COLORADO RIVER CUTTHROAT TROUT SPAWNING OPERATIONS AT DOUGHERTY BASIN LAKE IN 2019

A Sport Fish and Native Cutthroat Trout Restoration Project

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INTRODUCTION

A wild brood stock of Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) (CRCT) was developed as a cooperative effort between the Utah Division of Wildlife Resources (UDWR) and Dixie National Forest at Dougherty Basin Lake on Boulder Mountain in the late 1990s. The project began in 1997-99 when wild CRCT were transplanted to Dougherty Basin Lake from the east and west forks of Boulder Creek. Both Boulder Creek and Dougherty Basin Lake are located in the Escalante River drainage, where remnant CRCT were first discovered in the mid 1980s (Behnke 1992). By 2013, a total of seven remnant populations of native cutthroat trout had been found throughout this drainage (Hepworth et al. 2001, Hadley et al. 2008, Hadley et al. 2014). The CRCT brood stock is part of a native trout conservation program outlined in cooperative agreements (CRCT Conservation Team 2006a) and strategies (CRCT Conservation Team 2006b). The Dougherty Basin brood was originally intended to provide a source of fish to establish new CRCT conservation populations and augment flat-water sport fisheries associated with those populations. In addition, it was hoped that enough CRCT could be produced to increase sport fishing opportunities for native trout within the historic range of CRCT in the Lower Colorado River Geographic Management Unit (GMU).

Eggs have been collected from CRCT in Dougherty Basin Lake since 1999. Annual production of the brood has ranged from less than 2,000 to nearly 20,000 fish stocked out in the Southern Region. In an effort to produce additional eggs, a brood was also established at Kolob Reservoir and spawning was conducted there from 2010 to 2014. Egg take logistics were difficult and variable at Kolob, however, leading to returns much lower than what was anticipated and the brood operation was abandoned. Also beginning in 2014, improvements made to the trap at Duck Fork Reservoir in the Southeastern Region (Lower Green River GMU) allowed for the collection of an excess of CRCT eggs. The resulting fry were offered to help fill sport fish quotas in the Southern Region. For the first time, all cutthroat sport fish needs in the Colorado River drainage in the region were filled by CRCT. Previously, shortages were met by excess Bonneville cutthroat trout (BCT) produced at Manning Meadow Reservoir. A new sport fish management plan developed for Boulder Mountain lakes in 2014 recommended that the stocking of BCT cease in Colorado River basin waters (Boulder Mountain Sport Fish Advisory Committee 2014). The stocking of CRCT from Duck Fork was instrumental in addressing all of these concerns and has provided more than 50% of the total CRCT stocking in the southern region during each year since 2014.

A draft spawning protocol developed in 2018 identifies the purpose of the progeny from egg takes at Dougherty Basin under five separate scenarios:

- **Scenario 1: Wild broodstock are used to produce sport fish (attached to conservation populations)**
    - These fish are considered conservation because the waters they are stocked in are connected to streams with conservation populations and the stocked fish could intermix with those conservation populations.
    - Currently constitutes approximately 26% of egg production needs.
- **Scenario 2: Wild broodstock are used to produce sport fish (separate from conservations populations)**
    - These fish are not used for conservation purposes.
    - These lakes are not connected to current CRCT stream populations and may be stocked with CRCT from other brood sources outside the GMU (eg. Duck Fork).
    - This scenario comprises 71% of typical annual CRCT quotas.

- **Scenario 3: Wild broodstock are used in Fish Restoration Projects**
    - The goal is to produce fish for repopulating or restoring conservation populations.
    - Requirements for this scenario are short term and irregular, though they may comprise a significant portion of any year's brood production. In addition, transfer of adult CRCT from remnant stream populations is combined with brood production to ensure genetic diversity in newly restored conservation stream populations.
- **Scenario 4: Wild broodstock are used to develop captive brood program**
    - The goal is to produce fish to be used for hatchery propagation, future restoration projects, and sport fish stocking purposes (scenarios 1-3).
- **Scenario 5: Wild broodstock maintenance**
    - The goal is to produce fish to be used to replace fish in the wild broodstock at Dougherty Basin Lake and Tall Four Reservoir (3% of total brood requests).

Egg take prioritization is identified as follows:

- 20,000 eggs collected for Scenario 1, 3, and 5.
- 2,000-3,000 eggs collected for Scenario 4 (sent to FES for quarantine).
- All additional egg production collected for Scenario 2

In recent years, CRCT eggs collected at Dougherty Basin have experienced diminished and/or fluctuating levels of survival through eye-up, hatching, and rearing. Inbreeding stress caused by years of collecting eggs from small groups of fish – compounded by an original founding by less than 300 individuals – was identified as a potential factor contributing to poor egg survival by staff at the Fisheries Experiment Station (FES) (Wagner and Oplinger 2012). They recommended that gametes be collected from single-mated pairings (ie. one female to one male) at brood locations where less than 200 fish were spawned in a given year. This practice was implemented at Dougherty Basin from 2015 to 2017. Beginning in 2018, a modified factorial spawn design was prescribed, where eggs from five females are pooled, mixed, then split into five equal lots, which are then fertilized by five individual males. In addition to altering fertilization strategy, CRCT from remnant populations not previously represented in the brood – primarily Pine Creek – have been introduced to Dougherty Basin since 2014 (Table 1). These wild fish have contributed gametes to egg take operations during most of those years and have likely increased the genetic diversity of the brood satisfactorily.

Dougherty Basin CRCT fry have continually experienced high rates of mortality during rearing due to encephalitis (inflammation in and around the brain). Encephalitis occurs intermittently among larval cutthroat and rainbow trout groups in Utah hatcheries (Wade Cavendar, FES fish pathologist, personal comm.), though not to the extent which has been observed in Dougherty Basin CRCT. Because encephalitis is not an infectious agent itself, there is no treatment available and aquaculture personnel typically take measures to reduce stress and, over time, most groups recover following a small spike in mortality. Although Dougherty Basin CRCT also typically recover, the mortality spikes have been much larger and more frequent.

The cause of such a high incidence of encephalitis is currently unknown, though various factors may contribute. Former UDWR fish pathologists Ron Goede and Chris Wilson hypothesized that the condition occurs when fry congregate in large groups, which yields a local reduction in oxygen, though FES has never been able to confirm this scenario (Wade Cavendar, personal comm.). Another factor identified by regional aquatic staff as having a high potential of

negatively affecting CRCT rearing is the difference in water temperature between the origin waters of the Dougherty Basin CRCT and the hatcheries where the fry are raised. The brood was founded by transfers of CRCT from the forks of Boulder Creek, 80% of which came from the population confined to the short (0.3 mi; 0.5 km) headwater meadow section of the east fork (Table 1). This population has evolved in a very unique setting where eggs are laid and fry hatched in a spring channel where more oxygen and spawning gravel is present, but annual water temperature rarely exceeds 50° F (10° C). Later, fry enter the main stream channel, which is slightly warmer, where growth rate increases enough that they are able to survive their first winter. By contrast, most hatcheries where Dougherty Basin CRCT fry have been reared maintain water temperatures exceeding 55° F (13° C). Although no correlation between encephalitis and any environmental factor has been documented, the disparity in temperature between origin waters and hatcheries presents a potential stumbling block. The short spawning window retained by CRCT in Dougherty Basin Lake further exemplifies that this unique population may have very specific requirements for successful propagation.

