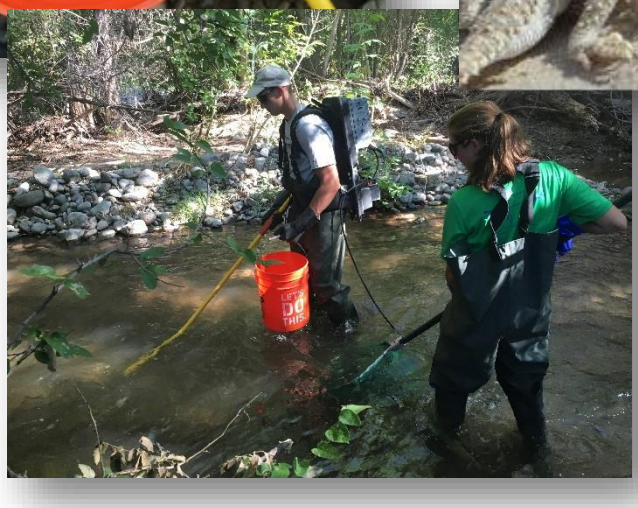
Arizona Cooperative Fish and Wildlife Research Unit – 2016 Annual Report



The Unit is a Cooperative Program of the following:

USGS science for a changing world

Arizona Game & Fish

U.S. Fish & Wildlife Service, Department of the Interior

Wildlife Management Institute, Washington, D.C.

College of Agriculture & Life Sciences
School of Natural Resources & the Environment

ANNUAL REPORT
2016

Arizona Cooperative Fish and Wildlife Research Unit
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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

TABLE OF CONTENTS

MISSION STATEMENT ..... **i**

COORDINATING COMMITTEE MEMBERS ..... **ii**

UNIT STAFF ..... **iii**

RESEARCH TECHNICIANS, GRADUATE STUDENTS and RECENT GRADUATES ..... **iv**

CURRENT RESEARCH PROJECTS **1**

Aquatic:

Assessing Modified Prepositioned Areal Electrofishing Devices (PAEDs) for Surveying Fish Habitat Use in Desert Streams 1

Relationship between native and nonnative fish presence and components of the hydrograph in streams of the Mogollon Rim Emphasis Area, Arizona 2

The Role of Riparian Vegetation and Instream Habitat on Fish Communities in Intermediate-Sized Arizona Rivers 2

Habitat Suitability Criteria for Native Fishes in Intermediate-Sized Arizona Rivers and Habitat Suitability Criteria for Non-Native Fishes in Intermediate-Sized Arizona Rivers 3

Habitat Suitability Criteria for Zuni Bluehead Sucker *Catostomus discobolus yarrowi* and Navajo Nation Genetic Subunit Bluehead Sucker *Catostomus discobolus* 4

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* 5

AFS Standard Fish Sampling Techniques and Environmental DNA (eDNA) for Characterizing Fish Relative Abundance, Biomass, and Species Composition in a Large Reservoir 6

AFS Standard Fish Sampling Techniques and Environmental DNA (eDNA) for Characterizing Fish Relative Abundance, Biomass, and Species Composition in Small Standing Waters (< 23 ha) 7

Use of Ultrasonic Imaging to Evaluate Egg Maturation of Humpback Chub Gila cypha in Grand Canyon...8

Can Ultrasonic Imaging be Used in Remote Field Environments? A Case Study in Grand Canyon 8

Habitat Suitability Criteria for Apache Trout 9

Habitat Suitability Criteria for Northern Crayfish 10

Environmental Conditions Utilized by Endangered Moapa Dace While Spawning 11

Captive Rearing and Propagation of Critically Endangered Moapa Dace 11

Using Remote Videography to Investigate Relationships Between Environmental Conditions and Spawning Behavior in Devils Hole Pupfish 12

Construction of a Mesocosm Re-Creation of Devils Hole 13

Enhancing Hatch Rate and Survival in Laboratory-Reared Hybrid Devils Hole Pupfish through Application of Antibiotics to Eggs and Larvae 14

Is Lack of Adequate Food a Bottleneck to Survival of Devils Hole Pupfish Larvae? 15

Habitat Variables Associated with Stream Temperature Resiliency in the White Mountains of Arizona with Implications for Apache Trout Distribution in Response to Climate Change 16

Rapid Thermal Imaging of Surface Water Temperatures of Streams: Techniques and Relationship to Subsurface Temperatures 17

Habitat Requirements of Larval and Adult Desert Fishes in Cherry Creek, Arizona: Implications for Protection of In-Stream Flow Water Rights 17

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 18

Standard Methods for Sampling North American Freshwater Fishes 19

Fisheriesstandardsampling.org:
A Simple Web-Accessible Tool to Compare Standard Fish Sampling Data 20

Human Dimensions:

Development of Low-Cost, High Definition Videography Methods for Documenting Underwater Flora and Fauna and Developing Education Presentations 21

Use of High-Definition Video Technology to Acquaint the Public with Cryptic Desert Fishes of the Southern Nevada/Death Valley Region 21

Videography Presentations to Educate the Public about Arizona Trouts 22

Providing Data to Educators to Support Increased Teaching of the Concept of "Carrying Capacity" in Core Curriculum 22

Jaguar Critical Habitat Designation Causes Concern for Southwestern Ranchers 23

Can Incentives Help Overcome Landowner Concerns About Endangered Species Critical Habitat? A Rancher Case Study from the Southwestern United States 23

High-Definition Videography Presentation of Gila Chub at Sabino Canyon Recreation Center to Increase Public Awareness and Conservation 24

Use of Citizen Scientists to Monitor Cameras for Jaguar and Ocelot Detection 25

Arizona Jaguar and Ocelot Conservation Outreach Project 25

Arizona Jaguar and Ocelot Grantwriting Project 25

Genetics:

Jaguar Surveying and Monitoring in the United States 26

Research on Bobcats and Urbanization in the Tucson Mountain District, Saguaro National Park.....26

Conservation Genetics and Population Dynamics of Black Bears in Arizona.....27

Genetic Sampling Method to Estimate Black Bears Population Size in Arizona.....27

Effects of Fragmentation of Desert Habitat in Baja California Sur, on Population Genetics.....28

Population Genetic Diversity and Structure in Yellow-Billed Cuckoos *(Coccyzus americanus)*.....28

Genetic Diversity and Structure for Arizona Bald Eagles.....29

Evaluating the Use of Molecular Scatology for Monitoring Mammalian Species Diversity in National Parks.....29

Genetic Diversity of Caracara in Florida.....29

Evolution of the Jaguar in Arizona, US and Sonora, Mexico.....30

Evolution of the Ocelot in Arizona.....30

Conservation Genetics and Population Structure of Chiricahua Leopard Frogs *(Rana chiricahuensis)* in New Mexico, Arizona and Mexico.....31

Taxonomy of Anodonta Mussels in Arizona and Mexico Using Genetic Markers.....31

Genetic Characterization of the Invasive Quagga Mussel *(Dresseina bugensis)* in Southwestern US Lakes.....32

Determine Genetic Variability Within Wild and Captive Populations of Sonoran Pronghorn.....32

Investigation into the Phylogeography of the Desert Tortoise and its Application to Conservation.....33

Genome Approach for Noninvasive Diet Assessment of Mule Deer from Scat.....33

Puma Connectivity and Landscape Genetics in the Southwestern US to Resolve the Source of Newly Established Puma Populations at Kofa National Wildlife Refuge.....34

Assessment of Abundance and Diet of Felids at Kofa National Wildlife Refuge.....34

Assessment of Population Size and Prey Selection Patterns of Mexican Gray Wolves on the San Carlos Apache and Fort Apache Indian Reservations, Arizona.....35

Characterizing Marine Faunal Community Composition Across the Gulf of California Using Next-Generation Sequencing of Environmental DNA.....35

Conservation Genetics of the Tiger Rattlesnake.....36

Using Genetic Methods to Estimate Social Structure and Reproductive Success of a Puma Population and Implications on Effects of Sport-Hunting.....36

Developing SNP Markers in Pumas for Genome-Wide Association Study and Population Genetics.....36

The Effects of Extirpation and Reintroduction on the Mexican Wolf (*Canis lupus baileyi*) through Genome-Wide Association.....37

Assessment of trophic cascades for the Mexican wolf.....37

Functional Genomics of the Endangered Florida Panther 38

Epigenomics of the Endangered Sonoran Pronghorn 38

Determine Relatedness of Certain Mexican Races of Bobwhite (*Colinus virginianus*) 39

Black-Tailed Prairie Dog Taxonomy and Population Connectivity 39

PEER-REVIEWED PUBLICATIONS 40

TECHNICAL REPORTS 43

PRESENTATIONS GIVEN 44

THESES AND DISSERTATIONS OF UNIT GRADUATE STUDENTS 48

TEACHING 49

AWARDS 50

PROFESSIONAL SERVICE 51

EMPLOYMENT OF FORMER STUDENTS 52

MISSION STATEMENT

This past year has been a time of great activity at the Arizona Cooperative Fish and Wildlife Research Unit. Many projects were conducted during 2016 and many new graduate students and research associates were added to the staff. 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

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

Project Partners:	USFWS, USGS, University of Arizona
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. Field work on this project commenced fall, 2016.

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, University of Arizona
Project Duration:	June 2016 to December 2018
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. Mining companies and others want to harvest flood flows in addition to baseflows in Southwestern streams. In late summer 2015, expert witnesses were questioned in a recent Arizona water rights trial on the importance to fish of the five different parts of the hydrograph (water level, flow duration, rate of change, frequency, and timing as outlined by Poff et al. 1997), and the effects of altering these. 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. Hydrograph components will be expressed in two ways: as discharge and mean velocity, and history of these flows and their relationship with fish presence will be examined as well. Flow information is being obtained from field observations, available data from in-stream flow models and USGS gauging stations. Fish presence data is being obtained from prepositioned electrofisher surveys. This information will improve in-stream flow management, inform the use of flow management to manage interactions among native and nonnative fishes, provide additional information for habitat improvement projects, and help provide information for upcoming water rights litigation. Field work on this project starts spring, 2017. A thesis and publication will result from this project.

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

Project Partners:	USFWS, USGS, University of Arizona
Project Duration:	June 2016 to December 2018
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) have been selected based on high priority. Prepositioned areal electrofishing devices (PAEDs) will be used to sample fishes in randomly selected sites within each stream. Overhead canopy will be measured using hemispherical photography within each site. Other aspects of the riparian vegetation such as length, width, and percent type with be assessed using ArcGIS. Relationships examined will include various components of the riparian community with common native and nonnative fish species presence, and components of the riparian community with stream channel mesohabitat type (e.g., pool, run, riffle). Field work on this project will commence spring, 2017.

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

Project Partners: USFWS, USGS, University of Arizona
Project Duration: June 2016 to December 2018
Principal Investigator: Scott Bonar
Graduate Research Assistant: Zach Nemec

The native fish populations of the southwestern United States are highly endangered and drastically declining due to multiple anthropogenic stressors. In order to manage these populations, information about the microhabitat the fishes occupy is needed. Physical habitat has been defined for several native species in Arizona through habitat suitability criteria (HSC), yet this can vary among streams and or fishes can inhabit different microhabitat due to presence of other species. It is critical to develop HSC for native fish species across multiple rivers to better understand how the distribution is formed under various circumstances. Four streams within central Arizona (Verde River, Blue River, San Francisco River, Tonto Creek) have been selected based on high priority in which to develop generalized habitat criteria. Prepositioned areal electrofishing devices (PAEDs) will be used to sample fishes in randomly selected sites within each stream. Depth, substrate, and flow will also be measured at each site. Habitat suitability criteria will be developed for species found within these streams. Field work on this project will commence spring, 2017. Information will be presented in a publication and thesis.

