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Research Branch Mission, Vision, and FY18 Goals

Our Mission:
To conduct robust research and provide scientific information to inform and support the sound management and professional stewardship of Arizona’s fish and wildlife resources, and to ensure the credibility of the Department’s science.

Our Vision:
To be recognized as the Department’s lead source of scientific information both internally and externally. To be widely recognized for scientific and technical expertise, which enhance Department efficiency, decision making, and credibility, by maintaining the professional excellence of its staff, quality of its processes, and credibility of its science.

Fiscal Year 2018 Goals

Research: Address the Department’s programmatic management information needs.

Information Transfer: Provide research findings, scientific expertise, guidance, and training to inform management decisions and activities, sustain a skilled Department workforce, and maintain the Department’s role as a leader in wildlife management.

Capacity and Partnership Building: Build and maintain research partnerships, outside funding, and a high level of expertise within the Branch to maximize Research Branch productivity and quality.
# Research Branch Programs and Personnel

Esther Rubin, PhD  
Research Branch Chief

Julie Tolby  
Programs & Projects Specialist I

Vicki Kearney  
Administrative Assistant

## Aquatic Research Program

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## Terrestrial Research Program

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## Biometrics Program

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Aquatic Research Program: Current Projects

Fate of Stocked Trout: Trout Stocking Strategies, Movement & Mortality

Background
The Arizona Game and Fish Department allocates around $2.7 million per year to operate its hatchery program, much of which is devoted to trout stocking. The demand for trout is high and the requests often outweigh production. Thus, how do we best manage for angler satisfaction, the number one priority for the stocking program, while minimizing cost? To this end, the Research Branch is conducting an extensive study of our trout stocking practices, the fate of trout once stocked, and overall satisfaction of the anglers that catch them.

Objectives
- Evaluate stocking densities and frequencies that maintain or improve angler effort and satisfaction.
- Evaluate movement of stocked Apache Trout and Rainbow Trout.
- Evaluate mortality of stocked Apache Trout and Rainbow Trout.

Project Location and Timeline
Three study streams (East Verde River, Tonto Creek, and Canyon Creek) are located along the Mogollon Rim outside Payson, AZ and three study streams (Little Colorado River, East Fork of the Black River, and Silver Creek) are located in the White Mountains near Pinetop. This project was initiated in 2013 and was scheduled to end in September of 2017, but due to vacancies has been extended to May 2018.

Approach
A series of techniques were employed to address our research objectives. Creel surveys were conducted to assess angler effort, catch and harvest rates, total catch and harvest, return to creel rates, proportional angling success, overall angler satisfaction, and angler demographics across varied stocking densities. Radio telemetry techniques provided information such as persistence, movement distances, and mortality. Depletion surveys were conducted to assess population levels throughout the year. Diet sampling was used to assess acclimation from hatchery feeds to natural food sources and its impact on survival. All of this information is necessary for managers to make informed decisions about stocking practices in the future.

Current Project Status
We are currently finishing up the final report for this project. We completed four years of creel surveys resulting in over 4,984 angler interviews. Total angler effort varied from 3,618 angler hours to 13,481 angler hours. Total catch of stocked trout (i.e., Rainbow Trout and Apache
Trout) varied from 1,918 to 14,288 trout. Total harvest of stocked trout varied from 1,027 to 9,350 trout. Return to creel rates varied from 12.0 to 66.4%. Proportional angling success varied from 14.9 to 56.3%. Results from multinomial logistic regression suggest catch rate, age, and terminal tackle were the most important factors influencing angler satisfaction. Older anglers were generally less satisfied with their fishing experience at lower catch rates than were younger anglers. Anglers using a combination of gear types were also less satisfied with their fishing experiences at lower catch rates than those using a single gear type. Hurdle model results indicate that days post stocking, the number of trout stocked per km, and terminal tackle type were the most important factors influencing angler catch rates. Days post stocking had a strong negative relationship with angler catch rates and appeared to be the most important factor influencing angler catch rates. The number of trout stocked per km had a weak relationship with angler catch rates across the weekly stocking densities used in the study. Adjustments in stocking numbers, locations, and days of the week have already been implemented based on results from creel surveys on this project.

Radio tags were implanted in 101 Rainbow Trout released in the East Verde River in 2014, in 147 Apache Trout released in the Little Colorado River in 2015, in 97 Apache Trout and 39 Rainbow Trout released in the East Fork Black River in 2015, and in 106 Rainbow Trout released in the East Fork of the Black River in 2016. In general, greater than 50% of Rainbow and Apache Trout were still alive after one week in the stream. Angler harvest varied from 18 to 25%. Predation varied from 6 to 30%. The number of trout that survived to December of the year in which they were stocked varied from 0 to 5%. The majority of stocked trout did not move far from their release locations (i.e., < 200 m). In general, 80% of angler interviews took place within 80% of stocked trout movement distances from a stocking location, suggesting that anglers are overlapping with the distribution of stocked trout.

A diet and condition component was initiated in 2016. Over 3,400 catchable trout were marked between the East Verde River and Tonto Creek. We recaptured 575 marked fish at various days post stocking. Stomach contents were collected from a sub-sample of these recaptures, and have been processed. The dominant taxa found in trout diets were Ephemeroptera (Mayflies), Trichoptera (Caddisflies), Diptera (True Flies), and Hymenoptera (Ants, Bees, and Wasps). A final report will be completed in 2018. Included in this report will be two to three peer-reviewed manuscripts.

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Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov
An Evaluation of Feed Type to Improve Growth and Survival of Hatchery-Reared Trout

Background
The Department devotes substantial resources to produce healthy trout to meet fishing demands. Over 69% of Arizona anglers fish for trout and natural reproduction often cannot keep up with angler demand. The most produced fish for recreational fishing in Arizona is the rainbow trout (Oncorhynchus mykiss) and the Department has seen an increase in mortality in recent years, mainly in the early life stages (fry and fingerling). Hatchery personnel have identified feed quality as a potentially limiting factor to trout survival in the hatcheries. Nutrition at early life stages is critical for growth, condition, and disease resistance to produce thriving adults for stocking. Therefore, we have initiated a study to evaluate three different types of feed (Rangen®, BioOregon®, and BioOregon® with probiotics) and to determine their impact on hatchery production for early life stages of trout reared in Arizona hatcheries.

Objectives
1. Evaluate the effects of feed type on survival and growth of hatchery-reared rainbow trout 14 to 31 days post-hatch. These fish are kept in indoor raceways.
2. Evaluate the effect of feed type on survival and growth of hatchery-reared rainbow trout upon being moved from indoor raceways to outdoor raceways.

Project Location and Timeline
This study is being conducted at the Department’s Sterling Springs Hatchery, Tonto Creek Hatchery, and Canyon Creek Hatchery. The project was initiated in late 2016 and is scheduled to be completed in 2018.

Approach
For Objective 1, this study is being conducted at all three hatcheries identified above. Indoor raceways are randomly divided among feed types to ensure equal numbers. Every week after hatching, three subsamples of 50 fish are randomly sampled and weighed for an eight week period. For the Objective 2, methods follow those of the first objective, but with 25 fish per subsample for a six week period.

For both objectives three different metrics are used to evaluate feed types:
1. Feed conversion ratio is calculated by dividing the total weight of feed fed to each raceway by the total weight of fish in the raceway (estimated from weight subsamples).
2. Percent survival (cumulative; over the course of the trial) will be calculated by dividing the total number of fish survived by the total fish at the beginning of the trial.
3. Growth rate is average fish weight calculated for each week by dividing each subsample weight by the number of fish within the sample (25 or 50 depending on objective).

Current Project Status
This project began in late 2016. We have completed a total of 11 trials for Objectives 1 and 2. Seven trials for indoor raised fish and four trials for fish moved outdoors were also completed. We currently have ongoing trials for fish at both Canyon Creek Hatchery and Tonto Hatchery. These remaining fish will transition to the outdoor phase soon and the project will complete this year. Preliminary analyses using a mixed model repeated measures approach show no consistent pattern in survival between feed types. There do not appear to be any significant differences in growth while fish are reared indoors, but when fish were measured during the outdoor phase BioOregon® diets outperformed Rangen® in both length and weight. We anticipate data collection for the final trials to complete this summer and will begin a final analysis and report in late summer 2018. Results from the project will help hatchery staff to make informed decisions relating to feed performance during various stages of production.

