provinces across North America; (2) allows easy entry of new data collected using standardized methods, so averages of commonly-used fishery indices can be updated; and (3) allows users to compare condition, growth and abundance of fish collected in a particular waterbody with regional (continent, ecoregion and state) and range wide averages and percentiles, thus increasing resource information in a variety of areas. The database is programmed in a PHP-based Drupal framework and is in the pre-release testing stage. Please visit http://fisheriesstandardsampling.org for further information. The site is fully functional. An article describing the program was published in 2015 in *Fisheries*.

HUMAN DIMENSIONS

Development of Low-Cost, High Definition Videography Methods for Documenting Underwater Flora and Fauna and Creating Education Presentations

Project Partners:	USFWS, Nevada Department of Wildlife, USGS, UA
Project Duration:	June 2016 to Present
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Taylor Ulrich

Freshwater biotic communities are complex, magnificent ecosystems, but are often unseen by the general public. In the southwestern United States, underwater views of these communities are rarely obtained. Until recently, methods for aquatic biologists and educators to communicate with the public about these systems required fish and other organisms be brought to the surface, or expensive underwater video and camera techniques be employed. However, with the accelerating development of inexpensive, ultra-high definition underwater video technology and the advancement of personal computer systems to process such video, high quality educational video presentations are now within reach of biologists and educators to use to educate the public. We developed inexpensive methods that can be used by most biologists and educators with little to no background experience to produce stunning presentations of underwater viewscapes of freshwater systems. Methods were developed and tested while filming underwater aquatic communities of southern Nevada and California. A thesis chapter was completed December 2018, and a publication is underway.

Using Social Psychology in Videos to Acquaint Environmentally Apathetical People with Little Known Fishes

Project Partners:	USFWS, Nevada Department of Wildlife, USGS, UA
Project Duration:	January 2016 to Present
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Taylor Ulrich

Desert fishes are cryptic, and infrequently seen by the public. Apathy of the public toward these fishes and their ecosystems hinders their conservation. Fortunately, advanced technological means to acquaint the public with these species is becoming increasingly common. We created low-cost educational videography presentations featuring the unique and often rare desert fishes of Nevada and Death Valley. Using these videos, I tested the inclusion of various widely recognized social psychology principles in these videos to test their effectiveness at increasing presentation effectiveness when displayed to an audience that was apathetic towards the environment. Social psychology additions were screened by panels of university faculty, graduate students, undergraduate students, and human subjects' experts to ensure they were ethical and truthful, not altering the accuracy of the information presented. I used text-only treatments surveyed through Qualtrics in the first round of treatment videos; enhanced text and different background image treatments surveyed through Qualtrics in the second round of treatment videos and enhanced text and different background image treatment videos surveyed through Mturk in the third round of treatment videos. In all three rounds of testing, regardless of control/treatment group, viewers' knowledge significantly improved post-viewing. However, no significant differences in change in knowledge scores were found among groups in Round 1, 2, or 3. In addition, post-viewing New Ecological Paradigm (NEP) score, a measure of environmental attitude, was significantly higher than the pretest score, regardless of group. Significant differences in change in NEP scores among groups were only found in Round 3 with the reciprocity group scores significantly higher than similarity and anthropomorphic group scores. These results indicate that all types of underwater videos, no matter the treatment type, have a positive effect on previously-apathetic viewers' knowledge and ecological attitude. In addition, adding specific social psychology elements in videos had a subtle, but positive effect on viewers' learning outcome and ecological attitude. This research was presented in a thesis chapter completed in December 2018, and a publication is underway.

Videography Presentations to Educate the Public about Arizona Trouts

Project Partners: Doris Duke Conservation Scholars Program, USGS, UA
Project Duration: June 2016 to December 2018
Principal Investigator: Scott Bonar
Graduate Research Assistant: Taylor Ulrich

Gila Trout *Oncorhynchus gilae*, and Apache Trout *Oncorhynchus apache* are critically threatened species that can be found in various streams of the Southwest. The general public is often unaware that these species exist due to many factors including a dissociation of fish and desert environments and limited availability of high quality underwater and surface footage of Arizona streams. Surface and underwater videography was utilized to create an educational video on Gila and Apache trout from Mount Graham streams to be displayed at a Coronado National Forest visitor center and other locations. We captured high definition quality footage with low cost equipment with the intention of enabling natural resource managers to produce similar conservation videos easily in the future. To evaluate what aspects make a conservation video most effective, the footage was shown in a public space. By analyzing which images people viewed the most, we were able to understand how we might produce more engaging presentations. Macro images, contrasting colors, texture, and movement held audience attention the longest. These results allowed us to draw conclusions about which factors and characteristics of the film contributed to optimal audience engagement. Well-designed videos will better acquaint people with species that are not commonly seen, thus aiding in their conservation. Videos were produced for display for the U.S. Forest Service, Coronado District.

Can Incentives Help Overcome Landowner Concerns About Endangered Species Critical Habitat? A Rancher Case Study from the Southwestern United States

Project Partners: USFWS
Project Duration: June 2013 to Present
Principal Investigators: Scott Bonar, Laura Lopez-Hoffman
Graduate Research Assistant: Colleen Svancara

We were interested in if payments for ecosystem services (PES) programs can encourage ranchers to conserve threatened and endangered (T&E) species on private land. Harboring threatened or endangered species on private land can introduce regulatory burden according to landowners because of implications from the Endangered Species Act (ESA). Because of landowners' apprehension, PES programs likely have to be uniquely designed to address these concerns about additional regulation or possible loss of autonomy to make decisions for their operation. We used three methods to assess the interest of ranchers in southern Arizona and southwestern New Mexico in participating in PES programs for T&E species' conservation, and to determine what specific considerations need to be included in the design of such a program. Participants were generally interested in hypothetical programs for T&E species' conservation. Results demonstrated that the funding source for the program is important, programs must result in a net benefit to landowners, and regulatory assurances must be provided to landowners and their neighbors. These results are useful during preliminary stages of designing a PES program in the region of study, recognizing that further investigation into landowner preferences will be needed. Our approach is also a model for how other regions can evaluate stakeholder preferences before the initiating PES program design. This work was presented in a thesis and is being submitted for publication.

High-Definition Videography Presentation of Gila Chub at Sabino Canyon Recreation Center to Increase Public Awareness and Conservation

Project Partners:	USGS, Desert Fishes Council, USFS
Project Duration:	August 2014 to Present
Principal Investigator:	Scott Bonar
Research Assistant:	Chelsea Powers

Gila Chub, *Gila intermedia*, are federally endangered and occupy streams in New Mexico, Arizona, and Mexico (Minckley 1973). Gila chub are threatened by humans due to habitat loss, non-native species invasions, and direct removal. To help reduce these threats, we are using visual media to interact and communicate with the public. We developed a presentation of underwater footage of Gila chub for display on a high definition 4K 55"-TV in the exhibit hall of a visitor center. The video is about 4 minutes long and displays pop-up facts about the fish and their conservation. Specifically, our objectives were (1) to help produce a video on Gila chub and (2) record visitor reaction to the video. Our exhibit averaged 67 visitors per weekend day and 46 per week day. This translates roughly into a total of 3,484 visitors observing the exhibit on weekends over the course of a year; and a total of 11,960 observing the exhibit during the week over a course of a year, for a total of 15,444 visitors per year. From feedback from both visitors and staff, and the results of our observations, this exhibit seems to be a huge success in the visitor center with the public successfully becoming informed about Gila chub. We are providing the exhibit itself, and data of visitor reactions to our exhibit to staff at the Sabino Canyon Visitor Center, and a report of the exhibit to the Desert Fishes Council. The video presentation can be viewed on YouTube at https://www.youtube.com/watch?v=LVJpw1sOwqo. This served as an initial project to support underwater videography of Nevada and Death Valley, California species presented elsewhere in this report. Opportunities to develop other educational presentations are currently being developed.

