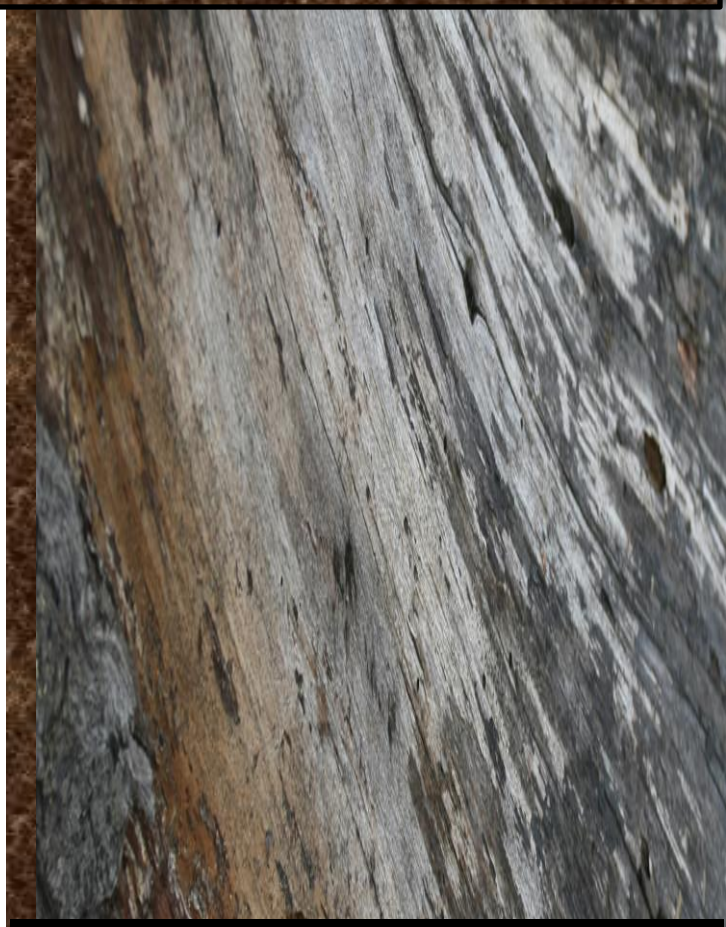
Spring 2019

Research Branch Annual Update



Research Branch

Arizona Game and Fish Department

Spring 2019

(For work completed during 2018)

Table of Contents

Research Branch Mission, Vision, and FY19 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 2019 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

Amber Aram
Administrative Assistant II

Aquatic Research Program

Ryan Mann, MS	Program Manager
Dave Rogowski, PhD	Wildlife Specialist Regional Supervisor
Kristopher Stahr, MS	Wildlife Specialist III
Devon Oliver, MS	Wildlife Specialist II
Jan Boyer, MS	Wildlife Specialist II
Zachary Beard, MS	Wildlife Specialist II
Joshua Walters	Fish Hatchery Manager I
Pilar Wolters, MS	Wildlife Specialist I
Hannah Smith	Fish Culturist I
Lorraine Avenetti	Wildlife Technician
Sam Simmons	Wildlife Technician

Terrestrial Research Program

Larisa Harding, PhD	Program Manager
Kirby Bristow, MS	Wildlife Specialist II
Jacob Mesler, MS	Wildlife Specialist I
Michelle Crabb, MS	Wildlife Technician
Brianna Russo	Wildlife Technician
(vacant)	Wildlife Technician

Biometrics Program

Matt Clement, PhD	Biometrician

Aquatic Research Program: Current Projects

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

Background

The 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 was extended to March 2019.

Approach

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.

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, terminal tackle, the number of anglers on the stream, and the size of the group an angler was fishing with 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. Futhermore, anglers were generally more satisfied with their fishing experiences when there were more anglers on the stream, and they were fishing in large groups. Hurdle models indicated that days post stocking, number of trout stocked per km, terminal tackle type, and the species of trout stocked were the most important factors influencing angler catch rates. The number of days post stocking was more important to the probability of catching at least one trout, while the number of trout stocked per km was more important for angler catch of stockers (i.e., Rainbow and Apache Trout) per unit effort. 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. Rainbow Trout were sampled on two separate occasions from the East Verde River (EVR) and one occasion from Tonto Creek (TC). Sampled Rainbow Trout had been in stream for either one day, one week, two weeks, three weeks, or four weeks at the time of sampling (hereafter referred to as duration). Mixed Effects linear and generalized linear models were used to compare differences, in the amount of materials consumed by Rainbow Trout, W_R of Rainbow Trout, and diet composition of Rainbow Trout across durations. One hundred and seventy-five diet samples were collected from Rainbow Trout. Diet samples contained 17 different invertebrate taxa; Ephemeroptera was the most prevalent taxa found in diet samples followed by Hymenoptera and Trichoptera. Only Rainbow Trout with a two week duration consumed significantly more digestible materials. Mean non-digestible materials consumed by Rainbow Trout did not differ significantly across durations. Mean relative weights were only significantly lower for Rainbow Trout with a three week duration. Rainbow Trout diet composition did not differ across durations. Rainbow transitioned to natural prey items within 1 day of stocking, but may not be consuming enough to sustain themselves for long periods of time (i.e., > 1 month).

A final report will be completed in 2019. Included in this report will be results from three peer reviewed manuscripts.

For more information, please contact:

Zachary Beard, Wildlife Specialist 2, zbeard@azgfd.gov
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 angler's 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 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 initiated a study to evaluate three different types of feed (Rangen®, BioOregon®, and BioOregon® with probiotics) and 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 mortality and growth of hatchery-reared rainbow trout for up to 9 weeks post-swim up in indoor raceways.
2. Evaluate the effect of feed type on mortality of hatchery-reared rainbow trout upon being moved from indoor raceways to outdoor raceways.

Project Location and Timeline

This study takes place at the Department's Sterling Springs Hatchery, Tonto Creek Hatchery, and Canyon Creek Hatchery. Data collection for this project was initiated in late 2016 and was completed in 2018.

Approach

For Objective 1, this study was conducted at all three hatcheries identified above. Indoor raceways were randomly divided among feed types. Mortality, number of fish in a tank at the start of the week, and total amount of feed fed per fish (total feed/# of fish in tank) were recorded weekly. Three subsamples of 50 fish were randomly sampled and weighed weekly for the 9-weeks. Individual fish weight was calculated as the total sub-sample weight divided by the number of fish in the sub-sample

To meet Objective 1:

- Weekly mortality was evaluated using Random Forest regression.

- Differences in estimated weight of fish were evaluated using a generalized linear mixed effects model (Gamma distribution, Log Link) accounting for amount of food fed

For the Objective 2, 25 fish per sub-sample were measured weekly for a six week period. Individual fish weight was calculated as the total sub-sample weight divided by the number of fish in the sub-sample. Mortality, number of fish in a tank at the start of the week, and total amount of feed fed per fish (total feed/# of fish in tank) were recorded weekly. Mortality will be evaluated using the same methodology as in the first objective.

Current Project Status

We conducted a total of 21 trials (11 indoor and 10 outdoor) across the three hatcheries. Results indicate that feed type was not an important driver of weekly mortality rate for indoor trials. However, the factors associated with tank density levels (fish size and number in tank) were likely the main driver in reduced survival. Furthermore, keeping the number of Rainbow Trout in a tank below 50,000 fish and achieving a mean size of 0.7 grams at a faster rate could improve survival of fish in indoor tanks. For outdoor trials, preliminary results indicate that feed type was also not an important driver of weekly mortality.

BioOregon® with probiotics produces a statistically larger fish on average. However, whether or not this difference is biologically meaningful has yet to be determined. Preliminary results for outdoor trials illustrate a similar pattern. The use of BioOregon® with probiotics may reduce the time needed for Rainbow Trout to reach a mean size of 0.7 grams. Results from this project will help hatchery staff to make informed decisions related to feed performance and aide in improving hatchery survival of young Rainbow Trout.