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Efficacy of Commercial-scale Propagation of Native Baitfish in Arizona

Background
Live bait fishing is an economically and socially important form of recreational fishing in Arizona and across the United States. Popular fishes used for live bait include fathead minnows, red shiners and goldfish (none of which are native to Arizona). When these and other bait species are improperly introduced (whether intentionally or not), they can cause severe negative impacts on native fish populations. Because of the risks involved with the introduction of non-native baitfish, a need exists for the availability of live bait that do not possess the same degree of ecological risk to fish populations. Therefore, the Research Branch has initiated a study to evaluate using native fish species for live bait.

Objectives
1. Evaluate the feasibility of commercial-scale propagation of Sonora suckers and longfin dace to meet current baitfish needs in Arizona.
2. Conduct a cost assessment of producing native baitfish in Arizona.
3. Evaluate hooking mortality between non-native and native fish when used as baitfish.

Project Location and Timeline
This study is being conducted at the Research Branch’s Aquatic Research and Conservation Center (ARCC) and at the Bubbling Ponds State Fish Hatchery. The project was initiated in late 2015 and scheduled to be completed in 2018.

Approach
Longfin dace and Sonora suckers will be collected from the wild and transported to Bubbling Ponds Hatchery and the ARCC. Fish will be initially spawned within tanks and reared until the target market size for each species (50 to 75mm for longfin dace and 100 to 150mm for Sonora suckers). We will investigate and evaluate several methods for propagation and rearing with the eventual goal of providing a set of optimal conditions for the culture of these species. In addition, using these data we will estimate the cost of producing longfin dace and Sonora suckers to replace current baitfish needs within the state. Finally, we will evaluate live-hooking mortality between non-native baitfish and native baitfish using fathead minnows, desert suckers, and longfin dace. With all of these approaches we hope to provide a framework for producing and using native baitfish in Arizona.

Current Project Status
Sonora suckers were collected from Oak Creek and held at ARCC in March 2016. Captured adults were injected with OvaPlant and OvaPrim hormone to induce spawning. One female and two male Sonora suckers ripened enough to spawn, and eggs/milt were stripped from each fish
and subsequently fertilized. Fertilized eggs were placed within McDonald Hatching Jars, and eggs began hatching 7 days post-fertilization. We obtained approximately 300 larval fish from this hatching event. The process was repeated in 2017, but we were unable to spawn any fish due to predation at ARCC. We continued measuring growth of the sucker fry, and continued to monitor sucker activity monthly through 2017/2018 to determine when peak spawning occurs. In 2017 we also collected longfin dace and placed them in a raceway and 6 aquaria in an attempt to manipulate the environment and promote natural spawning. This has been unsuccessful to date.

In an attempt to determine the suitability for native baitfish to be raised and/or spawned in a pond environment, we collected mature longfin dace and Sonora suckers and placed them in two cooperative research ponds located on the Valle Vista golf course in Kingman, AZ. We aim to determine from these populations if longfin dace can spawn naturally in a production pond environment. We will also determine if Sonora suckers will undergo sexual maturation and become available for spawning in a pond environment. Plans have also been made to perform a mark-recapture study in some dace-only ponds to determine the carrying capacity of a natural pond. This information will be used for potential stocking density recommendations in potential rearing ponds.

Previous spawning efforts involved transporting adult fish to holding tanks at ARCC and using hormone treatments to induce spawning. Adult fish did not transition well to captivity or commercial feed, and were subject to predation. This hindered our ability to spawn fish in 2016 and 2017. Therefore, in 2018, we decided to focus our efforts on streamside spawning and bringing fertilized eggs back to ARCC. We have obtained approximately 25,000 eggs to date and this information will inform fecundity estimates for future fish collections. We continue to monitor Oak Creek and will collect eggs from those fish. Fish from Oak Creek can be raised as potential broodstock for future use if needed.

In late 2017, based on direction from Aquatic Wildlife Branch staff, we shifted focus of the original study plan objective, exploring differences in predator selection between native and non-native prey, to assessing performance on hook. In early 2018, we performed an experiment comparing mortalities between fathead minnows, desert suckers, and longfin dace that were hooked as baitfish. We sought to compare time-to-mortality between species in an effort to inform anglers about potential differences in the quantity of fish they may need for any given fishing trip. We did not find any differences between species and generally all species performed well on hooks.

For more information, please contact:
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Managing for the Blue Ribbon Rainbow Trout Fishery at Lees Ferry

Background
The recreationally-important blue-ribbon Rainbow Trout (*Onchorhyncus mykiss*) fishery at Lees Ferry is a key resource of the Colorado River in Glen Canyon. The tailwater portion of the Colorado River from Glen Canyon Dam to the Paria River was created by the impoundment of Lake Powell in 1964. With ideal conditions for trout (constant, cold, clear flowing river), the Department stocked Rainbow Trout in the reach and began managing this section as a blue ribbon trout fishery. The fishery has contained a self-sustaining and naturally reproducing Rainbow Trout population since the mid 1990’s.

Objectives
As a management priority to maintain this blue ribbon fishery, the Department began a long-term monitoring program in 2000, to monitor the health of the Rainbow Trout and provide information on the influence of Glen Canyon Dam operations, management actions, and natural disturbances on the fishery.

Additionally, the Research Branch conducts Lees Ferry angler (creel) surveys year round. These surveys provide information on angler effort, angler harvest, and satisfaction of the recreational fishery, as well as how changes to the Colorado River ecosystem affect angler use.

Project Location and Timeline
This project takes place in the 15-mile tailwater from Glen Canyon Dam to the Lees Ferry boat launch and including the angler walk-in area just downstream. It is a long-term monitoring project that has been ongoing since 1991.

Approach
- Conduct standardized boat electrofishing surveys three times a year (spring, summer, fall) to monitor the Rainbow Trout population.
- Sample 36-40 sites, using a stratified random design, over three nights in three sections of river for each trip.
- Perform standardized angler (creel) surveys to monitor fishing metrics, such as impact of recreational fishing on the fishery (harvest of fish, catch rates), angler use (economic impact), and angler satisfaction.

Current Project Status
In 2017, we conducted three standard electrofishing sampling trips in the spring, summer, and fall. We sampled 122 sites in total, with 41, 41, and 40 sites sampled each season, respectively. Rainbow trout dominated the fish community comprising 97.7% of fish captured. Brown Trout (*Salmo trutta*) numbers were equivalent to last year, but made up only 1.59% of the fish community. Lower juvenile numbers suggest there was little recruitment of Brown Trout.
compared to last year. Rainbow Trout mean catch-per-unit-effort across seasons was 3.55, 95% CI [2.98, 4.11] fish/minute. This was a significant increase over the last two years, primarily resulting from high recruitment. Approximately 89% of the Rainbow Trout collected during autumn sampling were below 152 mm (6 inches), with a CPUE of 5.67 [4.70, 6.63] fish minute, indicating a good cohort of fish recruited this year.

Average Rainbow Trout relative condition (an index of weight to length) for catchable fish ≥ 12 inches was above 1.00 for all trips and size categories. A condition of one is considered normal for a Lees Ferry Rainbow Trout, thus, the population appears to be healthy overall.

One night during our summer electrofishing was dedicated to identifying rare nonnative fishes present in the reach. One Walleye (Sander vitreus) was captured at the base of the Glen Canyon Dam spillways. At a large backwater area referred to as the slough (river mile -12.0), 32 Common Carp (Cyprinus carpio) were captured along with two native Flannelmouth Sucker (Catostomus latipinnis), two Brown Trout, one Smallmouth Bass (Micropterus dolomieu) and 12 Rainbow Trout.

Angler surveys were conducted on 72 days during the period of 1 January - 31 December 2017. During these surveys a total of 1,265 anglers were interviewed (977 boat anglers and 280 walk-in anglers). In the upriver section, anglers interviewed reported a total of 4,845 Rainbow Trout being caught with an average catch rate of 0.71 [0.66, 0.76] fish/hr. Harvest rates in the upriver section continue to be fairly low with only 3.5% of the total catch of Rainbow Trout harvested. In the walk-in section of the fishery 351 Rainbow Trout were caught by anglers interviewed, resulting in an average catch rate of 0.38 [0.28, 0.48] fish/hr. Fishing satisfaction remained similar to 2016 for both boaters and walk-in anglers, averaging 3.58 and 3.30 on a scale of 1 – 5, respectively (compared to 3.54 and 3.21 for 2016). Estimated relative angler use has significantly declined since the 1980s.