Citizen Science Program for Jaguar and Ocelot Monitoring

Project Partners:	USFWS, DHS, USGS
Project Duration:	2013 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Emily Reynolds
Research Specialist	Susan Malusa

Goal: To develop and implement a citizen science program to survey and monitor for jaguars and ocelots within southern Arizona and southwestern New Mexico. Long-term monitoring is a necessary and valuable component of any study, particularly when it comes to monitoring wildlife species and/or evaluating ecosystem change over time. Citizen scientists remain an untapped resource for helping scientists collect data in these days of reduced funding and the need to do long-term monitoring. This study follows the project *Jaguar Surveying and Monitoring in the United States* awarded November 2011 to detect and monitor jaguars along the northern side of the U.S.-Mexico border. To date, 21 highly trained citizen scientists are continuing to monitor the trail cameras set in place by the monitoring project and are continuing to monitor jaguars, ocelots and other wildlife on the landscape.

Combining Classroom and Laboratory Education with Scientific Publication

Project Partners:	UA, AZGFD, NMSU and Shikar Safaris
Project Duration:	2016 and 2018
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Karla Vargas
Graduate Research Assistant:	Alex Erwin

Goal: To develop and implement a new model for teaching conservation genetics laboratory at the University of Arizona which involves conducting all the conservation genetic laboratory (wet lab) methods and data analyses methods on an actual tissue samples which are needed to inform an actual conservation management related question. In addition to laboratory experience gained in collecting and analyzing data, the students published (or are in the process of publishing) a peer-reviewed journal article on the results for each year the lab class was taught. The students, under the guidance of two PhD graduate student TAs, gained experience in all aspects of scientific research and publishing. The 2016 course investigated whether gene flow from an outside population had occurred into an Arizona Desert bighorn sheep population (*Ovis canadensis*), as a potential empirical example of genetic rescue. In 2018, our study investigated scat samples of Argali sheep (*Ovis ammon*) from the Kangai and Altai regions of Mongolia, to examine if these two regions are consistent with 1 or 2 genetic populations.

GENETICS

BOUNDARIES/GENE FLOW

Conservation Status and Genetic Management of Imperiled Species Along the US-Mexico Border.

Project Partners:	UA, CONACyT
Project Duration:	2018 to Present
Principal Investigators:	Michael Bogan, Melanie Culver and Alejandro Varela
Graduate Research Assistant:	Karla Vargas

Goal: Freshwater habitats are extremely rare in the Sonoran Desert, yet they support endemic species, including the Sonoyta pupfish (*Cyprinodon eremus*) and mud turtle (*Kinosternon sonoriense longifemorale*) restricted to Quitobaquito spring and pond (Organ Pipe Cactus National Monument) and small reaches of the Río Sonoyta (Sonora, Mexico) along the international border. There is immense conservation concern for these species due to many human and drought related risk factors, however, refuge populations were established without considering the genetic variation and structure of source populations. This lack of genetic consideration could hamper reintroduction efforts if maladapted or genetically bottlenecked refuge populations were used to restock natural habitats. Our project will develop microsatellite markers for the mud turtle and use existing markers for the pupfish to determine genetic connectivity, assess population viability within natural and refuge populations (e.g. genetic bottlenecking and inbreeding), and quantify how genetically representative the refuge populations are of the natural populations. PIs will work together on both sides of the border and engage in collaborative efforts with U.S. National Park Service staff, CONANP staff, non-profit NGOs, and local communities that maintain refuge populations. The PIs will also produce a genetic management plan for both species. Additionally, this project includes capacity building for Mexican researchers via bioinformatics trainings at the University of Arizona.

Research on Bobcats and Urbanization in the Tucson Mountain District, Saguaro National Park

Project Partners:	Friends of Saguaro National Park
	Pima Community College Summer Internship Program
Project Duration:	2008 to Present
Principal Investigator:	Melanie Culver
Summer Intern:	Steve Mackie

Goal: Examine the relationship between bobcats living in Tucson Mountain District of Saguaro National Park and those living in the surrounding urban interface and to gather basic ecological information on both. First, we conducted a thorough pre-research literature review, evaluated field and genetic techniques, identified discrete research objectives, and assessed bobcat use of the Tucson Mountain District and surrounding lands using noninvasive techniques (field observation and genetic sampling). Our results to date show that there is fairly strong connectivity for bobcats across portions of Tucson, in particular on the west side of Tucson across Interstate-10. In addition to the scientific objectives, this project was designed to create a model for conducting wildlife research at parks in close proximity to urban areas. Like other mid-sized carnivores, bobcats play an integral role in the biologically rich Sonoran Desert ecosystem. In addition, the species may be a model for studying urban impacts, because bobcats appear to both benefit and be harmed by human encroachment. Although the public has a high awareness of bobcats and the species has been thoroughly studied in other parts of its range, little research on bobcats in urban and arid environments existed before our study. This project provided a basis for conservation of bobcats and other native cats in the Park and in other urban areas. In addition, and just as importantly, we designed and created a model for involving the public in urban wildlife research by working closely with park neighbors, visitors, and other governmental and private entities. This study is continuing through an internship program at Pima Community College which has funded one intern every summer since 2012 to collect and process bobcat samples from in and around Tucson to add to our baseline dataset.

Population subdivision and connectivity flat-tailed horned lizards in Arizona, California, and Mexico, with an emphasis in Arizona

Project Partners:	AZGFD, T&E Inc, Department of Defense
Project Duration:	2006 to 2011, new funding 2015-Present
Principal Investigators:	Matt Goode and Melanie Culver
Graduate Research Assistant:	Karla Vargas

Goal: Characterize the extent of genetic variation and uniqueness within and among the Arizona population(s) of *Phrynosoma mcallii*, and among the Arizona, California, and Mexico populations. A hypothesis we are testing is the Arizona population(s) represent a unique gene pool isolated from those of California and Mexico. Through development and use of 10 polymorphic nuclear microsatellite DNA markers, for the flat-tailed horned lizard, this study is provided a dataset to resolve finer scale population differentiation than was previously performed using mitochondrial DNA, and thus is characterizing the potential genetic uniqueness of different populations. Results of this study will be used in future wildlife management decisions. Additional sampling of lizards is already being conducted to add more information to the boundary questions will occur on both sides of the US-Mexico border and on Barry M Goldwater Army Range to look at connectivity across roads used for military activities, and will employ RAD-seq genome data methods. To date we have developed novel microsatellites for the flat-tailed horned lizard, generated a DNA sequence dataset, complete microsatellite genotypes, and data analyses. We are currently completing final analyses following a break in the project due to medical issues of the graduate student. The data indicate strong connectivity of lizards between the U.S. and Mexico and an ecological or physical barrier further south in Mexico. Further analyses will elucidate the population boundaries.

Determine Genetic Variability Within Wild and Captive Populations of Sonoran Pronghorn

Project Partners:	USFWS, Cabeza Prieta National Wildlife Refuge
Project Duration:	2009 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Erin Vaughn

Goal: The Sonoran pronghorn population experienced a population crash down to 21 individuals in 2002 and the captive population is partially maintaining the genetic health of the species. Today the population is estimated at 68 individuals, however, there are still some important genetic questions that need to be addresses for the pronghorn subpopulation residing within the US. We have helped determine paternity (and maternity) for key offspring from the captive Sonoran pronghorn population; estimate levels of inbreeding, genetic variability, and relatedness within the captive population; compared genetic variability among all remaining free-ranging populations of Sonoran pronghorn; confirmed the feasibility of using pronghorn scat samples to characterize genetic variability for populations in Mexico; determined degree of relatedness among all members of the Sonoran pronghorn captive population; and determined the relatedness of Sonoran pronghorn to nearby pronghorn populations in Mexico and Arizona (*Antilocapra americana mexicana*, *Antilocapra americana peninsularis*, and *Antilocapra americana Americana*).

Population Structure and Kinship of Harris Hawks in Baja Salifornia Sur

Project Partners:	CONACyT
Project Duration:	2018 to Present
Co-Principal Investigators:	Melanie Culver and Ricardo Estrella
Graduate Research Assistant:	Gergorio Herrera

Goal: Use microsatellite markers to assess genetic diversity of samples from nest sites in agricultural areas in Baja California where the habitat has become fragmented. Analyze the data among nesting areas to determine the amount of connectivity across broad agricultural areas for this raptor specices in the southern Baja California. We will estimate the level of inbreeding for each fragmented area, estimate levels of subdivision among populations, and infer if barriers to gene flow are present in this agricultural landscape. Additionally, we will examine kinship at each nest to look for paternal relationships. In this collaborative effort the PhD student, Gregorio, will do a paid internship at the UA in the Culver Conservation Genetics Laboratory in the Fall of 2018 and early Spring 2019, to learn the techniques needed to perform the analyses, then continue the analyses in La Paz, BC with assistance from the Culver Lab.

