BRIGHT ANGEL CREEK COMPREHENSIVE BROWN TROUT CONTROL PROJECT
October 1, 2020 –March 1, 2021

SEASON REPORT

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KEY FINDINGS

- Annual Bright Angel Creek-wide electrofishing and fall-winter season weir operations were conducted between 10/1/2020 and 3/1/2021.
- A large increase in both Brown and Rainbow Trout occurred in 2020, driven by a large cohort of Age-0 fish between 100-200 mm total length (TL), following a dry year (favorable to trout production).
- Native fish abundance estimates continue to be well above baseline levels since the beginning of the project (with the highest estimate of Bluehead Sucker to date), despite the near-absence of native fish young-of-year captures in a dry year that disfavored native fish production and high trout numbers.
- The Lees Ferry Brown Trout telemetry project ended in 2021 and is summarized herein; it provided useful information about timing of Brown Trout spawning between November and January at Lees Ferry with increased seasonal vulnerability to electrofishing during that period and downstream migrations documented into Grand Canyon as far as the Little Colorado River.
- Brown and Rainbow Trout captures at the Bright Angel Creek weir increased modestly (8 BNT and 18 RBT in 2020-21, compared to 4 BNT and 7 RBT in 2019-20) and electrofishing captures of mostly ripe fish below the weir continued to be high (26 BNT and 96 RBT), documenting the importance of the weir in blocking access to the creek by spawning trout running up from the Colorado River.
- Continued production of trout in Bright Angel Creek indicates suppression will continue to be necessary to maintain low abundance of trout and reduce the threat of predation and competition posed by Brown and Rainbow Trout to Humpback Chub and other native fishes.

BACKGROUND

In the Colorado River and its tributaries in Grand Canyon, non-native Brown Trout (BNT; *Salmo trutta)* and Rainbow Trout (RBT; *Oncorhynchus mykiss*) may compete with and selectively prey upon native fishes, including Flannelmouth Sucker (FMS; *Catostomus latipinnis*), Bluehead Sucker (BHS; *Pantosteus discobolus*), Speckled Dace *(SPD; Rhinichthys osculus*), and the threatened Humpback Chub (HBC; *Gila cypha*; see Valdez and Ryel 1995, Gloss and Coggins 2005, Yard et al. 2011, Coggins et al. 2011, Walters et al. 2012, Whiting et al. 2014, Spurgeon et al. 2015), leading to population-level impacts (Yackulic et al. 2018, Healy et al. 2020). Bright Angel Creek and associated main-channel Colorado River habitat historically supported thriving populations of native fishes. As recently as the 1970s, Brown Trout, a species native to Europe and Asia, were rare in Bright Angel Creek (Minckley 1978, Otis 1994). By the 1990s, however, Brown Trout had become a predominant component of the fish community in the creek, and a corresponding decline in native fish such as Speckled Dace was observed (Otis 1994). Bright Angel Creek became an important spawning site for Brown Trout, and a large aggregation of Brown Trout had become established by the early 2000's in the Colorado River near the confluence with Bright Angel Creek (Speas 2002, Makinster et al. 2010).

In an attempt to restore the native fish fauna to Bright Angel Creek, an ambitious program of mechanical removal of nonnative trout has evolved. Current operations under the Bright Angel Creek trout control project were established through the National Park Service (NPS) Comprehensive Fisheries Management Plan process (CFMP; NPS 2013); prior to the completion of the CFMP, operations were guided by the "Bright Angel Creek Trout Reduction Project" Environmental Assessment (EA) and Finding of No Significant Impact (FONSI; NPS 2006). U.S. Fish and Wildlife Service (USFWS) Biological Opinions on the operation of Glen Canyon Dam have outlined conservation measures to conduct trout reduction efforts in Bright Angel Creek, or other areas where Brown Trout may establish populations, in Grand Canyon National Park (USFWS 2016). In partial fulfillment of these measures, with financial support by the Bureau Of Reclamation (Reclamation), Grand Canyon National Park re-initiated the Bright Angel Creek Trout Reduction Project in 2010 under the 2006 EA, with the primary goals of restoring and enhancing, to the extent feasible, native fish populations that once flourished in Bright Angel Creek, and to benefit Humpback Chub and other native fishes in the Colorado River by reducing the risk of predation (NPS 2006; Omana Smith et al. 2012).

From 2010-2012, trout reduction efforts included the installation and operation of a weir and backpack electrofishing in the lower 2900 meters of the creek (confluence to Phantom Creek; Omana Smith et al. 2012). Beginning in the fall of 2012, removal efforts were expanded to encompass the entire length of Bright Angel Creek (approx. 16 kilometers) and Roaring Springs (approx. 1.5 kilometers). The operation of the weir was also extended from October through February to capture greater temporal variability in the trout spawn (Omana Smith et al. 2012; NPS 2013). A peer-review of a 5-year summary report (Healy et al. 2018) led by the Glen Canyon Dam Adaptive Management Program Science Advisors recommended refocused electrofishing to areas of remnant high Brown Trout density, and experimental translocations of Humpback Chub (Braun 2018).

This report summarizes non-native fish removal and native fish monitoring activities in Bright Angel Creek and Roaring Springs for the 2020-2021 season from October 1, 2020 – March 1, 2021.

Project Goals

The goal of this project is to reduce the abundance of nonnative Brown and Rainbow Trout in the Bright Angel Creek drainage by at least 80% of baseline to restore the native fish community (NPS 2013). Eradication of invasive trout is ultimately desired. Other specific objectives are described in the CFMP and are assessed periodically (on a 5-year cycle). This report summarizes the ninth season of intensive removal including the following:

1. Installation and operation of a weir and fish trap to intercept spawning Brown and Rainbow trout (October to March) moving between the Colorado River and Bright Angel Creek.
2. Three-pass depletion backpack electrofishing to remove trout from the entire Bright Angel Creek drainage, with additional single-pass trout control as time allows in higher trout density areas.
3. Monitoring of the Bright Angel Creek fish community response to trout removal by estimating relative abundances and population sizes of native and nonnative fishes.

All trout removed from Bright Angel Creek are prepared and distributed for beneficial use, according to stipulations in a Memorandum of Agreement between the Arizona State Historic Preservation Office and the NPS, in compliance with Section 106 of the National Historic Preservation Act. In addition, because electrofishing and the weir are visible along the corridor, crews pursue outreach as opportunities arise by sharing project objectives and methods with Phantom Ranch staff and park visitors.

METHODS

Weir and fish trap --- 10/1/20-3/1/21

On October 1, 2020, a modified resistance board weir with a downstream-orientated fish trap was installed approximately 170 meters up Bright Angel Creek from its confluence with the Colorado River, and operated continuously through March 1, 2021. The weir was checked twice daily, once in the morning and once in the evening throughout this period. The time and date of each check were recorded as well as the water temperature and the operator's name. Fish handling and data collection for all captures followed the Standard Operating Procedures for the Weir at Bright Angel Creek (NPS 2016a), which stipulates the release of native fishes above the weir.

Electrofishing --- 10/22/20-1/31/21

The 2020-21 Bright Angel Creek electrofishing season spanned from October 22, 2020–January 31, 2021 and followed Bright Angel Creek Trout Reduction Project Standard Operating Procedures (2016b) except that block-nets were eliminated for the third consecutive season. Three-pass depletions were implemented at each of 129 stations (typically 100-150 m long, circumscribed by natural hydrographic features). Given enough time, repeat single-pass removals in high trout density areas would have been conducted as recommended by peer reviewers (Braun 2018), but a large year-class of trout this season resulted in high catch rates and long workup times, leaving no time for additional single-pass "trout hunts" in reaches other than -1 (between the weir and Colorado River). Ultimately, our goal is to identify the minimum effort required to suppress trout enough to prevent population rebounds in Bright Angel Creek.

Helicopter support included five long-line supply flights over the course of the season, with the first delivery to Manzanita bunkhouse on October 22, 2020. Electrofishing crews were based at Manzanita until December 9, 2020, when the transition was made to the Phantom Ranch bunkhouse. The date of the transition is set to approximately the time when downstream progress puts the crew at near the halfway point on the trail between Manzanita and Phantom Ranch. Crew size varied from 3 (just during the first week while fishing Angel Springs) to 8 personnel (most often 8) and included NPS staff, ACE interns, and volunteers. Table 1 below summarizes the electrofishing effort in the Bright Angel Creek (BAC) and its tributaries including Angel Springs (ASP), Roaring Springs (RIS), Transept Creek (TSP), Wall Creek (WAL), and Phantom Creek (PHA).