For more information, please contact:

Devon C. Oliver, Wildlife Specialist 2, doliver@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

Efficacy of Commercial-scale Propagation of Native Baitfish in Arizona

Background

Live baitfishing 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 (all of which are not 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 species that do not possess the same degree of ecological risk to fish populations. Therefore, the Research Branch was asked to initiate 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. Data collection for this project was initiated in late 2016 and scheduled was completed in 2018.

Approach

Longfin Dace and Sonora Suckers were collected from the wild and transported to Bubbling Ponds Hatchery and the ARCC. Fish were 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 investigated and evaluated several methods for propagation and rearing with the eventual goal of providing a set of optimal conditions for the culture of these species. Finally, we evaluated 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

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 2 years in a row. Therefore in 2018 we decided to focus our efforts on streamside spawning and bringing fertilized eggs back to ARCC. We obtained ~ 38,000 eggs via streamside spawning in hopes that

they could be raised as potential broodstock for future use. However, survival rate to hatch was low and 100% mortality of fry was observed within the first few weeks.

In November of 2017 in an attempt to determine the suitability for native baitfish to be raised and/or spawned in a pond environment, we collected 232 mature Longfin Dace and 84 Mature Sonora suckers and placed them in two cooperative research ponds located on the Valle Vista golf course in Kingman, AZ. We aimed to determine from these populations if Longfin Dace and Sonnora Suckers could spawn naturally in a production pond environment. The production ponds were reevaluated ~ 1 year later in November of 2018. To date there is no evidence of Sonora Sucker recruitment or spawning activity. However, there was approximately a 21X increase in Longfin Dace population from 232 to 5,048 individuals, indicating both spawning activity and recruit is occurring.

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 this research has been submitted and accepted for publication in a regional journal:

Mower, E. and L. Avenetti. 2019. A comparison of live-hooked persistence time between non-native and native baitfish in Arizona. Journal of the Arizona-Nevada Academy of Science. In Press.

Longfin Dace is likely a viable native baitfish candidate based on the highly successful pond propagation and the similarity in time-to-mortality relative to that of non-native Fathead Minnow. Propagation of Longfin Dace to meet the demand for small bodied baitfish could likely be done with a small commercial pond production facility. It is unlikely that we could produce enough Sonora Suckers to replace non-native bait fish. Thus, it is currently not a viable solution without further refinement of culture techniques.

For more information, please contact:

Devon C. Oliver, Wildlife Specialist 2, doliver@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

Managing for the Blue Ribbon Rainbow Trout Fishery at Lees Ferry

Background

The recreationally and economically important blue-ribbon Rainbow Trout fishery at Lees Ferry is a key resource of the Colorado River in Glen Canyon. This cold, clear, tailwater was created by the impoundment of Lake Powell in 1963. The same year, the Department stocked Rainbow Trout and began managing this reach as a blue ribbon trout fishery. Stocking ended in 1998 when natural reproduction was sufficient to maintain the population, although stocking non-reproductive trout has been maintained as an option if angler catch rates drop.

Objectives

The Department began a long-term electrofishing monitoring program in 1991, 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, we conduct angler (creel) surveys year-round to provide information on angler effort, harvest, and satisfaction; 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. It is a long term monitoring project that has been ongoing since 1991.

Approach

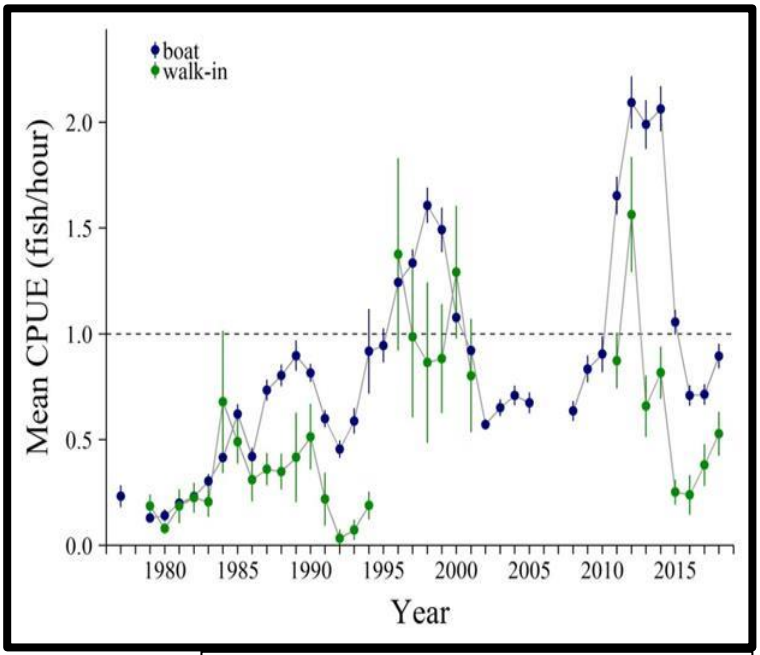
- Conduct standardized boat electrofishing surveys two to three times a year (spring, summer, fall) to monitor the Rainbow Trout population. In 2018 the spring trip was cancelled due to budget constraints
    - Sample 36-40 sites, using a stratified random design, over three nights in three sections of river for each trip
- Conduct targeted electrofishing surveys in habitat likely to hold warmwater nonnative fish in order to provide early detection of population increases or new invasions by warmwater predators
- Perform standardized angler (creel) surveys to monitor fishing metrics

Current Project Status

In 2018, we conducted two electrofishing sampling trips in the summer and fall, sampling 80 sites in total, with 38, and 39 sites sampled each season, respectively. Rainbow trout dominated the fish assemblage comprising 98.3 % of fish captured. Brown Trout comprised only 1.38% of the fish assemblage, similar to last year, and there was little recruitment of Brown Trout compared to 2015 and 2016. Rainbow Trout mean catch-per-unit-effort (CPUE) across seasons was 4.15 fish/minute, 95% CI [3.57, 4.73], similar to last year. We saw fewer young of the year fish this year, with approximately 59.9% of the Rainbow Trout collected during fall sampling below 152 mm (6 inches), with a CPUE of 2.51 fish/minute [1.98, 3.04]. We saw an increase in small catchable fish

(152-305 mm, 6-12 inches). Condition of Rainbow Trout was good, with $K_n > 1.0$ (management goal) observed in summer for all size classes. One night during each electrofishing trip was dedicated to capturing rare nonnative fishes. Rare nonnative fish captured included 51 Brown Trout, 69 Common Carp, 1 Smallmouth Bass, and 2 Green Sunfish. The warmwater nonnatives were primarily captured at a large backwater area referred to as the slough (river mile -12.0). As in most years no rare nonnative fish were reported in our angler surveys.

Angler surveys were conducted on 72 days in 2018. A total of 1,012 boat and 313 walk-in anglers were interviewed. Boat anglers reported a total of 6,495 Rainbow Trout being caught with an average CPUE of 0.89 fish/hr [0.84, 0.95], which is higher than last year (0.71 fish/hour [0.66, 0.76]). Walk-in anglers reported 634 Rainbow Trout caught with a mean annual CPUE of 0.53 fish/hr [0.42, 0.63]. Angler catches are lower than the management goal of 1.0 fish/hr. Consequently AGFD stocked catchable sterile Rainbow Trout (*n* = 526) at Lees Ferry for the first time since 1997.