Genetic Structure of Great Horned Owls in Baja California Sur

Project Partners:	CONACyT
Project Duration:	2017 to Present
Co-Principal Investigators:	Melanie Culver and Ricardo Estrella

Goal: Use microsatellite markers to assess genetic diversity of samples from nest sites in agricultural areas in Baja California where the habitat has become fragmented. Analyze the data among nesting areas to determine the amount of connectivity across broad agricultural areas for this raptor specices in the southern Baja California. This project is a collaborative effort with Ricardo Estrella who has studied these owls in the Baja for a couple decades. More than 50 blood samples from unrelated adults are available, which we will use to genotype and estimate population-level genetic characteristics. From this information we will estimate inbreeding and potential isolation, and be able to inform managers of any lack of gene flow among populations.

A Population Genetic Analysis of Northern Crested Caracara (*Caracara cheriway*) from the Endemic, Threatened Florida Population

Project Partners:	USFWS, UA
Project Duration:	2019 to 2021
Principal Investigator:	Melanie Culver
Postdoctoral Researcher:	Alex Erwin

Goal: To investigate genetic isolation of the Florida caracara population using molecular techniques. In fact, to our knowledge, no population genetic studies have ever been performed in *C. cheriway*. Though caracara are highly mobile, and have been known to travel large distances, there is no evidence to suggest that breeding and genetic exchange occurs between the Florida population and other caracara populations (USFWS 2017). As these caracara are habitat-specific and isolated, they are more significantly at risk to stochastic environmental and demographic changes. Small isolated populations are also more likely to lose genetic diversity. Understanding the extent of their isolation, the current genetic diversity of the population, and whether or not there is any population subdivision or barriers to gene flow is critical for continued management of this imperiled population. We have comparison samples from Texas and Arizona in addition to over 100 Florida individuals sampled from Florida. Results will be used by Florida Fish and Wildlife Conservation Commission in their management and recovery efforts for the Florida caracara.

Genetic Diversity and Structure for Arizona Bald Eagles

Project Partners:	AZGFD, USFWS
Project Duration:	2012 to 2016
Principal Investigator:	Melanie Culver
Postdoctoral Researcher:	Michael Wierda

Goal: To investigate genetic isolation of the Sonoran Desert Bald Eagle (BAEA) population in Arizona. This research will provide genetic information to an ongoing debate over whether or not the Sonoran Desert BAEA should be managed as a distinct population, separately from all other BAEA populations in North America. In the first phase of the study, we used established genetic markers to investigate genetic diversity within the Sonoran Desert BAEA population. In the second phase, we investigated gene flow between the Sonoran Desert BAEA population and surrounding BAEA samples. Our results indicated a slightly lower heterozygosity in Arizona bald eagles compared to other populations, and a slight differentiation between the southern part of the state and the northern part. Compared to bald eagles that were migrants into Arizona, there were no differences observed between northern Arizona and the migrants. We would like to perform additional genetic analyses with additional samples from neighboring states to tease out the complicated evolutionary history of bald eagles in the southwest rather than to draw conclusions based on a small number of migrant (comparison) samples.

TAXONOMY

Investigation into the Phylogeography and Species Status of the Desert Tortoise and its Application to Conservation

Project Partners:	USFWS
Project Duration:	December 2009 to 2016
Co-Principal Investigators:	Melanie Culver, Phil Rosen, and Robert Murphy
Graduate Research Assistant:	Taylor Edwards

Goal: To define the phylogeographic units for the desert tortoise in the presence of a secondary contact zone between Mojave and Sonoran populations, and between Sonoran and Sinaloan populations. We investigated genetic divergence among the three lineages of the desert tortoise, *Gopherus agassizii* (Sonoran, Mojave, and Sinaloan) employing a multilocus approach and reconstructing gene trees for several independently inherited markers representing multiple regions across the genome. We also investigated ecotones form the boundaries among the three lineages of desert tortoises. These were tested by assessing whether the distributions of gene trees correlated with the geographic distribution of vegetative communities. We found all three lineages to be monophyletic and equally divergent, suggesting the occurrence of three separate species for desert tortoises. We also found naturally occurring introgression among genetic lineages/species along ecotone boundaries by identifying hybrid individuals existing, beyond the F1 generation, between California and Arizona and at the Sonora/Sinaloa boundary in Mexico. These results have already been used with respect to decisions not to list the Sonoran desert tortoise under ESA and currently the Sinaloan desert tortoise is being investigated as to its status and threats for long-term survival.

Conservation Genetics and Population Structure of Chiricahua Leopard Frogs *(Rana chiricahuensis)* in New Mexico, Arizona and Mexico

Project Partners:	AZGFD, USFWS
Project Duration:	2006 to 2016
Principal Investigator:	Melanie Culver
Research Technician:	Karla Vargas
Associate Researcher	Hans-Werner Herrmann

Goal: This study examined genetic relationships among populations, Recovery Units (RU), and Recovery Unit subgroups as defined by the Draft Recovery Plan (2005), and can be used to guide Chiricahua leopard frog recovery efforts. The Chiricahua leopard frog, *Rana chiricahuensis*, occurs at elevations of 3,281 to 8,890 feet in central and southeastern Arizona; west-central and southwestern New Mexico; and the sky islands and Sierra Madre Occidental of northeastern Sonora and northwestern Chihuahua, Mexico (Draft Recovery Plan 2005). Chiricahua leopard frog populations have declined precipitously throughout Arizona and New Mexico. Since the species was listed as threatened in 2002 data suggests that the decrease in numbers is due primarily to drought and chytridiomycosis (believed to be a fungal skin disease), the number of likely extant populations has declined by 27-33% in the last 4 years. Molecular genetic analyses were conducted using microsatellite and mitochondrial DNA markers and determined that although 8 RUs had previously been defined, genetic results were more consistent with 14 distinct populations. This information will help determine the most appropriateness of moving frogs among populations, for translocations into declining and extirpated populations and RUs. Results will also be used for future population viability analyses and to develop a decision tree for how to select appropriate source populations for reintroductions. This study was done in two parts, and funded separately.

Genetic lineage Assessment of Gila Topminnow Samples from Santa Cruz River and Parker Canyon.

Project Partners:	Bureau of Reclamation, USFWS, AGFD
Project Duration:	2004 to 2018
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Karla Vargas

Goal: Use microsatellite loci to assess the lineage of topminnow samples collected in 2004, 2016, and 2017 from the wild, but from unknown lineages. These samples are from populations that previously were not known and the genetic assessment will help managers learn if the population colonized naturally or were introduced from elsewhere in the topminnow range. The data were compared to 13 known Gila topminnow genetic lineages from the literature. The 2004 and 2016 unknown populations were found to be most closely related to the Santa Cruz Gila topminnow lineage. The exclusion analysis of the 2017 unknown population indicate Cienega Creek as the most likely lineage of origin for these samples.

BEHAVIORAL ECOL

Genome Approach for Noninvasive Diet Assessment of Mule Deer from Scat

Project Partners:	Navajo Tribe Natural Resources
Project Duration:	2013 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Chase Voirin

Goal: Use next-generation sequencing on scat samples collected from mule deer for a high-resolution diet assessment. Very little is known about the precise diet components for mule deer. In this study scat samples are collected seasonally to sample both the winter and summer range. Samples also were collected over 2 years to have sampling in different years to test variation by year. Next-generation sequencing (NGS) using a (meta-amplicon sequencing approach or meta-barcoding) was performed and compared to a micro-histology approach. Analyses to determine all the plant species consumed by mule deer, seasonally, in different mountain ranges, and in different years, the NGS approach identified far more plants to species 98%, and 2% to genus, in all comparisons, whereas, micro-histology identified 21% to species and 74 % to genus and 2% to family. If possible, diet variation among individuals will also be examined in the future.