CRCT were raised at the Mammoth Creek hatchery from 2007 to 2012 and experienced rearing success of 28% (eyed eggs to stocked fish) to 78% (mean: 52%). From 2013 to 2016, CRCT were reared at Fountain Green hatchery and experienced 29% to 50% survival from eyed egg to stocking (mean: 38%). In 2016, FES hatched and raised a group of 3,000 eyed CRCT eggs with the intent of monitoring the encephalitis outbreak. Following encephalitis-induced mortality and the more typical mortality resulting from crippling and lack of feeding conversion, the group experienced a total loss. In 2017, all 10,986 eyed eggs were transported to FES to begin the process of establishing a captive brood population. By fall 2017, only 901 CRCT remained (92% loss). When the group was finally moved to the Mammoth Creek hatchery (now an exclusive native cutthroat station) in summer 2018, only 34 fish remained – a mere 0.3 percent survival rate while at FES.

Improvements to fish collection and handling at the trap, egg collection and transport, and infrastructure at the Fountain Green isolation facility have improved eyeing success for Dougherty Basin eggs in recent years. Eyeing rate fell to less than 50% in 2017 and 2018, however. It is presumed that logistical issues during egg collection contributed to these poor rates, since the rates varied between egg takes and specific problems were identified during those takes (Hadley 2017, 2018). The potential causes of poor egg survival varied from delayed fertilization, to physical damage during mixing, to dripping water on the eggs before fertilization. Implementation of the factorial spawn likely contributed to poor survival as trap personnel tried to adjust to the new design, but failed to maintain all conditions necessary for favorable egg survival. In addition, aging holding cages have continually lost fish, contributing to sex ratio imbalance. Males are particularly effective at finding holes that go unnoticed when the cages are being repaired.

Despite the issues leading to poor egg survival, Fountain Green hatchery achieved improved rearing success in 2018, with 66% of eyed eggs reaching stocking. This was the highest rearing rate observed since they started raising Dougherty Basin CRCT in 2013. 4,200 of the 2018 eyed eggs (40% of total) were shipped to FES for captive brood quarantine. Installation of a water chilling system there improved egg survival over the extremely poor return of the 2017 cohort. However, rearing success was much lower than that at Fountain Green, with 23% of eyed eggs making it to two different “stock out” stages. 500 CRCT fry were stocked in one lake in fall 2018, while 480 were sent to Mammoth Creek hatchery in spring 2019.

STUDY SITE

Dougherty Basin Lake covers 3.7 acres at an elevation of 9,720 ft (2,963 m) and is located in Garfield County on the Dixie National Forest (Figure 1). Access is gained by a 0.75-mile foot trail from Barker Reservoir at the end of the North Creek Road. The inlet spring is about 0.25 mile upstream from the lake and rarely exceeds a temperature of 46° F (8° C) during the year. The outlet from Dougherty Basin flows for about 0.25 mile before entering Tall Four Reservoir (0.67 acres) and then from Tall Four into a sink hole. The two lakes are thus isolated from other systems containing wild trout. Springs below Tall Four presumably originate from the sink hole and flow into other headwater lakes, eventually becoming part of North Creek, an Escalante River tributary. The canals feeding Dougherty Basin Lake and Tall Four Reservoir were constructed some time prior to 1960 and are maintained by UDWR to provide stable water levels in the lakes for fish habitat. The brood population has been maintained with annual stocking of 1,000 CRCT in Dougherty Basin Lake (Table 1) and 100 CRCT in Tall Four Reservoir.

METHODS

Fish traps (Fig. 2) were installed on June 10, 2019, in the inlet and outlet at Dougherty Basin Lake, as well as in the inlet in Tall Four Reservoir to capture CRCT leaving the lakes. In addition to the traps, two small fyke nets were set in Dougherty Basin and one was set in Tall Four and were allowed to fish through the entirety of the operation (Fig. 3). Traps consisted of portable aluminum frames with removable rods spaced 0.5 inches apart. These frames could be adjusted to various stream widths and depths and were set to funnel trout into holding compartments. UDWR personnel were stationed at Barker Reservoir (trailhead to Dougherty Basin Lake) for 24 hours per day while traps were in operation. Traps and fyke nets were checked twice a day from June 10 through June 23 and fish captured were transported to live cages in the two lakes. Traps and nets were checked once daily after June 23. CRCT were held in live cages suspended in the lake between 4 and 8 feet deep until they were ready to spawn or until the project ended. Fish were held at depths below the surface in order to maintain a lower temperature (<60° F; <16° C) and reduce mortality during the holding period.

Egg collection was conducted on June 17, 24, and July 1, 2019 (Table 2) and was supervised by personnel from the UDWR Egan fish hatchery. On spawning dates all captive fish were sorted and ripe CRCT were spawned using standard state methods. The modified factorial spawning strategy was implemented during the second egg take: eggs were collected from five females on a cloth screen, with ovarian fluid being collected underneath for disease testing. The eggs were then gently mixed with a rubber spatula and separated evenly into five bowls. Milt was filtered from a single male across a metal screen to remove feces, then combined with diluent and a single lot of eggs, and allowed to fertilize for 5-10 minutes. During the first and third egg collections, when fewer ripe CRCT were available, male-female pairings varied in count and ratio. Eggs were rinsed with clean hatchery water and water hardened for one hour, then transported to Fountain Green Fish Hatchery for eyeing. Following eye-up, a portion of eggs were sent to FES for captive brood quarantine, while the rest remained at Fountain Green for hatching and rearing. Eggs were treated with an iodine solution prior to loading for transport to Fountain Green and again at the hatchery.

Disease certification was completed as required by standard protocol. A total of 60 trout collected in the canal in between the two lakes on June 10 were used in disease testing. Samples of ovarian fluid were taken from the first 60 females spawned (samples were combined from

groups of five females). All samples were analyzed at FES. The inlet and outlet were also inspected for the presence of New Zealand mudsnails and other AIS as per UDWR protocols.

RESULTS & DISCUSSION

The historic, high snowpack and late spring of 2019 contributed to one of the latest trap start times in the history of the Dougherty Basin brood (Table 2), as well as the latest ever egg take on July 1. 2011, another year with a high snowpack, marked the last time that trap operation was delayed about two weeks. While the first egg take was conducted a week after trap set up in 2019 – as has been standard protocol for several years – very few fish were ripe at that time, so effective egg collection was about three weeks later than normal.