Rainbow Trout catch per unit effort for anglers interviewed in AGFD angler surveys at the Lees Ferry fishery on the Colorado River

Fishing satisfaction (scale of 1 – 5) was similar to 2017 for boat anglers (2018: 3.67 [3.57, 3.75], 2017: 3.58) but increased in 2018 for walk-in anglers (2018: 3.71 [3.56, 3.86), 2017: 3.30)

Most anglers at Lees Ferry catch and release fish; harvest rates have dropped since angler surveys began in 1977. Of anglers interviewed that caught at least one fish, only 12.4% harvested a fish, 87.6% of anglers released every fish they caught.

Experimental dam releases (steady low flows on weekends May-August), meant to improve aquatic invertebrate survival, benefitted anglers; catch rates were significantly higher on weekends with bug flows. Anglers reported being able to better fish the river at lower steady flows, compared to high water or when water levels were increasing or decreasing.

We have submitted an annual report on our 2018 monitoring to USGS-Grand Canyon Monitoring and Research Center:

Boyer, J.K., Rogowski, D.L. 2019. Status of the Lees Ferry Trout Fishery 2017 Annual Report. Submitted to: Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

For more information please contact:

David Rogowski, Wildlife Specialist Regional Supervisor, drogowski@azgfd.gov
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 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). This information helps us understand mechanisms controlling fish population dynamics, determine effects of dam operations, and identify threats presented by nonnative 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 species distribution and the composition of the fish assemblage.

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 from Lees Ferry to Pearce Ferry (281 river miles), one fall trip from Diamond Creek to Pearce Ferry (55 river miles), and 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 400-600 sites, and hoop nets at 250-500 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.

Current Project Status

In 2018, we conducted two 12-night spring trips (5 – 18 April and 26 April – 6 May) between Lees Ferry (River Mile 0) and Pearce Ferry Rapid (RM 281.6), and a four day sampling trip between Diamond Creek (RM 226) and Pearce Ferry Rapid (27 Sept. – 1 Oct.), and a three night trip downstream of Pearce Ferry Rapid (23-26 Oct.). We electrofished 445 sites, and set hoop nets at 334 sites. We captured 3,918 fish with electrofishing and 2,408 fish with hoop netting.

Native fish accounted for 83% of the 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. More juvenile fish were captured as we moved downstream, suggesting that the Western Grand Canyon provides important spawning and juvenile rearing habitat for native fish. Humpback Chub were relatively common near the Little Colorado River Confluence and downstream of RM 190 in the Western Grand Canyon. 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. Captures of young of the year Humpback Chub as well as a ripe female (at river mile 195.4) suggest that Humpback Chub are reproducing in the mainstem Western Colorado River. We captured one other endangered species, a wild untagged Razorback Sucker captured at river mile 243. Razorback Suckers are rare and we are lucky to capture one a year. The only wild population (unsupported by stocking) occurs in Lake Mead and the Colorado River above Lake Mead.

We submitted an annual report on our 2018 monitoring to USGS-Grand Canyon Monitoring and Research Center, and have a published manuscript from this project.

Rogowski, D.L. and Boyer, J. K. 2019. Colorado River Fish Monitoring in the Grand Canyon, Arizona—2018 Annual Report. Submitted to: Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Rogowski, D.L., R.J. Osterhoudt, H.E. Mohn, J.K. Boyer. 2018. Humpback Chub (*Gila cypha*) Range Expansion in the Western Grand Canyon. Western North American Naturalist 78(1) Article 4.

For more information please contact:

David Rogowski, Wildlife Specialist Regional Supervisor, drogowski@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

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 (*Xyrauchen texanus*) 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 (*Catostomus latipinnis*), 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

1. Evaluate egg viability, juvenile survival and swimming ability of hybrid Razorback Sucker and Flannelmouth Sucker.
2. Quantify meristics and analyze shape of Flannelmouth/Razorback hybrids and develop tools for field identification of young hybrids.
3. Continue meristic counts and shape analyses of hybrid Razorback and Flannelmouth suckers as they develop adult characteristics.
4. Determine the potential for gene introgression by evaluating egg viability and juvenile survival of laboratory backcrosses and second generation Razorback/Flannelmouth hybrids.
5. 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 a grant from the Bureau of Reclamation. Most of this work is being conducted in laboratories using offspring produced from hatchery Razorback Sucker and wild Flannelmouth Sucker collected 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. Adult Razorback and Flannelmouth suckers were artificially spawned to make four types of progeny: Razorback Sucker, Flannelmouth Sucker, Razorback female *x* Flannelmouth male hybrid, and Flannelmouth female *x* Razorback male hybrid. Hatching success, survival, as well as meristic and morphometric (shape) analyses were conducted on the progeny (objectives 1-2 have been completed). The

resulting offspring will be used for competition experiments, swim trial studies, and backcrossing experiments.

Current Project Status

Flannelmouth Suckers are the most common fish species in the Colorado River within the Grand Canyon, while Razorback Suckers are very rare. Ongoing experiments are an attempt to examine various hypotheses about why Razorback Suckers are so rare. Could it be related to competition with Flannelmouth Suckers and the current temperature regime? Or perhaps is it related to differences in physiology?

We recently completed a laboratory study investigating competition between Flannelmouth Suckers and Razorback Suckers at different temperatures and food rations (high and low). We measured growth at a temperature similar to current Colorado River conditions (15° C) and at temperature more similar to historic conditions (20° C). Preliminary results suggest that competition at these two temperatures for fish of this size (32mm ±0.65) is probably not the constraining factor for Razorback Recruitment. Limitation in Razorback Recruitment likely occurs before wild fish reach ~30 mm in length.

A second experiment is been conducted to examine how these two species and their hybrids differ in physiology. We are using a swim flume to determine critical swimming speed of both species and their hybrids. Preliminary results reveal the Flannelmouth Suckers have a higher critical swimming speed then Razorback Suckers. Hybrids were intermediate, with swimming ability more consistent with their paternal species. Our results are consistent with Razorback Suckers being more common in Lake Mead and Flannelmouth Suckers more common in the Colorado River. Based on these results the physiology of Flannelmouth Suckers appears to be better adapted to flowing water than Razorback Suckers.

For more information please contact:

Pilar Wolters, Wildlife Specialist 1, pwolters@azgfd.gov
David Rogowski, Wildlife Specialist Regional Supervisor, drogowski@azgfd.gov

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 the overall project will continue 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 began in April 2018.

For more information please contact:
Kristopher Stahr, Wildlife Specialist 3, kstahr@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

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 fishes. These fish are held as a refuge against possible extinction in the wild and propagated to 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 distinct genetic lineages of Spikedace, four lineages of Loach Minnow, one lineage of Roundtail Chub, and 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 18 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 systems 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 research projects are focused on determining optimal spawning methods for Spikedace and Loach Minnow and the feasibility of tagging these fishes to aide in both hatchery broodstock management and repatriation efforts.

Current Project Status

The ARCC is two years removed from a facility renovation designed to increase the holding and spawning capability of fishes held on station. This past year a broodstock density study was conducted to determine the optimal number of spawning adults to maximize larval production. We found the lowest density to be the most successful, and the study resulted in the highest Spikedace and Loach Minnow larval production in the facility's history. In the upcoming year further experiments will examine other potentially important factors to ensure continued success for Loach Minnow and Spikedace propagation.

For more information please contact:

Joshua Walters, Hatchery Manager 1, jwalters@azgfd.gov
Kristopher Stahr, Wildlife Specialist 3, kstahr@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

Return to Creel and Movement of Catchable-Size Hatchery-Reared Gila Trout

Background

The Department is considering opportunistically stocking Gila Trout *Oncorhynchus gilae*, a native trout species, for recreational opportunities in streams throughout their historical range that are currently stocked with Rainbow Trout *Oncorhynchus mykiss*. Switching from Rainbow Trout stocking to Gila Trout stocking provides a potential "win-win" for the Department, as it could provide a popular sport fishery for anglers, while promoting the conservation of a native species. However, little is known about how a switch to Gila Trout may affect Arizona's stream trout fisheries (i.e., angler catch rates, return to creel rates, and angler satisfaction). To understand what impacts this change may have on the economically and culturally important stream trout fisheries present in that range, information is needed regarding return to creel of Gila Trout, angler satisfaction, angler catch rates, and movement of Gila Trout. This project will provide insight into the differences between Rainbow and Gila Trout fisheries, as well as differences in behavior between Rainbow and Gila Trout. This information will give the Department the ability to make a science-based management decision regarding the switch to Gila Trout.