We have submitted an annual report on our 2017 monitoring to USGS-Grand Canyon Monitoring and Research Center.


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Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov
Long-Term Fish Monitoring in the Grand Canyon

Background
The Department has been sampling the Colorado River in Grand Canyon since 2000. This long-term monitoring provides managers and stakeholders with information on the species composition, status, and trends of the fish assemblage in Marble and Grand Canyons, and can be used to inform and manage Glen Canyon Dam operations. We use standardized boat electrofishing and hoop net sampling at randomly selected sites, and angling at camps, to collect a representative sample of the fish assemblage. With these data, we can describe the relative abundance, size structure, and spatial distribution of native Flannelmouth Sucker, Bluehead Sucker, Speckled Dace, and Humpback Chub, and nonnative Rainbow Trout, Brown Trout, and Common Carp. Additionally, our sampling detects small numbers of rare non-native fishes (e.g., Red Shiner, Striped Bass, Green Sunfish). This information helps us understand mechanisms controlling fish population dynamics, determine effects of dam operations, and identify threats presented by non-native fishes.

Objectives
To obtain a representative sample of fish within the Colorado River between Lees Ferry and Lake Mead (296 miles), determine distribution and relative abundance of native and nonnative fish, and describe long-term trends in the fish assemblage and distribution.

Project Location and Timeline
This is a long term monitoring project that has been ongoing since 2000 and sampling occurs in the Colorado River between Lees Ferry and Lake Mead.

Approach
- Conduct two motor boat river trips during spring and one fall trip for the system-wide monitoring project. Conduct one additional trip upstream from South Cove on Lake Mead to sample areas between Pearce Ferry Rapid and the Lake Mead inlet.
- Nighttime boat electrofishing at 500-700 sites, and hoop nets at 300-500 sites. Stratified random sampling is used to select reaches and sites for sampling. Angling was conducted at camp each night in areas downstream from the Little Colorado River.
- Record species, length, weight, reproductive status, and tag number for captured fish. Tag native fish.

We cooperate with USGS Grand Canyon Monitoring and Research Center on this project; they provide logistics and database support, and we share our data with other agencies working in the Grand Canyon as part of the Glen Canyon Dam Adaptive Management Program.
Current Project Status
In 2017, we conducted a two-day trip downstream of Pearce Ferry Rapid (February 21 – 22), two 16-day spring trips (April 2 – 16 and May 25 – June 6) between Lees Ferry (River Mile 0) and Pearce Ferry Rapid (RM 281.6), and a 4-day sampling trip between Diamond Creek (RM 226) and Pearce Ferry Rapid (October 6 - 9). We electrofished 632 sites, and set hoop nets at 495 sites. We captured 4,854 fish with electrofishing and 4,421 fish with hoop netting.

Native fish accounted for 77% of the electrofishing catch and 99% of the hoop net catch. Nonnative Rainbow Trout dominated the fish assemblage in Marble Canyon (RM 0 – 61.4), but downstream of the Little Colorado River (RM 61.4), Flannelmouth Sucker were the most abundant species captured and native fish outnumbered nonnative fish. Mean total length of native fish decreased with increasing river mile, suggesting that the Western Grand Canyon (downstream of Kanab Creek RM 144) provides important spawning and juvenile rearing habitat for native fish. Our hoop net samples allowed us to describe Humpback Chub distribution throughout the Grand Canyon; Humpback Chub were relatively common near the Little Colorado River Confluence and in the Western Grand Canyon, and most abundant downstream of Diamond Creek (RM 226). This distribution differs from historic accounts of distribution, suggesting that Humpback Chub have recently expanded their range into large areas of the Western Grand Canyon.

Our methods are standardized to maintain continuity with past years, but we do adjust methods to adapt to changing river conditions and address new questions. Reductions in Lake Mead elevation have extended the length of the Colorado River; in 2017 we sampled between Pearce Ferry Rapid and the current Lake Mead inlet (~ 15 river miles) for the first time. We captured one Humpback Chub in this reach, documenting presence in habitat which was inundated under Lake Mead until recently. We also began weighing native fish on our October trip. Weight data will be used by cooperators to investigate links between dam operations, aquatic invertebrate abundance and distribution, as well as fish condition and growth.

We have submitted an annual report on our 2017 monitoring to USGS-Grand Canyon Monitoring and Research Center, and have a manuscript from this project in press.


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Investigations into Razorback and Flannelmouth Sucker Hybridization

Background
Historically, the Colorado River ran unimpeded for 1,450 miles with flows ranging from 2,500-150,000 cubic feet per second. It was home to eight native fish species. The alteration of habitat by hydroelectric dams created cold, clear, regulated river segments which are less than ideal conditions for native fish. The Razorback Sucker is endangered due to habitat alterations caused by hydroelectric dams and predation/competition with nonnatives. The range of Razorback Sucker has been greatly reduced and they are now confined to relatively small sections of the Colorado River resulting in overlap in timing and location of spawning with the more common Flannelmouth Sucker, leading to hybridization between the two species. This project examines how hybridization may be impacting existing Razorback Sucker populations by investigating egg viability and juvenile survival of hybrid individuals. Additionally, a reliable means for differentiating hybrids from pure individuals in the field is needed. This study is investigating the accuracy and usability of various identification methods.

Objectives
- Evaluate egg viability, juvenile survival and swimming ability of hybrid Razorback Sucker (*Xyrauchen texanus*) and Flannelmouth Sucker (*Catostomus latipinnis*).
- Quantify meristics and morphometrics of Flannelmouth/Razorback hybrids and develop tools for field identification of young hybrids.
- Continue meristic and morphometric measurements of hybrid Razorback and Flannelmouth suckers as they develop adult characteristics.
- Determine the potential for introgression by evaluating egg viability and juvenile survival of laboratory backcrosses and second generation Razorback/Flannelmouth hybrids.
- Evaluate growth and survival of juvenile Razorback Sucker in the presence of Common Carp (*Cyprinus carpio*).

Project Location and Timeline
This project is funded for five years (2015-2020) through an external grant from the Bureau of Reclamation. Most of this proposed work will occur in laboratories; Razorback Sucker used in this study have been obtained from hatcheries, and Flannelmouth Sucker have been obtained from the Paria River.
Approach
We are cooperating with USGS (Grand Canyon Monitoring and Research Center) and Northern Arizona University to address the research objectives for this study. To investigate hatch success, adult Razorback and Flannelmouth suckers were artificially spawned to make four types of progeny: Razorback Sucker, Flannelmouth Sucker, Razorback female × Flannelmouth male hybrid, and Flannelmouth female × Razorback male hybrid. Fertilized eggs were placed into individual labeled containers to hatch. Eggs and larvae were counted to calculate percent hatch. Larval mortality was monitored for 37 days to determine survival rates. Fish produced were used for meristic counts and morphometric analyses. Future studies with these fish will include competition experiments, swim trial studies, and backcrossing.

Current Project Status
In 2016, Razorback Sucker and Razorback female × Flannelmouth male hybrids were produced in the laboratory, and in 2017 Flannelmouth Sucker and Flannelmouth female × Razorback male hybrids were successfully produced. All of the fish necessary to carry out our investigations into meristic and morphometric analyses have been produced and we can begin swim trial studies.

Pilar Wolters, graduate student at Northern Arizona University (and AGFD employee), completed her thesis entitled *Investigations into Razorback Sucker – Flannelmouth Sucker hybrid viability and identification using shape*. She evaluated hatch success, juvenile survival, and shape of hybrids compared to pure Razorback and Flannelmouth Suckers. Results from her thesis revealed that we were unable to detect a difference in hatch success or larval survival between hybrids and pure fish. She also discovered that fish shape is an unreliable metric to discriminate between pure fish and hybrids smaller than 137mm total length.