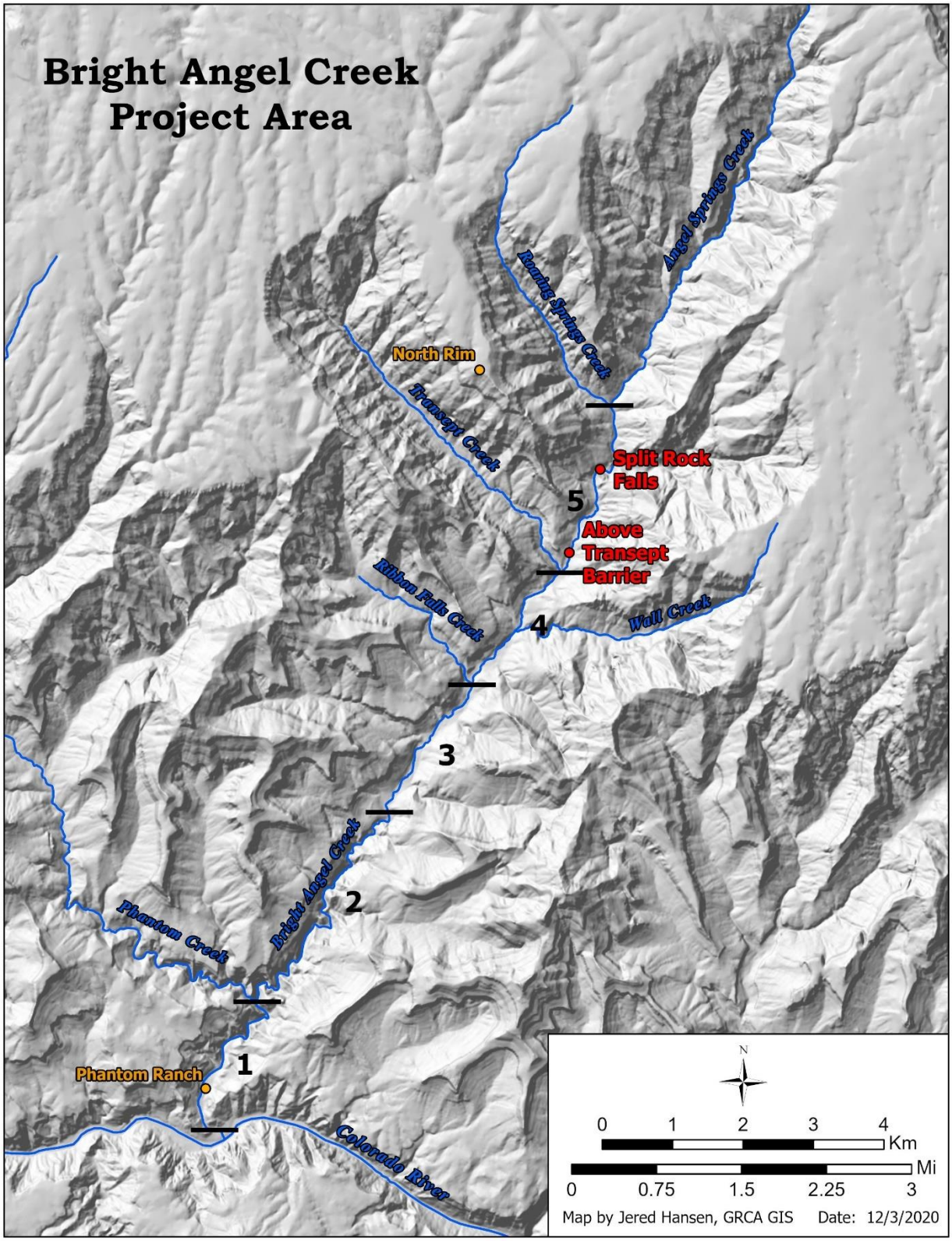

Figure 1. Map of Bright Angel Creek drainage showing reaches and tributaries, as well as the barriers above Transept Canyon and at Split Rock falls.

Table 1. The total electrofishing (EF) effort across Bright Angel Creek (BAC) reaches and tributaries for the 2020-21 season was 201 hours. Trout hunts (TH) represent single passes in low-volume tributary creeks and/or additional single pass electrofishing targeting higher-density trout locations in Reaches 1-5 when time allowed upon completion of full 3 pass depletion. This season there was not time for trout hunts following 3 pass depletions in Reaches 1-5. Un-sampled reaches denoted by (-).

Stream / Reach	Effort	EF Hours
Roaring Springs	single pass	0.49
Angel Springs	single pass	4.85
Transept Creek	TH	1.28
Wall Creek	TH	0.21
Phantom Creek	TH	0.69
BAC Reach 5: RS/AS confluence to Transept	3 pass depletion	24.57
BAC Reach 4: Transept to Ribbon	3 pass depletion	35.74
BAC Reach 3: Ribbon to beaver ponds	3 pass depletion	36.24
BAC Reach 2: beaver ponds to Phantom Creek	3 pass depletion	58.91
BAC Reach 1: Phantom Creek to Weir	3 pass depletion	36.26
BAC Reach -1: Weir to Colorado River	TH	1.78
Ribbon Falls	-*	*

*Electrofishing in and near Ribbon Falls Creek was discontinued following consultation with the Pueblo of Zuni.

Beneficial Use

As determined through consultation with Traditionally Associated Tribes, trout removed from Bright Angel Creek via the weir or electrofishing were prepared and distributed for beneficial use, to the extent possible. Trout >200 millimeters (mm) total length (TL) were cleaned for human consumption, and trout <200 mm TL were preserved for consumption by eagles at the Zuni aviary. All trout removed from Bright Angel Creek were placed in vacuum sealed bags and frozen until distributed to employees, volunteers, tribal members, the general public, or the aviary for consumption.

Abundance Estimation

We followed methods described in Healy et al. (2020; 2018) to estimate station- and reach-specific abundance of all species from three-pass depletion stations distributed throughout Bright Angel Creek for the 2020 –21 season. Briefly, we used closed-population depletion models (Huggins 1989) in Program MARK (White 2008) to account for capture probability biases related to size-selectivity and behavioral responses common to electrofishing (Peterson et al. 2004; Korman et al. 2009; Saunders et al. 2011) to generate estimates for Bluehead Suckers, Flannelmouth Suckers, Rainbow Trout, and Brown Trout. Because some species were rare, we pooled stations across all reaches to generate pass-specific pooled capture probability estimates, and derived station-specific abundance for all species. We used Akaike's Information Criterion (AIC) adjusted for small sample size to compare models (Burnham and Anderson 2002; White 2008; Saunders et al. 2011), and used model averaging to generate estimates of abundance when multiple models were supported (i.e., $\Delta AIC_c < 2$), which occurred for all species except

Speckled Dace. Our abundance estimation procedures for Speckled Dace differed slightly, in that no individual covariates were available to account for size-related biases since only a subset were measured. We truncated the lower confidence intervals for model-averaged abundance estimates on the assumption that the lower bound cannot be less than the number of fish captured and handled.

Lees Ferry Brown Trout Telemetry (2017-2021)

A telemetry study using dual sonic/RF tags began in February 2017, with the surgical implantation of tags in 10 Brown Trout captured at -4 mile bar above Lees Ferry. The study's purpose was to improve understanding of Brown Trout movements, seasonal habitat use, vulnerability to electrofishing, and timing of spawning. Although ideally brown trout would have been tagged in Grand Canyon and Lees Ferry, the logistical challenges to capturing large Brown Trout and performing surgeries in Grand Canyon restricted the capture location to -4 mile bar, where dozens of large fish could be captured in one night during spawning. With additional tagging events in December 2017 and January 2018, a total of 39 Brown Trout were ultimately implanted with tags and monitored through active and passive telemetry through 2021. Active telemetry involved towing a hydrophone from a jonboat in Glen Canyon between the dam and Lees Ferry; such active passes were conducted weekly for the first month after tagging, and then on a monthly schedule for multiple years. Passive telemetry was conducted with an array of submersible ultrasonic receivers (SURs) deployed in the river at four locations above Lees Ferry and at regular intervals throughout Marble and Grand Canyons, set up to detect any passing tagged Brown Trout. With an expected battery life of around three years, the sonic tags are now falling silent, and the final active telemetry pass was conducted in summer 2021. The results of this study are summarized below.

RESULTS

Weir

Weir captures increased modestly in 2020-21, but were still low, with only eight Brown Trout and 18 Rainbow Trout captured during the entire season (Table 2). All but one of these trout were ripe. As has become standard protocol, on three occasions in December and January electrofishing passes were conducted between the weir and the Colorado River confluence, capturing 26 Brown Trout and 96 Rainbow Trout total (Table 3). These below-the-weir removal passes have become an important tool to remove spawning trout that are trap-avoidant but nevertheless congregate in the stretch of creek downstream of the weir and would likely run upstream to spawn. In other systems, preventing immigration from outside areas where focused removal has occurred has been found to be important in successfully removing nonnative fish (Franssen et al. 2014). These observations justify continued operation of the weir and increased electrofishing passes between the weir and the confluence in order to disrupt any spawning that may be taking place in the short section of creek downstream of the weir by trout that are unable to move further upstream.