Objectives

- Evaluate the return to creel of catchable-size Gila Trout, angler satisfaction, and angler catch rates.
- Evaluate the movement of catchable-size Gila Trout.
- Evaluate the suitability of Gila Trout as an alternative to Rainbow Trout in Arizona's stream trout fisheries in its native range.

Project Location and Timeline

Our two study streams (East Verde River and Tonto Creek) for this project are located along the Mogollon Rim outside of Payson, AZ. This project was to be initiated in 2018, but due to slower than anticipated growth of Gila Trout in the hatchery and other complications, it was delayed until 2019 and is expected to run through 2021.

Approach

Gila Trout will only be stocked in the East Verde River, while Tonto Creek will be stocked with Rainbow Trout as a control. Gila Trout will be stocked in the same numbers as are typically used for Rainbow Trout in both study streams. This project will consist of two major components. The first component will consist of creel surveys 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 Gila Trout and Rainbow Trout fisheries. Radio telemetry techniques will be used to provide specific information about the persistence, movement, and mortality of Gila Trout stocked in the East Verde River. This information will be used to compare

Gila Trout and Rainbow Trout fisheries and assess the suitability of Gila Trout as an alternative to Rainbow Trout throughout their historic range.

Current Project Status

Currently, the project is delayed, primarily due to timing of when Gila Trout eggs become available and the slower than anticipated growth of Gila Trout in the hatchery. However, we have learned much about the use of Gila Trout as an alternative to Rainbow Trout for Arizona's put-and-take stream trout fisheries. For example, it is now clear that Gila Trout will need to be on a two year production schedule to reach catchable size. We have also learned much about culture techniques that improve the growth and survival of Gila Trout in the hatchery (e.g., the use of circular tanks, automatic feeders, minimal interaction). In summer 2019, we will stock 60 radio-tagged Gila Trout in the East Verde River at two events. The first event will happen at the end of June or early July, and the second event will be at the end of August. Thirty radio-tagged Gila Trout will be stocked at each of these events. Immediately after each stocking event, radio tagged trout will be monitored daily for 10 days using mobile radio antennas. After the first 10 days radio tagged trout will be monitored once per week using mobile radio antennas until the fish is confirmed to be dead or two consecutive weeks of monitoring indicates the radio tagged fish is no longer present. When an individual radio-tagged Gila Trout is located we will attempt to determine the fate of the trout (e.g., alive, dead), GPS coordinates will be recorded, and the macrohabitat (i.e., pool, riffle, run) will be recorded. The information collected this summer will provide preliminary information about the movement and persistence of catchable-size Gila Trout released in Arizona Streams. During the summer of 2020, the East Verde River will be stocked solely with catchable-size Gila Trout and both the creel component and radio telemetry components of the project will be implemented.

For more information, please contact:

Zachary Beard, Wildlife Specialist 2, zbeard@azgfd.gov
Ryan Mann, Aquatic Research Program Manager, rmann@azgfd.gov

Terrestrial Research Program: Current Projects

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

Background


Photo: Sally King (NPS)

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 catastrophic 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, while 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*) 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 sought 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 was 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 occur 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-km^2 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

This project has been finalized. Field work was completed in 2016 with contracted help from the Wildlife Contracts branch after our lead biologist moved out of state with another job. Wildlife Contracts staff finalized contractual agreements with a report detailing the results of the project late in 2017. Research staff then prepared and submitted a manuscript for external peer review and publication in *Wildlife Society Bulletin* in June 2018. We also sent the draft manuscript to AGFD Region 2 habitat personnel in 2018 to help inform some collaborative efforts for 4FRI actions in the Region. We received reviewer comments back in late October 2018 and are evaluating the reviews to determine our next steps with the manuscript.

For more information, please contact:

Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov

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 Department, 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. Department biologists in Region 2 collared 36 mule deer does in 2012-2013 to evaluate the efficacy of habitat improvement actions relative to deer habitat use on the winter range and to examine movements between winter and summer ranges to identify other priority areas for future treatments. In 2014, the Research Branch was asked to analyze the mule deer location data to address 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

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, the manuscript had some inherent limitations due to data constraints and we therefore did not proceed with submission for publication.

We wrote a second manuscript detailing the habitat selection of mule deer does on the west side of the Kaibab Plateau. 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. Results suggested 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. We submitted this manuscript for external peer review and publication in *The Western North American Naturalist*. Significant revisions were requested from reviewers, so we are now evaluating reviewer criticisms to plan a course of action for the manuscript.


Photo: Tom Koerner (USFWS)

For more information please contact:
Kirby Bristow, Wildlife Specialist II, kbristow@azgfd.gov
Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov

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 (as above) 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 and data deficiencies delayed final data preparation and analyses. Analyses for Objective 2 were finished in 2018. Additional data for Objective 1 were collected from USFS partners across Arizona and from the USFS Region 2 office; however, a lack of appropriate and necessary historical data layers and technical resources precluded completing Objective 1 as proposed.

Approach

To examine factors influencing contemporary aspen forest health in Arizona, we used available remote sensing products (Landsat) to identify specific aspen stands that have expanded, contracted, or remained unchanged (i.e., static). Detailed field data (e.g., ungulate presence via pellet counts, soil and plant community composition, environmental data, aspen sapling counts) were collected from these sites across the state to address contemporary aspen forest health.

Project Status

We prepared a manuscript for publication detailing the results of Objective 2. Interestingly, this analysis suggests that fire suppression, conifer encroachment, drought and disease all play more important roles in decreasing aspen recruitment than do wild ungulates in contemporary aspen stands in Arizona. However, that does not exclude the possibility that aspen recruitment may certainly be impacted heavily by ungulate browsing at a more localized scale. The manuscript has been through two rounds of reviews at *Forest Ecology and Management* and has just been accepted (in 2019) for publication.

For more information, please contact:

Matt Clement, Biometrician, mclement@azgfd.gov
Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov

A Framework for Estimating Elk Abundance in Arizona

Background

The Department has historically managed elk populations using relative indices from sex and age ratios observed on 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 seeks 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 the first survey year to take advantage of elk collared there as part of a project conducted by the Wildlife Contracts Branch. 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

This project is now completed. 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 km^2 in GMU 1 and documented ~910 elk. We flew 472 km^2 in 7E and counted ~460 elk. In 2014, we also surveyed 512 km^2 in GMU 3C and observed ~1050 elk. Survey results were similar in 2015 for GMU 7E, but we expanded the area flown in unit 1 to include 668 km^2 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 was submitted for publication in January 2018, and has recently (in early 2019) been published.

For more information, please contact:

Kirby Bristow, Wildlife Specialist II, kbristow@azgfd.gov
Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov

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.

