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Research Article

# Mortality of Landlocked Fall Chinook Salmon Broodstock After Electrofishing or Ascending a Fish Ladder

**Brandon C. Maahs[1], Hilary A. Meyer[1], Nathan D. Huysman[2], Jill M. Voorhees[2] and Michael E. Barnes[2*]**

[1]South Dakota Department of Game Fish and Parks, 20641 South Dakota Hwy 1806 Fort Pierre, South Dakota 57532

[2]South Dakota Department of Game, Fish and Parks McNenny State Fish Hatchery19619 Trout Loop, Spearfish, South Dakota 57783

*Corresponding author:* Barnes M E, South Dakota Department of Game Fish and Parks, E-mail: mike.barnes@state.sd.us, Tel: 605-642-1262

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**Abstract**

Landlocked fall Chinook salmon (*Oncorhynchus tshawytscha*) broodstock can be obtained either passively after broodfish ascend a fish ladder, or actively through electrofishing. This study examined the mortality of broodstock Chinook salmon obtained by either method in Lake Oahe, South Dakota, USA in 2017. Overall, 10% of the 594 salmon that ascended the ladder died prior to spawning, which was significantly less than the 19% of the 344 salmon that died after electrofishing. More importantly, only 4% of the female broodstock that ascended the ladder died, which was also significantly less than the 12% mortality of females that were electrofished. Mortality of the ladder-run males was also significantly lower than that of males obtained by electrofishing. The salmon broodstock that ascended the ladder survived for a slightly longer duration. These results strongly suggest a negative effect of electrofishing on landlocked fall Chinook salmon broodstock survival. The use of electrofishing to obtain landlocked Chinook salmon broodstock is only recommended if the number of fish ascending a fish ladder cannot provide the desired number of broodstock.

**Keywords**

Chinook salmon; *Oncorhynchus tshawytscha*; Spawning; Broodstock ;Mortality.

## Introduction

Feral broodfish collection is a common practice for many fisheries management agencies. Active capture methods, such as electrofishing, are used for broodstock collection, as are passive methods such as fish ladders or weirs [1, 2]. Typically, broodstock must remain alive for days after such capture to allow for ovulation or to maximize artificial spawning operational efficiencies. However, mortality rates may vary with broodstock collection methods [3].

Although electrofishing is commonly used to collect feral fish [4], there is risk of injury to fish when it is employed as a capture method [5-7]. Both internal and external damage to salmonids due to electrofishing has been reported [8-10]. In contrast to electrofishing, broodfish ascending a fish ladder to holding raceways experience relatively little stress and risk of injury. They are not subjected to electrical current, and are not netted or removed from the water.

Because of a lack of suitable spawning habitat, fall Chinook salmon in Lake Oahe, South Dakota do not naturally reproduce; the population is maintained entirely by artificial spawning and hatchery production [11]. The majority of salmon broodstock are generally obtained via a fish ladder at Whitlock's Spawning Station, near Gettysburg, South Dakota. How ever during years when inadequate numbers of female broodstock return to the spawning station, additional females are obtained by boat electrofishing. While broodstock mortality has been observed in both electrofished and ladder-run fish, we hypothesized that electrofishing, coupled with increased handling required to capture and transport the fish to the spawning station holding raceways, was negatively impacting broodstock survival. Thus, the objective of this study was to determine the survival-to-spawning of landlocked fall Chinook salmon captured by electrofishing or after ascending the fish ladder.

## Material and Methods

Data were collected in October 2017. Broodfish were obtained from the South Dakota portion of Lake Oahe, a mainstem Missouri River storage reservoir extending approximately 370 km from Pierre, South Dakota to Bismarck, North Dakota. At full pool, Lake Oahe has a surface area of 150,144 ha and contains approximately 47,755 ha of permanent, coldwater habitat [12]. The fish ladder, located at Whitlock's Spawning Station, was run for 37 days, starting in late September and continuing through all of October. The ladder leads into a catch raceway, with three additional raceways to separate and hold male, unripe female, and ripe (gravid) female fish for weekly egg collection operations.

Shoreline electrofishing occurred twice per week for 3.5 weeks (a total of seven times) in October. Three electrofishing boats (Generator power pulsator; Smith-Root Inc. Vancouver) were used to collect broodstock salmon from Lake Oahe embayments. Pulsed direct current at 120 pulses per second was used. Voltage varied between 240 and 340 volts, and amperage varied between 18-20 A, depending on water depth and substrate. All salmon captured by electrofishing were placed into an on-boat live well with a recirculating pump and subsequently loaded into truck-based insulated tanks filled with lake water and fitted with aerators and compressed oxygen for transport to the spawning station raceways. Salmon were unloaded from transport trucks and tagged with uniquely numbered t-bar anchor tags (Floy Tag Inc., Seattle, Washington). Date of capture, tag number, sex, and reproductive status (ripe or unripe females) were recorded for all salmon captured with electrofishing prior to placement in designated spawning station raceways. Any electroshocked salmon which were dead-on-arrival to the spawning station were discarded and were not tagged or counted.