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

Project Partners: USFWS, USGS, University of Arizona
Project Duration: June 2016 to December 2018
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 will sample four Arizona streams containing a variety of habitats and document habitat used by nonnative fishes. Furthermore, we will develop habitat suitability curves for the nonnative fishes based on this use. This information will be useful for fisheries biologists to manage habitat of Arizona's native and nonnative fish communities. Field work on this project will commence spring, 2017. Information will be presented in a publication and thesis.

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

Project Partners:	USFWS, NFWS
Project Duration:	May 2013 to January 2017
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 submitted for publication, fall 2016, 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, University of Arizona, 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 submitted for publication in the fall of 2016 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 Small Standing Waters (< 23 ha)

Project Partners:	AZGFD, USGS, University of Arizona, USGS-Upper Midwest Environmental Sciences Center
Project Duration:	September 2013 to June 2016
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 small standing waters (<23 ha). We compared fish relative abundance, biomass, and species composition measured through eDNA methods and established American Fisheries Society (AFS) standard sampling methods in 12 small standing waters throughout southern Arizona. Our primary objective was to investigate the relationship between relative abundance, biomass, and catch composition of largemouth bass *Micropterus salmoides* and bluegill *Lepomis macrochirus* captured during electrofishing surveys and number of DNA copies of all fish species collected in water samples (surface and bottom water combined) from Arizona small standing waters. We found no relationship between relative abundance and biomass of Largemouth Bass and Bluegill measured by established methods and their DNA copies across the 12 waterbodies. Environmental DNA reflected the relative proportions of Largemouth Bass and Bluegill in total catch composition in some, but not all of 12 small Arizona waterbodies. The ease of eDNA sampling over established fish sampling makes it appealing to natural resource managers. Compared to current established fish sampling methods, eDNA sampling can be less laborious, less time consuming, and more cost effective. However, further refinement of eDNA techniques is necessary before the procedure can be used with confidence to evaluate fish species composition in small lakes. A thesis on this work was completed May 2016 and results are now being prepared for publication.

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

Project Partners:	USGS
Project Duration:	June 2013 to March 2017
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 currently being prepared for publication.

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

Project Partners:	USGS
Project Duration:	June 2013 to March 2017
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 are currently being prepared for publication.

Habitat Suitability Criteria for Apache Trout

Project Partners:	USFWS, AZGFD
Project Duration:	August 2011 to Present
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 the January 2017 issue of 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. Currently this work is being formatted for journal publication.

Captive Rearing and Propagation of Critically Endangered Moapa Dace

Project Partners: USFWS
Project Duration: October 2011 to Present
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. Currently this work is being formatted for journal publication.

Using Remote Videography to Investigate Relationships Between Environmental Conditions and Spawning Behavior in Devils Hole Pupfish

Project Partners:	USFWS, NPS, Nevada Division of Wildlife
Project Duration:	September 2008 to December 2015
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Ambre Chaudoin

Population decline to record lows and renewed interest in captive propagation of the endangered Devils Hole pupfish *Cyprinodon diabolis* has highlighted information deficits in some aspects of the species' reproductive ecology. We conducted a monitoring study from February to December 2010 to investigate environmental factors associated with spawning activity in Devils Hole pupfish in Devils Hole, Death Valley National Park, Nevada. A fixed underwater camera provided continuous monitoring of a portion of a shallow, submerged rock shelf used for spawning. Dissolved oxygen, temperature, and light intensity datalogging meters continuously recorded environmental data from a fixed point on the shelf, and we conducted once or twice monthly algal/cyanobacterial surveys to measure percent cover of key species across the shelf. Water level and precipitation data provided by the National Park Service recorded earthquake and storm-induced flash-flood disturbances. Visual surveys conducted at the water surface from January to December 2010 provided additional information on spatial preferences in spawning. Zero-inflated Poisson regression showed greatest spawning activity was associated with the following conditions: dissolved oxygen 2.6–4.8 mg/L, total daily light intensity 133,250–400,300 lux, mean percent cover filamentous algae/cyanobacteria 24–60% and especially 24–27%, and presence of earthquake disturbance in the form of seiches. Among significant interaction effects, more spawning occurred at approximately 2.6 mg/L dissolved oxygen when diel dissolved oxygen variation was low (approximately 0.3–1.6 mg/L); at lower to mid-range monthly mean percent cover filamentous algae/cyanobacteria (approximately 24–32%) when total daily light intensity was lower to mid-range (110,000–330,000 lux); and post-earthquake when diel dissolved oxygen variation was low (0.6–1.3 mg/L). Increases in spawning activity occurred after earthquakes on 27 February and 21 October 2010; however, an earthquake during the peak spawning period (4 April 2010) was not associated with increased spawning activity. There was significant spatial variation in spawning, with most spawning activity occurring over the northeast area of the shelf. Our study provides new information on spawning in Devils Hole pupfish in Devils Hole, Nevada, including: temporal and spatial patterns, associated environmental factors, and effects of mechanical disturbance. Dissolved oxygen, diel dissolved oxygen variation, total daily light energy, percent cover filamentous algae/cyanobacteria, earthquake disturbance, and location on the shelf are the strongest predictors of spawning behavior in Devils Hole pupfish within Devils Hole. These factors in spawning might be utilized in adaptive management of the wild population, captive propagation to produce reserve populations, and efforts aimed at the recovery of the species. This work was provided in a thesis and a report to the USFWS. This work was published December, 2015 in the *North American Journal of Fisheries Management.*

Construction of a Mesocosm Re-Creation of Devils Hole

Project Partners:	USFWS, NPS, Nevada Division of Wildlife
Project Duration:	September 2008 to June 2016
Principal Investigator:	Olin G. Feuerbacher, Scott Bonar
Graduate Research Assistant:	Olin G. Feuerbacher

Captive propagation of desert pool and spring fishes, whether for conservation or research purposes, faces obstacles in construction of appropriate habitats given the unique and often challenging environments these fish utilize in the wild. High temperatures, low dissolved oxygen, minimal water flow, and highly variable lighting are some of the conditions a researcher might be tasked with recreating when attempting to maintain these fishes in conditions resembling their natural environments. One such habitat is Devils Hole, Death Valley National Park, Nevada/California, USA, home of the critically endangered Devils Hole pupfish, *Cyprinodon diabolis*. Devils Hole is a considerably challenging environment to recreate. It is an underground spring system of unknown depth, with low (2.0 ppm) dissolved oxygen, and high water temperatures (33-34°C). Lighting on the surface of Devils Hole is of short duration, usually at most 4 hours a day of direct sunlight, and almost all pupfish activity occurs on a small shallow shelf about 0.5 m below the water's surface. Here we describe a mesocosm-scale habitat recreated to maintain hybrid Devils Hole x Amargosa pupfish (*C. diabolis x C nevadensis mionectes*) under conditions similar to those found in Devils Hole. This 13,000-L system utilized flow control and natural processes to maintain these conditions rather than utilizing complex and expensive automation. We designed a rotating solar collector to provide natural sunlight in a controlled manner, a biological reactor to consume oxygen while buffering water quality, and a reverse- daylight photosynthesis sump system to stabilize nighttime pH and swings in dissolved oxygen levels. This system successfully controlled many of the parameters desired; was used to help inform development of a larger desert fish conservation facility at Ash Meadows National Wildlife Refuge; and due to its scalable and modular design lends itself to adaptation for husbandry of other aquatic species from unique habitats at a reasonable cost. This information was provided in a report to the USFWS, in a thesis, and was published June, 2016 in the *North American Journal of Aquaculture*.

Enhancing Hatch Rate and Survival in Laboratory-Reared Hybrid Devils Hole Pupfish through Application of Antibiotics to Eggs and Larvae

Project Partners:	USFWS, NPS, Nevada Division of Wildlife
Project Duration:	September 2008 to December 2016
Principal Investigator:	Scott Bonar
Research Specialist:	Olin G. Feuerbacher

Laboratory cultivation of Devils Hole pupfish, *Cyprinodon diabolis*, has proved to be problematic for many years. Although various attempts have been made, long term maintenance and cultivation of this species over multiple generations has thus far been unsuccessful under laboratory conditions. Several strategies are being employed to elucidate the mechanisms behind these difficulties, utilizing hybrid Devils Hole pupfish, *C. diabolis x C. nevadensis mionectes* as a model. Microbiological and histological analyses are being performed to understand potential pathogens that may affect the physiology of *C. diabolis*, as well as to design strategies that maximize hatch success. Because many of the bottlenecks previously identified in the captive breeding of Devils Hole pupfish have been during larval rearing, particular effort has been placed on maximizing early survival. Several prophylactic antimicrobial therapies have been compared as they relate to egg hatch rate, larval survival, and long term clearance of targeted pathogens. Treatments of moderate and broad-spectrum antimicrobials were successful in improving hatch rates and larval survival. Both formalin and iodophor disinfection of pupfish eggs led to better survival of larvae, albeit with slightly reduced hatch rates in the iodine treated eggs. Broad-spectrum antibiotics, particularly trimethoprim sulfamethoxazole and chloramphenicol were especially effective in increasing both hatch rate and juvenile survival. Combinations of formalin plus antibiotic further increased survival, while iodophor disinfection plus antibiotic treatment significantly decreased fifteen-day survival of larvae compared to untreated controls. Results were submitted to the USFWS as a final report, presented in a thesis, and were published in the *North American Journal of Aquaculture* in December, 2016.

Is Lack of Adequate Food a Bottleneck to Survival of Devils Hole Pupfish Larvae?

Project Partners:	USFWS, NPS, Nevada Division of Wildlife
Project Duration:	September 2008 to Present
Principal Investigator:	Scott Bonar
Research Assistant:	Justin Mapula

The Devils Hole pupfish *Cyprinidon diabolis* is a relic of the last ice age; stranded as receding glacial lakes moved across a drying and warming landscape. Found in a single limestone fissure in Death Valley National Park, the Devils Hole Pupfish has survived in its current location—perhaps the smallest vertebrate distribution in the world—for the last 25,000 years. The Devils Hole pupfish itself is an iridescent blue, 2.5mm-long fish that lacks pelvic fins. The spring-fed Devils Hole remains a constant 33°C, and contains approximately 2 ppm dissolved oxygen. Recent, dramatic declines in the Devils Hole pupfish population have raised concerns over the future of the species. As there are no remaining refugia for pure-strain pupfish outside of Devils Hole, the possibility of extinction has become quite real. Previous lack of success for rearing fish in laboratory settings coupled with low egg viability further complicate recovery efforts. Census divers and scientists associated with the Devils Hole program have reported sighting larval pupfish on the stone shelf, as well as adult fish throughout the upper reaches of the water column. However, there are few reports of middle-age class fish, and with numbers of adults that are significantly lower than previous years, it seems that many larval fish are simply not surviving to the adult age class. Surveys have suggested that food available to larval pupfish has shifted from the 1970's to current times. To identify if food bottlenecks to larval growth and survival are currently occurring in Devils Hole, we evaluated dietary adequacy of the most important constituents of the algal and invertebrate assemblages from the 1970's and from 2001, as well as a flake food that is currently being used in supplemental feeding of the pupfish. To do this, we examined growth and survival of larval hybrid Devils Hole pupfish, *Cyprinidon diabolis* x *Cyprinidon nevadensis mionectes*, fed Rio Grande Silvery Minnow flake food; and monospecific cultures and combinations of cyanobacteria Cyanophyta, green algae *Spirogyra* spp., ostracods Ostracoda, amphipods *Hyallela azteca*, diatoms Bacillariophyta, and copepods Cyclopoida. We quantified survival, growth, and lifespan of larval hybrids among 14 food treatments. Larvae fed flake food had significantly higher survival and lifespan than those fed natural food types. Of the natural food types, larvae fed algae or cyanobacteria in monospecific cultures or in combination with invertebrates had the highest survival and lifespan. Pure invertebrate treatments yielded the lowest survival and lifespan. No significant difference in total length at 14 days was found among treatments. These results were presented in a thesis and are now being prepared for publication.