Table 2. Trout captured in the Bright Angel Creek weir near the Colorado River confluence.

Species	Date	Total Length (mm)	Sex	Condition
Brown Trout (8)	10/21/2020	345	Female	Not Ripe
	11/17/2020	315	Female	Ripe
	11/21/2020	389	Male	Ripe
	11/22/2020	332	Female	Ripe
	11/25/2020	139	Female	Ripe
	12/6/2020	386	Female	Ripe
	12/10/2020	287	Female	Ripe
	12/16/2020	336	Female	Ripe
Rainbow Trout (18)	11/19/2020	316	Female	Ripe
	11/20/2020	306	Female	Ripe
	11/21/2020	297	Male	Ripe
	11/25/2020	133	Male	Ripe
	12/1/2020	262	Male	Ripe
	12/4/2020	334	Female	Ripe
	12/9/2020	505	Female	Spent
	12/14/2020	342	Female	Ripe
	12/18/2020	267	Male	Ripe
	1/9/2021	338	Female	Ripe
	1/19/2021	285	Female	Ripe
	1/22/2021	363	Male	Ripe
	1/24/2021	301	Female	Ripe
	2/3/2021	382	Female	Ripe
	2/8/2021	420	Male	Ripe
	2/27/2021	380	Male	Ripe
	3/1/2021	280	Male	Ripe
	3/2/2021	274	Male	Ripe

Table 3. Summary data for trout captured in Bright Angel Creek between the weir and the Colorado River confluence using electrofishing.

Species	Date	Total Length (mm)	Sex	Total #
Brown Trout (26)	12/5/2020	313-539	Females	7 (all Ripe)
	12/5/2020	334-390	Males	3 (all Ripe)
	12/5/2020	118-150	Unknown	3
	12/25/2020	270-416	Females	7 (all Ripe)

	12/25/2020	280-368	Males	2 (all Ripe)
	12/25/2020	131-181	Unknown	3
	1/31/2021	109	Unknown	1
Rainbow Trout (96)	12/5/2020	252-411	Females	3 (all Ripe)
	12/5/2020	137-447	Males	15 (all Ripe)
	12/5/2020	109-322	Unknown	24
	12/25/2020	287-389	Females	5 (4 Ripe)
	12/25/2020	161-412	Males	17 (all Ripe)
	1/31/2021	309-351	Females	8 (7 Ripe)
	1/31/2021	129-412	Males	24 (all Ripe)

Electrofishing

Three-pass removal lasted until January 31, 2021. Total electrofishing effort was 201.0 hours this season (Table 1), which was higher than the last 2 seasons but almost identical to the 201.1 hours expended in 2017-18. The high numbers of small trout kept netting crews busy during three-pass depletions, which may have prolonged the time spent on each pass and increased the number of electrofishing seconds logged on each device. So much time was required to complete three passes in reaches 1-5 that no extra time was available for single-pass trout hunts (single passes in areas of high trout abundance in addition to and after completion of three-pass removal) this season, except for a few passes below the weir.

Following the lowest captures of Brown Trout to date in 2019-20 (n=311), a surge in Brown Trout numbers was observed in the 2020-21 season (Table 4, Figs 2-4; n=8301, 62-539 mm TL, mean 136 mm TL) which was driven by a large young-of-year class. A similar surge was seen in Rainbow Trout as well (Table 4, Figs 5-7; n=5632, 57-532 mm TL, mean 147 mm TL), both in the isolated Angel Springs population and in downstream reaches (only 981 Rainbow Trout were removed in 2019-20). It should be noted that in the Angel Springs reach, a few recruits were under 80 mm TL, with the smallest at 57 mm TL (Fig. 7), possibly indicating a more prolonged spawning period or repeat spawning into the spring/summer.

Table 4. Total electrofishing captures by species across Bright Angel Creek (BAC) reaches and tributaries for the 2020-21 season. BNT = Brown Trout, RBT = Rainbow Trout, BHS = Bluehead Sucker, FMS = Flannelmouth Sucker, SPD = Speckled Dace, and HBC = Humpback Chub. Recaptures of tagged BHS, FMS, and HBC were counted only on first capture – SPD were released without tagging and may have been recounted.

	BNT	**RBT**	**BHS**	**FMS**	**SPD**	**HBC**
Roaring Springs	1					
Angel Springs	16	408				
Transept Creek	9					
Wall Creek	39					
Phantom Creek	13	21	3		25	

BAC Reach 5: Roaring Springs/Angel Springs confluence to Transept	727	223				
BAC Reach 4: Transept to Ribbon	3888	599	2	1	1	
BAC Reach 3: Ribbon to beaver ponds	2683	820	107		1025	4
BAC Reach 2: beaver ponds to Phantom Creek	749	1937	287	7	10232	19
BAC Reach 1: Phantom Creek to Weir	150	1506	328	31	10853	1
BAC Reach -1: Weir to Colorado River	26	118	1		90	
TOTAL:	**8301**	**5632**	**728**	**39**	**22226**	**24**

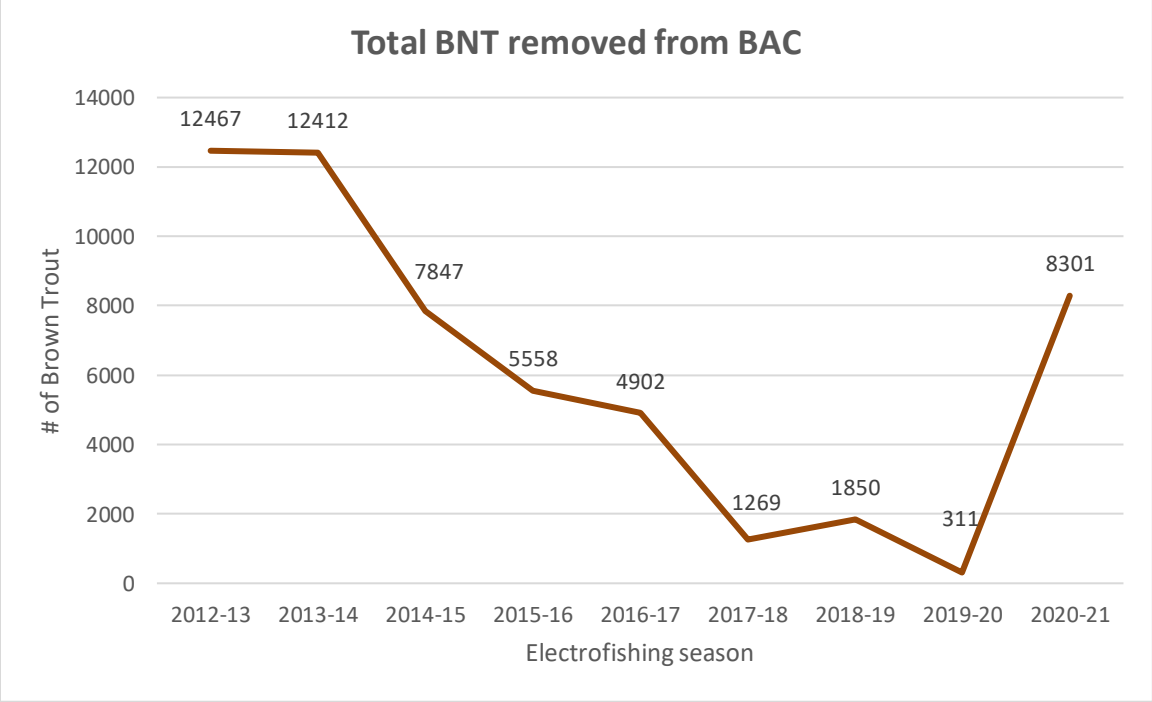

Figure 2. Total numbers of Brown Trout removed from Bright Angel Creek during winter electrofishing seasons since 2012-13.