Using RAD-seq Genomic Methods to Estimate Social Structure and Reproductive Success of a Puma Population and Implications on Affects of Sport-Hunting

Project Partners:	Colorado DNR, Summerlee Foundation
Project Duration:	December 2009 to Present
Co-Principal Investigators:	Melanie Culver, Ken Logan
Graduate Research Assistant:	Alex Erwin

Goal: Examine substructure and connectivity of pumas on the Uncompahgre Plateau of Colorado; describe relatedness, paternity, and reproductive success of adults in the population. We will examine different genomic signals of a puma population that was not hunted, then subsequently hunted, to reveal if hunting may change the relatedness, social structure, and reproductive success of individuals in the population in a manner that may signal potential changes in fitness and phenotypic traits. This could inform managers and stakeholders about potential outcomes of current management models, and if necessary provide alternate management models to modify management for pumas to lessen the fitness impact from hunting. We are still gathering the RAD-seq data.

Assessment of Trophic Cascades for the Mexican Wolf

Project Partners:	UA, AGFD
Project Duration:	2015 to 2018
Principal Investigator:	Melanie Culver
MS Student:	Joshua Hoskinson

Goal: Predator removal efforts have highlighted the vital role apex predators play in biological communities through the maintenance of biodiversity and the regulation of essential ecosystem functions through mechanisms such as the maintenance of biogeochemical cycles and carbon sequestration. Mexican wolves have been largely absent from these kinds of studies, especially in regards to how Mexican wolves have impacted the biological community of the Blue Range Wolf Recovery Area. The main objective of this study is to investigate the relative abundance of Mexican gray wolves and coyotes in the White Mountain Apache Reservation, a non-invasive genetic study using microsatellite markers on scat samples (genetic mark-recapture), and a trail camera study in areas where coyote and fox occur with known wolf populations (in collaboration with AGFD wolf biologists). Analysis of data is ongoing.

BIODIVERSITY

Jaguar Surveying and Monitoring in the United States

Project Partners:	USFWS, DHS
Project Duration:	December 2011 to 2016
Principal Investigator:	Melanie Culver
Research Associate Senior:	Susan Malusa

Goal: To establish a defensible method to non-invasively and accurately conduct an intensive survey and monitoring system for jaguars in Arizona and New Mexico. This system included a total of 140 camera sites with paired trail cameras (280 cameras), GIS analyses to delineate areas most likely to detect jaguars, and genetic analyses of scats collected with the help of a scent detector dog. Cameras were set at differing densities in the 3 priority zones among 16 mountain ranges. When scats were collected, they were first analyzed using genetic techniques to determine if from a jaguar. Genetic data was analyzed for additional data points to aid in habitat analyses for jaguars, and to assess genetic diversity for jaguars detected during this study. Photo data was analyzed for species richness, species detection rates, species accumulation, activity patterns, and proportion of locations occupied for each species - for predators and prey species alike. Our results provided abundant monitoring information on endangered felids to Arizona wildlife managers. We detected one male jaguar and three male ocelots in 3 of the 16 mountain ranges surveyed. The jaguar was detected 118 times by photo/video and 13 times by scat, and we detected him every month of the year for the study duration. The minimum home range for the jaguar was estimated to be 90km^2. We consider three of these individuals to be non-breeding resident males because the jaguar remained for the study duration, one ocelot remained for 6 months, and another ocelot remained for the study duration. A variety of other sensitive species were detected (gila monster, desert tortoise, Sonora mud turtle, Mexican spotted owl). For future work, science-based management of these endangered felids will benefit from similar long-term monitoring of travel corridors between the core jaguar and ocelot populations in Mexico and the U.S.

eDNA of Water and Sediment to Assess Biodiversity in the Gulf of California.

Project Partners:	CONACyT, Private Foundation
Project Duration:	2016 to Present
Co-Principal Investigators:	Melanie Culver
Graduate Research Assistant:	Eldridge Wisely

Goal: To integrate genetic and phylogenetic diversity approaches using innovative tools to an issue of biodiversity concern. Tools for assessing biodiversity have undergone a rapid development across the previous two decades. This development includes both a greater commitment to low technology methods such as long-term population and community monitoring as well as utilization of increasingly advanced methods in genomics, landscape genetics, modeling, biometrics, DNA barcoding and environmental DNA (eDNA). We will perform a high-resolution assessment of phylogenetic diversity, for the vertebrate species sampled, enhanced by new high throughput eDNA meta-amplicon sequencing biodiversity surveys at sites throughout the Gulf of California. eDNA samples have been collected from the water column and from the sediment in several locations throughout the Gulf of California. DNA analysis is being conducted and results will be forthcoming. Preliminary funding $20,000 CONACyT. $10,000 private foundation. 2015 – Present.

CONSERVATION GENOMICS

The Effects of Extirpation and Reintroduction on the Mexican Wolf (*Canis lupus baileyi)* through Genome-Wide Association

Project Partners:	USFWS, NSF-IGERT
Project Duration:	December 2009 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Bob Fitak

Goal: The objectives are to assess if admixture with other canids is present, and the distribution of genetic variability across ~170,000 SNP markers, and to identify regions experiencing positive or purifying selection in the Mexican wolf prior to their extirpation from the wild. These markers will also be used to reveal the genes, or genomic regions, showing strong association with inbreeding depression in captive populations. Because the domestic dog and the wolf are closely related, the available genome sequence (genome enabling with ~170,000 SNPs) of the domestic dog were genotyped in 96 Mexican wolf samples. Admixture was examined with respect to domestic dog and none was found, and important result as many claims have been made since the captive breeding program started that domestic dog hybrids have occurred. Inbreeding and overall low genetic variability was found, as expected with a population with only 7 founders. We examined the genome for regions of positive and negative selections, attempting to find linkage to traits associated with inbreeding depression, but no significant associations resulted. We did however, find important errors in the pedigree and clarified for the captive program certain individuals that were cross lineage wolves but were identified as pure lineage wolves. Using our genomic data in combination with the available microsatellite data, we have improved upon the existing captive management and reintroduction plans. The errors we eliminated from the pedigree, and the improvement in accuracy we made to the inbreeding estimates, from our whole genome data, will help minimize the effects of inbreeding depression for future matings. These results aid in optimizing the management strategies of captive and wild populations of Mexican wolves to protect against concerns like inbreeding depression, and may provide a foundation for the design of recovery plans in other endangered taxa.

Functional Genomics of the Endangered Florida Panther

Project Partners:	CONACyT, NSF-IGERT, Calder Scholarship
Project Duration:	2011 to 2017
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Alex Ochoa

Goal: Correlate genetic diversity in genome with fitness traits in the Florida panther, and evaluate the success of the Texas introduction as a function of purged detrimental variation vs. genetic swamping of Florida panther ancestry. Genome-wide association studies (GWASs) have been used to uncover the genetic basis of many adaptive and detrimental traits in human populations and represent a powerful tool for the proper conservation and management of endangered wildlife. This project performed genome sequence for several trios of Florida mother, Texas father, and offspring. From the genomic data – genome-wide SNPs informative for adaptive and detrimental variation were developed. SNPs are the marker of choice to detect selection at a larger scale. Compared to other felid and carnivore genomes available, the we found 540 gene family expansions and 2613 gene family contractions in the puma genome. These results are similar to those reported for the cheetah. Of note of the expanded gene families is fatty acid metabolism, important since the puma is unable to synthesize certain fatty acids and must obtain them from their carnivorous diet. Contracted gene families were associated with the sensory perception of smell, however positive selection was found associated with a specific type of smell associated with the vomeronasal organ which plays a role in behavioral traits such as territory ownership (detection of urine and phermones). Information derived from this study will be essential to optimize efforts for the captive breeding, management, and conservation of the endangered Florida panther. In the future, we intend to use this SNP array to then genotype the Texas puma population, the bottlenecked Florida panther population, and the current Florida panther population.

Epigenomics of the Endangered Sonoran Pronghorn

Project Partners:	NSF-IGERT
Project Duration:	2013 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Erin Vaughn

Goal: Correlate genetic diversity to epigenetic diversity in pronghorn raised in captivity at Cabeza Prieta NWR. Epigenetic data can be used to assess for environmentally adaptive traits. In Sonoran pronghorn that have been held in captivity, we examined epigenetic signature (reflecting differential adaptation) between pronghorn in captivity versus those in the wild. Additionally, we looked for temporal epigenetic variation as our samples span 5 years of sampling and compared epigenetic variation to genomic variation and look for correlation. This was the first examination of epigenetic variation in wild populations of mammals, and provided preliminary results on whether epigenetic variation exists in a severely bottlenecked species. We found a weak signal of higher epigenetic variation relative to genomic variation in the Sonoran pronghorn relative to the American pronghorn, but these results are not highly significant.