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.

Rapid Thermal Imaging of Surface Water Temperatures of Streams: Techniques and Relationship to Subsurface Temperatures

Project Partners:	USFWS, AZGFD
Project Duration:	August 2013 to December 2015
Principal Investigator:	Scott Bonar
Research Assistant:	Sally Petre

We evaluated a ground-based hand-held thermal imaging system for measuring water temperatures using data from eight southwestern USA streams and rivers. We found hand-held thermal imagers could provide considerably more spatial information on water temperature (for our unit one image = 19,600 individual temperature measurements) than traditional methods could supply without a prohibitive amount of effort. Furthermore, they could provide measurements of stream surface temperature almost instantaneously compared to most traditional means such as hand-held thermometers (> 20 seconds per reading). Spatial temperature analysis is important for measurement of subtle temperature differences across waterways, and identification of warm and cold groundwater inputs. Hand-held thermal imaging is less expensive and equipment intensive than airborne thermal imaging methods, and is useful under riparian canopies. Disadvantages of hand-held thermal imagers include their current higher expense compared to thermometers, their susceptibility to interference when used incorrectly, and their slightly lower accuracy than traditional temperature measurement methods. Thermal imagers can only measure surface temperature, but this usually corresponds to subsurface temperatures in well-mixed streams and rivers. Using thermal imaging in select applications, such as where spatial investigations of water temperature are needed, or in conjunction with stationary temperature data loggers or hand-held electronic or liquid-in-glass thermometers to characterize stream temperatures by both time and space, could provide valuable information on stream temperature dynamics. These tools will become increasingly important to fisheries biologists as costs continue to decline. This work was published in the December, 2015 issue of the *North American Journal of Fisheries Management.*

Habitat Requirements of Larval and Adult Desert Fishes in Cherry Creek, Arizona: Implications for Protection of In-Stream Flow Water Rights.

Project Partners:	USFS, USGS, AZGFD
Project Duration:	September 2008 to October 2016
Principal Investigator:	Scott Bonar
Research Specialist:	Norman Mercado Silva

Knowledge of flow, temperature and other habitat requirements are critically important for protecting desert fish communities. Recently, mining companies and other interests have been challenging flow requirements for desert streams. As part of team of riparian ecologists, in-stream flow modelers, and fish ecologists we determined the habitat and flow requirements for fishes in Cherry Creek (Tonto National Forest), Arizona. Using a variety of sampling techniques, our goal was to determine which habitats in the creek are suitable for each fish species in the community. We assessed substrate type, water current velocity, depth, and other physical habitat, and water variables, and sampled the fish community. We then analyzed data to unveil the relationships between a given species and the habitat attributes. This information was used to develop habitat suitability criteria. These criteria were used for in-stream flow models of the creek to determine how different water levels affect desert fish communities. The US Forest Service used this information in test cases for aquatic habitat protection in desert streams. A technical report was published, preparation for trial re: Cherry Creek commenced, and before the trial, in January 2016, the mining company dropped objection for the protection of in-stream flow in Cherry Creek. In October 2016, the State of Arizona awarded a water right to protect in-stream flow in Cherry Creek to the United States.

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 Present
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. However, the court has not yet provided a decision on the case.

Standard Methods for Sampling North American Freshwater Fishes

Project Partners:	USGS, 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.

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. Current research is concentrating on data sharing, method calibration, and standardization of additional methods, and collaboration with international researchers. Last year an invited talk on the project by the lead editor was given to fisheries biologists and managers at the United Nations in Rome, Italy, to investigate opportunities for international collaboration, and an international symposium, led by AZ Coop personnel and sponsored by the American Fisheries Society, was presented at the 2015 AFS Annual Meeting. This symposium featured research on fisheries sampling standardization from biologists from five continents. This year, the lead editor was asked to co-convene a symposium on standard fisheries sampling at the World Fisheries Congress in Pusan, South Korea with the former president of the Inland Fisheries Society of British Isles, and was asked to provide an overview of standard sampling to the South Korean Inland Fisheries Institute, National Institute of Fisheries Science. Publications concerning this work since 2015 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.*

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, University of Arizona, 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 rangewide 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, USGS, University of Arizona
Project Duration:	June 2016 to December 2018
Principal Investigator:	Scott Bonar
Graduate Research Assistant:	Taylor Ulrich

Freshwater biotic communities are complex, magnificent ecosystems, but are usually unseen by the general public. In the southwestern United States, underwater views of these communities are almost never 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 new, inexpensive, high-definition underwater video technology and the advancement of personal computer systems to process such technology, ultra- high quality educational video presentations now lie within reach of biologists and educators to use to educate the public. We are developing inexpensive methods that can be used by most biologists and educators 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. Data are now being compiled, and methods will be presented in a thesis chapter and publication.

Use of High-Definition Video Technology to Acquaint the Public with Cryptic Desert Fishes of the Southern Nevada/Death Valley Region

Project Partners:	USFWS, USGS, University of Arizona
Project Duration:	June 2016 to December 2018
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 are creating low-cost educational videography presentations featuring the unique and often rare desert fishes of Nevada and Death Valley. Here we provide examples of high-definition underwater and aerial footage possible with current low-cost, advanced technology. Techniques used to collect this footage are specifically tailored to be used by field biologists when creating educational presentations. Furthermore, we will test marketing and educational research methods to maximize presentation effectiveness. Low cost technology can provide spectacular visual results and could potentially serve as an effective tool to acquaint the public with rare desert fishes. Data collection on this project is now ongoing. A thesis and publication are underway.

Videography Presentations to Educate the Public about Arizona Trouts

Project Partners:	Doris Duke Conservation Scholars Program, USGS, Univ. of Arizona
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.

Providing Data to Educators to Support Increased Teaching of the Concept of "Carrying Capacity" in Core Curriculum.

Project Partners:	USGS, University of Arizona
Project Duration:	June 2016 to December 2016
Principal Investigator:	Scott Bonar

In the latest four Gallup polls, only 1–3% of Americans consider environmental problems the most pressing issue our country faces. Approximately 40% of Americans think that climate change is a natural cycle, contrasted with 97% of climate studies which state that humans are causing it. Natural resource scientists hear government officials, newscasters, and members of the general public offer as ecological "facts" notions that are breathtakingly wrong. These data suggest that scientific information has outpaced the efforts of science educators and communicators to help society move towards understanding the concept of carrying capacity and taking action to live within our environmental means. We teamed with K-12 science teachers to compile data about societies that have collapsed because they reached levels in excess of their carrying capacity, argued that data supported increased emphasis on teaching the concept, and identified educational units designed to present the concept to varying-aged school children. This information was published in the October, 2016 issue of *The American Biology Teacher*.

Jaguar Critical Habitat Designation Causes Concern for Southwestern Ranchers

Project Partners:	USFWS
Project Duration:	June 2013 to August 2016
Principal Investigators:	Scott Bonar, Laura Lopez-Hoffman
Graduate Research Assistant:	Colleen Svancara

The United States Fish and Wildlife Service designated critical habitat for jaguars (*Panthera onca*) in April 2014, in southern Arizona and southwestern New Mexico. Ranchers in the region have expressed concern and apprehension toward the designation. Our objective was to understand what specifically ranchers are concerned about, and investigate the larger political setting of federally designated critical habitat for jaguars. We conducted semi-structured, key informant interviews with nine leaders in the ranching community. To address our objective, we investigated the interviewees' attitudes of wildlife conservation in general, perceived impacts that jaguar critical habitat designation could have on their operation, and opinions of the government's role in managing resources for wildlife. The interviewees were fully supportive of wildlife conservation and felt they were intrinsically important to providing habitat for wildlife. All interviewees agreed jaguars were a unique, rare species, but they were all against federally designated jaguar critical habitat. Their concerns fell out into three categories: direct impacts to ranching operations, political concerns, and concerns resulting from larger, overriding issues in the region. We found that interviewees' concerns are likely a reflection of deeper-seated values pertaining to centralized government. The issue is more complex and nuanced, and moves beyond concerns about limitations on range management. To best work with this population for jaguar conservation, the role of adaptive management and conservation incentives should be explored as possible remedies. This work contributed to a thesis and a publication in *Rangelands*.

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 August 2016
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 readied 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. We are currently investigating other opportunities to present similar information on other Southwestern fishes.

Use of Citizen Scientists to Monitor Cameras for Jaguar and Ocelot Detection

Project Partners:	USFWS, DHS, USGS
Project Duration:	2012 to Present
Principal Investigator:	Melanie Culver
Graduate Student	Emily Reynolds
Research Specialist	Susan Malusa

A large scale camera monitoring effort to detect jaguars and ocelots, across southern Arizona and southwestern New Mexico requires extensive camera-checking hours to retrieve data from all the almost 200 cameras. This study will explore the possibility that citizen scientists can be trained by the team of experts conducting the project, coordinated by a graduate student (Emily Reynolds) and volunteer coordinator (Susan Malusa), and collect reliable data. The data was collected in the same way as data from the scientific-based project, then tested for reliability against data collected by the team members. All data is housed together is a large database managed for the jaguar monitoring project at the University of Arizona. Educational objectives were also addressed to assess how much learning took place for the citizen scientists from start to end of the MS portion of this project. Additional citizen scientists are continually being trained and are currently at 21; they are monitoring 8 mountain ranges in southern Arizona for jaguars and ocelots.

Arizona Jaguar and Ocelot Conservation Outreach Project

Project Partners:	USFWS, DHS, USGS
Project Duration:	2013 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Pinau Merlin

Jaguars and ocelots are of interest to the general public at many levels, and provide an excellent outreach opportunity. Pinau developed a powerpoint program on jaguars and ocelots, and another one on the four cats of Arizona (jaguar, ocelot, puma, and bobcat) and she presented these programs at special events and at community locations around southern Arizona. She gave 5-10 presentations per year to places like meetings of the Audubon Society or Sky Island Alliance, and at nature festivals, for example. She also gave presentations as the local zoos and other venues. Pinau also wrote a couple popular magazine articles on jaguars and ocelots. Pinau discussed issues related to the endangered status of jaguars and ocelots, and their conservation in Arizona and Mexico.

Arizona Jaguar and Ocelot Grantwriting Project

Project Partners:	USFWS, DHS, USGS
Project Duration:	2013 to 2016
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Ashwin Naidu

As the DHS/USFWS funded jaguar and ocelot monitoring project nears completing, we obtained funding to seek other sources of funding to continue some if not all aspects of the project. We are submitting on average six grant proposals per year to a variety of agencies and foundations to continue and to add components to this broad project.

GENETICS

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 will include GIS analyses to delineate areas most likely to detect jaguars, and dividing the study area into 3 zones of survey intensity and probability of jaguar detection. Cameras will be set at differing densities in the 3 zones and will be checked at differing frequencies in the 3 zones. During the entire study, opportunistic scats will be collected and analyzed using genetic techniques to determine if from a jaguar. If a jaguar detection occurs by photo or opportunistic scat collection, this will initiate a 6-week full time scat detection dog effort searching for jaguar scats in the area of the detection to gain additional detections and genetic material. Genetic data will be 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 will be 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.