Table 3 summarizes results of the spawning operation at Dougherty Basin Lake in 2019. The total number of CRCT trapped (379) represented a slight increase over low values in 2017 and 2018, while the 68 female CRCT spawned was similar to those years (Table 4). 25,344 eggs were collected in 2019, also similar to the previous two years (Fig. 4). Mean number of eggs per female was among the lowest ever recorded. Most spawners measured between 240 mm and 340 mm (Fig. 5). Mean total length of female (276 mm) CRCT spawned was the lowest value observed in 20 years of spawning, while mean male length (290 mm) was among the lowest (Fig. 6). Males spawned have consistently been larger than females since 2009, though the two sexes have been fairly similar in size for the last five years. Thirty-three CRCT (13 female, 20 male) introduced from Pine Creek in 2017 and 2018 contributed gametes to the 2019 egg take (Table 5). This contribution was, by far, the largest ever infusion of wild gametes to the egg take. The number of transferred fish spawned in 2019 was greater than the total of all previous years (2015-2018) combined. Pine Creek fish made up 19% off all female CRCT spawned and 31% of the males.

From 2014 to 2016, the number of CRCT captured during the spawn operation averaged over 630 fish (Table 4). Total capture in each of 2017 and 2018 was less than half of that, yielding much lower egg collection. While the catch increased to nearly 400 in 2019, it was still much lower than the catches achieved from 2014 to 2016. While those three years have proved to be anomalous when compared to catch in all other years of spawn operation, they also represent three of only four years when total egg take came close to fulfilling requested fish needs. (Interestingly, the fourth year was 2013 when, although total catch was only 332, eggs were collected from 82% of all females trapped. That figure is typically closer to 50%.) When observing the composition of catch during those three years, there is no clear pattern as to why so many more fish were trapped. In general, all capture methods were simply more effective from 2014 to 2016 than during most other years (Table 4). One consistent trend observed for many years is that fyke nets tend to capture many more fish than the inlet and outlet traps do. This probably results from a combination of the nets blocking fish from reaching the traps and a potential dampening of tributary-searching behavior during successive generations reared through brood propagation. Beginning in the early 2010s, an effort was made to allow more fish to naturally reach the traps by delaying fyke net deployment until just a day or two before the fish egg take. The next few years coincided with higher catch overall and it was difficult to evaluate whether the change in netting timing had any effect on trapping success. Only in 2017 did the trap and net catches catch similar numbers of CRCT. In 2018, however, trap catch plummeted despite the delayed net timing. In addition, net catch was also low due to problems with net deployment caused by lack of experience among trap personnel. In 2019, it was decided to run the fyke nets throughout the trap operation period. In addition, the nets were frequently

moved to new locations as the catch declined. These changes resulted in a favorable increase in CRCT catch and spawners available for egg collection. While such methods require additional time, effort, and personnel, the result was worth the effort and those methods should continue.

Collection of CRCT from the canal between Dougherty Basin and Tall Four Res was halted after 2012 to allow a natural population to establish. These fish can migrate downstream to Tall Four, but upstream migration to Dougherty Basin is blocked by natural barriers. Because the canal population had been undisturbed for 6+ years, it was assumed that it could sustain some collection efforts to boost egg production. However, the delayed start in trapping efforts in 2019 forced personnel to collect and sacrifice 60 fish from the canal for pathogen testing. The collection needed to be conducted on June 10, before trap operations began so the only way to fill the sample was electrofishing in the canal. While this collection depleted the canal population somewhat, it could be monitored more closely in the future if the need for additional spawners continues.

Although 2019 trapping efforts yielded a higher catch and larger pool of spawning CRCT to draw from, the total number of fish spawned remained low due to losses from holding cages. The cages used to hold captured fish are aging and, despite continual repair efforts, too many fish are lost each year to escapement through unnoticed holes in the mesh. It is becoming more difficult to maintain and repair all the cages and keep them in working condition. By contrast, the region does have some larger cages that can hold more than twice the number of fish (100+, opposed to 40 for the smaller cages). The smaller cages have been used at Dougherty Basin primarily because they are more easily transported on a backpack frame. Pack animals are now used regularly to transport gear to the lake, however, and should be able to handle a lesser number of the larger cages. Metal boxes were installed next to each trap location in 2019 for long-term storage of the aluminum bars, so the packing burden has been reduced significantly. Fewer cages should also be easier to repair, maintain, and keep organized during trapping.

Eggs collected during 2019 experienced differences in eye-up rate, based on egg take (Table 3). The first egg take experienced an eye-up success of only 50%, which is not unexpected for such a small lot of eggs. The second egg take yielded the highest numbers of ripe fish and eggs collected, as well as the greatest rate of eyeing success at 82%. This rate has often been difficult to achieve. A higher proportion of ripe fish naturally increases success in egg fertilization and survival because less time is spent sorting through unripe fish to find the few fish that can be utilized. There were other improved practices in the egg collection in 2019, however, that may have contributed to the improved success at the second take. Additional oxygenated live wells were placed next to the spawning table where males and females could be stockpiled. This allowed spawn personnel to more quickly sort for ripe fish as they were in the process of collecting gametes. Previously, fish were transported from cages in five-gallon buckets. This often led to eggs sitting on the screens for too long while fish were moved and sorted, especially when most fish were unripe. (Sorting for ripe fish is delayed until fish are brought to the table to avoid wasting limited eggs and milt from these small fish.) In addition, more care was given to avoid introducing water to collected eggs prior to fertilization. The third egg take once again experienced 50% egg survival. The primary challenge during that take was the limited number of fish available. Many fish were lost to cage escapement, while there was still a significant proportion of available fish that were unripe or even spent. Delays in sorting led to variable ratios in spawn group pairing and, likely, poorer survival for some of the egg lots.

The 2019 egg collection plan called for factorial spawning only during the first or largest egg take (when eggs targeted for the captive brood would be fertilized). However, available numbers of ripe fish did not allow for effective employment of the strategy during the first and

third collections anyway. While review of the 2018 spawn identified the extra work and handling of the factorial strategy as a potential factor in poor egg survival, that was certainly not the case in 2019 as the second take yielded an eye-up rate of 82%. It is possible that other logistic improvements detailed previously had a larger impact on egg survival, or that personnel were simply better practiced at the factorial technique and performed it more efficiently. Regardless of these various factors, all improvements made in 2019, along with suggested changes to holding cages, should continue as should the limited employment of factorial spawning.