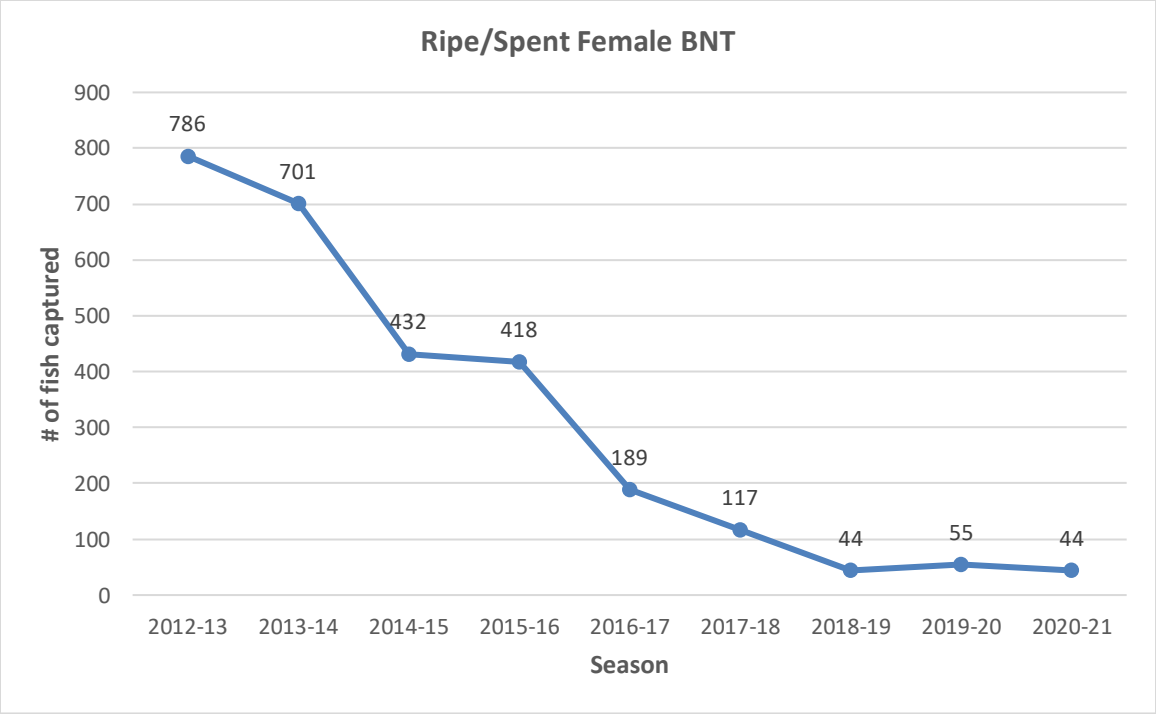

Figure 3. Total numbers of ripe and spent female Brown Trout removed from Bright Angel Creek during winter electrofishing seasons (October through January, with the exception of 2018-19, when electrofishing ended in December) since 2012-13.

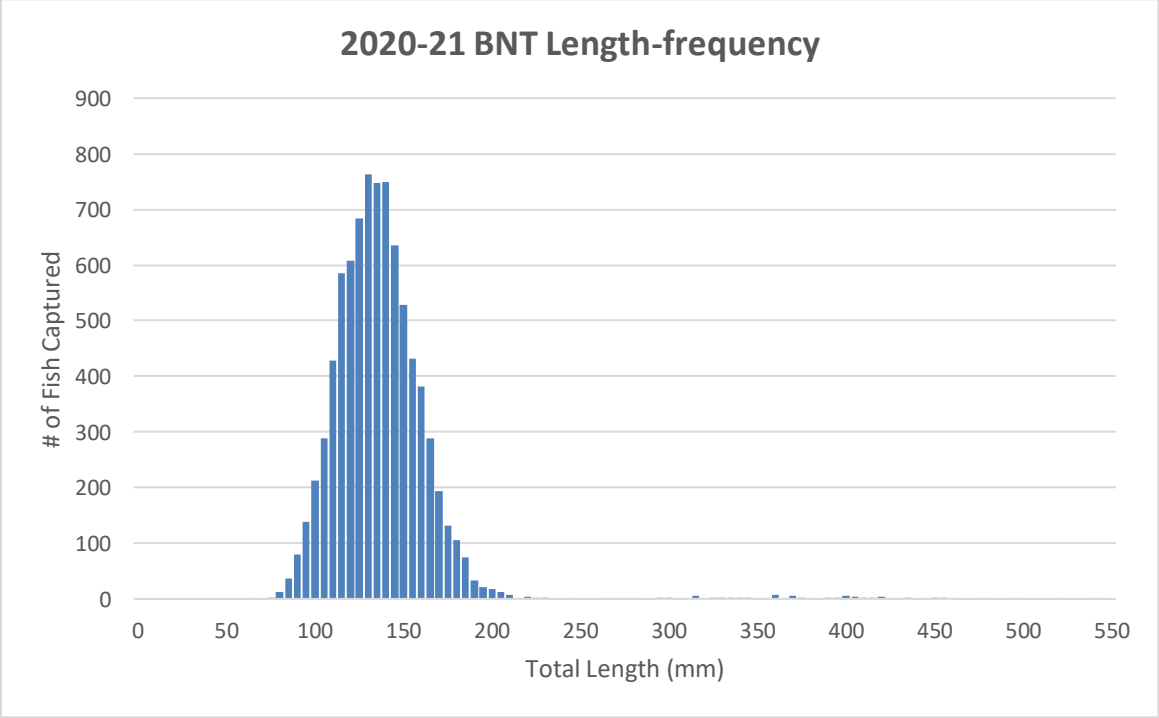

Figure 4. Length-frequency of Brown Trout (BNT) captured by electrofishing during the 2020-21 season (n=8301).

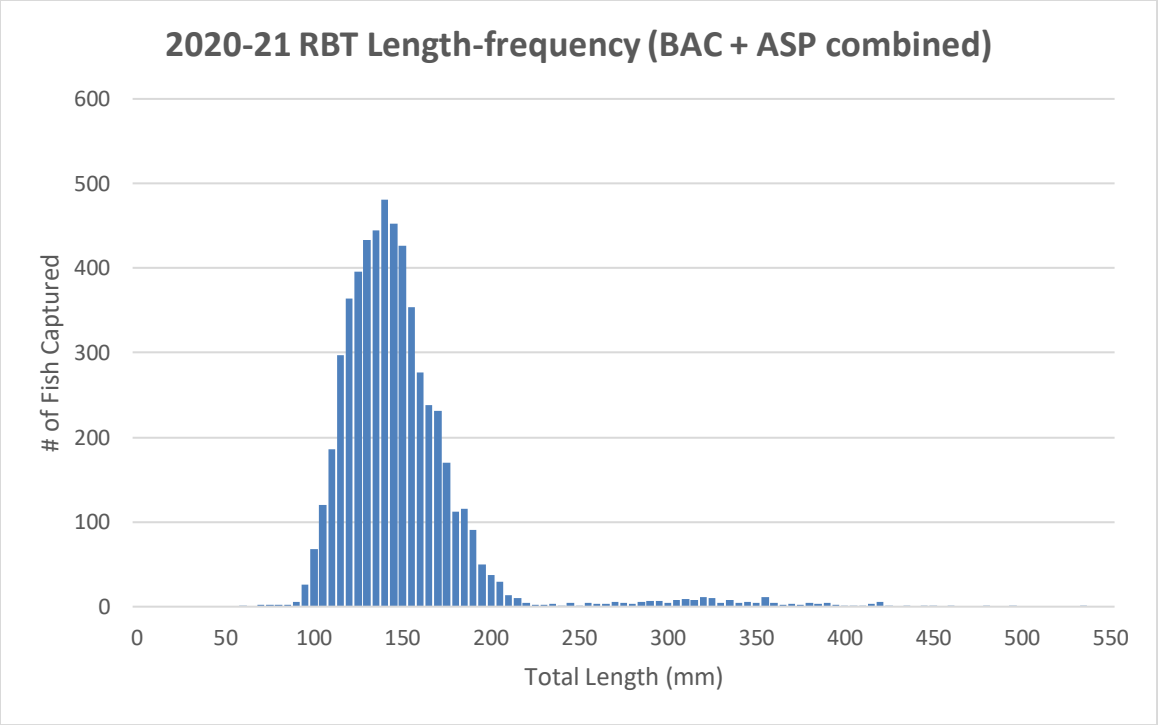

Figure 5. Length-frequency of Rainbow Trout (RBT) captured by electrofishing in Bright Angel Creek (BAC) and Angel Springs (ASP) during the 2020-21 season (n=5632).