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

Project Partners:	Friends of Saguaro National Park
Project Duration:	2008 to Present
Principal Investigator:	Melanie Culver
Research Specialist:	Lisa Haynes

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. Specifically, this project will conduct a thorough pre-research literature review, evaluate field and genetic techniques, identify discrete research objectives, and assess bobcat use of the Tucson Mountain District and surrounding lands using noninvasive techniques (field observation and genetic sampling). In addition to the scientific objectives, this project is 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 it appears 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, there is a paucity of research on bobcats in urban and arid environments. This project will fill in that gap in our knowledge of the species and provide 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 plan to design and create a model for involving the public in urban wildlife research by working closely with park neighbors, visitors, and other governmental and private entities.

Conservation Genetics and Population Dynamics of Black Bears in Arizona

Project Partners:	AZGFD, USGS
Project Duration:	2006 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Cora Varas

Goal: Examine black bear evolution in Arizona, current genetic structure among populations, and bear movements among sky islands of Arizona and northern Mexico. Fragmentation or perturbation of a species habitat can lead to genetic changes among the separate populations. Frequently these changes can have adverse implications for the conservation of the species. There is increasing concern about the long-term survival of black bear *Ursus americanus* populations in Arizona and the southwest deserts. In southwest deserts, black bear habitat occurs in mountain "sky islands" which are separated by a "sea" of desert and grasslands. A continuous and careful monitoring of connectivity among sky islands and management units is important to ensure the black bear's continued existence in the southwest deserts of North America. Molecular markers (mitochondrial DNA and microsatellites) will be used to perform the genetic analyses on the black bear samples. These molecular markers can determine the amount of gene flow, as well as estimate the genetic variability, population size, amount of inbreeding and pairwise genetic distances among populations. This analysis of genetic structure of southwestern bear populations, from historical times through current populations, will be used to understand the ecological factors that may be influencing the long-term survival of black bears in the southwest desert habitats, and aid resource agencies to improve black bear population management.

Genetics Sampling Method to Estimate Black Bears Population Size in Arizona

Project Partners:	AZGFD
Project Duration:	December 2011 to Present
Principal Investigator:	Melanie Culver
Research Technician:	Cora Varas
Graduate Research Assistant:	Michelle Crabb

Goal: Use data from hair snags in a 4-km grid system to estimate black bear population size in select mountain ranges. Two mountain ranges have been sampled, one in the sky island region of Arizona, and one in the White Mountains, which are both isolated and relatively small**.** The White Mountains study area, falls within the largest block of black bear habitat in the state, and hair snags were placed at sites easily accessible and likely to have black bear activity. Our objective is to develop a method for using data from hair snags, combined with harvest records of an area, to generate mark-recapture estimates of abundance of black bears in Arizona. We will use data from the 2 study areas mentioned in Arizona, along with harvest data, to develop a cost-effective method to sample all black bears in Arizona, and develop a strategy that is feasible to implement annually to provide accurate abundance estimates on which to base black bear harvest levels.

Effects of Fragmentation of Desert Habitat in Baja California Sur, on Population Genetics

Project Partners:	CONACyT
Project Duration:	2009 to Present
Co-Principal Investigators:	Melanie Culver, Ricardo Estrella
Graduate Research Assistant:	Adrian Munguia Vega

Goal: Determine patterns of genetic variation at nuclear microsatellite loci among fragmented vertebrate populations that occur in patches of natural vegetation in the area of study. Comparisons between variation at different patches and non-fragmented surrounding areas will be used to estimate the effect of fragmentation relative to the species basal levels of variation. Because the Baja California Peninsula and its surroundings harbor extraordinary levels of endemism, particularly in reptiles (more than 50% of over 130 species), and mammal species (some 20 endemic rodent species), we will include several species in our comparisons. Many of the endemic forms share some common characteristics derived of their moderate or extreme degree of isolation, such as having evolved *in-situ*, usually through founder effects, and present restricted distributions and dispersion, and, sometimes, low local abundances. All these events together can contribute to an overall depletion of genetic variation on endemic species, which in turn could make them more vulnerable to a further loss of variation due to habitat fragmentation mediated by human activities. Also, because some of these endemic species evolved relatively recently, few mutations may have accumulated between lineages. To test the hypothesis that fragmentation effects are stronger on endemic vs. non endemic species, and on low dispersal vs. highly mobile species, we have contrasted pairs of species from two different vertebrate groups (reptiles and mammals). We include an endemic species of low mobility, besides a high dispersal, widely distributed and closely related species, which will serve as within group controls.

Population Genetic Diversity and Structure in Yellow-Billed Cuckoos *(Coccyzus americanus)*

Project Partners:	Smithsonian Institution
Project Duration:	2010 to Present
Principal Investigator:	Melanie Culver
Graduate Student:	Shannon McNeil

Goal: 1) assess evidence of reduced genetic diversity or increased inbreeding levels in western yellow-billed cuckoos within isolated breeding sites, 2) measure genetic structuring between eastern and western cuckoos. Due to the extensive loss and fragmentation of western riparian forest, yellow-billed cuckoos (*Coccyzus americanus*, 'cuckoos') have suffered range-wide declines and in the western United States are now restricted to small, isolated breeding sites. Conflicting evidence exists both for local interbreeding within isolated sites, and for strong dispersal capabilities in this long-distance Neotropical migrant. It is unclear if the current small acreage and isolation of western riparian forest is unfavorable to dispersal and population growth, further reducing genetic diversity in this threatened population. Analysis of microsatellites (simple DNA sequence repeats) from individuals representing geographically distinct breeding sites of varying size and level of isolation may inform the recovery of this threatened population, such as recommending minimum breeding patch sizes and levels of spatial connectivity. This study also provides further insight into the nature of genetic differentiation between eastern and western cuckoos.

Genetic Diversity and Structure for Arizona Bald Eagles

Project Partners:	AZGFD, USFWS
Project Duration:	2012 to Present
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 will use established genetic markers to investigate genetic diversity within the Sonoran Desert BAEA population. In the second phase, we will investigate gene flow between the Sonoran Desert BAEA population and surrounding populations of BAEA.

Evaluating the Use of Molecular Scatology for Monitoring Mammalian Species Diversity in National Parks

Project Partners:	NPS
Project Duration:	2006 to Present
Principal Investigator:	Melanie Culver
Research Technician:	Tony Dee

Goal: Compare a genetic survey technique with other existing survey techniques for terrestrial mammals, especially infrared-triggered (remote) photography. Monitoring natural resources is critical to the National Park Service mission of preserving resources for future generations. In cooperation with the NPS Sonoran Desert Network, Saguaro National Park is nearing completion of a 3-year inventory of mammals using a repeatable, randomized study design that will form the basis of a long-term monitoring program. Despite the high profile of mammals, many species are rare and difficult to sample, and several new species have been documented at the park as a result of the current effort. However, developing scientifically valid monitoring programs remains a major problem throughout the NPS due to the high costs involved. We will identify mammal species using DNA obtained from scat gathered at established monitoring plots in the Tucson Mountain District in 2003; mtDNA from scat will be compared to mtDNA sequences from published sources and tissue samples collected near the park. We will use established techniques to identify both predator and prey species from predator scat. The final product of this research will be a completed inventory of mammals at SNP that includes a cost/benefit assessment of genetic surveys in comparison with more traditional techniques.

Genetic Diversity of Caracara in Florida

Project Partners:	Trinity College
Project Duration:	2011 to Present
Co-Principal Investigators:	Melanie Culver, Joan Morrison
Graduate Research Assistant:	Erin Vaughn

Goal: Develop microsatellite markers using whole genome sequencing and assess genetic diversity of samples from Florida. This project is a collaborative effort with Joan Morrison at Trinity College who has studied the caracara in Florida for more than a decade. She has more than 100 blood samples from unrelated adults, which we will use to genotype and estimate population-level genetic characteristics. From this information we will estimate inbreeding, potential bottlenecks, and be able to inform managers of the genetic health of this endangered population.

Evolution of the Jaguar in Arizona, US and Sonora, Mexico

Project Partners:	USFWS, DHS, T&E
Project Duration:	2007 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Alex Ochoa Hein

Goal: Determine if jaguars in the northernmost part of their range, the Sonoran Desert ecosystem of Arizona and Mexico, constitute a major taxonomic designation below the species level (such as subspecies) vs. a unique population. This project is part of a binational effort to help to the conservation and protection of jaguars on both sides of the border. This study uses molecular genetic markers to examine population characteristics of jaguars in Arizona and Sonora, Mexico. Microsatellite molecular markers are utilized to allow estimates for overall genetic diversity (an indicator for genetic health and inbreeding status of the population). Additionally, this study will gain insights into the evolutionary significance of the Sonoran jaguar as this study will examine the relationship of the southern Arizona/northern Mexico jaguar population relative to other jaguar populations in Central and South America.

Evolution of the Ocelot in Arizona

Project Partners:	AZGFD Heritage
Project Duration:	2012 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Alex Ochoa Hein

Goal: Determine the relationship of ocelots in Arizona to ocelots in neighboring populations in Mexico. The ocelot (*Leopardus pardalis*) once occurred along both coasts and inland in northern Mexico, and into Texas and Arizona in the US. They reached southeastern Arizona as occasional wanderers from Mexico. There is little known about the genetic relationships of these occasional ocelots in Arizona, to ocelots in northern Mexico, to ocelots further south and east in their range. In order to gain better information on the evolutionary history and how ocelot population are subdivided in the northern part of their range, we will address the following objectives: Collect samples from museums (hide, bone) and other verifiable sources (blood, tissue, scat, hide, other) from northern, Mexico and Arizona. Perform appropriate genetic analyses on samples for species identification (for unknown origin samples) and DNA genotyping for relatedness estimates. Analyze genetic data to determine relatedness within populations, and between Arizona and northern Mexico. Compare samples from Arizona and northern Mexico to samples from other parts of Mexico, Texas and the remainder of the ocelot range, using data from other ocelot studies. Collect morphological data on all museum specimens and other skins and skulls.

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 present
Principal Investigator:	Melanie Culver
Research Technician:	Karla Vargas
Associate Researcher	Hans-Werner Herrmann

Goal: This study will examine genetic relationships among populations, metapopulations, and Recovery Units (RU), as defined by the Draft Recovery Plan (2005), that 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). There may have been a historical metapopulation relationship between montane and valley floor populations, with the intervening bajadas being only sparsely or temporarily occupied. 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 will be conducted using microsatellite and mitochondrial DNA markers to quantify genetic relationships among populations, metapopulations, and RUs. This information will help determine whether northern and southern populations are distinct species, and direct the appropriateness of moving frogs among populations, metapopulations, and RUs. This work will estimate genetic diversity within and among populations and metapopulations, and the need for augmentation of individuals into declining populations. Results will also be used for future population viability analysis.