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Evaluation of Predator Recognition in Bonytail and Razorback Sucker

Background
Bonytail and razorback sucker are two critically endangered fishes native to the Colorado River Basin, and both species are sustained largely by hatchery stocking programs to increase the number of fish in the wild. Previous work has suggested that more than 95% of stocked fish mortality in the large Colorado River reservoirs is due to non-native fish predators such as striped bass and flathead catfish. The Bureau of Reclamation has provided funding to the Department through the Lower Colorado River Multi-Species Conservation Program to investigate methods for improving the survival of hatchery-raised fish to ultimately aide in the recovery of these species in the wild.

Objectives
The current project focuses on five separate experimental objectives to determine the best management practices to increase the survival of hatchery-raised razorback suckers and bonytail:
- Experiment 1: Effect of predator avoidance conditioning frequency on survival
- Experiment 2: Retention of learned antipredator behavior
- Experiment 3: Development of a large-scale conditioning protocol
- Experiment 4: Evaluation of artificial habitat structures
- Experiment 5: Feasibility of avian predator conditioning

Project Location and Timeline
This project is being conducted at the Department’s Aquatic Research and Conservation Center (ARCC) located in Cornville. Experiment 1 began in fall of 2017 and is scheduled to be completed in spring 2018, with the overall project continuing until 2021.

Approach
Bonytail and razorback sucker are conditioned to avoid fish predators using previously developed methods at ARCC. Fish are “trained” to recognize and avoid predators by exposing naïve hatchery-raised fish to a hindered predator with the presence of an alarm pheromone found in the fish’s skin tissue. To prevent predation during the conditioning process, the “trainer” bass has its jaw musculature partially paralyzed with botulinum toxin (Botox). Experiment 1 is designed to test the optimal number of predator conditionings by conducting one hour predation trials evaluating zero conditionings ( naïve fish), one predator conditioning, and three predator conditionings.
Current Project Status
Experiment 1 trials were completed in March 2018 and data are currently being compiled and analyzed for a final experimental report. Experiment 2 trials are scheduled to begin in April 2018.

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Aquatic Research and Conservation Center

Background
The primary focus of the Research Branch’s Aquatic Research and Conservation Center (ARCC) is to maintain populations of endangered desert fish. These fish are held as a refuge against possible extinction in the wild and propagated to help support threatened populations and re-establish extirpated populations. This facility is primarily supported by contracts with the Bureau of Reclamation. These funds are supplemented by State Wildlife Grant funding and contracts through partners such as the Lower Colorado River Multi-Species Conservation Program and the National Fish and Wildlife Foundation for conducting a variety of research projects in support of native fish conservation.

Objectives
The ARCC holds three lineages of Spikedace, four lineages of Loach Minnow, three lineages of Roundtail Chub, and one lineage of Desert Pupfish, as well as a variety of aquatic species used for research and outreach/education.

Project Location and Timeline
The ARCC is located in Cornville and facility operations are in year 17 of a 30-year agreement with the Bureau of Reclamation.

Approach
Fish are held in a variety of circular and raceway tanks. All tanks have flow-through well water from an artesian well and are protected against mammalian and avian predation. All lineages are spawned separately on an annual basis and larval fish are repatriated into the wild in an effort to establish new self-sustaining wild populations.

Current Project Status
Phase 2 of a massive facility overhaul was completed in late 2017 and added many new features to the property. These include a 400’ long retaining wall defining the main levels of the facility, a 10’ tall chain link perimeter fence, a runoff collection trough and pond,
plumbing for future tank installation, and two new PVC lined ponds approximately four times larger than their predecessors, each with an independent collection sump. Many other improvements were made by hatchery staff and contractors between each phase of the renovation including: increasing the power supply to the property from 200 to 800 amps, adding an electric wire to the top of the perimeter fence, installing a net cover over the spawning cage and the installation of 20 new raceway sump combination tanks. Each tank is equipped with a programmable variable speed pump allowing artificial flows to be created from 75 – 250 gallons per minute. Additionally, three 12’ x 32’ sheds were donated by the Development Branch and transported to the ARCC for future upgrades. The first shed is in the process of having a concrete foundation poured with plumbing and is being renovated to provide the facility with a dedicated quarantine building with 6 isolated tanks, chemical storage, disinfection sink, footbath and dedicated gear. The second shed will be separated into a gear storage area and insulated temperature controlled feed storage. The final shed will be used for tool storage and project work space.

After a review of existing research papers on Spikedace and Loach Minnow propagation revealed little information, and past efforts conducted at the facility were found to be minimally documented, staff initiated a more robust process for collecting comprehensive data on all future propagation efforts. Detailed records were kept in 2017 on holding conditions and treatment throughout the spawning and winter seasons. This included data on diet, feeding frequency and schedule, light and temperate data for each raceway, flow rates for both artesian and recirculation, algae growth and removal, mortality and larval fish produced weekly. A new annual spawn report was initiated to better document these efforts and to help with future analyses, and a yearly study plan outlining goals for the coming spawn season was developed.

Current stock counts, 2017 production and stockings are listed in the table below. Fish stocked included fish from previous year’s spawn that were either not added back to the brood or had no stocking locations available.

<table>
<thead>
<tr>
<th>Species</th>
<th>Lineage</th>
<th>Brood count</th>
<th>Last year collected/#</th>
<th>2017 larval count</th>
<th>Stocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spikedace</td>
<td>Aravaipa</td>
<td>382</td>
<td>2017/162</td>
<td>1341</td>
<td>1141</td>
</tr>
<tr>
<td>Spikedace</td>
<td>Gila Mainstem</td>
<td>267</td>
<td>2009/148</td>
<td>384</td>
<td>327</td>
</tr>
<tr>
<td>Spikedace</td>
<td>Gila Forks</td>
<td>122</td>
<td>2011/148</td>
<td>1183</td>
<td>1000</td>
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<tr>
<td>Loach Minnow</td>
<td>Aravaipa</td>
<td>490</td>
<td>2017/100</td>
<td>305</td>
<td>0</td>
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<tr>
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<td>Blue River</td>
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<td>2016/12</td>
<td>47</td>
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<tr>
<td>Loach Minnow</td>
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<td>2013/41</td>
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<td>243</td>
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<tr>
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<td>Gila Forks</td>
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<td>2017/110</td>
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<td>159</td>
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<tr>
<td>Roundtail chub</td>
<td>Eagle Creek</td>
<td>99</td>
<td>2012/100</td>
<td>57</td>
<td>0</td>
</tr>
</tbody>
</table>

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Terrestrial Research Program Projects

Understanding the Effects of Tree Group Size on Wildlife Abundance and Occupancy

Background
Ponderosa pine forests in many areas of the southwestern U.S. have been transformed dramatically over the past century from open parklands to crowded stands lacking structural and compositional diversity. Crowded conditions set the stage for large, hot wildfires near urban areas and across the forests. Recent wildfires in Arizona have strengthened management efforts to proactively restore forest health, reduce fire risk to human communities, and improve ecological functions and habitat for wildlife. Recent proposed forest treatments by the Four Forest Restoration Initiative (4FRI) in Arizona seek to thin and restore pine forests in four national forests (Coconino, Kaibab, Tonto, and Apache-Sitgreaves National Forests) to healthier conditions. Yet as restoration treatments modify existing forest structure, they may affect wildlife species and alter various ecosystem characteristics. For example, tree thinning may reduce vertical structure for nesting birds, yet an increase in herbaceous vegetation following thinning treatments may improve foraging conditions for many other birds and mammals. Given the spectrum of potential impacts on wildlife, it thus becomes critical to identify the structural and compositional features of the forest that are important to wildlife when developing forest management plans that address restoration.

The tassel-eared squirrel (Sciurus aberti; above) has received particular attention in this respect. Prior research evaluated the benefit of “winter core areas” (WCAs) to squirrels in a small area near Flagstaff. These WCAs were dense stands (< 80 acres in size) of medium-to-large diameter trees with highly interlocking canopies embedded in a forest matrix that had been extensively thinned in areas and moderately thinned in others. Though specifically designed and tested for the habitat needs of tassel-eared squirrels, WCAs should also benefit a variety of other species that prefer more closed-canopy habitats.