2,128 eyed eggs collected at the second take were sent to FES for quarantine. By late October 2019, approximately 500-600 fish were still swimming at FES, for a rearing success (eyed egg to stocked fish) of 23-28%. These fish will be transferred to Mammoth Creek hatchery in spring 2020. The remaining 16,160 eyed eggs were hatched and raised at Fountain Green hatchery. 9,512 fingerling CRCT were stocked in fall 2019, while another 3,000 are being held over to spring 2020 for stocking in Forsyth Reservoir. This equates to a rearing success of 77%, pending overwinter survival of the Forsyth quota. This is the highest rate yet observed at Fountain Green – surpassing the high of 66% in 2018 – and represents a marked reduction in losses to encephalitis. The 2019 brood production met all conservation quotas except UM Creek, in addition to four sport fish quotas. An additional 29,729 CRCT from the Duck Fork brood production were stocked to meet the remainder of sport fish quotas (Table 6).

Contribution of "wild" gametes to the brood from Pine Creek CRCT hit an all-time high in 2019 (Table 5). The genetic diversity provided by these fish will greatly benefit the future captive brood program. BYU geneticist Paul Evans (personal comm.) recently stated that even a 5% proportion of wild fish annually could provide enough diversity to avoid a genetic bottle neck. The 2018 and 2019 Dougherty Basin cohorts that make up the captive brood met and surpassed that rough threshold.

A total of 53 brook trout were captured in fyke nets set in Dougherty Basin Lake during the 2019 brood operation. Full documentation of brook trout caught during the spawn operation was not recorded prior to 2018 when 22 were caught, but it is clear that the brook trout population has increased. Most brook trout caught in 2019 appeared to be similar in size, indicating that the increased abundance may be the result of one large cohort. The fish exhibited poor or only fair condition. For many years, the brook trout population remained at a low density, producing a small number of fish that experienced accelerated growth but didn't exert overt competition pressure on CRCT. The increased density and reduced condition and growth suggest that brook trout could now have a negative impact on CRCT growth. Informal sampling in fall 2019 observed still more brook trout. Efforts at targeted removal of brook trout should be increased in the coming years. Fall may provide the ideal time to attempt removal as brook trout congregate for the spawn. Careful documentation of brook trout caught during the spring CRCT trapping should also continue.

As the development of the captive CRCT brood continued in 2019, Salt Lake and regional staff coordinated to devise a strategy for maintaining the captive brood into the future. The primary concerns that this strategy is intended to address are: 1) to ensure that genetic diversity is maintained, 2) threat of hatchery domestication is reduced, and 3) workload to maintain pathogen testing is not excessive. While the specific schedule of work is still being determined and will depend on the pending success of the captive brood, the strategy will prescribe a cycle where collection of eggs at Dougherty Basin can be abandoned for six years (about two "generations") at a time. This means that three cohorts of CRCT produced by Dougherty Basin would support stocking and brood replacement, followed by three cohorts of fish produced by the captive brood. It is felt that this cycle will not yield a significant increase in

domestication. Following this cycle, the entire brood would be replaced by spawn from three cohorts at Dougherty Basin. In theory, the "off" cycle for Dougherty Basin would commence in 2021 (2018, 2019, and 2020 cohorts sent to Mammoth Creek). However, regional staff has requested that collection at Dougherty Basin continue until after the captive brood begins producing eggs and the combined production exceeds all requested stocking needs. This means that the captive brood will likely start out with a minimum of four cohorts. If the initial production cycle proves to be successful as designed, then the three-cohort replacement strategy will be employed in the future.

The captive brood strategy should help to significantly reduce the amount of time and effort employed trapping fish, collecting eggs, and maintaining pathogen clearance for gamete production. In addition, wild gene infusion will be conducted from another population (ie. Pine Creek, forks of Boulder Creek) to the wild brood each 10 to 12 years to continually ensure genetic diversity. It would be best to schedule this transfer for the year prior to the first collection of the three-year wild brood cycle. As possible and feasible, pathogen clearance for the captive brood, Dougherty Basin brood, and wild gene sources will be scheduled to avoid overlap.

It is imperative that regional, aquaculture, administrative and FES staff continue to work toward improving the success of the Lower Colorado CRCT brood by maintaining communication and exploring all potential avenues for enhancement of protocol, infrastructure, equipment, etc. The ultimate goal of the brood should be to efficiently and consistently meet the needs of both conservation and sport fish stocking in the Lower Colorado GMU. Until that time, the production of the Duck Fork brood has been and will continue to be instrumental in meeting sport fish needs. Since 2014, Duck Fork CRCT have comprised more than 60% of the total CRCT stocked annually in the Southern Region (Table 6). While these fish have been beneficial in meeting sport fish management goals, full evaluation of their performance – in comparison with Dougherty Basin CRCT – should be pursued to ensure that they are fully adequate to satisfy both management and anglers.

RECOMMENDATIONS FOR BROOD OPERATION

1. Efforts should continue to improve egg and fry survival during every step of brood operation: trapping, spawning, transport, eyeing, and rearing. Full and unimpeded communication among regional, administrative, and hatchery personnel will be critical in ensuring that the best practices are being implemented.
2. Egg collection should be conducted at 4-5 day intervals. Two egg collections have long been most successful, but additional efforts can be made if sufficient green fish are left after the second take.
3. Set fyke nets near the beginning of the brood operation and run through the final egg take. Two people should be assigned at a time during at least the first week of the operation to handle potential high net catches and should include at least one experienced biologist. Net locations and orientation (floating vs diving) should be altered frequently to avoid depressed catch due to net avoidance and localized depletion. Catch and length data of brook trout should be recorded.
4. Maintain the current stocking rate of 1,000 CRCT at Dougherty Basin and 100 CRCT at Tall Four.
5. Fewer, larger cages should be used for holding trapped CRCT. These cages should be meticulously inspected for holes and repaired. Immature fish, spent females, and excess males may be retained in these larger live cages to prevent recapture. A few well-maintained small cages should also be used to hold brook trout for inclusion in the pathogen sample.
6. If sufficient CRCT are not trapped in the brood lakes, collect additional fish from the canal in between the lakes. Canal fish may also be transferred downstream to Tall Four to bolster future spawn catch.
7. Egg-take protocols at Dougherty Basin should be reviewed and modified as necessary to comply with approved statewide protocols and ensure that best methods are employed.
8. Employ modified factorial spawning during the first or largest egg take only. Pairwise mating should be used during subsequent takes to improve fertilization potential and survival.
9. Hold CRCT in oxygenated live wells next to the egg take table to reduce excessive handling and delayed fertilization. Set up a tarp over the table to prevent sun exposure.
10. The canal between Dougherty Basin and Tall Four should be monitored and improved as needed to maintain water level at Tall Four. The sinkhole in Tall Four should also be monitored.
11. Survey brook trout spawning activity in the fall.
12. CRCT from Duck Fork brood production should be stocked only in sport fish waters. Southern Region staff should contribute effort to the Duck Fork brood operation, when possible.
13. Continue coordinated development of the captive Lower Colorado CRCT brood, along with its pertinent strategy.