Taxonomy of Anodonta Mussels in Arizona and Mexico Using Genetic Markers

Project Partners:	AZGFD Heritage
Project Duration:	2011 to Present
Principal Investigator:	Melanie Culver
Research Technician:	Terry Myers
Graduate Research Assistant:	Bob Fitak
Graduate Research Assistant	Alex Erwin

Goal: Historically, freshwater mussels of the genus *Anodonta* inhabited at least portions of many or most of the major drainage systems in Arizona. Today, the known distribution of native *Anodonta* in Arizona is restricted to a few miles of perennial flowing waters in the upper Black River of the Colorado River system. In fact, some information indicates this to be the only known extant population of *Anodonta* remaining in the entire Colorado River system, although it is likely that *Anodonta* exist elsewhere in the Rio Yaqui system in Mexico. Freshwater mussels from Arizona are considered to be *Anodonta californiensis*, however, the relatedness of these mussels to other con-generic species in western North America has not been determined. The relationship of Arizona's *Anodonta* to populations in western Mexico is unknown. The objective of this study is to quantify the genetic relatedness between populations of freshwater mussels of the genus *Anodonta* in Arizona and western Mexico to enable a clarification of their taxonomic relationships.

Genetic Characterization of the Invasive Quagga Mussel *(Dresseina bugensis)* in Southwestern US Lakes

Project Partners:	National Geographic Society
Project Duration:	2010 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Ely Jennett

Goal: To genetically distinguish the population of quagga mussels at each of 4 Southwest lakes so that future invasions can be traced back to their source. This study seeks to use genetic markers to examine historical lineages for the population of quagga mussels *(Dresseina bugensis)* in Lake Mead, Lake Mohave, Lake Pleasant in Arizona, and Lake Otai in California. Specifically, analyses of the genetic variability within the population and relatedness between individuals could resolve whether they originate from a single, or multiple, contamination / invasion event. The preliminary analysis was performed using the mitochondrial DNA COI region, with primers developed for use in mussels by Folmer et al. (1994). Subsequent analyses were performed using the six published microsatellite markers available for *Dreissena bugensis* (Wilson, et al, 1999).

Determine Genetic Variability Within Wild and Captive Populations of Sonoran Pronghorn

Project Partners:	USFWS
Project Duration:	2009 to Present
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 plan to: 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; compare genetic variability among all remaining free-ranging populations of Sonoran pronghorn; test the feasibility of using pronghorn scat samples to characterize genetic variability for populations in Mexico; develop pedigree and determine degree of relatedness for all members of the Sonoran pronghorn captive population; and determine the relatedness of Sonoran pronghorn to nearby pronghorn populations (subspecies) (*Antilocapra americana mexicana*, *Antilocapra americana peninsularis*, and *Antilocapra americana americana*).

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

Project Partners:	USFWS
Project Duration:	December 2009 to Present
Co-Principal Investigators:	Melanie Culver, Phil Rosen
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 hypothesize that there are 3 lineages of the desert tortoise, *Gopherus agassizii* (Sonoran, Mojave, and Sinaloan) and that gene trees within each lineage will be in concordance. This hypothesis will be tested by employing a multilocus approach and reconstructing gene trees for several independently inherited markers representing multiple regions of the genome. A second hypothesis is that ecotones form the boundaries among the 3 lineages of desert tortoises. This will be tested by assessing whether the distributions of gene trees correlate with the geographic distribution of vegetative communities. We hypothesize that we will not find naturally occurring introgression among genetic lineages. We will test this hypothesis by identifying if hybrid individuals exist beyond the F1 generation. Lastly, we will look for evidence of additional speciation among lineages in Mexico.

Genome Approach for Noninvasive Diet Assessment of Mule Deer from Scat

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

Goal: Use next-gen sequencing on scat samples collected from mule deer for a high-resolution diet assessment. Very little in 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. Also collected over 2 years to have sampling in different years to test variation by year. Next-generation sequencing will be performed using primers specific for plants to determine all the plant species consumed by mule deer, seasonally (spatially), temporally, and in different years. If possible, diet variation among individuals will also be examined.

Puma Connectivity and Landscape Genetics in the Southwestern US to Resolve the Source of Newly Established Puma Populations at Kofa National Wildlife Refuge

Project Partners:	AZGFD, Arizona Desert Bighorn Sheep Society
Project Duration:	2010 to 2015
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Ashwin Naidu

Goal: Approximately 500 tissue samples from hunter-harvested individuals have been collected throughout Arizona in the 2008-2012 hunting seasons for genetic analysis. Additional samples from New Mexico, Texas, Nevada, California, and Mexico have been obtained. These samples have been analyzed using microsatellite DNA markers and puma SNP markers which, combined, give high resolution for recent gene flow. Analysis of the data will determine if major highways in Arizona are disrupting gene flow for Arizona pumas. In addition, overall genetic diversity and population size estimates for puma populations sampled will be performed. Of particular interest is the source population for pumas newly established on the Kofa mountain complex of southwestern Arizona. We have generated relatedness (including parentage and kinship) estimates through a comparison of the genotypes of recently identified individual pumas on the Kofa mountain complexes with those of puma populations obtained in Arizona, California and Mexico. And identified the geographic locations of pumas most closely related to those recently identified on the Kofa mountain complexes. The most closely related populations are south of the Kofa including Mexico, and we have mapped puma movement/dispersal corridors connecting mountain complexes in southwest Arizona.

Assessment of Abundance and Diet of Felids at Kofa National Wildlife Refuge

Project Partners:	AZGFD, USFWS, Desert Bighorn Sheep Society
Project Duration:	2008 to Present
Principal Investigator:	Melanie Culver
Research Technician:	John Clemons
Graduate Research Assistant:	Ashwin Naidu

Goal: The present abundance and distribution of pumas is unknown on Kofa NWR. Through examination of photographs and tracks, the refuge has determined that at least 5 individual pumas were present on the Kofa in 2006 (a female with 2 kittens and 2 males), but the population size and its impacts on desert bighorn sheep and mule deer is unknown. A population estimate is the first required piece of information for any future management decisions regarding pumas. Puma predation has been documented as limiting some small, isolated bighorn populations; this is a concern especially on Kofa NWR for bighorn sheep management. Bobcats have also been captured on remote cameras on the refuge; their abundance and prey selection is also unknown. Bobcats are capable of predating bighorn lambs and this is another concern for bighorn sheep management. DNA analysis of scat can potentially provide a way to identify individual pumas and bobcats and generate a reliable population estimate, and DNA from bone fragments found inside in scat can provide information on puma and bobcat prey selection.

Assessment of Population Size and Prey Selection Patterns of Mexican Gray Wolves on the San Carlos Apache and Fort Apache Indian Reservations, Arizona

Project Partners:	USFWS
Project Duration:	2009 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Sarah Rinkevich

Goal: To estimate the minimum population size, identify unique individuals, and investigate prey selection of wolves through analyses of DNA recovered from scat. The reintroduction of Mexican gray wolves in the southwest has been, and continues to be, extremely controversial. Reliable estimates of reintroduced Mexican gray wolves are unknown. Currently, the FWS speculates that there could be anywhere from 35 to 50 wolves existing in the wild with only 22 having radio-collars. A major concern expressed by stakeholders associated with the Mexican Wolf Program is that the number of wolves in the wild is much greater than the numbers reported by the FWS. Of particular interest to the FWS is the number of wolves on the San Carlos and Fort Apache Indian Reservations. In any wildlife reintroduction, the desire is to reach a point at which the wild population no longer needs enhancement by release of captive individuals. Captive releases are costly in terms of time, money, and other resources. Thus, a population estimate of wolves on the San Carlos and Fort Apache Indian Reservations will provide valuable information to the FWS regarding management of the Mexican wolf program.

Characterizing Marine Faunal Community Composition Across the Gulf of California Using Next-Generation Sequencing of Environmental DNA

Project Partners:	UABCS-Mexico
Project Duration:	Fall 2016 to Present
Co-Principal Investigators:	Melanie Culver
Graduate Research Assistant:	Eldridge Wisely

Environmental DNA (eDNA) is showing promise as non-invasive method for identifying the presence and abundance of fish in the marine environment. Water sampling can yield eDNA from fish, mammals and birds that have recently come into contact with the water. For this project, we sampled 37 sites throughout the Gulf of California. These sites, ranging in depth from 5 meters to 35 meters were sampled in triplicate. At the same time conventional fish and invertebrate census data was collected and will be compared to the eDNA samples. Environmental DNA samples will be sequenced with high-throughput sequencing and analyzed bioinformatically to determine the amount of DNA signal for each taxonomic group present in the samples. This project aims to calibrate eDNA signal strength in an open ocean environment with presence/absence and abundance measures from conventional census data, determine the spatial limits of eDNA, and provide targeted monitoring of stocks of both ecologically significant marine species as well as those used commercially.

Conservation Genetics of the Tiger Rattlesnake

Project Partners:	NPS
Project Duration:	2005 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Matt Goode

Goal: Use genetic data to assess the effects of fragmentation on tiger rattlesnakes, and examine relatedness/paternity. The rocky foothill areas preferred by tiger rattlesnakes are also considered prime real estate, offering dramatic views and beautiful surroundings. As urban sprawl encroaches on park boundaries, increased threats to wildlife are inevitable. This is especially true for rattlesnakes, which are often perceived as dangerous pests that should be killed or otherwise removed. Urbanization and subsequent fragmentation is considered a primary threat at Saguaro National Park. In this study we have developed additional microsatellite markers to examine genetic variation for several populations of tiger rattlesnake surrounding Tucson. We will utilize the levels of genetic variation within and between populations to infer relatedness, level of gene flow, and barriers to gene flow among populations as well as paternity.

Using Genetic Methods to Estimate Social Structure and Reproductive Success of a Puma Population and Implications on Effects 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 Unconpahgre Plateau of Colorado; describe relatedness, paternity, and reproductive success of adults in the population. We will examine the genetics of a puma population that was not hunted for five years, then subsequently hunted again for five years, 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.

Developing SNP Markers in Pumas for Genome-Wide Association Study and Population Genetics

Project Partners:	AZGFD
Project Duration:	2011 to Present
Principal Investigator:	Melanie Culver
Postdoctoral Researcher:	Bob Fitak
Graduate Research Assistant:	Alex Erwin

Goal: In this study, we will use 454 (Next Generation) sequencing of expressed transcripts in several Arizona puma populations to identify single nucleotide polymorphisms (SNPs). Because pumas in North America have suffered a continent-wide founder effect, genetic variation at microsatellite loci is found at lower levels than their South American counterparts. Also, microsatellites cannot address the question of selection across the genome. After genotyping many individuals for selected SNPs, we will be addressing two issues: 1) characterizing selection on the puma correlated with a recent radiation into the Kofa region of the Sonoran Desert and 2) defining the origin of the Kofa population in the Sonoran Desert.

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 Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Bob Fitak

Goal: The first objective is to assess the distribution of genetic variability across ~170,000 single nucleotide polymorphism (SNP) markers and identify regions experiencing positive or purifying selection in the Mexican wolf prior to their extirpation from the wild. Secondly, the same markers will be analyzed from captive and wild individuals to observe how the distribution of variability and selected regions have changed as a result of captive propagation and reintroduction into the wild. The third objective is to use these markers to reveal the genes, or genomic regions showing strong association with inbreeding depression in captive populations. Last, in combination with the available microsatellite data, we will improve upon the existing captive management and reintroduction plans. Because the domestic dog and the wolf are closely related, the available genome sequence of the domestic dog can be a valuable tool for studies of the Mexican wolf ("genome-enabling"). The genome-enabled Mexican wolf promotes one of the first opportunities in any species to investigate the consequences of extirpation, captive propagation, and reintroduction on a genomic scale. Our study will expose the consequences of these events on the genome of the Mexican wolf. The study has the potential to characterize the genetic loci responsible for lost adaptive and accrued detrimental variation. The results will aid in optimizing the management strategies of captive and wild populations of Mexican wolves to protect against concerns like inbreeding depression, and will provide a foundation for the design of recovery plans in other endangered taxa. The improvement will best simulate the Mexican wolf population prior to their extirpation, while attempting to minimize the effects of inbreeding depression.