Project Location and Timeline

This project was conducted at two sites in Arizona. Objectives 1- 3 were addressed in the Santa Catalina Mountains (SCM) in Region 5, while all objectives were addressed in the Arrastra Mountain Wilderness (AMW) in Region 3. The project began in November 2013 and finished 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 used GPS collar data to observe sheep behaviors and identify sheep use sites where we measured habitat characteristics, including horizontal visibility and topographical features. We used the data to evaluate which behavioral and habitat factors may influence bighorn sheep mortality. We also used GPS data to analyze home range characteristics and conduct habitat sampling to evaluate whether bighorn sheep selected 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 also collected on survival and cause-specific mortality. Finally, we used 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

This project is being finalized. Project field work has been completed, following collar drop-off at the AMW and SCM study sites, and completion of field work objectives. In total, we recorded horizontal visibility at 5,810 locations across the 2 study sites. Additionally, we recorded 809 observations of collared sheep at AMW and 1,230 observations at SCM. Currently, we have completed analyses addressing all objectives. We found that bighorn sheep generally selected habitat in accordance with presumed predator avoidance and reproductive strategies. Specifically, selection was positively related to ruggedness, slope, and decreased horizontal obstruction. Our mortality risk models showed that increased values of ruggedness, steeper slopes, and larger group size all decreased the risk of mortality due to lion predation. We are completing manuscripts detailing these findings and others. Our primary biologist spearheading these efforts promoted to another Department work unit in fall 2018, but he is continuing to work with us to complete the manuscript for submission.

At AMW, we attempted to trap all resident mountain lions, assuming there would be several. But we documented few lions on the landscape via observations and trail cameras set in strategic locations, and 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 279 mountain lion kill sites. Of note is the observation that one male primarily killed and consumed feral juvenile burros. Domestic calves also represent a significant dietary element, and we documented the lions eating mule deer, javelina, a few coyotes and bighorn sheep, and even a beaver (below Alamo Dam). We are preparing a manuscript detailing mountain lion prey composition in this study area.

For more information, please contact:

Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov
Jacob Mesler, Wildlife Specialist I, jmesler@azgfd.gov

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

Background

Arizona is home to 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 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 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 has been difficult to determine because they often move large distances, 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 to inform management decisions. 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

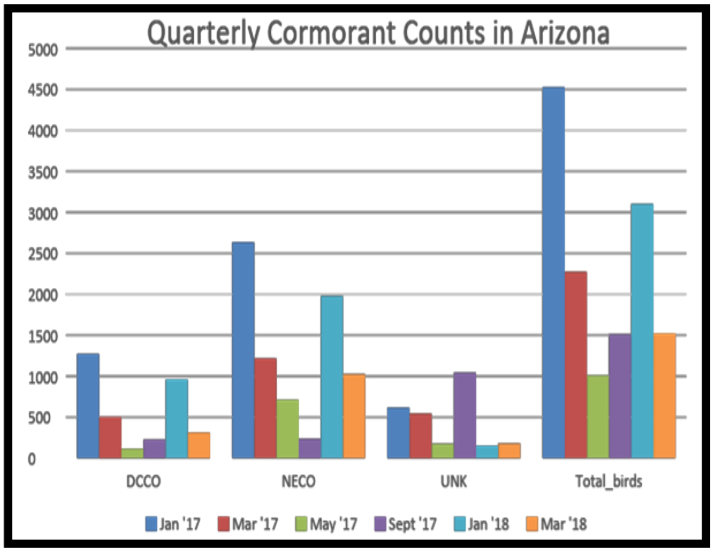
This study included the entire state of Arizona, but some objectives focused on areas where cormorants concentrated. Objectives 1–4 and 6 included all of Arizona, with an emphasis on areas

of high concentration, and Objective 5 focused on community fishing program waters primarily in the Phoenix metro area but also several waters statewide. The majority of our field work was conducted from winter 2017 through summer 2018.

Approach

In summary, our study methodology included three primary approaches and required a large citizen science effort. In 2017–2018, we employed volunteers and staff statewide to count both species of cormorants from 7am-12pm on 6 specified dates in January, March, May, and September. From those 6 quarterly counts, we estimated a minimum population estimate each season for cormorants in Arizona. We trapped and tagged cormorants to examine bird movements. Volunteers and staff conducted feeding observations to document the size and shape of fish taken as prey by cormorants at community fishing waters and select waters statewide. We also obtained a scientific collection permit from USFWS late in 2018 and contracted Wildlife Services (APHIS) to conduct lethal sampling of cormorants from January–March 2019 to sample stomach contents to inform objective 4. Additionally, at Community Fishing Program waters, we collected habitat measurements to characterize various a/biotic factors that may be altered to help reduce cormorant predation on fish.

Current Project Status



This project is being finalized. We successfully coordinated, trained, and deployed more than 100 citizen scientists to help with our quarterly counts and assist with feeding observations. We successfully trapped and tagged 4 double-crested (DCCO) and 24 neotropic (NECO) cormorants in the metro area. Observers reported 51 sightings of tagged cormorants, with a few birds moving from opposite corners of Phoenix and many being seen multiple times over several months. Volunteers and staff also conducted almost 7,000 feeding observation periods, of which more than 1,000 observations of feeding cormorants were documented. We are currently analyzing data and preparing a manuscript for publication.

For more information, please contact:

Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov

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.
3. Assess, describe, and quantify the effect of burros on wildlife, focusing on changes in species composition and, as 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. Where natural water sources are available, we will also include a survey of aquatic macroinvertebrates.
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 summer 2019, and we anticipate finalizing analyses and manuscripts by the end of 2019.

Approach

To address Objective 1, we conducted aerial surveys in 2017 to estimate burro abundance in each study site using established Department protocols for big game species and adopted by the Bureau of Land Management and the US Geological Survey for estimation of burros. To address Objectives 2-4, we stratified study sites into areas with high and low (or no known) occurrence of burros, and we are 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 aquatic macroinvertebrates. Our measures of interest for wildlife taxa is species diversity, age composition and, for some species, relative abundance. Our measures of interest for vegetation includes species diversity, age composition, ground cover/plant density, and physical plant structure. To address Objective 5, we will develop recommendations for a long-term and site-specific framework for monitoring the effects of burros, possibly using an experimental approach via established monitoring plots in an exclosure and in an adjacent matched unfenced area.

Current Project Status

In 2018, we completed vegetation surveys with 240 transects on 120 survey plots at the Havasu and Lake Pleasant study sites. We also conducted spring surveys for herpetofauna at approximately 120 plots and surveyed plots again as the monsoons arrived and continued. We contracted an outside contractor to complete point-count surveys for birds at 120 plots as well. We sampled several natural waters for aquatic macroinvertebrates in the summer and completed small mammal trapping grids at 28 plots on each study area in the late fall/early winter. After the first year of surveys, we conducted preliminary analyses and refined some of our methods to increase sample sizes for key datasets. We are continuing to collect data for this project.