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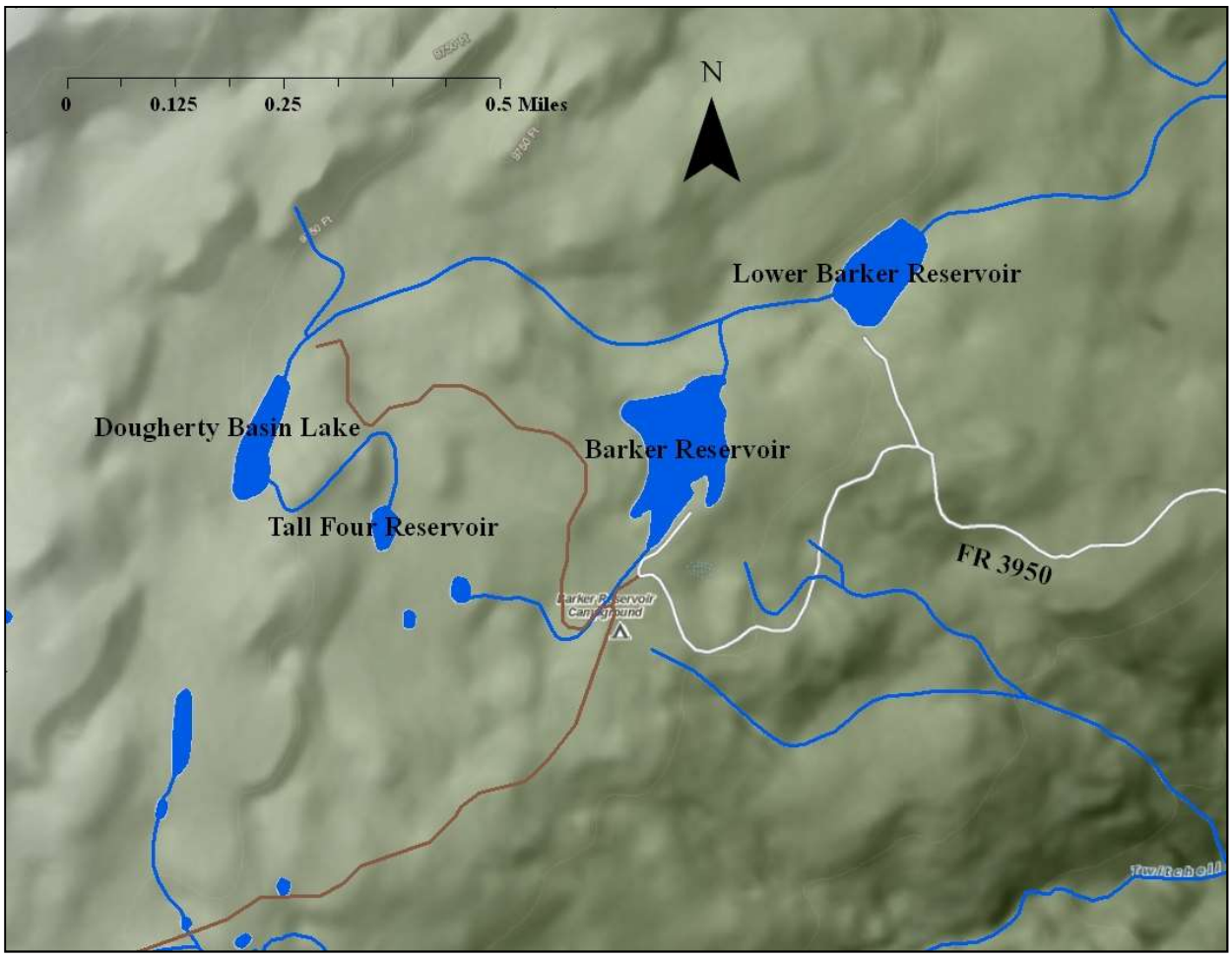

Figure 1. Map of Dougherty Basin Lake, Tall Four Reservoir, and the surrounding area.

Figure 2. Portable fish traps installed in the Dougherty Basin Lake inlet (top) and outlet (bottom).

Figure 3. Fyke net used to collect spawning Colorado River cutthroat trout at Dougherty Basin Lake.