Assessment of trophic cascades for the Mexican wolf.

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

Goal: The first objective is to assess the distribution of coyotes across the landscape where Mexican wolves are present in Arizona at high density. Then also assess coyote density in the same habitat types with the absence of wolves. The ultimate goal is to make a comparison of the coyote densities with and without wolves to estimate if wolves are having an impact on the carnivore community structure in a similar way as they did in the Yellowstone ecosystem – in the Yellowstone ecosystem the wolves are hypothesized to be responsible for a trophic cascade effect. A minor objective is to assess the distribution of other canids. such as fox, in the same study areas, and analyze fox to wolf densities in the same way.

Functional Genomics of the Endangered Florida Panther

Project Partners:	CONACyT, Calder Scholarship
Project Duration:	2011 to Present
Principal Investigator:	Melanie Culver
Graduate Research Assistant:	Alex Ochoa

Goal: Correlate genetic diversity in genome with fitness traits in the Florida panther, 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 involves genome sequence for trios of Florida mother, Texas father, and offspring. From the genomic data – genome-wide SNPs informative for adaptive and detrimental variation will be developed. SNPs are the marker of choice to detect selection at a larger scale and 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. In addition to identifying selection through our SNP array. Finally, we will perform a Bayesian population assignment analysis to determine the level of Texas genetic introgression in the Florida panther gene pool. Information derived from this study will be essential to optimize efforts for the management and conservation of the endangered Florida panther.

Epigenomics of the Endangered Sonoran Pronghorn

Project Partners:	NSF-IGERT
Project Duration:	2013 to Present
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 may be able to detect a different epigenetic signature (reflecting differential adaptation) between pronghorn in captivity versus those in the wild. Additionally, we will look for temporal epigenetic variation as our samples span 5 years of sampling. We will also compare epigenetic variation to genomic variation and look for correlation. This will be the first examination of epigenetic variation in wild populations of mammals, and provide preliminary results on whether epigenetic variation exists in a severely bottlenecked species. It could have important implications for adaptation of wild population experiencing environmental changes, particularly wild populations with low genomic variation.

Determine Relatedness of Certain Mexican Races of Bobwhite (*Colinus virginianus*)

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

Goal: Use contemporary and museum samples and a high-throughput targeted capture approach to examine taxonomic differences among relevant subspecies of Mexican bobwhite. We propose a phylogenomic analysis of individuals from each subspecies with a goal of at least 40 individuals from *C. v. ridgewayi, C. v.* graysoni, *C. v. nigripectus, C. v. coyolcos, C. v. insignis, C. v. salvini,* and *C. v. godmani.* DNA was extracted from a total of 85 contemporary feathers and tissue samples as well as museum specimens in a dedicated ancient DNA laboratory. In this study, we will use ultra-conserved regions (UCEs) to interrogate genetic relationships among bobwhite subspecies in the southwestern US and Mexico. We will use any newly gained taxonomic information to aid the recovery efforts for the endangered 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 2009 to Present
Co-Principal Investigators:	Melanie Culver, John Koprowski
Graduate Research Assistant:	Alex Erwin

We are using a combination of modern and museum samples, combined with a whole genome approach, to examine taxonomic relatedness and level of connectivity of the ancestral populations of prairie dogs in Arizona compared to the rest of its range. 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 and Sonora were reintroduced in southern Arizona. Despite ongoing management efforts, little is known regarding the historical level of connectivity, taxonomic relatedness, and most importantly subspecies designation between populations native to Arizona and other populations in the southwestern US and Mexico. We have sampled modern and museum samples from across the range, with emphasis on Arizona, the Southwest, and the subspecies boundary. By performing genotyping-by-sequencing (GBS) on our modern samples we will discover SNPs; these SNPs will then be used to design probes for targeted capture, which we will perform on our museum samples. Ultimately, we hope to aid the reintroduction efforts by providing information on which extant black-tailed prairie dog species are closest related to those formerly found in Arizona and to the reintroduced population.

PEER-REVIEWED PUBLICATIONS

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. In Press. Standard methods for sampling freshwater fishes: Opportunities for international collaboration. *Fisheries.*

Bonar, S. A. 2016. Biological and communication skills needed for introduced fisheries biologists. *Fisheries* 41:466-467.

Bonar, S. A., D. A. Fife, and J. S. Bonar. 2016. How well are you teaching one of the most important biological concepts for humankind? A call to action. *The American Biology Teacher* 78(8)623.

Bonar, S. A., N. Mercado-Silva, M. Rahr, T. Torrey, and A. Cate Jr. 2015. A simple web-based tool to compare freshwater fish data collected using AFS standard methods. *Fisheries* 40(12):580-589

Bonar, S. A., and S. J. Petre. 2015. Ground-based thermal imaging of stream surface temperatures: Technique and Evaluation. *North American Journal of Fisheries Management* 35:1209-1218.

Bonar, S. A. 2015. Point-Counterpoint: Be flexible in the number of talks per speaker at meetings! *Fisheries* 40:7, 295-295.

Cassaigne, I, R. A Medellin, R. W. Thompson, M. Culver, A. Ochoa, K. Vargas, J. L. Childs, J. Sanderson, R. List, A. Torres-Gomez. Diet of pumas (*Puma concolor*) in Sonora, Mexico as determined by GPS kill sites and molecular identifies scat, with comments on jaguar (*Panthera onca*) diet. *Southwest Naturalist* 61(2)125- 132 dog: 10.1894/0038-4909-61.2.125

Chaudoin, A. L., O. G. Feuerbacher, S. A. Bonar and P. J. Barrett. 2015. Underwater videography outperforms above-water videography and in-person surveys for monitoring spawning of Devils Hole Pupfish. *North American Journal of Fisheries Management* 35:1252-1262.

Clark Barkalow, S. L., and S. A. Bonar. 2015. Effects of suspended sediment on survival of Yaqui Chub, an endangered US/Mexico Borderlands Cyprinid. *Transactions of the American Fisheries Society* 144:345-351.

Cooke, S.J., A.H. Arthington, S.A. Bonar, S.D. Bower, D.B. Bunnell, R.E.M. Entsua-Mensah, S. Funge-Smith, J.D. Koehn, N.P. Lester, K. Lorenzen, S. Nam, R.G. Randall, P. Venturelli and I.G. Cowx. 2016. Assessment of inland fisheries: A vision for the future. Pages 45-62 *in* C. Goddard, N. Leonard, W.W. Taylor and D. Bartley, Eds. *Freshwater, Fish, and the Future: Proceedings of the Global Cross-Sectoral Conference*. American Fisheries Society, Bethesda, MD.

Culver M. 2016. Jaguar Surveying and Monitoring in the United States. Final Completion Report for USFWS Contract Number F11PXO5778.

Edwards, T., M. Tollis, P-H. Hsieh, R. Gutenkunst, Z. Liu, K. Ksumi, M. Culver, R. W. Murphy. 2015. Assessing models of speciation under different biogeographic scenarios; an empirical study using multi-locus and RNA-seq analyses. *Ecology and Evolution* 6(2):379-96. DOI: 10.1002/ece3.1865

Edwards T., M. Vaughn, P. Rosen, C. Melendez Torres, A. E. Karl, M. Culver, R. W. Murphy. 2015. Shaping species with ephemeral boundaries, the distribution and genetic structure of desert tortoise (*Gopherus morafkai*) in the Sonoran Desert. *Journal of Biogeography* 43(3)484-497 DOI: 10.1111/jbi.12664

Edwards T., K. H. Berry, R. D. Inman, T. C. Esque, K. E. Nussear, C. A. Jones, M. Culver. 2015. Testing taxon tenacity of tortoises: Evidence for a geographical-selection gradient at a secondary contact zone. *Ecology and Evolution*, DOI: 10.1002/ece3.1500

Erwin J. A., R. R. Fitak, J. F. Dwyer, J. L. Morrison, M. Culver. 2015. Molecular detection and prevalence of bacteria in the families Rikettsiaccae and Anaplasmataccae in northern crested caracaras (*Caracara cheriway*). *Ticks and Tick-borne Diseases* 7(3):470-4 DOI: 10.1016/j.ttbdis.2016.01.015

Peer-Reviewed Publications (cont'd.):

Feuerbacher, O., S. A. Bonar, and P.J. Barrett. 2016. Design and testing of a mesocosm-scale habitat for culturing the endangered Devils Hole Pupfish. *North American Journal of Aquaculture* 78:259-269.

Feuerbacher, O. G., J. A. Mapula and S. A. Bonar. 2015. Propagation of Hybrid Devils Hole Pupfish, *Cyprinodon diabolis* x *Cyprinodon nevadensis mionectes*. *North American Journal of Aquaculture* 77:513-523.

Fitak R. R., T. L. Meyers, M. Culver. In Review. Phylogeography of mussels of the genus Anodonta in the U.S. and Mexico and implications for their conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*

Fitak R. R., A. Naidu, R. W. Thompson, M. Culver. PumaPlex 1.0: a new panel of SNP markers for the genetic management of North American pumas. 2015. Submitted to *Journal of Fish and Wildlife Management*.

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

Lorenzen, K., I. G. Cowx, R. E. M. Entsua-Mensah, N. P. Lester, J. D. Koehn, R. G. Randall, S. Nam, S. A. Bonar, D. B. Bunnell, P. Venturelli, S. D. Bower, and S. J. Cooke. 2016. Stock assessment in inland fisheries: a foundation for sustainable use and conservation. Reviews in Fish Biology and Fisheries.

Macías-Duarte, A., C. J. Conway, G. Holroyd, M. Culver. In Review. Genetic Variation and Divergence Times among Island And Continental Populations Of Burrowing Owl Subspecies (Athene cunicularia) in North America. *Canadian Journal of Zoology*.

McNeil S. E., D. Tracy, C. D. Cappello. 2015. Loop migration by a western yellow-billed cuckoo wintering in the Gran Chaco. *Western Birds* 46(3):244-255.

Ochoa A., D.P. Onorato, R. R. Fitak, M. E. Roelke, M. Culver. In Review. Evolutionary and functional mitogenomics: presence of potential deleterious SNPs in Florida panthers prior to and as a consequence of the introduction of Texas pumas. *Journal of Heredity*.

Ochoa A., S. A. Wells, G. West, M. Al-Smadi, S. A. Redondo, S. R. Sexton, M. Culver. Can captive populations function as sources of genetic variation for reintroductions into the wild? A case study of the Arabian oryx from the Phoenix Zoo and the Shaumari Wildlife Reserve, Jordan. *Conservation Genetics* 17(5)1145–1155

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. (now available on-line).

Recsetar, M. S., and S. A. Bonar. 2015. Effectiveness of Two Commercial Rotenone Formulations on the Eradication of Virile Crayfish. North American Journal of Fisheries Management 35:616-620.

Ruggirello, J. E., S. A. Bonar, O. G. Feuerbacher, L. Simons, and C. Powers. 2015. Spawning ecology and captive husbandry of endangered Moapa Dace. *Arizona Cooperative Fish and Wildlife Research Unit Research Report*, Tucson.

Schultz, A. A., and S. A. Bonar. 2016. Spawning and hatching of endangered Gila Chub Gila intermedia in captivity. *North American Journal of Aquaculture*. 78:279-283.

Svancara, C. M., A. M. Lien, W. T. Vanasco, L. López-Hoffman, S. A. Bonar, and G. B. Ruyle. 2015. Jaguar critical habitat designation causes concern for Southwestern ranchers. *Rangelands* 37(4):144-151.