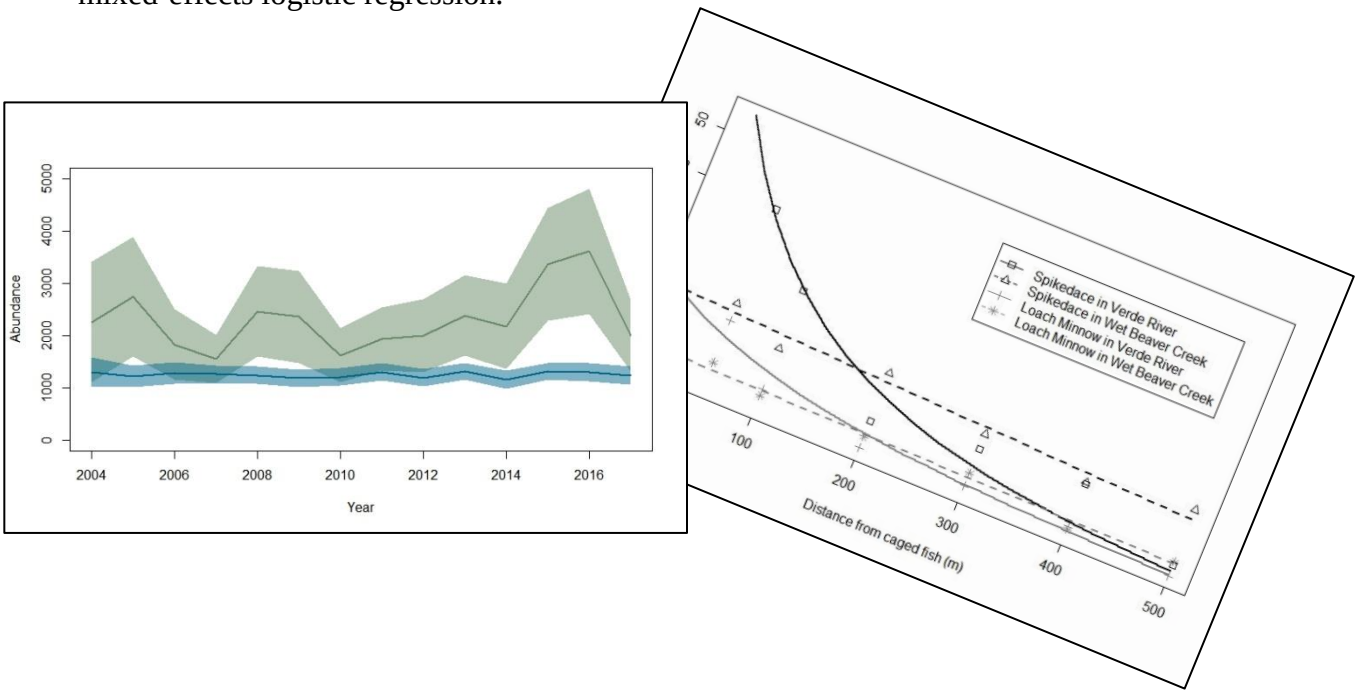
For more information, please contact:

Jacob Mesler, Wildlife Specialist I, jmesler@azgfd.gov
Larisa Harding, Terrestrial Research Program Manager, lharding@azgfd.gov
Esther Rubin, Research Branch Chief, erubin@azgfd.gov

Biometrics: Current Projects

During 2018, 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.
- Estimating survival and harvest rates of turkeys in northern Arizona using nest survival models.
- Developing hierarchical mark-recapture-distance-sampling-N-mixture model to estimating abundance of grouped animals.
- Estimating the effect of Parvo and Distemper on survival of Mexican gray wolves using mixed-effects logistic regression.



For more information, please contact:
Matt Clement, Biometrician, mclement@azgfd.gov
Esther Rubin, Research Branch Chief, erubin@azgfd.gov

Information Transfer

Recent Publications (2013-2018)

Published Journal Articles

Bair, L. S., **D. L Rogowski**, C. Neher. 2016. Economic value of angling on the Colorado River at Lees Ferry: using secondary data to estimate the influence of seasonality. North American Journal of Fisheries Management 36(6):1229-1239.

Beard, Z. S., M. C. Quist, R. S. Hardy, and T. J. Ross. 2017. Habitat associations of juvenile Burbot in a tributary of the Kootenai River. Transactions of the American Fisheries Society 146:1008-1015.

Beard, Z. S., M. C. Quist, R. S. Hardy, and T. J. Ross. 2017. Survival, movement, and distribution of juvenile Burbot in a tributary of the Kootenai River. North American Journal of Fisheries Management 37:1274-1288.

Beard, Z. S., M. C. Quist, R. S. Hardy, and T. J. Ross. 2018. Patterns in fish assemblage structure in a small western stream. Copeia 106:589-599.

Boyer, J. K., C. S. Guy, M. A. H. Webb, T. B. Horton, T. E. McMahon. 2017. Gear comparison for sampling age-0 Mountain Whitefish in the Madison River, Montana. North American Journal of Fisheries Management 37:189-195.

Boyer, J. K., C. S. Guy, M. A. H. Webb, T. B. Horton, T. E. McMahon. 2017. Reproductive ecology, spawning behavior, and juvenile distribution of mountain whitefish in the Madison River, Montana. Transactions of the American Fisheries Society 146:939-954.

Bunch, A. J., C. J. Walters, and L. G. Coggins, Jr. 2013. Measurement error in fish lengths: evaluation and management implications. Fisheries 38(7):320-326.

Carter, J. M., **M. J. Clement**, A. S. Makinster, C. D. Crowder, and B. T. Hickerson. 2018. Classification success of species within the Gila robusta complex using morphometric and meristic characters—a reexamination. Copeia 106(2):279-291. DOI: 10.1643/CG-17-614.

Clement, M. J. 2016. Designing occupancy studies when false-positive detections occur. Methods in Ecology and Evolution 7(12):1538-1547.

Clement, M. J., S. J. Converse, J. A. Royle. 2017. Accounting for imperfect detection of groups and individuals when estimating abundance. Ecology and Evolution 7:7304-7310. DOI10.1002/eca3.3284.

Clement, M. J., J. E. Hines, J. D. Nichols, K. L. Pardieck, and D. J. Ziolkowski Jr. 2016. Estimating indices of range shifts in birds using dynamic models when detection is imperfect. Global Change Biology 22(10):3273-3285.

Griffin, K. M., **Z. S. Beard**, M. C. Quist, and J. M. Flinders. 2017. Age estimation of Utah Chubs using pectoral fin rays, otoliths, and scales. Western North American Naturalist 77:189-194.

Harding, L. E., J. Heffelfinger, D. Paetkau, **E. Rubin**, J. Dolphin, and A. Aoude. 2016. Genetic management and setting recovery goals for Mexican wolves (*Canis lupus baileyi*) in the wild. Biological Conservation 203:151-159.

Harding, L. E., J. Heffelfinger, D. Paetkau, **E. Rubin**, J. Dolphin, and A. Aoude. 2016. Reply to Hedrick: Genetics and recovery goals for Mexican wolves. Biological Conservation, http://dx.doi.org/10.1016/j.biocon.2016.12.034.

Horncastle, V. J., **R. F. Yarborough**, B. G. Dickson, and **S. S. Rosenstock**. 2013. Summer habitat use by adult female mule deer in a restoration-treated ponderosa pine forest. Wildlife Society Bulletin 37(4):707-713. DOI: 10.1002/wsb.301.

Jones, A. S., J. J. Anderson, B. G. Dickson, S. Boe, and **E. S. Rubin**. 2016. Off-highway vehicle road networks and kit fox space use. The Journal of Wildlife Management 81(2):230-237.

Seibert, K. L., G. W. Whitledge, N. P. Rude, **D. C. Oliver**, A. Loubere, and J. R. Seibert. 2018. Population Demographics of Sauger and simulated effects of minimum length limits in the Kaskaskia and Ohio rivers. Journal of Fish and Wildlife Management 9(2): 431-445.

Perez, C. R., S. A. Bonar, J. J. Amberg, B. Ladell, C. Rees, **W. T. Stewart**, C. J. Gill, C. Cantrell, A. T. Robinson. 2017. Comparison of American Fisheries Society (AFS) Standard Fish Sampling Techniques and Environmental DNA. North American Journal of Fisheries Management 35(5):1010-1027.

Mann, R. D. and C. G. Snow. 2018. Population-specific migration patterns of wild adult summer-run Chinook salmon passing Wells Dam, Washington. North American Journal of Fisheries Management. DOI: 10.1002/nafm.10042

Mower, E. B., W. Strain, L. Rice, L. McCormick. 2017. Are standard protocols needed for performing weight counts? Journal of Applied Aquaculture DOI:10.1080/10454438.2017.1406421.

Kalies, E. L., and **S. S. Rosenstock**. 2013. Stand structure and breeding birds: implications for restoring ponderosa pine forests. Journal of Wildlife Management 77(6):1157-1165; DOI: 10.1002/jwmg.577.

Rogowski, D. L., R. J. Osterhoudt, H. E. Mohn, and **J. K. Boyer**. 2018. Humpback chub (*Gila cypha*) range expansion in the western Grand Canyon. Western North American Naturalist 78(1):26-38.