The collaborative 4FRI effort proposes to treat 2.4 million acres of ponderosa pine forest, ideally treating 30,000 acres annually over a 20 year span. 4FRI presents a unique opportunity to expand empirically on past research efforts with larger treatments and testing of various spatial arrangements of WCAs to inform future restoration actions and their corresponding impacts on wildlife. As such, this project seeks to collect baseline information on various wildlife species prior to proposed treatment implementations.

Objectives
1. Trap and tag tassel-eared squirrels on 3 treated forest areas and record incidence of feeding signs (i.e., clipped twigs, peeled cones and twigs, digs for fungi) on the same
areas to calibrate a regression equation that uses the incidence of feeding signs to estimate tassel-eared squirrel abundance in treated forest areas.

2. Establish baseline estimates of density and diversity of breeding songbirds, and where feasible, other small mammals, in a sample of forest polygons earmarked for thinning treatments to aid later in determining the optimal ‘winter core area’ size for songbirds and small mammals inhabiting ponderosa pine forests.

Project Location and Timeline
This project is being conducted in the 4FRI project area in Region 2 that includes parts of GMUs 6A, 6B, 7E, 7W, 8, and 11M. This project was scheduled to take 3 years from 2013 to 2016.

Approach
We conducted a mark-recapture study on tassel-eared squirrels and surveyed for squirrel feeding signs on the same sites 3 times per year since April 2014. Trapping typically occurred in January, April, and August at all sites simultaneously for 10-12 days, depending on weather and trap success. All squirrels were identified with uniquely numbered ear tags. We also conducted surveys for feeding signs (left) within one month of trapping. This information was used to calibrate a feeding sign index for these areas and will be critical to monitoring squirrel responses to 4FRI treatments and other forest alterations throughout Arizona. In spring 2014 and 2016, we contracted breeding bird surveys on 10 and 12 1-km² grids spread across plots designated by U.S. Forest Service for thinning treatments. These surveys provided baseline information on relative abundance and richness/diversity. The same points also served as centers of trapping webs for generating similar estimates for small mammals in 2016. We anticipate that these data could be compared with survey data post-treatment to help predict species’ responses in similar forest habitats to restoration treatments or to characterize suitable WCA for canopy species.

Current Project Status
Field work was completed in 2016. In total, we trapped squirrels in 3 sites 7 times (April and August 2014; January, April, August 2015; February and April 2016). We had high trap success with tassel-eared squirrels each winter and spring, but reduced success each fall. In 2016, we saw a significant increase in both animal presence and feeding sign on all three plots, but particularly on the plot with highest tree removal where squirrels had been less dense in 2014 and 2015. We completed feeding sign surveys after each trapping session, and analyzed data to characterize the correlations between known squirrel densities and feeding sign on each plot. We contracted Wildlife Contracts to help with field work in 2016, and worked with them to prepare an internal report in 2017. A manuscript is scheduled to be completed in 2018.

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Habitat Use and Movements of Mule Deer on the Kaibab Plateau

Background
The Kaibab Plateau supports one of the premier deer herds in the western United States and has been the focus of intensive management and research for decades. In recent years, winter range on the western portion of the Plateau (Unit 12A-W) has been impacted by several large wildfires and widespread establishment of invasive exotic weeds (e.g., cheatgrass). Over the past 5-10 years, the AZGFD, US Forest Service, and sportsman’s groups have undertaken extensive efforts to improve deer habitat via herbicidal control of cheatgrass, removal of encroaching woodland vegetation, seeding of forage plants, and installation of new water developments, but the effects of these habitat developments on deer movements and habitat use remain unknown.

A large management concern is maintaining the deer herd at levels commensurate with the available forage base, particularly on the winter range. AZGFD Region 2 biologists collared 36 mule deer does in 2012-2013 in hopes of ascertaining the efficacy of habitat improvement actions relative to deer habitat use on the winter range and to look at movements between winter and summer ranges to identify other priority areas for future treatments. Due to AZGFD personnel changes, Research Branch was given the mule deer location data in 2014 and asked to analyze it relative to the purposes stated above.

Objectives
As possible, the location data were analyzed to:
1. Identify seasonal movement patterns of mule deer does between summer, transitional, and winter ranges.
2. Assess habitat use, particularly with respect to recently burned areas, habitat treatments (e.g., juniper removal, reseeding), and newly-installed water developments.
3. Obtain estimates of adult female mule deer survivorship using telemetry information.

Project location and approach
This project was conducted primarily on Game Management Unit 12A-W.

Current Project Status
In the summer and fall of 2014, all collars from 36 mule deer does were retrieved and location data were downloaded, cleaned, and compiled into a geospatial database detailing individual movement patterns. Animal mortalities and/or collars that malfunctioned after deployment limited the availability of some data. The final database contained 51,771 locations from 30 individuals collected four times per day from March 2012 to June 2014. Of those locations, 21 individuals had location data over a period of 340 consecutive days or greater (i.e., over an entire migratory cycle from summer to winter grounds). Location data for 9 individuals were collected.
for a period of less than a year. Region 2 staff provided auxiliary spatial data (i.e., water locations, habitat improvement treatments, and fire history) in November 2014.

Two main products were initially proposed from the available telemetry data. One manuscript was written to discuss shifts in seasonal movement patterns of mule deer on the west side of the Kaibab plateau and the potential roles of population numbers, climate, invasive grasses, and habitat quality influencing migration movements. However, internal reviewers were uncomfortable with the resolution of some data layers and interpretations made from them, so the manuscript was rejected and we did not proceed with submission to external review. In the meantime, the biologist who initially led the analyses left the Department for other opportunities.

A second manuscript detailing the habitat selection of mule deer does on the west side of the Kaibab Plateau has been prepared and is going through internal review. Data analyses assessed the influence of wildfire and habitat treatments on mule deer habitat use on the Kaibab winter range. This included calculating and sampling a study area based on a 99% Utilization Distribution. We then used the number of locations within sampled areas as a response variable and several habitat covariates as factors/predictors. Preliminary results suggest that both fire severity and landscape treatments affected deer use. Increased deer use was associated with areas of lower terrain ruggedness, higher solar radiation, and reduced snow depths. Deer use also increased in areas that experienced higher average fire severity but decreased in areas closer to developed water sources. Lower vegetation heights and higher percentage of treated habitats were weakly associated with increased deer use. This manuscript is scheduled to be submitted for publication by June 2018.

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Biotic and Abiotic Factors Influencing Aspen (*Populus tremuloides*) in Arizona

**Background**
Quaking aspen (*Populus tremuloides*) is the most widespread tree species in North America, but reduced regeneration throughout western North America has raised concerns about stand resilience and persistence among land and wildlife managers. The geographic area experiencing aspen decline is broad enough and the temporal scale is narrow enough that the term ‘sudden aspen decline’ was coined to describe the generality and speed of the phenomenon. Declining aspen populations are problematic because aspen stands often represent biological hotspots of diversity surrounded by dominant conifer or meadow types in western forests. Many factors have been proposed to affect aspen regeneration and recruitment. These include herbivory, altered land management practices, conifer succession, wildfire, disease, and climate change. It remains unknown how the multiple contributing factors combine to drive changes in aspen populations and their distribution.

**Objectives**
1. Investigate how aspen stands in Arizona have recently (i.e., over the past 30 years) been affected by a suite of relevant covariates, and to determine the relative contributions of the set of landscape-level covariates (e.g., herbivory, disease, climate, fire, succession) on the observed expansion, contraction, or persistence of aspen stands over time.
2. Determine the relative importance of relevant landscape-level covariates in characterizing the condition of contemporary aspen stands.

**Project Location and Timeline**
This project established 91 study sites throughout the Kaibab, Coconino, Coronado, and Apache-Sitgreaves National Forests. Field data collection and lab work was completed in November 2016, but personnel vacancies delayed final data preparation and analyses. Analyses began late in 2017, and we anticipate they should be finished in 2018.

**Approach**
The activities of this study focused at two temporal and spatial scales of investigation. The first used available remote sensing products (Landsat) and other long-term data to examine how aspen populations have changed throughout Arizona over the past three decades. The second
used results from the remote sensing investigation to identify specific aspen stands that have expanded, contracted, or remained unchanged (i.e., static). Detailed field data were collected from these sites across the state to address contemporary aspen forest health.