Determine Relatedness of Certain Mexican Races of Bobwhite (*Colinusvirginianus*)

Project Partners:	USFWS
Project Duration:	2011 to Present
Principal Investigator:	Melanie Culver
Research Technician:	Sophia Amirsultan
Graduate Research Assistant:	Karla Vargas

Goal: Use museum samples and capture hybrid (UCE) whole genome approach to examine taxonomic differences among all relevant subspecies of Mexican bobwhite. We performed genetic analysis of 60 individuals from nine subspecies (including from *C. v. ridgwayi*, *C. v. coylocos*, and C. *v. graysoni*). DNA was extracted from the museum samples in a dedicated ancient DNA laboratory. Our taxonomic analyses indicate *C. v. ridgwayi*, *C. v. texanus*, and C. *v. graysoni* are more closely related to each other than to other subspecies of *C. virginianus*. The close relationship of these 3 subspecies has high statistical support. Our final analyses will also look at selection for captivity in the captive breeding population, traits that can be used for marker assisted breeding, and overall relatedness among taxa. These results will be used to aid the recovery efforts for the masked bobwhite, particularly with respect to potential translocations into masked bobwhite areas from Mexico.

Black-Tailed Prairie Dog Taxonomy and Population Connectivity

Project Partners:	AZGFD Heritage
Project Duration:	December 2012 to Present
Principal Investigators:	Melanie Culver
Graduate Research Assistant:	Alex Erwin

Goal: Use museum samples and whole genome approach to examine taxonomic relatedness and level of connectivity among populations of prairie dogs in Arizona, New Mexico, Texas, and northern Mexico. The black-tailed prairie dog (*Cynomys ludovicianus*) has experienced declines throughout its range over the past century, and was extirpated from Arizona in the 1960s. In 2008, individuals from New Mexico were reintroduced in southern Arizona. Despite ongoing management efforts, little is known regarding the historical level of connectivity and taxonomic relatedness between populations native to Arizona and other populations in the southwestern US and Mexico. We sampled live and museum specimens from Arizona, New Mexico, Texas, and northern Mexico and use a combination of next-generation sequencing method (Gentotype By Sequence, GBS, fresh samples) and capture hybridization method (Ultra Conserved Element, UCE, museum samples) will be needed to interrogate relationships among prairie dog populations in this region. Results indicated that the great plains individuals were differentiated from the Arizona, U.S., Sonora, Mexico and southern New Mexico samples. The striking finding was an additional divergence between Sonora, Mexico and Chihuahua, Mexico. These results have an impact on the recovery efforts in Arizona by re-directing were prairie dogs are drawn from for re-introduction efforts. Future work is directed at completing analyses of museum samples.

PEER-REVIEWED PUBLICATIONS

Amberg, J. J., S. A. Bonar, C. Perez, C. B. Rees, C. Jackson and R. M. Ulibarri. 2018. The importance of sound methodology in environmental DNA sampling: Response to comment. *North American Journal of Fisheries Management.* 38:597-600.

Bonar, S. A. and S. L. McMullin. 2018. Help us celebrate our 150th anniversary. *Fisheries* 43:223.

Bonar, S. A., and J. Trushenski. 2017. The skill we all need. *Fisheries* 42:397.

Bonar, S. A. 2017. The dark side of safety. *Fisheries* 42:183.

Bonar, S. A., N. Mercado-Silva, W. A. Hubert, T. D. Beard Jr., G. Dave, J. Kubecka, B. D. S. Graeb, N. P. Lester, M. Porath, I. J. Winfield. 2017. Standard Methods for Sampling Freshwater Fishes: Opportunities for International Collaboration. Fisheries 42:150-156.

Brizendine, M. E., D. L. Ward and S. A. Bonar . 2018. Effectiveness of Ultrasonic Imaging for Evaluating Presence and Maturity of Eggs in Fishes in Remote Field Locations. *North American Journal of Fisheries Management* 38:1017-1026.

Brown DE, Vargas K, Wisely E and M Culver. 2018. A resurrection of the Tamaulipas white-sided jackrabbit, *Lepus altamirae*, based on DNA seuquence data. Mexican Journal of Mammalogy, In Review.

Dominguez-Contreras JF, Munguia-Vega A, Ceballos-Vazquez, BP, Arellano Martinez M, Garcia-Rodriguez FJ, Culver M and H Reyes-Bonilla. 2018. Life histories predict genetic diversity and population structure within three species of octopus targeted by small-scale fisheries in Northwest Mexico.

Erwin JA, Vargas K, Blais BR, Bennett K, Muldoon J, Findysz S, Christie C, Heffelfinger JR, Culver M. 2018. Genetic assessment of a bighorn sheep population expansion in the Silver Bell Mountains, Arizona. PeerJ 6:e5978 http://doi.org/10.7717/peerj.5978

Erwin, J.A., Hybridizing Law: A policy for hybridization under the Endangered Species Act, 47 Environmental Law Reporter 10615 (2017).

Erwin, J.A., Hybridizing Law: A policy for hybridization under the Endangered Species Act (Abstract), 48 Environmental Law Reporter 10740 (2018). Condensed version of the original article was republished and designated an honorable mention in the 2018 Environmental Law and Policy Annual Review (ELPAR) as one of the top environmental policy-relevant articles from 2016-2017.

Fitak RR, Rinkevich S and M Culver. 2018. Genome-wide analyses of SNPs reveal a lack of domestic dog ancestry in the endangered Mexican wolf (*Canis lupus baileyi*). Journal of Heredity, https://doi.org/10.1093.jhered/esy009

Gervais, B., C. Voirin., et al. 2017. Native American Student Perspectives of Challenges in Natural Resource Higher Education. *Journal of Forestry.*

Macias-Duarte A, Conway CJ, Holroyd GL, Valdez-Gomez HE, and M Culver. 2018. Genetic variation among island and continental populations of burrowing owl subspecies (*Athene cunicularia*) in North America. Canadian Journal of Zoology, In Press.

Ochoa A, Onorato DP, Fitak RR, Roelke-Parker ME and M Culver. 2017. Evolutionary and functional mitogenomics associated with the genetic restoration of the Florida panther. Journal of Heredity, 108:449-455.

Peer-Reviewed Publications (cont'd.):

Overpeck, J. T. and S. A. Bonar. In Press. Southwester fish and aquatic systems: The climate challenge. *In* D. L. Propst, J. E. Williams, K. R. Bestgen and C. W. Hoagstrom, editors. Standing between life and extinction: Ethics and ecology of conserving aquatic species in the American Southwest. University of Chicago Press.

Perez, Christina R., Scott A. Bonar, Jon J. Amberg, Bridget Ladell, Chris Rees, William T. Stewart, Curtis J. Gill, Chris Cantrell, and Anthony T. Robinson. 2017. Comparison of American Fisheries Society (AFS) Standard Fish Sampling Techniques and Environmental DNA for Characterizing Fish Communities in a Large Reservoir. *North American Journal of Fisheries Management* 37: 1010-1027.

Petre, S. J. and S. A. Bonar. 2017. Determination of habitat requirements for Apache Trout *Oncorhynchus apache*. *Transactions of the American Fisheries Society* 146:1-15.

Ruggirello, J. E., S. A. Bonar, O. G. Feuerbacher, L. H. Simons, and C. Powers 2018. Propagation of endangered Moapa Dace. *Copeia*, 106:652-663.

Ulibarri, R. M., S. Bonar, C. Rees, J. Amberg, B. Ladell, and C. Jackson. 2017. Comparing Efficiency of American Fisheries Society Standard Snorkeling Techniques to Environmental DNA Sampling Techniques. *North American Journal of Fisheries* Management 37:644-651

TECHNICAL REPORTS

Culver M. 2017. Genetic assessment of a relatively isolated population of bighorn sheep in the Silverbell Mountains. U.S. Geological Survey Publication IP-088253.