Stahr, K. J., and M.A. Kaemingk. 2017. An evaluation of emergent macrophytes and use among groups of aquatic taxa. Lake and Reservoir Management 33(3):314–323.

Stahr, K. J., and **R. L. Knudsen**. 2018. Evaluating the efficacy of using time-lapse cameras to assess angling use: an example from a high-use metropolitan reservoir in Arizona. North American Journal of Fisheries Management 38(2):327–333.

Stahr, K. J., and **D. E. Shoup**. 2016. The effects of macrophyte stem density and structural complexity on foraging return of invertivorous juvenile largemouth bass. North American Journal of Fisheries Management 36(4):788-792.

Winters, L.K., and P. Budy. 2015. Exploring crowded trophic niche space in a novel reservoir fish assemblage: how many predators is too many? Transactions of the American Fisheries Society 144(6):1117-1128.

Yarborough, R. F., J. A. Gist, **C. D. Loberger**, and **S. R. Rosenstock**. 2015. Habitat use by Abert's squirrels (*Sciurus aberti*) in managed forests. The Southwestern Naturalist 60:166-170.

Book Chapters

Justice-Allen, A. E. 2013. "Mycoplasma" in Infectious Diseases of Concern to Captive and Free Ranging Animals in North America, 2nd ed. Gamble, K.C., and M.M. Clancy (eds). Infectious Disease Committee, American Association of Zoo Veterinarians, Yulee, Florida. 1098 pp. Website address: http://www.aazv.org/?page=IDM2013.

Stewart, W. T. and M. Burrell. 2013. Striped bass dispersion and effects of fisheries management in Lake Mohave and Pleasant, Colorado River Basin. Pages 431-441 in J.S. Bulak, C. C. Coutant, and J. A. Rice, editors. Biology and management of inland striped bass and hybrid striped bass. American Fisheries Society, Symposium 80, Bethesda, Maryland.

Popular Articles

Bristow, K., and **M. Crabb**. 2013. Black bears and the Wallow Fire. Arizona Wildlife Views 56(1):8-13.

Babb, R. and **A. Justice-Allen**. 2015. Water. Arizona Wildlife Views 58(1):8-13.

Harding, L.E., and **W.T. Stewart**. 2015. You can run, but you can't hide: using telemetry to track animals. Arizona Wildlife Views 58(2):23-29.

Stahr, K. 2019. Recipe for Conservation. Arizona Wildlife Views Magazine, January/February Issue: 34–35.

Stewart W. T. 2015. The Lifeline of the Southwest – Colorado River. Arizona Wildlife Views. July-August. Pp. 24-30.

Technical Reports, Proceedings, and Unpublished Final Reports

Bristow, K. D., **L. E. Harding**, S. R. Boe, **M. L. Crabb**, and **E. S. Rubin**. 2013. Pronghorn (*Antilocapra americana*) movements and habitat use in the Big Chino Valley, Arizona. Arizona Game and Fish Department Technical Guidance Bulletin 15, Phoenix, Arizona, USA.

Bristow, K. D., **L. E. Harding**, S. R. Boe, **M. L. Crabb**, and **E. S. Rubin**. 2015. Effects of Forest Thinning Treatments on Black Bear Habitat Use at the White Mountains Wildland-Urban Interface, Arizona. Arizona Game and Fish Department Technical Guidance Bulletin 16, Phoenix, Arizona, USA.

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.

Knox, A. C. 2014. FY 2013/2014 Chronic Wasting Disease report. Annual report. Arizona Game and Fish Department. Phoenix, Arizona.

Makinster, A. S., J. M. Carter, and A. K. Jones. 2014. Status and distribution of roundtail chub (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 Lower 1,200 meters-2013. Annual Report. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Reif, S., **R. F. Yarborough**, **S. R. Rosenstock**, E. L. Kalies, and S. Hedwall. 2013. Wildlife habitat values and forest structure in southwestern ponderosa pine: implications for restoration. Ecological Restoration Institute Working paper # 26, 9 pp.

Rogowski, D. L., **R. O. Osterhoudt**, and **P.W. Wolters**. 2014. Status of the Lees Ferry Rainbow Trout Fishery-2013. Annual Report. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Rogowski, D. L., and **P.W. Wolters**. 2014. Colorado River Fish Monitoring in Grand Canyon, Arizona-2013. Annual Report. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

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.

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.

Media Outreach in 2018

Zach Beard and **Ryan Mann**, 'Fate of stocked trout: 5 things learned from 4-year study', Fishaz blog post. October 10, 2018.

Zach Beard, 'Arizona Game and Fish implants radio transmitters in trout as part of study' Anita Roman, Fox 10 News live TV interview. October 10, 2018.

External Presentations in 2018

Beard, Z. S. 2018. Return to creel and movement of catchable-size hatchery-reared Gila Trout. 9th Annual Native and Wild Trout Conference. Phoenix, Arizona, April 12.

Beard, Z. S. and **R. D. Mann**. 2018. Movement of stocked Rainbow and Apache Trout in Arizona streams. Annual Meeting of the Arizona - New Mexico Chapter of the American Fisheries Society, Flagstaff, AZ, February 2.

Beard, Z. S. and **R. D. Mann**. 2018. Return to creel of catchable size trout and factors influencing angler satisfaction and catch rates in Arizona streams. Annual Meeting of the Arizona - New Mexico Chapter of the American Fisheries Society, Flagstaff, AZ, February 2.

Beard, Z. S., and **R. D. Mann**. 2018. Return to creel of catchable size trout and factors influencing angler satisfaction and catch rates in Arizona streams. Annual Meeting of the Western Division of the American Fisheries Society, Anchorage, Alaska, May 23.

Bristow, K., **L. E. Harding**, **R. Lucas**, and T. McCall. 2018. Responses of mule deer (*Odocoileus hemionus*) to recent wildfires and habitat treatments on the Kaibab Plateau, Arizona. International Deer Biology Congress, Estes Park, CO.

Bristow, K., **M. Clement**, **M. Crabb**, **L. E. Harding**, and **E. Rubin**. 2018. A framework for estimating elk abundance in AZ. International Deer Biology Congress, Estes Park, CO.

Clement, M.J., S.J. Converse and J.A. Royle. 2018. Accounting for imperfect detection of groups and individuals when estimating abundance. Joint Annual Meeting of the Arizona and New Mexico Chapters of TWS and AFS, Flagstaff, Arizona 1-3 February 2018.

Flinders, J. M., **Z. S. Beard**, and M. C. Quist. 2018. Standard weight (Ws) equation and length categories for Utah Chub. Annual meeting of the Idaho Chapter of the American Fisheries Society, Idaho Falls, Idaho, March 1.

Harding, L.E. 2018. An assessment of Arizona's cormorant populations, their impacts on fish, and potential management strategies to reduce impacts. Sun City Grand Fly Fishing Club. Sun City, AZ. (outreach event)

Harding, L.E. 2018. An assessment of Arizona's cormorant populations, their impacts on fish, and potential management strategies to reduce impacts. White Mountain Audubon Society, Lakeside, AZ. (outreach event)

Harding, L.E. 2018. An assessment of Arizona's cormorant populations, their impacts on fish, and potential management strategies to reduce impacts. Desert Rivers Audubon Society, Chandler, AZ. (outreach event)

Harding, L.E. 2018. Invited panel participant to CCURI STEM panel at Glendale Community College, Glendale, AZ. (outreach)

Rogowski, D. L. and **J. Boyer**. 2018. Hope in a Highly Regulated River: Native Fish Recovery in the Colorado River. Desert Fishes Council Annual Meeting, Death Valley National Park, CA 14-18 November 2018

Roth, C. J., **Z. S. Beard**, J. M. Flinders, and M. C. Quist. 2018. Population demographics of Utah Chub in Henrys Lake, Idaho. Annual Meeting of the Idaho Chapter of the American Fisheries Society, Idaho Falls, Idaho, March 1.