**Project Status**
The lead biologist on this project left the Department in February 2017 before many analyses were completed, also leaving several necessary databases in addressing Objective 1 incomplete. Our staff have been actively coordinating with the USFS and other partners to compile the remaining data. We anticipate that we are nearing the time when all relevant data sets will be complete enough to conduct analyses that look at the impacts of several landscape-level factors on long-term persistence of aspen.

Data were better compiled to address Objective 2, so the Department’s biometrician took the lead in analyzing collected field and lab data for Objective 2 to look at factors affecting contemporary aspen forest health, and a manuscript is being prepared. Interestingly, this analysis suggests that fire suppression, conifer encroachment, drought and disease all play more important roles in decreasing aspen regeneration and recruitment than do wild ungulates in contemporary aspen stands in Arizona.

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Photo of Arizona Snowbowl, courtesy of TripAdvisor
A Framework for Estimating Elk Abundance in Arizona

Background
The Department has historically managed elk populations using relative indices based on sex and age ratios observed during surveys and harvest trends as an indication of elk numbers across the state. Emerging management concerns, however, have suggested the need for more robust abundance estimates. For instance, questions related to elk browsing impacts on aspen regeneration, potential changes to elk carrying capacity following large fires, and the effects of reintroduced wolves on elk numbers have advocated for more numerically precise elk population estimates. To inform elk management actions and facilitate effective Department resource allocation, this project was designed to evaluate several existing candidate survey methods in developing a framework for estimating elk abundance.

Objectives
The objectives of this study are to:
1. Provide a literature review and evaluation of potential survey methods for estimating elk abundance in Arizona;
2. Conduct an empirical comparison of the accuracy and precision of a subset of candidate methods for estimating elk abundance in Arizona, including abundance estimates obtained from a concurrent mark-recapture survey;
3. Present recommended and alternate survey methods to estimate elk abundance in Arizona with a focus on:
   a. Resulting accuracy and precision of abundance estimates in a variety of habitat types; and
   b. Resource needs (costs) to conduct and analyze survey results.

Project Location and Timeline
Primary focal areas of this study were game management units (GMUs) 1 and 7E. We also included GMU 3C during the first survey year to take advantage of elk collared there as part of a Wildlife Contracts Branch project. Our project began in 2014 and was anticipated to be complete in 2016. Due to sample size concerns, we sought and received grant funding to extend the project one more year for aerial surveys, so field work was completed in spring 2017.

Approach
To estimate elk abundance, we compared a traditional mark-recapture approach to four additional candidate methods, including the population model currently used by the Department. A temporary increase in funding through the Wildlife and Sport Fish Restoration Program made it possible to purchase and deploy GPS and VHF collars to “mark” a large number of elk. Data to test each approach were collected during the same aerial surveys. Using the “marked” animals,
we generated population estimates for each area with each of five candidate methods. We then compared and quantified the accuracy, precision, and necessary resources associated with using each method.

**Current Project Status**
Over the course of the study, we trapped 100 elk in GMU 7E and 74 elk in GMU 1. Total elk collared in 2014 were 62 animals, 45 in 2015, and 66 in 2016. Approximately 40 satellite iridium collars were distributed on elk across both GMUs to assess how far elk moved between the time a helicopter survey initially passed overhead and observers went back to locate collared animals missed on surveys. Whenever possible, cause of death for collared elk was assessed when we recovered collars. Among known mortality sources, hunter harvest resulted in the highest mortality for collared elk in both GMUs between April 2014 and December 2016. Vehicle collisions also accounted for 5 elk mortalities, and one collared elk was documented to be killed by wolves.

In 2014, we flew roughly 243 km² in GMU 1 and documented approximately 910 elk. We flew 472 km² in 7E and counted approximately 460 elk. In 2014, we also surveyed 512 km² in GMU 3C and observed approximately 1050 elk. Survey results were similar in 2015 for GMU 7E, but we expanded the area flown in unit 1 to include 668 km² and documented roughly 3500 elk. We received grant funding for additional surveys and collars in February 2016, so we augmented the number of “marked” elk in GMUs 1 and 7E. In 2016, we surveyed distances similar to 2015, observing 345 elk in GMU 7E and 3,815 elk in GMU 1.

All survey data were finalized for analyses by February 2017. Our analyses indicated a hybrid model that draws on the strengths of two of the candidate models provided the most robust estimates of elk abundance. The hybrid model accounts for elk that go undetected on surveys as well as modeling detection heterogeneity due to observer position in the ship and observer experience. However, in instances where managers lack the time or resources to develop a hybrid model, or when management decisions can be addressed with estimates with lower precision or accuracy, methods such as the double observer or simultaneous double count may provide a more economical option. Our assessment provides information to help managers choose among several widely used methods for aerial elk survey to meet their specific objectives and resource availability. A manuscript describing these findings has been submitted for publication.

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Bighorn Sheep and Mountain Lions: A Study to Better Understand their Relationships and Help Guide Management Decisions

Background
Predation management is a challenging process, and in Arizona, wildlife managers need information on the influence that mountain lion predation has on bighorn sheep populations relative to other factors affecting sheep mortality and population viability. Management decisions may also benefit from knowing the composition of prey taken by mountain lions. The goal of this project is thus to improve our understanding of the factors that influence bighorn sheep mortality, especially mountain lion predation, and to provide data to inform lion and bighorn sheep management decisions.

Objectives
1. Examine which factors put bighorn sheep at increased risk of mortality, with an emphasis on lion predation. These may include habitat characteristics such as topography, vegetation type or cover, and burn history, as well as group size/composition, season, age/sex of sheep and time since release/transplant,
2. Document bighorn sheep habitat selection to a) describe if and how this changes with time after translocation/reintroduction, and b) examine whether bighorn sheep select habitat consistent with presumed predator avoidance strategies,
3. Describe survival and cause-specific sheep mortality at both study sites,
4. Describe mountain lion prey composition, and
5. Conduct a quantitative demographic analysis to examine the relative effectiveness of reducing mortality rates, such as through lion removal, on improving population viability in bighorn sheep populations of varying size, and with varying recruitment and mortality rates, as a tool for managers.

Project Location and Timeline
This project is being conducted at two sites in Arizona. Objectives 1-3 and 5 are being addressed in the Santa Catalina Mountains (SCM) in Region 5, while all objectives are being addressed in the Arrastra Mountain Wilderness (AMW) in Region 3. The project began in November 2013 and will finish in summer 2018.

Approach
In November 2013, 40 bighorn sheep were translocated to AMW, with 20 fitted with GPS-telemetry collars. In November 2014, an additional 40 bighorn sheep were translocated, with 22 fitted with radio collars. Thirty sheep were translocated to SCM in November 2013, 30 additional sheep were moved in late November 2014, and another 27 sheep moved in November 2015, with all but one fitted with GPS-telemetry collars. We are using GPS collar data to observe sheep behaviors and identify sheep use sites where we measure habitat characteristics, including
horizontal visibility and topographical features. We will use the data to evaluate which behavioral and habitat factors may influence bighorn sheep mortality. We will also use GPS data to analyze home range characteristics and conduct habitat sampling to evaluate whether bighorn sheep are selecting habitat in accordance with our current understanding of anti-predatory behavior. This can inform decisions related to land management, e.g., where to prescribe fire. We are also collecting data on lamb recruitment and survival and will conduct a quantified demographic analysis to examine alternative management scenarios. Finally, we are using GPS data from 4 collared mountain lions to identify and investigate mountain lion kill sites to determine proportion of kills comprised of bighorn sheep, proportion of lions killing bighorn sheep, and overall prey composition.

Current Project Status
Project field work was completed in September 2017, following study animal collar drop-off at the AMW and SCM study sites, and completion of field work objectives. In 2017, we recorded horizontal visibility measurements at 1,296 locations between the two study sites. This includes 261 plots at locations used by bighorn sheep at AMW and 318 at randomly-selected locations. At SCM, we recorded horizontal visibility measurements at 405 locations used by bighorn sheep and 312 at randomly-selected locations.