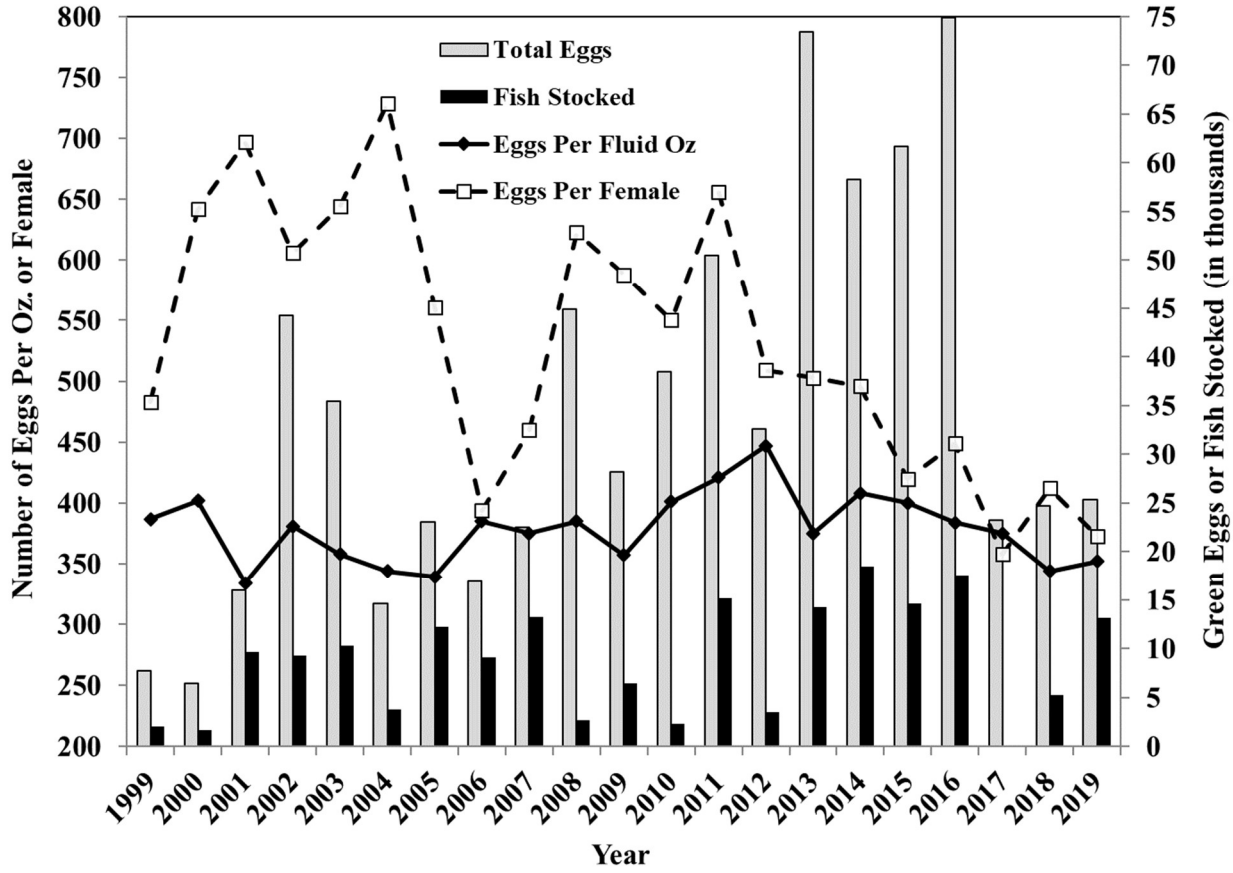

Figure 4. Total number of Colorado River cutthroat trout eggs collected during the brood operation at Dougherty Basin Lake, 1999-2019, as well as measures of eggs per fluid ounce, eggs per female, and numbers of fish stocked from the egg collection.

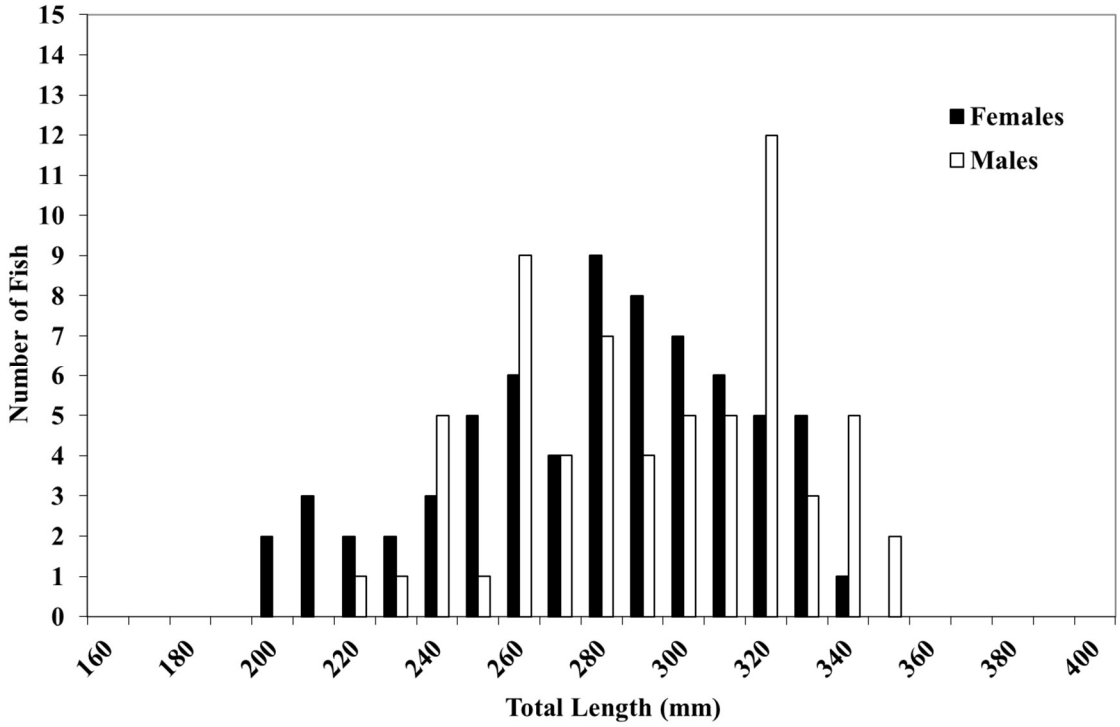

Figure 5. Distribution of total length (mm) of female and male Colorado River cutthroat trout spawned at Dougherty Basin Lake in 2019.

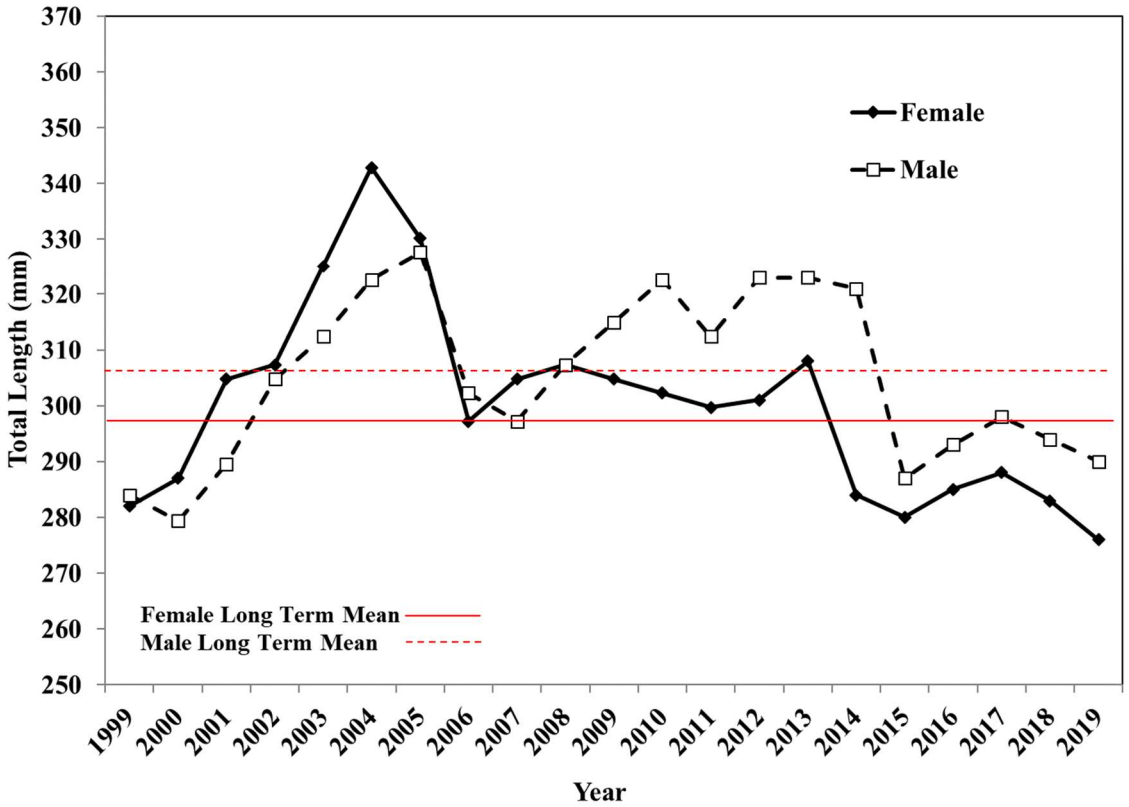

Figure 6. Mean total length (mm) of female and male Colorado River cutthroat trout spawned at Dougherty Basin Lake, 1999-2019.