PRESENTATIONS GIVEN

Bonar, S. A., W. A. Hubert and D. W. Willis. Development of AFS standard fish sampling methods. Process and lessons learned. 2017. Angler App Standards Workshop. 8th World Recreational Fishing Conference, Victoria, Canada, July 16-20.

Bonar, S. A. 2018. The conservation professional's guide to working with people. 148th Annual Meeting of the American Fisheries Society, Atlantic City, New Jersey, August 19-23, 2018

Culver, M., S. E. Rinkevich and R. R. Fitak. 2018. Genome-wide analyses of SNPs is consistent with no domestic dog ancestry in the endangered Mexican wolf (*Canis lupus baileyi*). AZ-NM TWS meeting, Flagstaff, NM February 2018.

Culver M. 2017. Genetic techniques applied for the conservation and management of reptiles and amphibians in the Southwest. Tucson Herpetological Society. August 16, 2017, Tucson, AZ.

Culver M. 2017. Jaguar monitoring, citizen science and conservation genetics. Tucson Chapter Meeting of the Sierra Club, June 8, 2017, Tucson, AZ.

Culver M., H-W. Herrmann , M. Sredl , and K. Vargas. 2017. Conservation genetics of the Chiricahua leopard frog (*Rana chiricahuaensis*). AZ-NM TWS Meeting, Farmington, NM, 9-11 February 2017.

Erwin, J.A., R. R. Fitak , and M. Culver 2018. Using genomics to inform the reintroduction of black-tailed prairie dogs back into southern Arizona. 2018 Graduate Interdisciplinary Program Showcase. December 2018. Tucson, AZ.

Lee, L. and S. Bonar. 2017. Using USGS StreamStats to Evaluate Relationships Between Fish Populations and Flow Regime. (2017) San Luis De Rio Colorado, Mexico: 49th Annual Meeting of the Desert Fishes Council.

Lee, L. and S. Bonar. 2017. Using USGS StreamStats to Evaluate Relationships Between Fish Populations and Flow Regime. (2017) Tampa, FL: American Fisheries Society 147th Annual Meeting; Fish Ecology I – Contributed Papers.

Lee, L. and S. Bonar. 2017. Using USGS StreamStats to Evaluate Relationships Between Fish Populations andFlow Regime (2017) Missoula, MT: Western Division of the American Fisheries Society 42nd Annual Meeting, Poster Presentation.

Lee, L. N., Z. C. Nemec, and S. A. Bonar. 2017. Assessing modified prepositioned areal electrofishing devices (PAEDs) for surveying fish habitat use in desert streams. 50th Joint Annual Meeting of the AZ/NM American Fisheries Society, AZ Chapter of The Wildlife Society, NM Chapter of The Wildlife Society, Farmington, New Mexico, February 9-11, 2017.

Lee, L. and S. Bonar. 2018. Go with the Flow: Fish Populations and Flow Regimes in Four Arizona Streams. (2018) Death Valley, CA: Desert Fishes Council 50th Annual Meeting, Oral Presentation.

Lee, L. and S. Bonar. 2018. Evaluating relationships between fish populations and flow regimes in Arizona streams (2018) Atlantic City, NJ: American Fisheries Society 148th Annual Meeting; Environmental Flows: Novel Findings, Challenges to Conventional Thinking, and Embracing Uncertainty, Oral Presentation.

Lee, L. and S. Bonar. 2018. Evaluating relationships between fish populations and flow regimes in Arizona streams" (2018) Anchorage, AK: Western Division of the American Fisheries Society 43nd Annual Meeting; Native Western Fishes, Oral Presentation.

Presentations Given (cont'd.):

Lee, L. and S. Bonar. 2018. Evaluating relationships between fish populations and flow regimes in Arizona streams" (2018) Flagstaff, AZ: 51st Joint Annual Meeting of the Arizona and New Mexico Chapters of the American Fisheries Society and the Wildlife Society, Oral Presentation.

Owens, C. and L. Lee. 2018. Turning the tide: Addressing diversity and inclusion in Western Division. (2018) Atlantic City, NJ: American Fisheries Society 148th Annual Meeting; Diversity and Inclusion in the Fisheries Profession: Leadership and Action, Oral Presentation.

Nemec, Z. and S. Bonar. 2017Through the fish's eye: Comparison of densiometer and inexpensive hemispherical photography to assess streamside canopy(2017) San Luis De Rio Colorado, Mexico: 49th Annual Meeting of the Desert Fishes Council.

Nemec, Z. and S. Bonar. 2017. Through the fish's eye: Comparison of densiometer and inexpensive hemispherical photography to assess streamside canopy. (2017) Tampa, FL: American Fisheries Society 147th Annual Meeting.

Nemec, Z. and S. Bonar. 2018. Stream-specific and generalized habitat suitability criteria for three native desert fishes. 148th Annual Meeting of the American Fisheries Society, Atlantic City, New Jersey, August 19-23, 2018

Nemec, Z. and S. Bonar. 2018. Stream-specific and generalized habitat suitability criteria for three native desert fishes. 43rd Annual Meeting of the Western Division of the American Fisheries Society Anchorage, Alaska, May 21 – 25, 2018.

Nemec, Z. and S. Bonar. 2018. Stream-specific and generalized habitat suitability criteria for three native desert fishes. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Flagstaff, Arizona. February 1-3, 2018.

Nemec, Z. and S. Bonar. 2018. Stream-specific and generalized habitat suitability criteria for three native desert fishes. The Desert Fishes Council Annual Meeting, Death Valley, California. November 14-18, 2018.

Ochoa A, Onorato DP, Fitak RR, Roelke-Parker ME, and M Culver. 2017. The puma genome: insights into the evolution and demographic history of Florida panthers and Texas pumas. AZ-NM TWS Meeting, Farmington, NM, 9-11 February 2017.

Teal, C., S. Bonar, D. Schill, and M. Culver. 2018. Developing trojan sex chromosome carriers (YY Males) to control nuisance fish populations in the Southwest. Gila River Basin Native Fish Program-Technical Committee Meeting, Silver City, NM, December 11-13, 2018.

Teal, C., S. Bonar, D. Schill, and M. Culver. 2018. Developing YY males to control nuisance fish populations in the Southwest. 50th Annual Desert Fishes Council Meeting, Death Valley, California, November 14-18, 2018.

Teal, C., S. Bonar, D. Schill, and M. Culver. 2018. Developing YY males to control nuisance fish populations in the Southwest. Arizona Native Fishes Conservation Team Statewide Meeting, Phoenix, Arizona, November 8, 2018.

Teal, C., S. Bonar, D. Schill, and M. Culver. 2018. Developing YY males to control nuisance fish Populations in the Southwest. Colorado River Aquatic Invasive Species Task Force Meeting, Online, September 26, 2018.

Teal, C., T. Caplow, N. Manzano, A. Farina., G. Barrocas. 2018. The Miami Science Barge: Developing a small-scale, portable environmental education platform. 148th Annual Meeting of the American Fisheries Society, Atlantic City, New Jersey, August 17-23.

Presentations Given (cont'd.):

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2017. Techniques for using simple, inexpensive high-definition video technology to film cryptic underwater species. The Desert Fishes Council Annual Meeting, San Luis Río Colorado, Sonora, Mexico. November 15-19, 2017.

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2017. Techniques for using simple, inexpensive high-definition video technology to film cryptic underwater species. The American Fisheries Society Annual Meeting, Tampa, Florida. August 20–24, 2017.

Ulrich, T., and K. Liebich. Fishing Program: A journey of firsts. US Fish and Wildlife Service, Region 7 Regional Office, Anchorage, Alaska. August 10, 2017.

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2017. Cryptic but reel: How videography can be used to promote fish conservation. US Fish and Wildlife Service, Region 7 Regional Office, Anchorage, Alaska. July 6, 2017.

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2017. Use of high-definition video technology to acquaint the public with cryptic desert fishes of the southern Nevada/Death Valley region. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Farmington, New Mexico. February 9-11, 2017.

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2018. Using social psychology principles in education videos to acquaint the public with cryptic desert fishes. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Flagstaff, Arizona. February 1-3, 2018.

Ulrich, T., S. Bonar, D. Bogner, and C. Sheehy. 2018. Cryptic but reel: using social psychology in videos to acquaint the public with lesser known fishes. The Western Division of the American Fisheries Society Annual Meeting, Anchorage, Alaska. May 21–25, 2018.