In total for the duration of field work (2013-2017), we recorded horizontal visibility at 3,303 locations across the 2 study sites. Additionally, we recorded 265 total group observations of collared sheep at AMW and 291 group observations at SCM. At SCM we coordinated with Region 5 staff and provided photos and observation notes for public information releases related to lamb recruitment and behavioral observations. At AMW we coordinated with Region 3 to provide information on bighorn mortality and movements for the People’s Canyon augmentation project performance reports. We have completed the analysis addressing Objective 1 and are currently conducting data analyses related to bighorn sheep habitat selection (Objective 2). We anticipate this analysis will be completed by May 2018. Both analyses will be included in a single manuscript, which will be submitted for publication in a peer-reviewed journal.

At AMW, we trapped and collared a total of 4 male mountain lions between 2014 and 2015. One of these animals was hunter-harvested in 2015. We completed kill site investigation sites for the remaining 3 lions in September 2017. In total, we investigated 277 mountain lion kill sites, 48 of which were investigated in 2017. We are combining this dataset with mountain lion kill site data gathered by Region 4 personnel, and will submit a manuscript for publication focused on mountain lion prey composition and predation patterns by mountain lions in the Southwest.

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An Assessment of Arizona’s Cormorant Populations, their Impacts on Fish, and Potential Management Strategies to Reduce Impacts

Background

Arizona is inhabited by two species of cormorants. Neotropic cormorants (*Phalacrocorax brasilianus*) are present as resident populations, while double-crested cormorants (*P. auritus*) are present in large numbers primarily during migration in the winter months. Annual bird counts and opportunistic observations suggest that both species are increasing in Arizona. Cormorants are fish-eating waterbirds, often found in large colonies which can collectively consume large numbers of fish. Their increased numbers have therefore resulted in concern about potential negative effects on fish, impacting both the sportfish industry, which represents an important revenue source for the Department and provides desirable angling opportunities, and also on native fish species, which the Department is mandated to manage for long-term sustainability. Although cormorants can readily be observed in large numbers at daytime feeding and loafing sites, night roosts, and nesting areas, their distribution and connectivity among colonies have been difficult to determine because cormorants have been reported to forage up to 62 kilometers (38.5 miles) from nesting or nighttime roosts, and daily foraging patterns are dynamic, with colonies changing feeding sites in response to changes in fish availability.

The Department seeks to better understand the minimum abundance and distribution of both cormorant species, as well as connectivity among colonies, to assess potential impacts and to provide baseline information in the event that management actions such as cormorant removal are necessary. Department managers also seek to better understand the effects that cormorants have on fish populations, and the factors that put fish at risk. This may include size and species of fish, time of fish stocking, availability and characteristics of fish habitat, and other factors such as distance to roosts or other water bodies. This information can inform management options and decisions related to fish stocking practices, fish habitat enhancement, the use of cormorant deterrents, and possibly cormorant management.

Objectives

1. Determine the spatial distribution of primary cormorant colonies in Arizona, with a focus on locations of feeding and nesting sites used by primary colonies,
2. Determine the level of connectivity among primary cormorant colonies in Arizona,
3. Estimate minimum population size of each species at primary colonies in Arizona,
4. Estimate the composition of fish by species and size, and associated fish losses (e.g., pounds of fish), taken by primary cormorant colonies in Arizona,
5. Estimate fish losses (e.g., pounds of fish) from cormorant predation at community fishing program locations, and examine factors that influence the loss of fish to cormorants at these sites.
6. Based on the outcomes of objectives 1-5, recommend methods of reducing fish losses.
Project Location and Timeline
This study includes the entire state of Arizona, but some objectives are focused on areas where cormorants concentrate and may have the highest impact on fish. Objectives 1-4 and 6 will include all of Arizona, with an emphasis on areas of high concentration, and Objective 5 will focus on community fishing program waters in the Phoenix and Prescott areas. Field work will be conducted from winter 2017 through summer 2018.

Approach
Our study methodology includes three primary approaches and requires a large citizen science effort to accomplish each. In 2017, we employed volunteers and staff in the Phoenix metropolitan area and select waterbodies statewide to count both species of cormorants from 7am-12pm on January 21, March 18, May 13, and September 16. Together with counts in January and March 2018, we will have minimum population estimates in Arizona. We have been trapping and tagging a number of cormorants across Phoenix and public reports of tagged birds help us to characterize bird movements and look at connectivity of cormorant populations on the landscape. Volunteers and staff also observe cormorants foraging and document the size and shape of fish taken as prey at community fishing waters and select waters statewide. We will also collect habitat measurements and make observations to characterize various factors that may be altered to reduce cormorant predation on fish.

Current Project Status
In 2017, we successfully coordinated, trained, and deployed more than 100 citizen scientists to aid us in completing four quarterly counts statewide (see figure). We have also successfully trapped and tagged 4 double-crested (DCCO) and 24 neotropic (NECO) cormorants in the metro area. Observers have reported 48 sightings of tagged cormorants, with a few birds making significant movements from opposite corners of Phoenix and many being seen multiple times over several months. We have collected data on cormorant feeding habits and habitat measurements for community fishing ponds in the Phoenix metro area and other waters in the state.

For more information, please contact:
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An Evaluation of Feral Burro Impacts on Wildlife and Wildlife Habitat

Background
Wild burros (*Equus asinus*) were brought from arid reaches in north Africa to the Southwest in the sixteenth century by Spanish explorers, where they quickly became a popular pack animal, particularly in mining operations. In the late 1800s, when mining activities declined, many burros were either set free or escaped and became feral. Burro populations have increased extensively in size and distribution since their introduction to the Southwest. Burros are managed federally under the 1971 Wild Free-Roaming Horse and Burro Act. The Act requires the Federal government to manage burros in a “thriving natural ecological balance” on public lands. Areas inhabited by burros at the time of passage of the Act were administratively designated as Herd Areas (HAs) by the Bureau of Land Management (BLM). The BLM further designated as Herd Management Areas (HMAs) those HAs in which burros could be managed at Appropriate Management Levels (AMLs). AMLs are defined as the number of burros (or horses) which can graze without causing damage to the range. Today, burro numbers exceed AMLs in most HMAs, leading to concern that high densities of burros are having negative effects on the natural environment and native wildlife. As there is no single definition of a “thriving natural ecological balance”, and this condition has been evaluated in a number of ways, a standardized threshold defining where the balance tips is lacking. Thus, empirical and robust data documenting potential effects of feral burros on wildlife and habitats is needed to guide management decisions.

Objectives
1. Estimate the number of burros in each study area.
2. Assess, describe, and quantify the effect of burros on habitat, focusing on vegetation impacts, with particular emphasis on reduction in range resources and loss of thriving ecological balance through changes in plant community structure, physical plant structure, loss of age classes, or reduced plant recruitment. Where comparable water resources are available, we will also include measures such as water turbidity, water temperature, and presence of benthic macroinvertebrates.
3. Assess, describe, and quantify the effect of burros on wildlife, focusing on changes in species composition and, when feasible, age structure and recruitment. Our assessment will focus on birds, herpetofauna, and small mammals, but will also include large mammals based on sign. A wide suite of species will be included to assess potential effects across the broad ecological environment.
4. Using data collected while addressing the above objectives, assess whether burros have affected the thriving natural ecological balance and, as feasible, evaluate potential effects on threatened and endangered species.
5. Develop a long-term monitoring protocol, incorporating experimental exclosures, for assessing the effects of burros in selected habitats. This will include recommendations for siting, development, and monitoring of exclosures.

**Project Location and Timeline**
Objectives 1-4 will be addressed at two study sites: the Havasu HMA and the Lake Pleasant HMA, each buffered by 15 miles. At the Havasu HMA, our study site will only include areas within Arizona. The protocol to be developed in Objective 5 may include additional areas in Arizona based on locations of biological resources, ability to obtain landowner approval, and access for long-term monitoring. This project will collect field data through June 2019, and we anticipate finalizing analyses and manuscripts by the end of December 2019.

**Approach**
To address Objective 1, we conducted aerial surveys to estimate burro abundance in each study site using established Department protocols for big game species and adopted by the BLM and the US Geological Survey for estimation of burros. To address Objectives 2-4, we are evaluating and quantifying the potential effects of feral burros by identifying areas with high and low (or no known) occurrence of burros and comparing characteristics of wildlife and wildlife habitat in each of these areas. Our assessment will be based on data from birds, mammals, herpetofauna, vegetation, and a limited set of measures on water resources. Our measures of interest for wildlife taxa will be species diversity, age composition and, for some species, relative abundance. Our measures of interest for vegetation will include species diversity, age composition, ground cover/plant density, and physical plant structure, while our measures of interest related to water resources will be stream (or spring) morphology, water turbidity and water temperature. To address Objective 5, we will develop a long-term and site-specific framework for monitoring the effects of burros using an experimental approach, possibly via established monitoring plots in an exclosure and in an adjacent matched unfenced area.