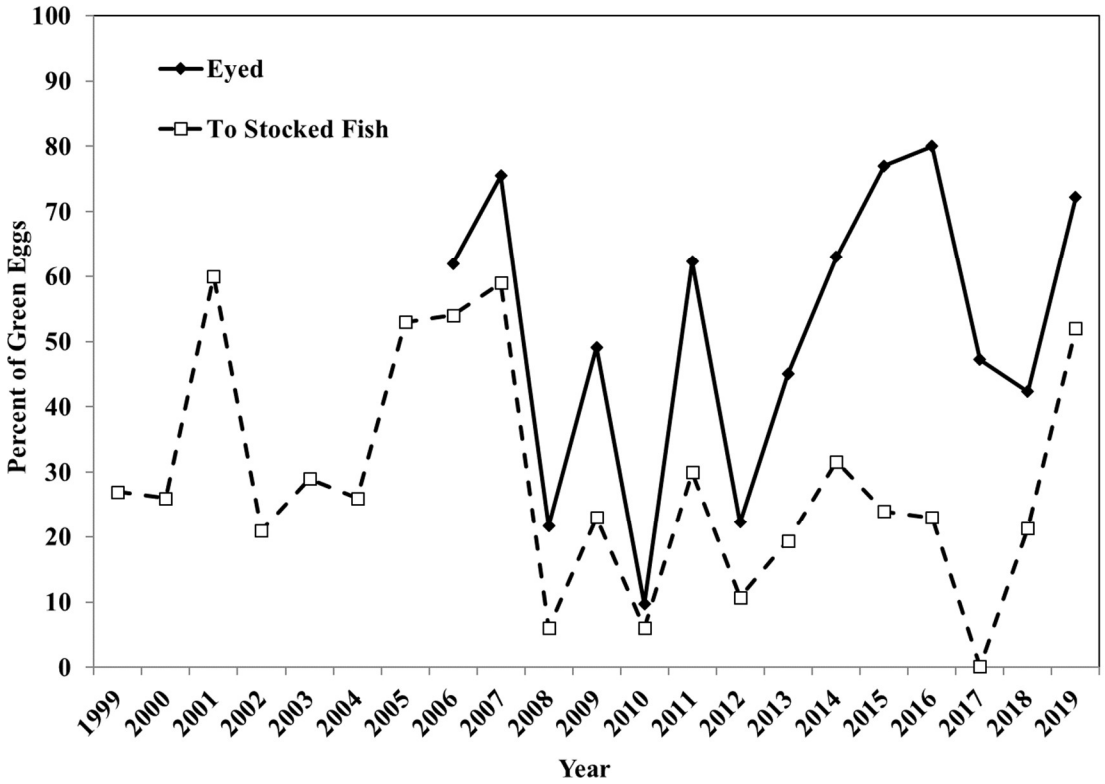

Figure 7. Percent of green eggs collected at Dougherty Basin Lake, 1999-2019, which reached the eye-up and stocking stages.

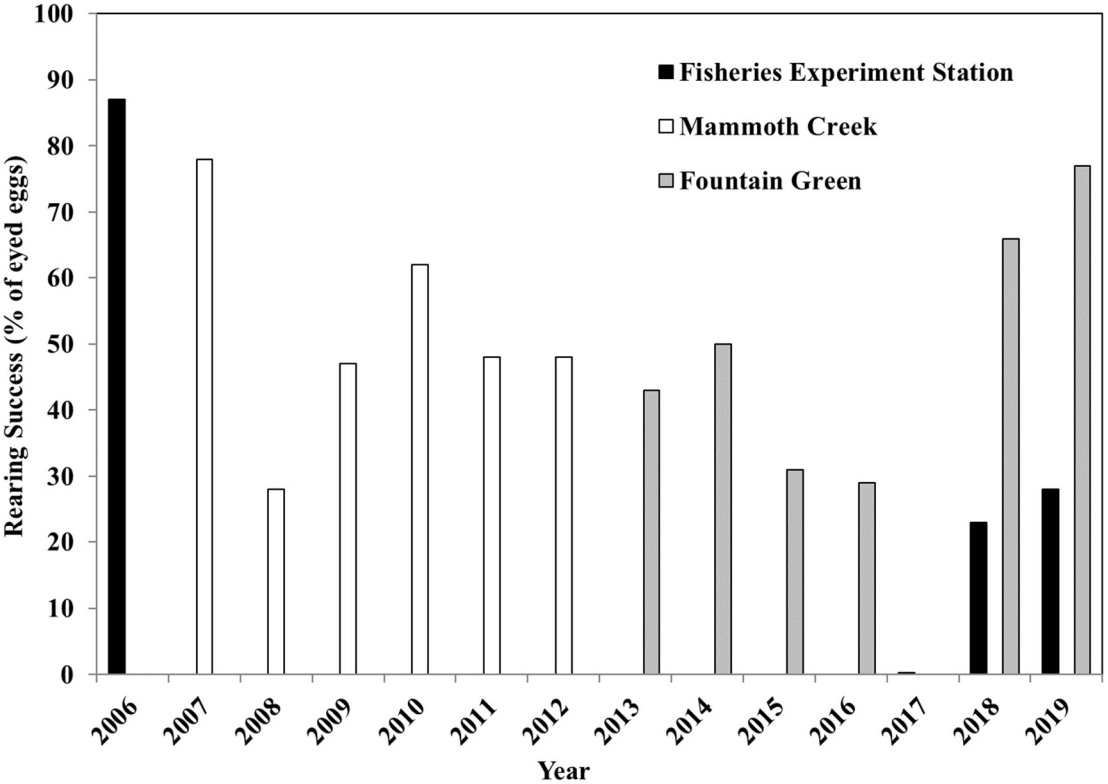

Figure 8. CRCT rearing success (percent of eyed eggs converted to stocked fish) yielded by various hatcheries, 2006-2019. (All eggs were sent to FES in 2017.)

Table 1. Total number, size, and/or source of Colorado River cutthroat trout stocked in Dougherty Basin Lake, Utah, as brood stock, 1997-2019. Transplants were of various sizes and ages, holdovers were age 1 (approximately 5-6 inches in mean total length), and fry were age 0 (approximately 2 inches mean total length). Holdovers were stocked in May and fry were stocked in September/October.