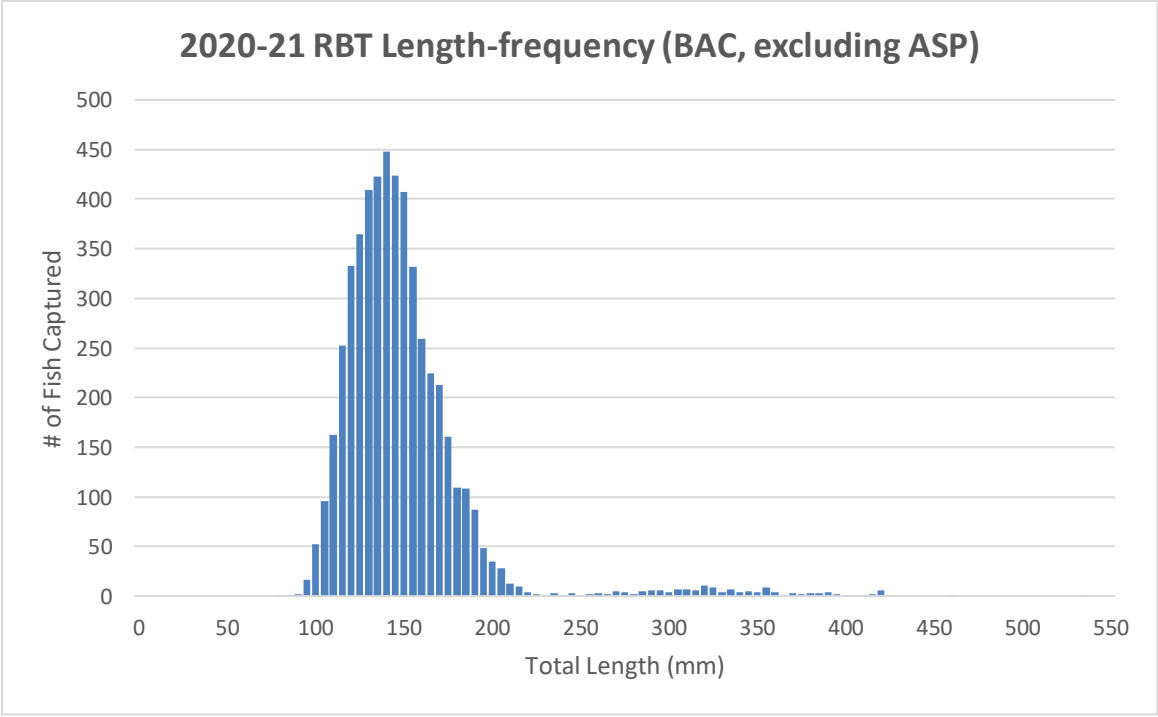

Figure 6. Length-frequency of Rainbow Trout (RBT) captured via electrofishing in Bright Angel Creek (BAC) and tributaries excluding Angel Springs (ASP) during the 2020-21 season (n=5224).

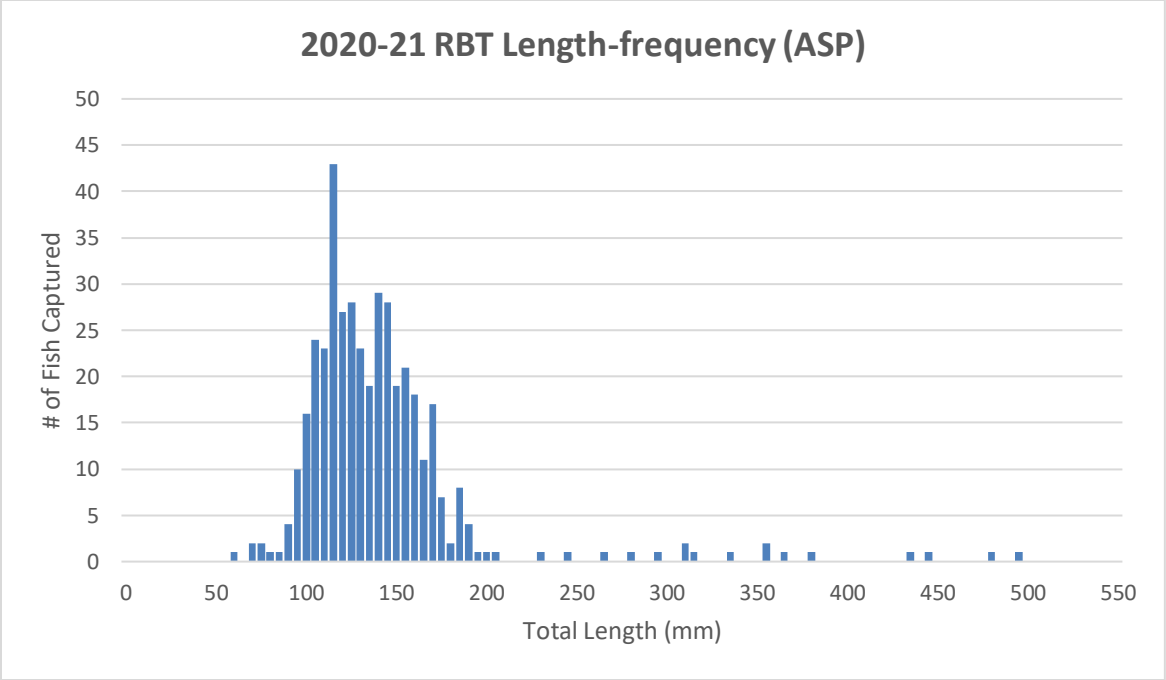

Figure 7. Length-frequency of Rainbow Trout captured via electrofishing in Angel Springs (ASP) only during the 2020-21 season (n=408).

The failed trout year-class in 2019-20 followed 2019 Bright Angel Creek flows that were punctuated with occasional floods (up to 450 cfs) in January and February, and a high-magnitude, prolonged spring runoff (sometimes pulsing above 300 cfs) extending through June. In contrast, the large year-classes of trout were produced in drought conditions in 2020 when steady baseflows were below 20 cfs and no flood pulses occurred through early March 2020; spring runoff flows never exceeded 100 cfs. Subsequently, a lack of monsoon flood pulses in July and August extended the flood-free period. This dry hydrology may have contributed to high survival of YOY trout in 2020 and contributed to such high captures of 100-200 mm TL Age-0 fish in 2020-21, despite such consistently low numbers of ripe/spent Brown Trout (Fig. 3). In Reach 5 in particular, physical attributes—a high gradient, including numerous complex cascades, and numerous deep pools that are somewhat or completely invulnerable to electrofishing—contribute to lower capture probabilities for trout (Fig. 8; Healy et al. *in review*). As a result, Reach 5 may provide a refuge for some larger trout even after repeated electrofishing passes, providing a source of recruits during dry years which favor high survival of newly-emerged trout. The fact that more downstream reaches are electrofished later in the season as crews move toward the confluence may allow for more trout to successfully spawn prior to being removed in lower reaches, possibly contributing to further to the number and spatial distribution of recruits.

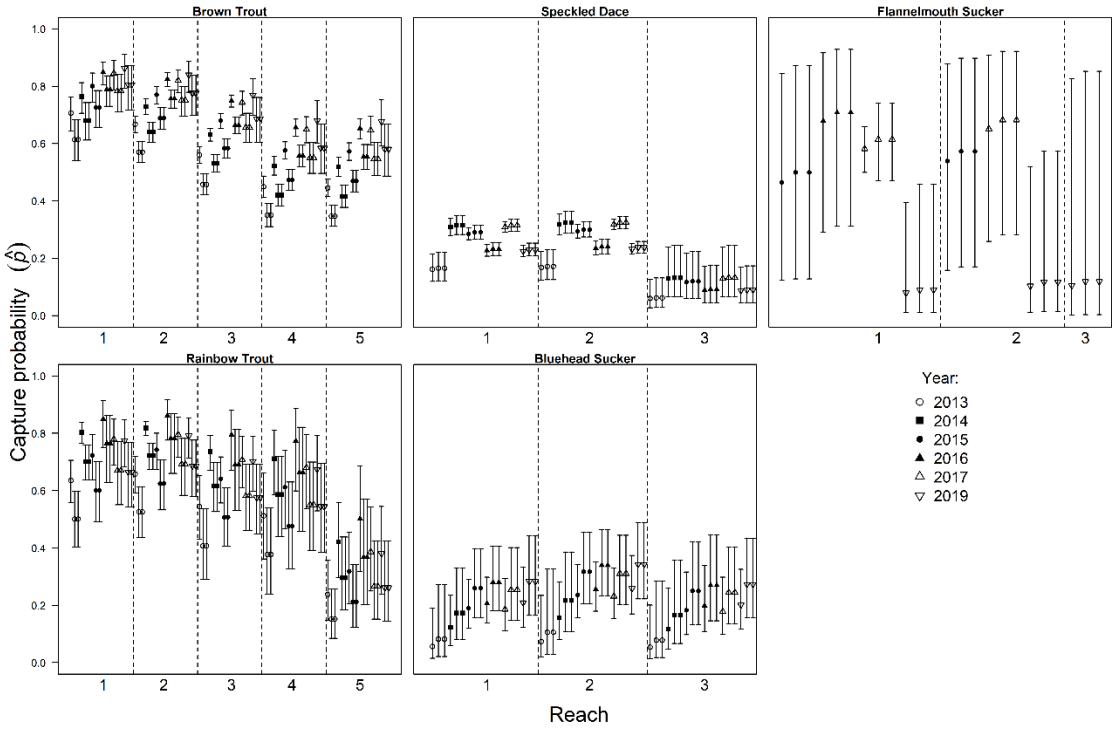

Figure 8. Capture probability by reach and species during winter Bright Angel Creek electrofishing seasons from 2013-2019 (and excluding 2018, when only 2-passes per station were conducted). Source: Healy et al. (*in review)*.