**Current Project Status**
We conducted aerial surveys for burros in March (Havasu HMA) and June 2017 (Lake Pleasant HMA) to estimate burro abundance at each site. Using all available burro occurrence data, we stratified our study areas into areas of low versus high burro occurrence, distance to perennial water, and primary vegetation types, and then randomly selected multiple 1-km² sampling plots in each stratum over which to conduct surveys. We initiated a pilot trial of bat detectors in early August 2017, conducted the first set of visual surveys for herpetofauna in fall 2017, and initiated small mammal trapping in 2017.

**For more information, please contact:**
Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov
Esther Rubin, Research Branch Chief, erubin@azgfd.gov
Biometrics: Current Projects

The Research Branch biometrician assisted research staff on the preceding projects, but also provided statistical support on other Department projects, such as:

- Virtual population analyses of harvest data to estimate abundance of bears and mountain lions in Arizona.
- Multinomial logistic regression and agglomerative clustering analysis of morphometric data to assess morphological differences among purported chub species in the Gila River basin.
- Estimating humpback chub migration rates in the Colorado River.
- Estimate survival and harvest rates of turkeys in northern Arizona using nest survival models.
- Developed hierarchical mark-recapture-distance-sampling-N-mixture model to estimating abundance of grouped animals.
- Estimate the effect of Parvo and Distemper on survival of Mexican gray wolves using mixed-effects logistic regression.

For more information, please contact:
Matt Clement, mclement@azgfd.gov
Esther Rubin, erubin@azgfd.gov
Information Transfer


Published Journal Articles


Book Chapters


Popular Articles


Technical Reports, Proceedings, and Unpublished Final Reports


Yarborough, R. F. 2013. Wildlife responses to restoration treatments in northern Arizona forests habitats. Unpublished report to Ecological Institute, Northern Arizona University. Research Branch, Arizona Game and Fish Department, Phoenix, AZ.

Justice-Allen, A., and A. C. Knox. 2014. The prevalence of pigeon paramyxovirus 1 and 
Trichomonas gallinae in band-tailed pigeons (Patagioenas fasciata), mourning doves
(Zenaida macroura), and white-winged doves (Zenaida asiatica). Final Report. US Fish
and Wildlife Service.

(Gila robusta) and headwater chub (Gila nigra) in the Lower Colorado River
Basin. Technical Guidance Bulletin No. 14 submitted to the Arizona Game and Fish
Department, Phoenix, Arizona. 130 pp.

Osterhoudt, R.O., and D.L. Rogowski. 2014. Little Colorado River Fish Monitoring in the
Monitoring and Research Center, Flagstaff, AZ.

and Research Center, Flagstaff, AZ.

Rogowski, D.L., and P.W. Wolters. 2014. Colorado River Fish Monitoring in Grand Canyon,
Research Center, Flagstaff, AZ.

Thinning Treatments on black Bear Habitat Use at the White Mountains Wildland-Urban
Interface. Arizona Game and Fish Department Technical Guidance Bulletin 16, Phoenix,
Arizona, USA.

Rogowski, D. L. and W. T. Stewart. 2015. Assessment of In-Lake Fisheries as related to Alamo
Dam and Reservoir. Final report submitted to the US Fish and Wildlife Service,
Albuquerque, New Mexico, by Arizona Game and Fish Department, Phoenix, Arizona.
18 p.

Stewart, W. T., N.L. Eiden, and J.D Olden. 2015. A Landscape Approach to Fisheries Database
Compilation and Predictive Modeling. Final Report submitted to the Bureau of
Reclamation, Denver, Colorado, by Arizona Game and Fish Department, Phoenix,
Arizona 68p.

Media Outreach in 2017

Harding, L. E., “takeover” of AZGFD Facebook Page; several formal and informal postings on
biologist activities, cormorant research project, and Q/A with public followers. 27 July
2017.
External Presentations in 2017


Crabb, M., Bristow, K., Boe, S. 2017. Spatial and habitat selection response of black bears (Ursus americanus) to the Wallow Fire wildfire in the White Mountains of Arizona. Biennial Conference of Science and Management on the Colorado Plateau and Southwest Region, Flagstaff, AZ. 11-14 September 2017.


Research Seminar Series

Better known as the ‘Science and Sweets Seminars’, this seminar series is hosted by the Research Branch once per month, with the goal of sharing information with others in the Department. The following talks, presented in 2017, represent projects conducted by the Research Branch, WMD colleagues and conservation partners.

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<th>Month</th>
<th>Title</th>
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<td>January 2017</td>
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<td>February 2017</td>
<td>One + One Makes Three: Hybridization in Razorback and Flannelmouth Suckers</td>
<td>Pilar Wolters</td>
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<td>March 2017</td>
<td>Little Pigs with Bad Bugs: Intestinal Infections in urban Javelina</td>
<td>Anne Justice-Allen</td>
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<td>April 2017</td>
<td>Home on the Range: Clarifying historical range of the Mexican wolf to aid recovery</td>
<td>Jim Heffelfinger</td>
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<td>May 2017</td>
<td>Eyes in the Skies: Evaluation of a small Unmanned Aircraft System for Big Game Survey</td>
<td>Robert L. Turner</td>
<td>Northern Arizona University</td>
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<td>June 2017</td>
<td>Something’s Moving in the Water! Charting a course for fish in watershed management planning</td>
<td>Nicole Eiden and Haley Nelson</td>
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<td>August 2017</td>
<td>Fates Unknown: Survival, Movements, habitat and species associations of juvenile Burbot in a tributary of the Kootenai River</td>
<td>Zach Beard</td>
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<td>September 2017</td>
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<td>October 2017</td>
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<tr>
<td>November 2017</td>
<td>What’s He Doing Over There? Behavioral responses of desert bighorn sheep to recreation and urban visitor use in the Pusch Ridge Wilderness Area</td>
<td>Bret Blum</td>
<td>University of Arizona</td>
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<td>December 2017</td>
<td>Model Me This: Relationships between species distribution models, expert opinion models, and measures of habitat quality for desert bighorn sheep in Arizona</td>
<td>Andrew Jones</td>
<td>Research Branch</td>
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Training Provided by the Research Branch to other Department Staff or Coordinated by the Research Branch

- Introduction to Fisheries Techniques
- Fish Identification
- Biopolitics
- Ethics
- 4x4 and Trailer Training
- Volunteer Training for Cormorant Impacts Study surveys
Interns Mentored During 2017

The Research Branch provided learning opportunities for the following students who assisted with the indicated projects:

- Jeremey Zelko, Northern Arizona University, Efficacy of Commercial-scale Propagation of Native Baitfish in Arizona, An Evaluation of Feed Type to Improve Growth and Survival of Hatchery-Reared Trout.
- Daniel Pasminski, Arizona State University, Lees Ferry Monitoring, ARCC O&M.
- Caitlin Gray, Arizona State University, An assessment of Arizona's cormorant populations, their impacts on fish, and potential management strategies to reduce impacts.
- Kenneth Peterson, Arizona State University, An assessment of Arizona's cormorant populations, their impacts on fish, and potential management strategies to reduce impacts.
- Kari Herbstreit, University of Arizona, Bighorn sheep and mountain lions: a study to better understand their relationships and guide management decisions.
- Edward Cini, Arizona State University, Bighorn sheep and mountain lions: a study to better understand their relationships and guide management decisions.
- Gabrielle Allgood, Northern Arizona University, Bighorn sheep and mountain lions: a study to better understand their relationships and guide management decisions (intern stayed less than 1 month).
Funding Sources

Fiscal Year 2017 Funding Sources

Contracts and Grants include:

- US Bureau of Reclamation
- US Geological Survey
- National Fish and Wildlife Foundation
- Arizona Habitat Partnership Comm.
- Safari Club International Foundation
- The Department of the Army