	Number of fish stocked		
	Transplants	Holdovers	Fry
1997	105[1]	--	--
1998	107[1]	--	--
1999	45[2]	--	--
2000	--	250	--
2001	--	350	699
2002	--	--	226
2003	--	--	831
2004	--	--	1,032
2005	--	250	1,000
2006	--	--	1,000
2007	--	--	1,009
2008	--	--	1,003
2009	--	--	1,002
2010	--	--	1,014
2011	--	--	1,001
2012	--	--	999
2013	--	--	1,023
2014	170[3]	--	997
2015	--	--	1,015
2016	--	--	1,045
2017	234[4]	--	--
2018	115[4]	--	1,000
2019	--	--	986

[1] – Transferred from East Fork Boulder Creek.
[2] – Transferred from West Fork Boulder Creek.
[3] – 120 transferred from Pine Creek (right pelvic clip), 50 from White Creek (left pelvic clip).
[4] – Transferred from Pine Creek (adipose clip).

Table 2. Colorado River cutthroat trout spawning times at Dougherty Basin Lake, Utah 1999-2019.

Year	Trap operation dates		Dates spawned		Number of days spawned	Lake water temp (F)	
	Begin	End	First	Last		First spawn	Last spawn
1999	15 June	23 June	17 June	23 June	2	55	58
2000	1 June	12 June	5 June	12 June	2	58	52
2001	25 May	13 June	6 June	13 June	2	58	60
2002	21 May	12 June	30 May	12 June	3	61	60
2003	29 May	24 June	10 June	24 June	3	58	57
2004	28 May	22 June	8 June	22 June	3	60	58
2005	8 June	28 June	20 June	28 June	3	55	54
2006	26 May	14 June	8 June	13 June	2	55	58
2007	29 May	12 June	5 June	12 June	2	52	54
2008	6 June	17 June	12 June	17 June	2	50	55
2009	2 June	16 June	8 June	16 June	3	50	50
2010	7 June	14 June	9 June	14 June	2	58	54
2011	8 June	20 June	14 June	23 June	3	56	56
2012	23 May	4 June	30 May	4 June	2	45	51
2013	28 May	10 June	3 June	10 June	2	55	52
2014	27 May	9 June	3 June	13 June	3	54	47
2015	26 May	11 June	1 June	11 June	4	48	[1]
2016	1 June	13 June	6 June	13 June	2	52	[1]
2017	31 May	12 June	6 June	12 June	2	55	[1]
2018	30 May	11 June	5 June	11 June	2	51	[1]
2019	10 June	1 July	17 June	1 July	3	49	[1]
Mean	31 May	15 June	7 June	15 June	-	54	55

[1] – Temperature not recorded.

Table 3. Colorado River cutthroat trout spawning results at Dougherty Basin Lake, Utah, in 2019.

Date	Lake water temp (F)	Number of females spawned	Mean Female TL (mm) (n)	Mean Male TL (mm) (n)	Total eggs	Eggs per fluid ounce	Mean number of eggs per female	Percent green eggs eyed
June 17	49	3	300 (3)	313 (5)	1,476	369	492	50%
June 24	51	46	273 (46)	287 (46)	17,550	351	382	82%
July 1		19	278 (19)	291 (13)	6,318	351	333	50%
Total	--	68	276 (68)	290 (64)	25,344	352	373	72%

Table 4. Colorado River cutthroat trout spawning totals at Dougherty Basin Lake, Utah, 1999-2019.

Year	Total number of trout trapped						Number of females spawned	Mean length (mm)		Eggs per fluid ounce	Mean number of eggs per female	Total eggs	Percent green eggs eyed	Percent survival (eggs to stocked fish)	Number of fish stocked
	Inlet	Outlet	Fyke nets	Tall Four	Canal	Total		Female	Male						
1999	31	11	--	--		42	16	282	284	387	483	7,734		27%	2,088
2000	12	9	--	--		21	10	287	279	402	642	6,428		26%	1,671
2001	149	35	--	--		184	23	305	290	334	697	16,032		60%	9,619
2002	245	52	--	15		312	73	307	305	381	606	44,258		21%	9,294
2003	130	78	--	--		208	66	325	312	358	644	35,479		29%	10,289
2004	94	50	--	--		144	20	343	323	344	729	14,589		26%	3,793
2005	46	36	48	--		130	41	330	328	339	561	23,022		53%	12,202
2006	32	68	105	32		237	43	297	302	385	394	16,927	62%	54%	9,141
2007	13	23	81	55		172	49	305	297	375	460	22,516	76%	59%	13,284
2008	9	22	121	103		255	72	307	307	385	623	44,880	22%	6%	2,693
2009	9	30	63	49		151	48	305	315	357	588	28,215	49%	23%	6,489
2010	7	6	134	79		226	70	302	323	401	550	38,496	10%	6%	2,310
2011	32	31	155	38		256	77	300	312	421	656	50,520	62%	30%	15,156
2012	15	37	71	38	78	239	64	301	323	447	509	32,598	22%	11%	3,488
2013	32	31	253	16		332	146	308	323	375	503	73,476	45%	19%	14,254
2014	26	27	259	163		475	118	284	321	408	496	58,253	63%	32%	18,500
2015	76	59	436	121		692	147	280	287	400	420	61,723	77%	24%	14,600
2016	157	85	358	128		728	167	285	293	384	449	74,930	80%	23%	17,559
2017	90	34	102	40		266	65	288	298	375	358	23,262	47%	<1%	34[a]
2018	15	16	171	56		258	60	283	294	344	412	24,744	42%	21%	5,290
2019	24	4	308	43		379	68	276	290	352	373	25,344	72%	52%	13,112
Means	59	35	178	65		272	69	297	306	379	531	34,449	52%	29%	8,803

[a] – Brood group transferred from FES to Mammoth Creek Hatchery in 2018.

Table 5. Colorado River cutthroat trout introduced from remnant populations and spawned at Dougherty Basin Lake, 2015-2019.

Year	White Creek		Pine Creek		Total
	Female (% total)	Male (% total)	Female (% total)	Male (% total)	
2015	3 (2%)	0	0	1 (0.7%)	4
2016	0	1 (0.7%)	5 (3%)	2 (1.4%)	8
2017	0	1 (2.3%)	1 (1.5%)	0	2
2018	0	0	6 (10%)	5 (8.3%)	11
2019	0	0	13 (19%)	20 (31%)	33
Total	3 (<1%)	2 (<1%)	25 (5%)	28 (6%)	58

Table 6. Colorado River cutthroat trout produced at the Duck Fork brood stocked for sport fishing purposes in the Southern Region.

Year	Number Stocked	Number of Waters	Percent of Total CRCT
2014	23,209	5	56%
2015	16,000	3	52%
2016	26,700	7	60%
2017	29,701	9	100%
2018	28,500	7	86%
2019	29,979	10	70%
Mean	25,640	7	71%