Vaughn E.E., J. L. Morrison, J. Dwyer, and M. Culver. 2015. Development and characterization of polymorphic microsatellite markers for the crested caracara, *Caracara cheriway*. *Conservation Genetic Resources*, 7(1):1877-7252.

Peer-Reviewed Publications (cont'd.):

Vaughn E., M. Culver. In Review. Impact of conservation efforts on genetic diversity and population structure in Arizona pronghorn, *Antilocapra Americana. Conservation Genetics*.

TECHNICAL REPORTS

Culver M. 2016. Jaguar Surveying and Monitoring in the United States. Final Completion Report for USFWS Contract Number F11PXO5778.

Merlin P, Haynes L, Gimblett HR, Culver M. 2015. Arizona Jaguar and Ocelot Conservation Outreach Project. Final Completion Report for Intra-Agency Agreement Number G13AC00222.

Naidu A, Sheehy J, Haynes L, Gimblett HR, Culver M. 2015. Grants for Jaguar Conservation, Final Completion Report for Intra-Agency Agreement Number G13AC00222.

Neils AM, Bugbee C, Gimblet HR, Culver M. 2015. Arizona Jaguar and Ocelot Conservation Education Project: K-12 Education Plan, Educational Materials, & Examples of Curricula. Final Report to the US Fish and Wildlife Service under Intra-Agency Agreement Number G13AC00222.

Reynolds E, Gimblett R, Malusa S, Culver M. 2015. Development and Implementation of a Citizen Science Program for Jaguar and Ocelot Monitoring. Final Report to the USFWS under Intra-Agency Agreement Number: G13AC00222. 33p.

PRESENTATIONS GIVEN

Bonar, S. A. 2016. An overview of stream flow effects on Western native/nonnative fish interactions. 146th Annual Meeting of the American Fisheries Society, Kansas City, Missouri, August 19-25, 2016. (Contributed Oral).

Bonar, S. A., W. A. Hubert and N. Mercado-Silva. 2016. An Overview of North American AFS Freshwater Fish Sampling Standardization. World Fisheries Congress, Busan, Korea, May 23-27. (Invited Oral).

Bonar, S. A., N. Mercado-Silva, W. A. Hubert, T. D. Beard, D. Goran, J. Kubecka, B. D. S. Graeb, N. Lester, M. Porath, and I. Winfield. 2016. Standard Methods for Sampling Freshwater Fishes: Opportunities for International Collaboration. World Fisheries Congress, Busan, Korea, May 23-27. Keynote Address.

Bonar, S. A. 2016. An Insider's View on Applying For and Succeeding In Graduate School! - Advice from a Professor. Presentation to the Annual Meeting of the Western Division of the American Fisheries Society, Reno, Nevada. March 20, 2016. (Invited Oral).

Bonar, S. A. 2016. Conservation Professional's Guide to Working with People. Seminar Presented to the University of Idaho, February 19th, 2016.

Bonar, S. A., and S. J. Petre. 2016. Ground-Based Thermal Imaging of Stream Surface Temperatures: Technique and Evaluation. 49th Joint Annual Meeting Arizona and New Mexico Chapters of The Wildlife Society and Arizona/New Mexico Chapter of The American Fisheries Society, February 4-6, 2016, Flagstaff, Arizona. (Contributed Oral).

Bonar, S. A., W. A. Hubert, and N. Mercado Silva, 2015. An Overview of North American AFS Freshwater Fish Sampling Standardization. 145th Annual Meeting of the American Fisheries Society, Portland Oregon, August 16-20, 2015. (Invited Oral).

Bonar, S. A. 2015. The conservation professional's guide to working with people. Invited Workshop Instructor, Texas Parks and Wildlife Department, Athens, Texas, August 25, 2015. (Invited Presentation).

Bonar, S.A. 2015. How standard fish sampling methods help improve biological assessment across political boundaries. Global Conference on Inland Fisheries, Food and Agriculture Organization of the United Nations, Rome, Italy, January 26-28, 2015. Presentation and Scientific Panel Member. Invited Presentation. (Invited Oral).

Bonar, S.A. 2015. Standardization and management of fish data for rivers and streams of the Southern U.S. Invited Workshop Instructor. Southern Division of the American Fisheries Society Annual Meeting, Savanna, Georgia, January 30, 2015. (Invited Presentation).

Brizendine, M. E., D. L. Ward, S. A. Bonar, and W. J. Matter. 2016. Use of ultrasonic imaging to evaluate egg maturation of humpback chub Gila cypha in the Grand Canyon. 49th Joint Annual Meeting of the Arizona and New Mexico Chapters of The Wildlife Society and Arizona/New Mexico Chapter of The American Fisheries Society, February 4-6, 2016, Flagstaff, Arizona (Contributed Oral).

Brizendine, M. E., D. L. Ward, S. A. Bonar, and W. J. Matter. 2015 ,Use of ultrasonic imaging to evaluate egg maturation of Humpback Chub, Gila cypha, in Grand Canyon. 47th Annual Meeting of the Desert Fishes Council, 18-22 November 2015 Death Valley National Park, California, U.S.A. (Contributed Oral).

Brizendine, M., D. Ward, S. A. Bonar, and W. Matter. 2015. Use of Ultrasonic Imaging to Evaluate Egg Maturation of Humpback Chub Gila cypha in the Grand Canyon. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon. (Contributed Oral).

Presentations Given (cont'd.):

Brizendine, M.E., D.L. Ward, S.A. Bonar, and W.J. Matter. 2015. Use of ultrasonic imaging to evaluate egg maturation of humpback chub Gila cypha. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 – February 7, 2015. Contributed Oral Presentation. (Contributed Oral).

Brizendine, M.E., D.L. Ward, S.A. Bonar, and W.J. Matter. 2015. Use of ultrasonic imaging to evaluate egg maturation of humpback chub Gila cypha. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5-7, 2015. (Contributed Oral Presentation).

Cowx, I. G., S. J. Cooke, K. Lorenzen, J. Koehn, S. A. Bonar, D. Bunnell 2015. Assessment of Inland Fish Populations and Fisheries: The Foundation for Sustainable Management. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon, August 16-20, 2015. (Invited Oral).

Hannifan, J. K., M. L. Caballero-Reynolds, T. L. Ulrich, and S. A. Bonar. 2016. Videography presentations to educate the public about Arizona trouts. 48th Annual Meeting of the Desert Fishes Council, November 15-19, 2016. Albuquerque, New Mexico. (Contributed, Oral).

Loftus, A., S. A. Bonar, and D. Austen. 2015. Data Management: A Companion to Standard Methodologies for Improving International Collaboration. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon, August 16-20, 2015 (Invited Oral).

Nemec, Z. C., Lee, L N., and S. A. Bonar. 2016. Assessing modified prepositioned areal electrofishing devices (PAEDs) for surveying fish habitat use in desert streams. 48th Annual Meeting of the Desert Fishes Council, November 15-19, Albuquerque, New Mexico. (Contributed, Oral).

Perez, C. R., S. A. Bonar, T. Edwards, B. Stewart, J. Amberg, B. Ladell, C. Rees, and C. Gill. 2016. Relationship between American Fisheries Society standard fish sampling techniques and environmental DNA (eDNA) for characterizing fish presence, relative abundance, biomass, and species composition in Arizona standing waters. 48th Annual Meeting of the Desert Fishes Council, November 15-19th, 2016. Albuquerque, New Mexico. (Contributed Oral).

Perez, C., S. Bonar, J. Amberg, C. Rees, T. Edwards, and W. Stewart, 2016. Relationship between AFS standard fish sampling techniques and environmental DNA (eDNA) for characterizing fish relative abundance, biomass, and species composition in Arizona standing waters. 41st Annual Meeting of the Western Division of the American Fisheries Society, March 21-24, Reno Nevada (Contributed Oral).

Perez, C. R., S. A. Bonar, J. J. Amberg, C. Rees, B. Ladell, T. Edwards, W. T. Stewart, C. Gill, and C. Cantrell. 2016. Relationship between AFS standard fish sampling techniques and environmental DNA (eDNA) for characterizing fish relative abundance, biomass, and species composition in Arizona standing waters. 49th Joint Annual Meeting of the Arizona and New Mexico Chapters of The Wildlife Society and Arizona/New Mexico Chapter of the American Fisheries Society, February 4-6, 2016, Flagstaff, Arizona (Contributed Oral).

Perez, C., S. Bonar, J. Amberg, C. Rees, B. Ladell, T. Edwards, W. Stewart, and C. Gill. 2015. Relationship between AFS standard fish sampling techniques and environmental DNA (eDNA) for characterizing fish relative abundance, biomass, and species composition in Arizona standing waters. Desert Fishes Council, 47th Annual Meeting 18-22 November 2015 Death Valley National Park, California, U.S.A. (Contributed Oral).

Perez C., S. A. Bonar, J. J. Amberg, C. Rees, B. Ladell, B. T. Stewart, C. Gill, and C. Cantrell. 2015. Standard Fish Sampling Techniques and Environmental DNA (eDNA) As Tools to Characterize Fish Presence and Relative Abundance in Arizona Standing Waters. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon, August 16-20. (Contributed Oral).

Presentations Given (cont'd.):

Perez, C., S. A. Bonar, B. T. Stewart, C.Gill, and C. Cantrell. 2015. Use of the AFS Standard Sampling Web Tool to Compare Length Frequency, Condition, and Catch per Unit Effort of Largemouth Bass Micropterus salmoides. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon, August 16-20, 2015. (Contributed Poster).

Perez, C. R., S. A. Bonar, J. J. Amberg, C. Rees, W. T. Stewart, C. Gill, C. Cantrell. 2015. Correlation of eDNA (Environmental DNA) surveys with traditional fish sampling surveys in standing waters. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 – February 7, 2015. Contributed Oral Presentation. (Contributed Oral).

Perez, C. R., S. A. Bonar, W. T. Stewart, C. Gill, and C. Cantrell. 2015. Comparison of length frequency, condition, and growth of select sport fish species in Arizona with those in other areas of North America. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 – February 7, 2015. Poster Presentation. (Contributed Poster).

Petre, S., J. J. Amberg, C. Rees, M. Brizendine, S. A. Bonar, A. Chaudoin, O. Feuerbacher, C. Perez, J. E. Ruggirello, and R. Ulibarri. 2015. Incorporating Technological Advances in Standard Inland Fish Sampling Programs: Challenges and Opportunities. 145th Annual Meeting of the American Fisheries Society, Portland, Oregon, August 16-20, 2015. (Invited Oral).

Powers, C. J., and S. A. Bonar. 2015. Display of underwater high-definition videography of Gila chub to increase public awareness and conservation. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 –7, 2015. Poster Presentation. (Contributed Poster).

Ruggirello, J. E., S. A. Bonar, O. G. Feuerbacher, and C. Powers. 2015. Spawning ecology and captive husbandry of endangered Moapa dace. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 – February 7, 2015. Contributed Oral Presentation. (Contributed Oral).

Svancara, C., A. M. Lien, W. T. Vanasco, S. A. Bonar, G. B. Ruyle, and L. López-Hoffman. 2016. Can incentives help overcome landowner concerns about conserving endangered species on their land? A rancher case study about jaguar critical habitat and rangeland conservation.; 49th Joint Annual Meeting Arizona and New Mexico Chapters of The Wildlife Society and Arizona/New Mexico Chapter of The American Fisheries Society, February 4-6, 2016, Flagstaff, Arizona. (Contributed Oral).