Ulrich, T., and K. Liebich. 2018. Hooked on Aquatic Sciences: a fishing program to teach diverse youth about aquatic ecology and conservation. The Western Division of the American Fisheries Society Annual Meeting, Anchorage, Alaska. May 21–25, 2018.

Ulrich, T., and S. Bonar. 2018. Cryptic but Reel: Using social psychology principles in educational videos to acquaint the public with cryptic fishes. The American Fisheries Society Annual Meeting, Atlantic City, New Jersey. August 19–23, 2018.

Ulrich, T., and S. Bonar. 2018. Cryptic but Reel: Using social psychology principles in educational videos to acquaint the public with cryptic fishes. The Desert Fishes Council Annual Meeting, Death Valley, California. November 14-18, 2018.

Vargas, K and M. Culver. 2018. Application of genomic analyses to inform management of the endangered masked bobwhite (*Colinus Virginianus ridgewayi*). Masked Bobwhite Recovery Team Meeting. Tucson, AZ. June 28th 2018

Vargas, K and M. Culver. 2018. Phylogenomic analysis of Bobwhite Quail in Southern Arizona and Mexico. AZ-NM TWS Meeting, Flagstaff, AZ, 1-3 February 2018.

Vargas, K and M Culver. 2017. Genetic lineage assessment of unknown and rediscovered Gila topminnow (*Poeciliopsis occidentalis*). AZ-NM TWS Meeting, Farmington, NM, 9-11 February 2017.

THESES AND DISSERTATIONS OF UNIT GRADUATE STUDENTS

Hoskinson, Joshua, 2018. Mexican gray wolves and the ecology of fear: a comparative assessment of community assemblages in Arizona. MS Thesis, University of Arizona, Tucson, AZ.

Ochoa-Hein, Alexander. 2017. Population genomics/genetics of endangered and vulnerable wildlife: the Florida panther (*Puma concolor coryi*) and the Arabian oryx (*Oryx leucoryx*).

Lee, Larissa N. 2018. Habitat suitability criteria for nonnative species and relationships between fish populations and flow regime in four Arizona streams. Master's Thesis.

Nemec, Zach C. 2019 (January). Development and evaluation of habitat suitability criteria for native fishes and assessment of the relationship among riparian areas and stream macrohabitat type and fish presence in four central Arizona streams. Master's Thesis.

Ulrich, Taylor. L. 2018. Using high-definition underwater videography and social psychology to increase public interest in rare fishes. Master's Thesis.

TEACHING

Bonar, S.A., Advisor, Student Subsection, University of Arizona, American Fisheries Society.

Bonar, S. A., Arizona Game and Fish Department Workshops: Essential, Practical Communication Skills for Natural Resource Professionals. AZGFD Headquarters, Phoenix. Summer 2017.

Bonar, S. A., Turning Up the Heat: Effects of Climate Change On the Fight to Conserve the Southwest's Rare and Spectacular Fishes. University of Arizona School of Natural Resources and the Environment Seminar Series. September 2017.

Bonar, S. A. WFSC 444 – Wildlife Management, guest lecturer on Habitat Analysis Techniques in Fisheries, Fall 2017

Bonar, S.A., WFSC 595A, Biopolitics. Communication in Natural Resources. University of Arizona. Spring 2017.

Bonar, S. A. WFSC 225 – Wildlife Conservation and Society, Guest Lecture on Arizona's Freshwater Fishes, Fall 2017, 2018.

Bonar, S. A. WFSC 444L – Wildlife Management Laboratory, guest lecturer on Sampling Techniques in Fisheries Science, Fall, 2017.

Bonar, S. A. RNR 195A – Careers in Conservation: Wildlife, Plants and Water, guest lecturer on careers in fisheries biology, Fall 2017, 2018.

Bonar, S. A. WFSC 555R – Fishery Management, Spring 2018.

Bonar, S. A. WFSC 455L – Fishery Management Laboratory, Spring 2018.

Bonar, S. A. Faculty Co-Supervisor of the Doris Duke Conservation Scholars Program 2012-

Culver, M., GENE 670 – Recent Advances in Genetics Spring 2017.

Culver, M., GENE 670 – Recent Advances in Genetics Fall 2017.

Culver, M., RNR 530, ECOL 530, GENE 530 – Conservation Genetics, Fall 2017.

Culver, M., RNR 195A – Careers in Conservation: Wildlife, Plants and Water, guest lecturer on A Career in Conservation Genetics, Fall 2017.

Culver, M., GENE 670 – Recent Advances in Genetics Spring 2018.

Culver, M, RNR 430, ECOL 430 – Conservation Genetics – Online, Summer 2018

Culver, M., RNR 530, ECOL 530, GENE 530 – Conservation Genetics, Fall 2018.

Culver, M., RNR 530L, ECOL 530L, GENE 530L – Conservation Genetics Laboratory, Fall 2018

Culver, M and Soto, J. RNR 696A – Natural Resources Seminar Lead, Spring 2019

Culver, M., RNR 195A – Careers in Conservation: Wildlife, Plants and Water, guest lecturer on A Career in Conservation Genetics, Spring 2019.

AWARDS

Bonar, S. 2017-2018. USGS Star Award awarded by USGS.

Erwin, J.A. 2017. 2nd Place Endangered Species Law Student Writing Competition

Erwin, J.A. 2017. Sol Resnick Water Resources Fellow

Erwin, J.A. 2017. Travel Grant, Graduate and Professional Student Council, University of Arizona

Erwin, J.A. 2017. Agnese Nelms Haury Social Justice Law Fellow, University of Arizona

Erwin, J.A. 2018. Order of the Coif, James E Rogers College of Law, University of Arizona

Lee, L. 2017. Miles McGinnis Memorial Award, AZ-NM Chapter of the American Fisheries Society.

Lee, L. 2017. Arid Channels Workshop Scholarship, Natural Channel Design, Inc.

Lee, L. 2017. Travel Grant, University of Arizona Graduate Student and Professional Council.

Lee, L. 2017. Travel Award, Western Division of the American Fisheries Society.

Lee, L. 2017. Eleanor and Anthony DeFrancis Scholarship, National Italian American Foundation.

Lee, L. and Nemec, Z. 2018. Stinky Boot Award, AZ-NM Chapter of the American Fisheries Society. Award of Recognition.

Lee, L. 2018. Travel Grant, University of Arizona Graduate Student and Professional Council.

Lee, L. 2018. Travel Award, Western Division of the American Fisheries Society.

Lee, L. 2018. Clifford W. Carstens, Jr. Scholarship, University of Arizona.

Lee, L. 2018. Arrington Memorial Scholarship, University of Arizona.

Lee, L. 2018. Skinner Memorial Award , American Fisheries Society.

Nemec, Z. 2018. Miles McInnes Memorial Student Award, Arizona/New Mexico Chapter of the American Fisheries Society

Nemec, Z. 2018. GPSC Travel Grant, University of Arizona Graduate Student and Professional Council.

Ulrich, T. 2017. Ervin H. Zube Scholarship.

Ulrich, T. 2017. Travel Award, Western Division of the American Fisheries Society.

Ulrich, T. 2017. Directorate Fellowship Program, US Fish and Wildlife Service.

Ulrich, T. 2018. Travel Grant, University of Arizona Graduate Student and Professional Council.

Ulrich, T. 2018. Travel Award, Western Division of the American Fisheries Society.

Awards (cont'd.):

Ulrich, T. 2018. Best Oral Presentation by a Master's Student, Western Division of the American Fisheries Society.

Vargas, K. 2017. University of Arizona GPSC (Graduate Professional Student Council) Travel Grant.

Vargas, K. 2017. University of Arizona CALS Rick F. Seegmiller Memorial Scholarship.

Vargas, K. 2017. University of Arizona CALS Martha I. Grinder Student Support Scholarship.

Vargas, K. 2017. University of Arizona CALS Clifford W. Carstens, Jr. Endowment.

Vargas, K. 2017. University of Arizona School of Natural Resources and the Environment, Student Leadership Award.

Vargas, K. 2017. University of Arizona CALS Graduate College Fellowship.