Stahr, K. J. 2018. An evaluation of three artificial structures to reduce predation on hatchery-reared Bonytail and Razorback Suckers. 50th Annual Meeting, Desert Fishes Council, Death Valley, CA.

Stahr, K. J., and **R. D. Mann**. 2018. The effect of predator recognition conditioning frequency on survival of hatchery-reared bonytail and razorback sucker. 51st Joint Annual Meeting, Arizona and New Mexico Chapters of the American Fisheries Society and The Wildlife Society, Flagstaff, AZ.

Stahr, K. J., **J. T. Walters**, and **H. V. Smith**. 2018. Broodstock density mediates larval production of captive-spawned Loach Minnow and Spikedace. 50th Annual Meeting, Desert Fishes Council, Death Valley, CA. Poster

Stahr, K. J., and **R. D. Mann**. 2018. The effect of predator recognition conditioning frequency on survival of hatchery-reared bonytail and razorback sucker. Colorado River Aquatic Biologists Annual Meeting, Laughlin, NV.

Wolters P. and **D. L. Rogowski** 2018. Should One Age a Warmwater Fish in a Coldwater System? Desert Fishes Council Annual Meeting, Death Valley National Park, CA 14-18 November 2018

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 2018, represent projects conducted by the Research Branch, WMD colleagues and conservation partners.

Month	Title	Presenter	Work Unit
January	Water Needn't Be a Fighting Word: Managing water in flood control reservoirs – it's complicated.	Ethan Mower	Research Branch
February	Life on the Rocks: Amphibians, reptiles and small mammals on the Barry M. Goldwater Range – west in Arizona.	Ryan O'Donnell	Wildlife Contracts Branch
March	The Struggle Behind the Mask: Methods for improving black-footed ferret recovery.	Holly Hicks	Terrestrial Branch
April	ReMARKable Opportunities: An informational session on MARK training.	Matt Clement	Research Branch
May	Trailing the Water: Springs of Arizona.	Larry Stevens & Jeri Ledbetter	Springs Stewardship Institute
June	(no seminar)		
July	(no seminar)		
August	Learning Lobo Habits: Modeling habitat suitability and connectivity of gray wolves in the Pacific Northwest.	Jacob Mesler	Research Branch
September	Fate of Stocked Trout in Arizona.	Zach Beard	Research Branch
October	A Perfect Storm for Deer: Monsoon rains, bugs and a new (to AZ) virus.	Anne Justice-Allen	Terrestrial Branch
November	Targeting the Titans: What are the evolutionary effects from hunting the largest?	Jim Heffelfinger	WMD/HQ
December	(no seminar: Department Holiday event)		

Training Provided in 2018

(coordinated by or assisted by the Research Branch)

- Becoming an Outdoors Woman program (BOW).
  Taught by Larisa Harding, January 28, 2018, Intro to Paddlesports, Saguaro Lake, AZ.

- 4x4 and trailer training.
  Taught by Larisa Harding, April 23, 2018, Department, Ben Avery Shooting Range, Phoenix, AZ.

- Arizona Fish Identification.
  Taught by Kristopher Stahr and Joshua Walters, May 31 – June 1, 2018, at ARCC, Cornville, AZ.

- Camera Trapping Study Design and Data Analysis.
  Taught by Matthew Clement, 6-8 June 2018, Smithsonian Conservation Biology Institute, Front Royal, VA.

- Introduction to Program MARK.
  Taught by Matthew Clement, 25-26 June 2018, Phoenxi AZGFD office.

- Biopolitics
  Taught by Esther Rubin and Tim Holt, September 10, Phoenix AZGFD office.

- Volunteer Training for Cormorant Impacts Study surveys.
  Taught by Larisa Harding. Multiple dates and locations.

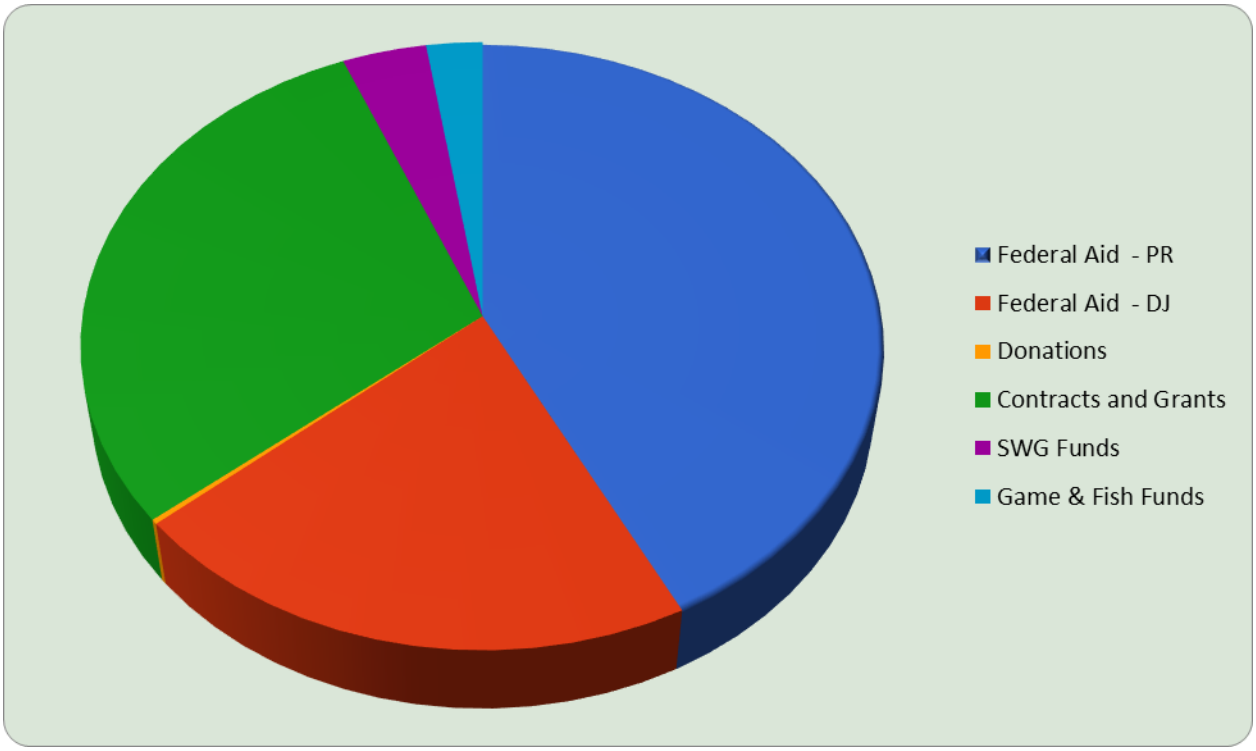
Interns Mentored During 2018

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

- **Sharon Maurer**, Arizona State University, An Evaluation of Feral Burro Impacts on Wildlife and Wildlife Habitat
- **Michael Gilboy**, University Of Arizona, An Evaluation of Feral Burro Impacts on Wildlife and Wildlife Habitat
- **Will Powell**, Northern Arizona University, An Evaluation of Feral Burro Impacts on Wildlife and Wildlife Habitat
- **Kari Herbstreit**, Arizona State University, An Evaluation of Feral Burro Impacts on Wildlife and Wildlife Habitat
- **Victoria Hoaglin**, University of Arizona, Bonytail and Razorback Sucker Predator Recognition (ARCC)

Funding Sources

Fiscal Year 2018 Funding Sources



Contracts and Grants include:

- U.S. Bureau of Reclamation
- U.S. Geological Survey
- National Fish and Wildlife Foundation
- Arizona Habitat Partnership Committee
- Safari Club International Foundation