In native fishes, a lack of captures of young-of-year cohorts following a sustained dry period is consistent with literature correlating strong year-classes with spring flooding (Propst and Gido, 2004; Gido et al., 2013; Healy et al. 2020). Nevertheless, the highest number of Bluehead Sucker (Table 4, Figs 9-10; n=728, 73-362 mm TL, mean 217.4 mm TL) were captured since the project's inception. A bimodal length-frequency analysis revealed a stronger Age-1 cohort spawned in 2019 than was evident in 2019-20 Age-0 captures, underscoring the reduced capture probability of Bluehead Suckers at smaller sizes (<100 mm TL) and with higher Brown Trout densities (Healy et al. *in review*). A relatively modest capture of Flannelmouth Sucker (Table 4, Fig 11; n=39, 115-495 mm TL, mean 290.4 mm TL) similarly reflects evidence of an Age-1 cohort produced in 2019, and no evidence of <100 mm TL individuals produced in 2020. A similar pattern was observed for Speckled Dace (Table 4; n=22,226, 22-163 mm TL, mean 87.4 mm TL); following a bimodal length-frequency last season including a strong young-of-year class, the 2020-21 Speckled Dace length-frequency histogram (Fig. 12) lacks bimodality and any peak of young-of-year fish under 60 mm TL. Finally, translocated Humpback Chub (Table 4, Fig 13; n=24, 120-333 mm TL, mean 165 mm TL) captures include two larger individuals from the 2018 translocation and 22 smaller individuals from the 2020 translocation, with no captures of young-of-year Humpback Chub produced in the creek to date.

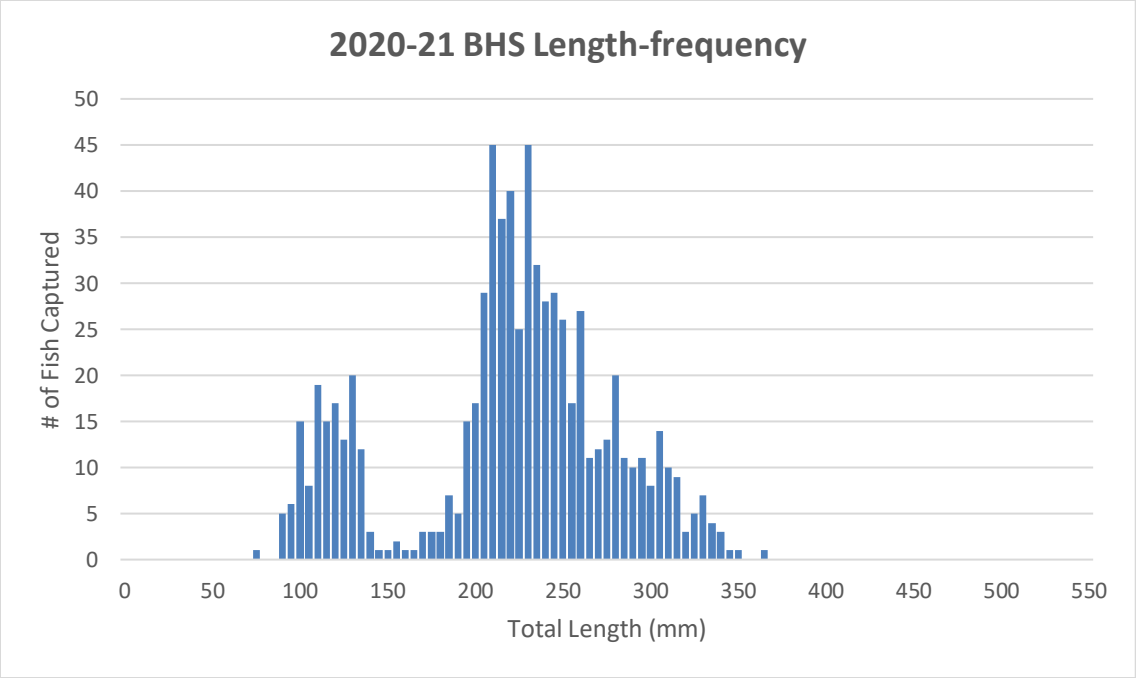

Figure 9. Length-frequency of Bluehead Sucker (BHS) captured via electrofishing during the 2020-21 season (n=728). Only the first capture is included for same-season repeat captures of PIT-tagged individuals.

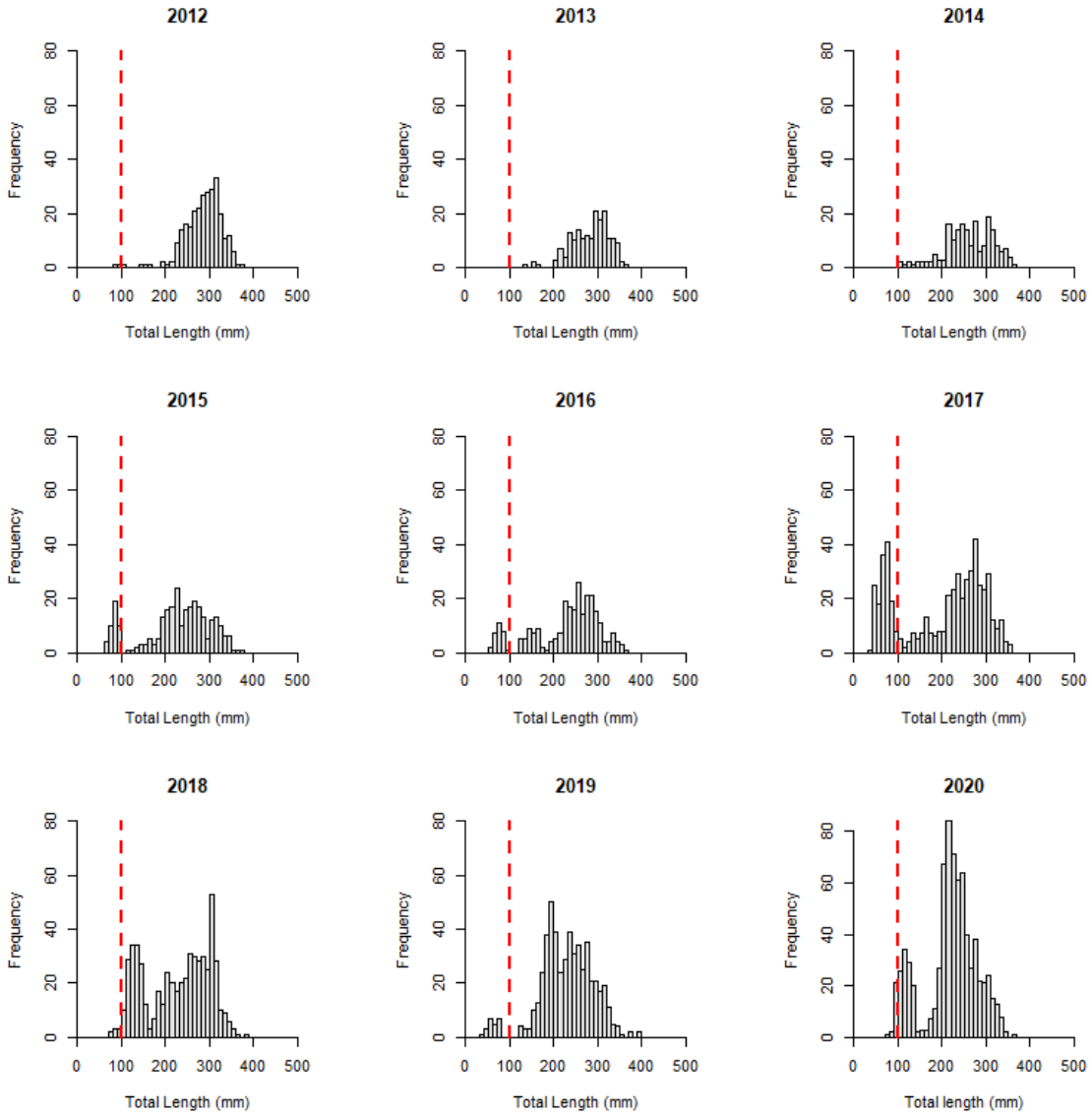

Figure 10. Length-frequency histograms for Bluehead Suckers for the last nine winter BAC seasons. The red dotted line represents the 100 mm TL cutoff; young-of-year produced in the spring should be to the left of this line.