Vargas, K. 2017. University of Arizona School of Natural Resources and the Environment Tuition Scholarship

Vargas, K. 2018. University of Arizona GPSC (Graduate and Professional Student Council) Research Grant.

Vargas, K. 2018. University of Arizona CALS Ervin H. Zube Scholarship.

Vargas, K. 2018. University of Arizona EEB William A. Calder Memorial Scholarship.

PROFESSIONAL SERVICE

Bonar, S. A. President Elect, American Fisheries Society. 2017 – Present.

Bonar, S.A. Member of the Education Section; Information and Technology Section, Fisheries Management Section; Western Division, and the Arizona/New Mexico Chapter of the American Fisheries Society, 2000-present.

Bonar, S. A., Past President, Introduced Fishes Section, American Fisheries Society.

Bonar, S. A. Member of the Desert Fishes Council.

Bonar, S. A. Expert Witness. In the Aravaipa Canyon Wilderness Area (W1-11-3342), in the General Adjudication of All Rights to Use Water in the Gila River System and Source, Ariz. Sup. Ct., Case Nos. W1-W4. Aravaipa Canyon Wilderness Area FRWR CLAIMS: Protection of Fish Resources.

Bonar, S. A. Expert Witness. Cherry Creek Reserved Water Rights Case on behalf of the United States Department of Agriculture, Forest Service.

Bonar, S. A. Desert Fishes Conservation Team – Arizona Game and Fish Department – Makes recommendations to AGFD Management on Desert Fish activities statewide. Coordinates activities with other agencies. Member March 2003-present.

Bonar, S. A. Desert Fish Scientific Advisor. U.S. Forest Service In-Stream Flow Legal Team. 2009-2017.

Culver, M. Past-President, Arizona Chapter of The Wildlife Society, 2016.

Culver, M. Secretary, Southwest Section of The Wildlife Society 2017.

Culver, M. Invited to serve as a member of the Genetics Graduate Interdisciplinary Program Executive Committee, at the University of Arizona, 2011-present.

Culver, M. Invited to serve as a member of the Arizona Biological and Biomedical Sciences Executive Committee, at the University of Arizona, 2011-present.

Culver, M. Invited to serve as Chair of the Genetics Graduate Interdisciplinary Program, at the University of Arizona, 2011-present.

Culver, M. Serving as a member of the USFWS Sonoran Pronghorn Recovery Team, 2009-present.

Culver, M. Invited to serve as member of the USFWS Technical Team for the Ocelot Recovery Team, 2005-present.

Teal, C. Editor-in-Chief, AZ/NM American Fisheries Society Newsletter- *Fish Soup*, January 2018-Present.

EMPLOYMENT OF FORMER STUDENTS

Thomas Archdeacon – MS – Fisheries Biologist, U.S. Fish and Wildlife Service, Albuquerque, New Mexico
Kathi Borgmann – Ph.D. – Restoration Ecologist, Audubon Society
Morgan Brizendine – MS – Fisheries Biologist, U.S. Fish and Wildlife Service, San Marcos, Texas
Anna Carlson – Teacher at Ventura College, CA
Samia Carrillo-Percastegui – Biologist, The World Wildlife Fund and The San Diego Zoo, CA
Cori Carveth – MS – Fisheries Biologist, Arizona Game and Fish Department, Ontario Ministry of the Environment
Ambre L. Chaudoin – MS - Biological Science Technician, National Park Service, Death Valley National Park, Nevada
Stephani Clark-Barkalow – Fisheries biologist at American Southwest Ichthyological Researchers LLC
Michelle Crabb – Biologist, Research Branch, Arizona Game and Fish, Phoenix, AZ
Karie Decker – MS – Invasive Species Coordinator, Nebraska Cooperative Fish & Wildlife Research Unit
Tony Dee – Contract Biologist for Department of Defense, CA
Alexander I. Didenko – MS - Fisheries Biologist, Ukrainian Institute of Fisheries, Kiev
Taylor Edwards – PhD - Assistant Staff Scientist, University of Arizona Genetics Core, Tucson, AZ
Robert Fitak – Postdoctoral Researcher, Duke University, Durham, NC
Matthew Goode – PhD - Research Scientist, School of Natural Resources and the Environment University of Arizona, Tucson, AZ
Jon Flinders – MS – Fisheries Research Biologist, Idaho Fish and Game, Salmon, Idaho
Vicki Garcia – MS – Ph.D. student, Virginia Tech
Celia Zoe Hackl – K-12 teacher at Tucson Waldorf, Tucson, AZ
Hans-Werner Herrmann – Postdoc - Biologist, Department of Plant Sciences, University of Arizona
Katie Hughes – MS – Senior Academic Advisor, SNRE, University of Arizona
Ely Jennett – K-12 Teacher, Casa Grande, AZ
Jason Kline – MS – Fisheries Biologist, Arizona Game and Fish Department, Biologist SWCA Consulting, Colorado
Yuliya Kuzmenko – Postdoctoral Fellow- Ukrainian Institute of Fisheries, Kiev.
Sarah Lantz – MS – Habitat Program Manager, Arizona Game and Fish Department
Laura Leslie – MS – Fisheries Biologist – Arizona Game and Fish Department; Montana Fish, Wildlife, and Parks; SWCA Consulting, Cody, Wyoming; Wyoming Game and Fish Department.
Alberto Macias-Duarte – Ph.D. – Professor, Universidad Estatal de Sonora, Hermosillo, Mexico
Justin Mapula – MS – Fisheries Biologist – U.S. Forest Service, Shasta, California
Shannon McNeil – MS – Conservation Biologist, Bureau of Reclamation
Adrian Munguia Vega – PhD - Associate Researcher, CIBNOR; PANGAS; and Sociedad de Historia Natural Niparaja, La Paz, Mexico
Ashwin Naidu – PhD - Research Specialist, Saguaro National Park; and Director Fishing Cat Conservancy, Tucson, AZ
Alexander Ochoa-Hein – PhD - Postdoctoral Researcher, Department of Ecology and Evolutionary Biology, Ohio State University
Mark Ogonowski – MS – Urban Wildlife Planner, Arizona Game and Fish Department
Karla Pelz Serrano – University Instructor, Universidad Autonoma Metropolitana-Lerma, Mexico
Sally Petre – MS -Fisheries biologist, Arizona Game and Fish Department, Tennessee Wildlife Resources Agency
Joy Price – Biology lecturer at local Arizona community colleges
Matthew Recsetar – MS – Research Aquaculturist – University of Arkansas Pine Bluff, Ph.D. University of Arizona
Sarah Rinkevich – PhD - Endangered Species Biologist, US Fish and Wildlife Service; and Tribal Liaison, Department of Interior, Tucson, AZ
Scott Rogers – MS – Fisheries Biologist, Arizona Game and Fish Department
David Rogowski – Colorado River Fisheries Biologist, Arizona Game and Fish Department, Phoenix, Arizona
Jack Ruggirello – Fisheries Biologist, US Forest Service, Tongass National Forest, Alaska (deceased).

Employment of Former Students (cont'd.):

Charles Schade – MS – Biologist, Harris Consulting, Tucson, Arizona
Andrew Schultz – Ph.D. – Research Fisheries Biologist, Bureau of Reclamation, Tracy, California
Matthew Smith – MS – Ph.D. student, University of Florida
Erica Sontz – MS – Biologist, University of Arizona
Tymofy Specivy – Postdoctoral Fellow – Ukrainian Institute of Fisheries, Kiev
Sonya Steckler – MS – Nongame Bird Biologist, Nebraska Game and Parks Commission
Roy Ulibarri – MS – Fisheries Biologist, U.S. Fish and Wildlife Service, Houston Texas.
Cora Varas Nelson – PhD - Program Coordinator, Genetics Interdisciplinary Program, University of Arizona; and Instructor, Pima Community College
Erin Vaughn – PhD - Postdoctoral Researcher, Australia National University, Canberra, Australia
Cristina Velez – MS – Biologist and Research Station Leader, National Park Service, , USAID Chase Voirin – MS – Wildlife Biologist, University of Arizona
David Ward – MS – Research Fish Biologist, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona
Ann Widmer – MS – Fisheries Biologist, SWCA Consulting, Denver Colorado
Mike Wierda – Assistant Professor Extension, Department of Entomology, University of Arizona, Tucson, AZ