Svancara, C., A. Lien, W. Vanasco, L. Lopez-Hoffman, S. Bonar, and G. Ruyle. Identifying ranching leaders' opinions of jaguar conservation and concerns with endangered species management through focused interviews. 47th Joint Annual Meeting of the Arizona/New Mexico Chapters of the Wildlife Society and the American Fisheries Society, Las Cruces, New Mexico, February 5-7, 2015. Contributed Oral Presentation. (Contributed Oral).

Ulibarri, R., S. Bonar , C. Rees, C, Jackson, M. Mata, G. Selby, J. Cole, Jeff. 2015. Comparing snorkelling and eDNA sampling techniques for monitoring presence and abundance of endangered Zuni Bluehead Sucker, Catostomus discobolus yarrowi, and Navajo Nation genetic subunit Bluehead Sucker, Catostomus discobolus, in Southwestern streams Desert Fishes Council 47th Annual Meeting 18-22 November 2015 Death Valley National Park, California, U.S.A. (Contributed Oral).

Ulibarri, R. M., S. Bonar, C. Rees, and J. Amberg. 2015. Detecting and quantifying biomass of Navajo Nation subunit bluehead sucker and Zuni bluehead sucker using environmental DNA. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 –7, 2015. Poster Presentation. (Contributed Poster).

Presentations Given (cont'd.):

Ulibarri, R., S. Bonar, M. Mata, G. Selby, and C. Kitcheyan. 2015. Habitat suitability criteria for Navajo Nation subunit bluehead sucker (Catostomus discobolus) and Zuni bluehead sucker (Catostomus discobolus yarrowi). The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5 – February 7, 2015. Contributed Oral Presentation. (Contributed Oral).

Ulibarri, R., S. Bonar, M. Mata, G. Selby, and C. Kitcheyan. 2015. Habitat suitability criteria for Navajo Nation subunit bluehead sucker (*Catostomus discobolus*) and Zuni bluehead sucker (*Catostomus discobolus yarrowi*). The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5-7, 2015. Contributed Oral Presentation.

Ulibarri, R. M., S. Bonar, C. Rees, and J. Amberg. 2015. Detecting and quantifying biomass of Navajo Nation subunit bluehead sucker and Zuni bluehead sucker using environmental DNA. The Joint Annual Meeting of the Arizona/New Mexico American Fisheries Society and the Wildlife Society, Las Cruces, New Mexico. February 5-7, 2015. Poster Presentation.

THESES AND DISSERTATIONS OF UNIT GRADUATE STUDENTS

Brizendine, Morgan E. 2016. Use of ultrasonic imaging to evaluate egg maturation of Humpback Chub *Gila cypha*. MS Thesis, University of Arizona, Tucson, AZ.

Edwards, Taylor. 2015. A biogeographic perspective of speciation among desert tortoises in the genus Gopherus. PhD Dissertation. University of Arizona, Tucson, AZ.

Goode, Matt. 2015. Conservation genetics of the tiger rattlesnake (*Crotalus tigris*) in the context of long- term ecological data. PhD Dissertation. University of Arizona.

McNeil, Shannon, 2015. Population Genetic Diversity and Structure in Yellow-billed Cuckoos across a Fragmented Landscape. MS. Thesis, University of Arizona, Tucson, AZ.

Naidu, Ashwin. 2015. Where mountain lions traverse: insights from landscape genetics in southwestern United States and northwestern Mexico. PhD Dissertation. University of Arizona, Tucson, AZ.

Perez, Christina, R. 2016. Relationship between American Fisheries Society standard fish sampling techniques and environmental DNA (eDNA) for characterizing fish presence, relative abundance, biomass and species composition in Arizona standing waters. MS Thesis, University of Arizona, Tucson, AZ.

Ramos, Seafha. 2016. Hlkelonah ue Meygeytohl: Traditional Ecological Knowledge in Wildlife Conservation and An Interdisciplinary Approach to Culturally Sensitive Research with the Yurok Tribe. PhD dissertation, University of Arizona, Tucson, AZ

Svancara, Colleen M. 2015. Human dimensions of endangered species conservation: Southwestern ranchers' concerns about jaguar (*Panthera onca*) critical habitat designation and interest in conservation incentives. MS. Thesis, University of Arizona, Tucson, AZ.

Ulibarri, Roy M. 2016. Habitat suitability criteria for Zuni Bluehead Sucker *Catostomus discobolus yarrowi* and Navajo Nation Genetic Subunit Bluehead Sucker *Catostomus discobolus* and comparing efficiency of AFS standard snorkeling techniques to eDNA sampling techniques. MS. Thesis, University of Arizona, Tucson, AZ.

Vaughn, Erin, 2016. Conservation Genetics and Epigenetics of Pronghorn, *Antilocapra Americana.* PhD. Thesis, University of Arizona, Tucson, AZ.

Voirin, Chase, 2016. Exploring techniques to investigate mule deer diet composition on the Navajo Nation. MS. Thesis, University of Arizona, Tucson, AZ.

TEACHING

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

Bonar, S. A. WFSC 444 – Wildlife Management, guest lecturer on Habitat Analysis Techniques in Fisheries, Fall 2015, 2016.

Bonar, S. A. 2015. The conservation professional's guide to working with people. Invited Workshop Instructor, Texas Parks and Wildlife Department, Athens, Texas, August 25, 2015. Invited Presentation.

Bonar, S.A., WFSC 595A, Biopolitics. Communication in Natural Resources. University of Arizona. Spring 2015.

Bonar, S. A. WFSC 225 – Wildlife Conservation and Society, Guest Lecture on Arizona's Freshwater Fishes, Fall 2015, 2016.

Bonar, S. A. WFSC 444L – Wildlife Management Laboratory, guest lecturer on Sampling Techniques in Fisheries Science, Fall 2015, 2016.

Bonar, S. A. RNR 195A – Careers in Conservation: Wildlife, Plants and Water, guest lecturer on careers in fisheries biology, Fall 2015, 2016.

Bonar, S. A., AFS Standard Methods for Sampling and Comparing Your Data with North American Standards. Instructor, AFS Southern Division Annual Meeting, Savannah, Georgia, January 2015.

Bonar, S. A. WFSC 555R – Fishery Management, Spring 2016.

Bonar, S. A. WFSC 455L – Fishery Management Laboratory, Spring 2016.

Bonar, S. A. The Rarest Fish in the World. Guest lecture in Wildlife Management, University of Idaho.

Bonar, S. A. Standard fish sampling techniques. Invited Seminar to the South Korean Inland Fisheries Institute, Near Seoul, South Korea, Spring 2016.

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

Culver, M., RNR 195A – Careers in Conservation: Wildlife, Plants and Water, guest lecturer on A Career in Conservation Genetics, Fall 2015, Fall 2016.

Culver, M., GENE 670 – Recent Advances in Genetics Fall 2015, Fall 2106, Spring 2015, 2016.

Culver, M., ECOL 485 – guest lecturer for Mammalogy Fall 2016.

Culver, M., RNR 530, ECOL 530, GENE 530 – Conservation Genetics, Fall 2015, 2016.

Culver, M., RNR 530L, ECOL 530L, GENE 530L – Conservation Genetics Laboratory, Fall 2016

AWARDS

Bonar, S. et al. Conservationist of the Year - Cherry Creek Legal and Scientific Team awarded by Arizona/New Mexico American Fisheries Society

Bonar, S. et al. Conservationist of the Year - Aravaipa Canyon Legal and Scientific Team awarded by Arizona/New Mexico American Fisheries Society

Bonar, S. Elected Fellow, The American Institute of Fishery Research Biologists awarded by The American Institute of Fishery Research Biologists

Bonar, S. USGS Star Award awarded by USGS, 2015, 2016.

Svancara, C. 2015. Best Student Paper Award Finalist, 47th Joint Annual Meeting of the Arizona/New Mexico Chapters of the Wildlife Society and the American Fisheries Society.

Svancara, C. 2015. University of Arizona Graduate and Professional Student Council Travel Grant.

Svancara, C. Best Student Paper Award Finalist awarded by 47th Joint Annual Meeting of the Arizona/New Mexico Chapters of the Wildlife Society and the American Fisheries Society

Svancara, C. Dr. Bonar Student, University of Arizona Graduate and Professional Student Council Travel Grant awarded by University of Arizona Graduate and Professional Student Council

Vargas, K. 2015-16. University of Arizona College of Agriculture and Life Sciences Arrington Memorial Scholarship.

Voirin, C. 2014-2016 USDA – Natural Resources Conservation Service (NRCS) Conservation Innovation Grant (CIG) - $56,000

Voirin, C. 2015 UA School of Natural Resources and the Environment (SNRE) Public Service and Outreach Award.

Voirin, C. 2016 UA School of Natural Resources and the Environment (SNRE) Student Leadership Award.

Voirin, C. 2015 and 2016 The Wildlife Society's (TWS) Native Student Professional Development (NSPD) Program travel scholarship recipient. Funding to assist in travel to the 2015 TWS National Conference in Winnipeg, Manitoba, Canada, and the 2016 TWS National Conference in Raleigh, NC.

Voirin, C. 2016 Institute for Tribal Environmental Professionals (ITEP) Travel Scholarship to the Native American Fish and Wildlife Society (NAFWS) Southwest Region Conference

Voirin, C. 2016 University of Arizona Native American Student Affairs (NASA) Graduate Scholarship

Voirin, C. 2016 A.T. Anderson Memorial Scholarship

Voirin, C. 2016 Wasaaja Memorial Scholarship

Voirin, C. 2015-16 Graduate Professional Student Council (GPSC) Research Grant

Voirin, C. 2015-16 GPSF Travel Grant

Voirin, C. 2015-16 American Indian Graduate Center (AIGC) Travel Award

PROFESSIONAL SERVICE

Bonar, S. A. 2nd Vice President (Elected President), American Fisheries Society. 2016 – 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. Symposium Lead. August 16-20, 2015. International Standard Sampling Symposium at the 145th Annual American Fisheries Society Annual Meeting, Portland, Oregon.

Bonar, S. A. Symposium Co-Lead. August 21-25, 2016. Interactions Between Hydrology and Nonnative Aquatic Species. 146th Annual American Fisheries Society Annual Meeting, Kansas City, Missouri.

Bonar, S. A. Panel participant. January 21-31, 2015. Freshwater fish scientific assessment panel. Food and Agriculture Organization of the United Nations. Rome, Italy.

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. Devils Hole Pupfish Recovery Team – Asked to provide input to Devils Hole Pupfish recovery, U.S. Fish and Wildlife Service/National Park Service.

Bonar, S. A. Desert Fish Scientific Advisor. U.S. Forest Service In-Stream Flow Legal Team. 2009-2014

Culver, M. President, Arizona Chapter of The Wildlife Society, 2015-2016.

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. 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.

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 – Assistant Staff Scientist, University of Arizona Genetics Core, Tucson, AZ
Robert Fitak – Postdoctoral Researcher, Duke University, Durham, NC
Matthew Goode – 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 – 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
Adrian Munguia Vega – Associate Researcher, CIBNOR; PANGAS; and Sociedad de Historia Natural Niparaja, La Paz, Mexico
Ashwin Naidu – Research Specialist, Saguaro National Park; and Director Fishing Cat Conservancy, Tucson, AZ
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
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 – 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).
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

Employment of Former Students (cont'd.):

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 – Program Coordinator, Genetics Interdisciplinary Program, University of Arizona; and Postdoctoral Researcher Biosphere 2, University of Arizona, Tucson, AZ
Cristina Velez – MS – Biologist and Research Station Leader, National Park Service, Peace Corps, USAID
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