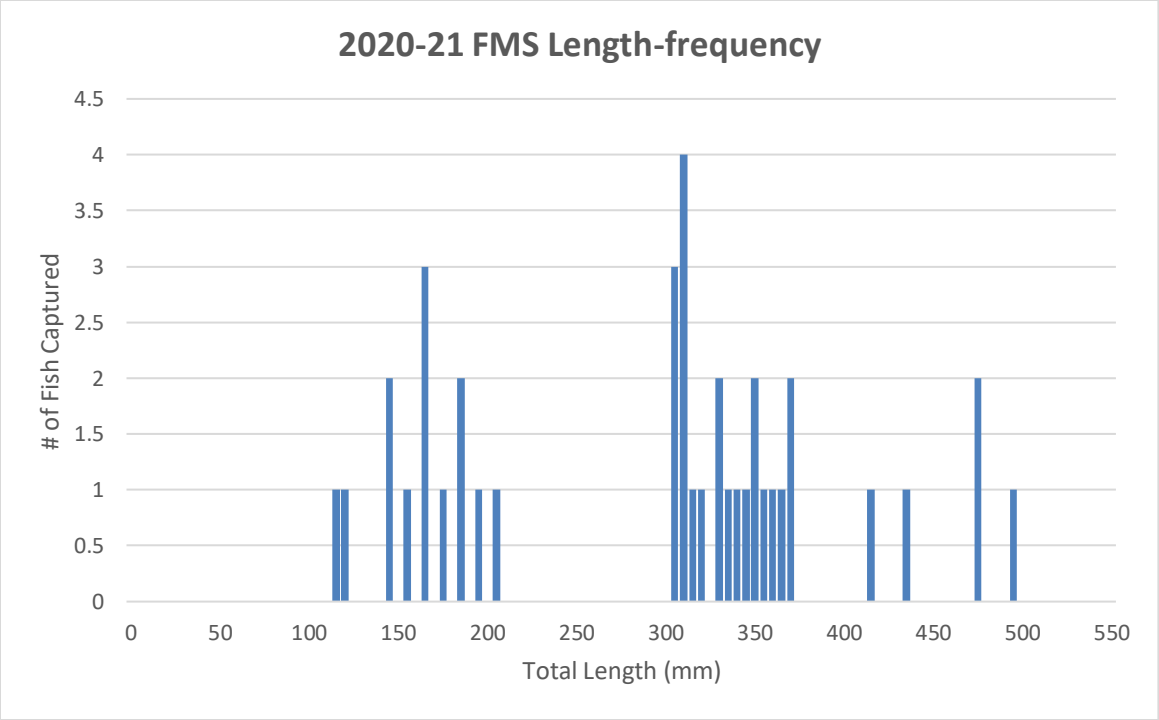

Figure 11. Length-frequency of Flannelmouth Sucker (FMS) captured via electrofishing during the 2020-21 season (n=39). Only the first capture is included for same-season repeat captures of PIT-tagged individuals.

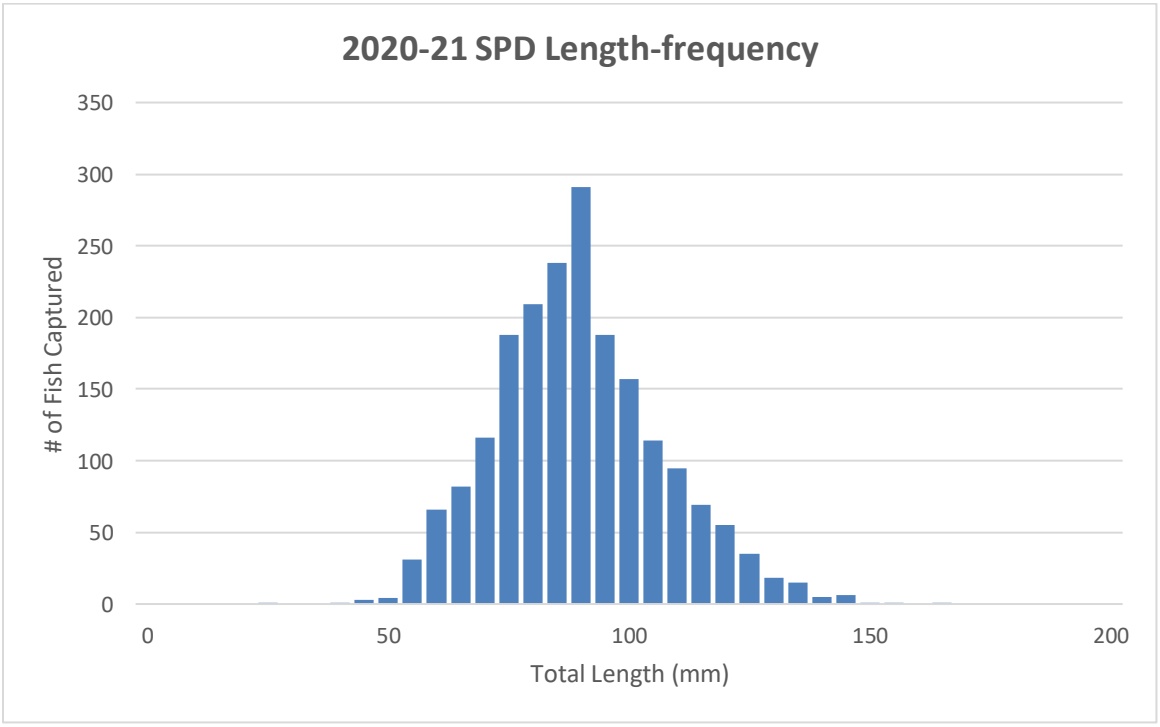

Figure 12. Length-frequency of Speckled Dace (SPD) captured via electrofishing during the 2020-21 season (A subset (1,990) of the total number of SPD (22,225) captured were measured and the subset is represented in the table.).

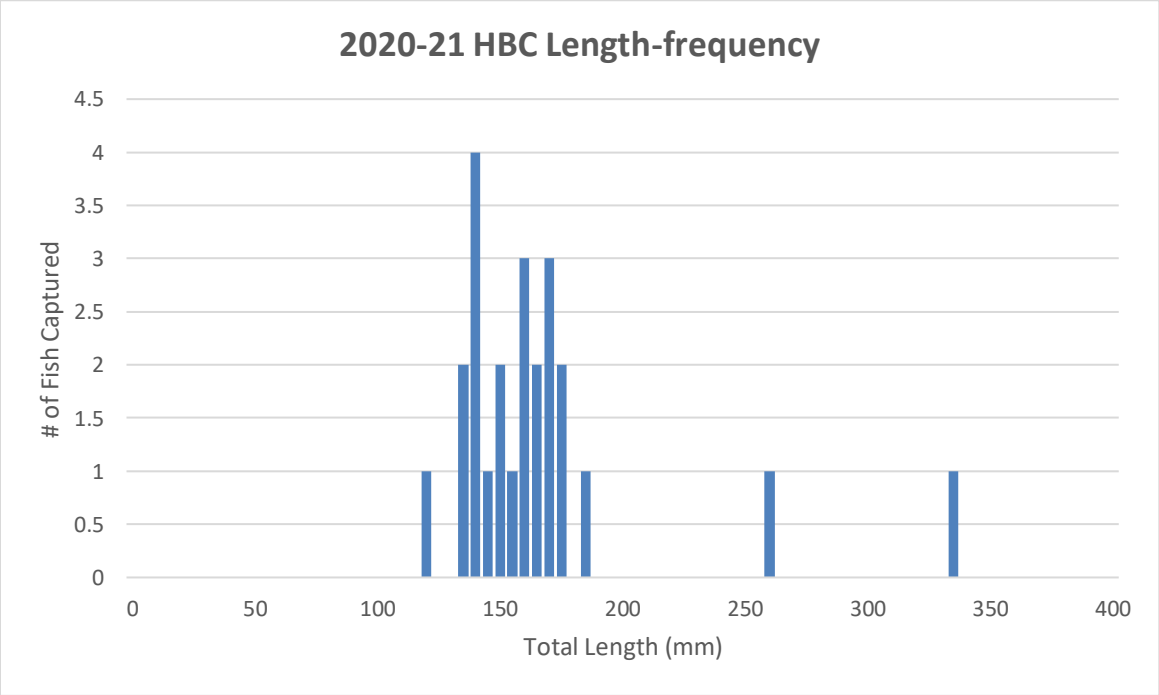

Figure 13. Length-frequency of translocated Humpback Chub (HBC) captured via electrofishing during the 2020-21 season (n=24). Only the first capture is included for same-season repeat captures of PIT-tagged individuals.

Plots of annual abundance estimates for Brown and Rainbow Trout, Bluehead Sucker, Flannelmouth Sucker, and Speckled Dace are shown in Figure 14. Despite the resurgence of trout numbers after a robust young-of-year class, native fish abundances do not yet exhibit an obvious negative response, and abundance estimates still markedly exceed baseline levels described in Healy et al. (2018). Our continued suppression of larger size-classes of trout may reduce the predatory impacts of this large trout young-of-year class, perhaps dampening the negative impacts on the resurgent BAC native fish fauna.

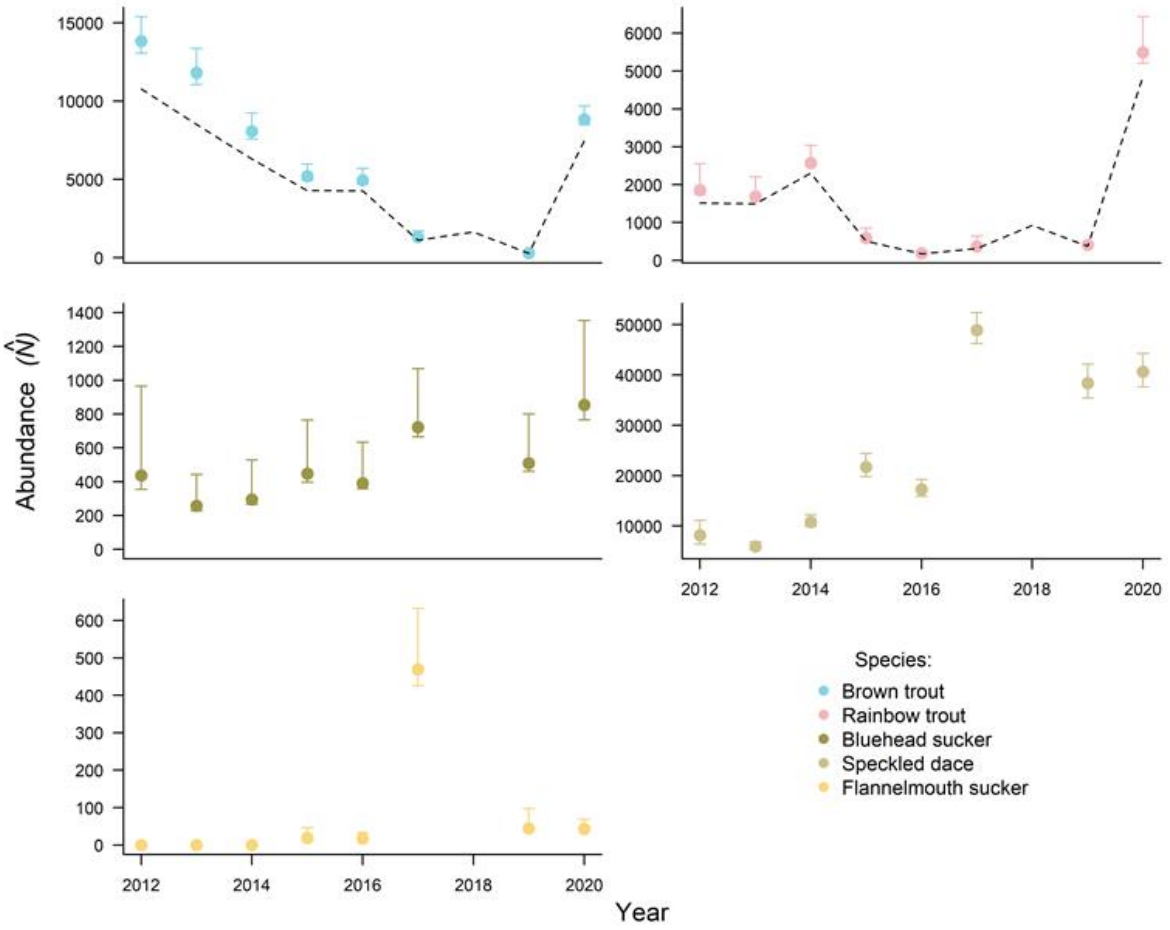

Figure 14. Annual estimated abundance by species (plotted points) based on three-pass depletion sampling, with dashed lines representing total number of Brown and Rainbow trout captured on the first two passes for the last nine winter BAC electrofishing seasons. (Each point is an estimate for a full winter season extending over two calendar years from October to January, with the x-axis label representing the year that sampling commenced in October.) Error bars indicate 95% confidence intervals for abundance estimates. Estimates of abundance for 2018 are absent because only two passes (instead of three) were conducted that year.

Lees Ferry Brown Trout Telemetry (2017-2021): Summary Results

Over the course of this study, most brown trout did not move far beyond the 15 mile reach from Glen Canyon Dam to Lees Ferry, and those that did move downstream often returned to Lees Ferry. However, the tagged Brown Trout were all large adults (> 450 mm, necessitated by the large size of sonic tags) and all tagged at -4 mile so the movement patterns may not be representative of smaller fish in Lees Ferry and fish of all size-classes downstream in Grand Canyon. Our results document movement of adults both downstream and upstream – one of the

brown trout appears to have moved in conjunction with a high flow experiment (HFE). Given the limitations of sonic telemetry studies (small sample size, requires large adults), we hope that other approaches (such as an incipient natal origins study utilizing microchemistry of otoliths and eye lenses to assess movements over a fish's lifetime) will help further elucidate movement patterns in Grand Canyon and Glen Canyon Brown Trout.

A few of the highlights of our study are included here. Five fish were detected on SURs moving downstream of Lees Ferry into Marble Canyon on one or more occasions. Of the five fish, two moved 8-12 miles downstream of Lees Ferry, and three were detected at least 39 miles downstream. Two individuals moved as far downstream as the LCR and were detected on an SUR just downstream of the confluence of the LCR (in June and November 2018). Some movements may have been associated with the 2018 fall High Flow Experiment (HFE): three fish were detected moving past the -2.7 mi SUR above Lees Ferry during the Nov 8-9 down-ramping portion of the HFE. One fish, which was recorded in Lees Ferry prior to the HFE, then 60 miles downstream near the vicinity of the LCR on November 9th, then returned to Lees Ferry by December 4th. Such movements support the hypothesis that HFEs stimulate brown trout migrations. Of the remaining 34 fish that were not detected venturing far outside of Lees Ferry, localized seasonal movements were the pattern. The majority of tagged fish were detected converging on the two-mile reach surrounding -4 mile bar during the peak spawning season from November to January. Summer home ranges were implied by detections outside of spawning season, with individuals spreading out between the Lees Ferry boatramp and -12 mile, and often being contacted repeatedly via active telemetry in the same individual locations until returning to -4 mile bar in the fall.

This study supports that the period of greatest vulnerability of Brown Trout to electrofishing removal, which is during occupancy of shallow spawning bars, occurs between November and January at Lees Ferry. It also provides evidence of that brown trout move downstream where they pose a threat to native fishes in Grand Canyon (PIT-tagged Brown and Rainbow Trout, some originating at Lees Ferry, have been detected even further downstream on the Bright Angel Creek antenna; see Schelly et al. 2019 for summary table.)

Bright Angel Creek PIT-tag Antenna Detection Summary

In May 2018, immediately preceding the first translocation of Humpback Chub to the creek, a PIT-tag antenna was installed below the lower campground bridge in the Bright Angel Creek delta. On August 17, 2021, the antenna was washed out and destroyed by a large monsoonal flood in Bright Angel Creek. (Plans are underway to install a replacement, at the same location, in newly armored streambed to be constructed around the new trans-canyon pipeline water intake structure.) During more than three years of continuous operation, the antenna has provided an excellent opportunity to remotely monitor PIT-tagged fish movements in Reach 1 of Bright Angel Creek upstream of the Colorado River confluence. Directionality of movement may be challenging or even impossible to ascertain with these detections, especially if only a single contact is made on one of the three antenna panels but tagging or release location and subsequent captures or detections can give context when interpreting movements. With that caveat about interpretation, hundreds of thousands of PIT-tag detections, representing over 2000 unique PIT-tags, have been logged, providing a window into seasonal spring and summer use of the creek, presumably for conditioning and spawning, by native fishes—including both translocated and

non-translocated Humpback Chub. In addition, the antenna has detected entry into the creek by tagged Brown and Rainbow Trout originating in the mainstem Colorado River, documenting breaches of the weir during high-flow events as well as immigration into the creek during periods outside of weir operation. Table 5 summarizes the number of unique PIT-tag detections on the Bright Angel Creek antenna by year and species.

Table 5. Unique PIT-tag detections on the Bright Angel Creek PIT-tag antenna array by species and year of operation. *NT=Non Translocated, **T=Translocated.

Fish Species	2018	2019	2020	2021	Total Unique detections
Humpback Chub (NT*)	1	15	7	11	34
Humpback Chub (T**)	22	61	12	9	104
Bluehead Sucker	18	112	54	146	330
Flannelmouth Sucker	23	840	332	561	1756
Brown Trout	0	3	0	0	3
Rainbow Trout	0	10	2	1	13

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