The catch raceway at Whitlock's Spawning Station was sorted three times per week (Monday, Wednesday, and Friday). All fish were tagged with a uniquely numbered t-bar anchor tag. All females that ascended the fish ladder were placed into the respective holding raceway (ripe or unripe). Date of capture, tag number, sex, and reproductive status were recorded for all fish that ascended the ladder.

All of the females (both electrofished and ladder-run fish) in the unripe holding raceway were sorted three times per week (Monday, Wednesday, and Friday) to determine any changes in reproductive status. Reproductive status of each fish was recorded and any newly ripened females were transferred into the ripe female holding raceway.

Fish were considered a mortality if they died while

being held in the spawning station prior to a weekly spawning event. Mortalities were recorded (tag number, sex, and date of mortality) and removed from the raceways during sort days. For fish that did not survive to a spawning event, the number of days a fish survived in the holding raceways post-capture was calculated.

Percent mortality comparisons were analyzed using chi-square tests with significance predetermined at $P < 0.05$. Analysis was conducted using SPSS statistical analysis software (SPSS, Inc., Chicago, Illinois).

**Results**

A total of 938 Chinook salmon were captured and tagged, with 1.1% tag loss (10 lost tags). Over the five weeks of this study, 594 fish ascended the fish ladder and 344 were captured by electrofishing **(Figure 1).**

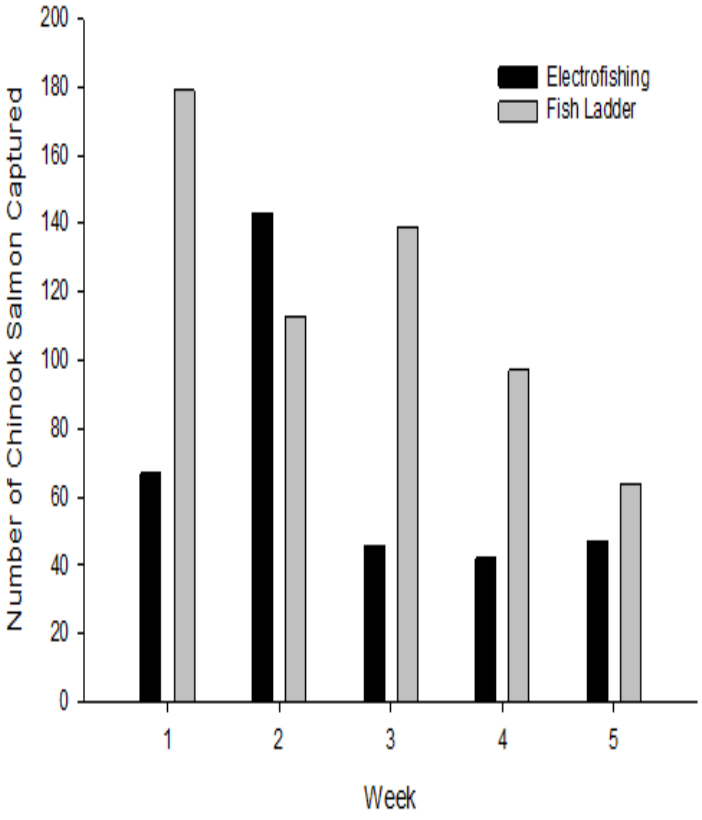


**Figure 1:** Number of Chinook salmon broodstock captured by electrofishing or a fish ladder, by week on Lake Oahe, South Dakota during typical egg collection operations in October, 2017.

Overall, 10% of the salmon that ascended the ladder died prior to spawning, which was significantly less than the 19% that were electro fished **(Figure 2**; $\chi^2 = 14.379$, d.f. = 1, p-value = 0.001). More importantly, only 4% of the female broodstock that ascended the ladder died, which was significantly less than the 12% mortality of females that were electrofished ($\chi^2 = 6.134$, d.f. = 1, p-value = 0.013). At 13%, mortality of the ladder-run males was also significantly less than the 19% for those obtained by electrofishing ($\chi^2 = 3.975$, d.f. = 1, p-value = 0.046).

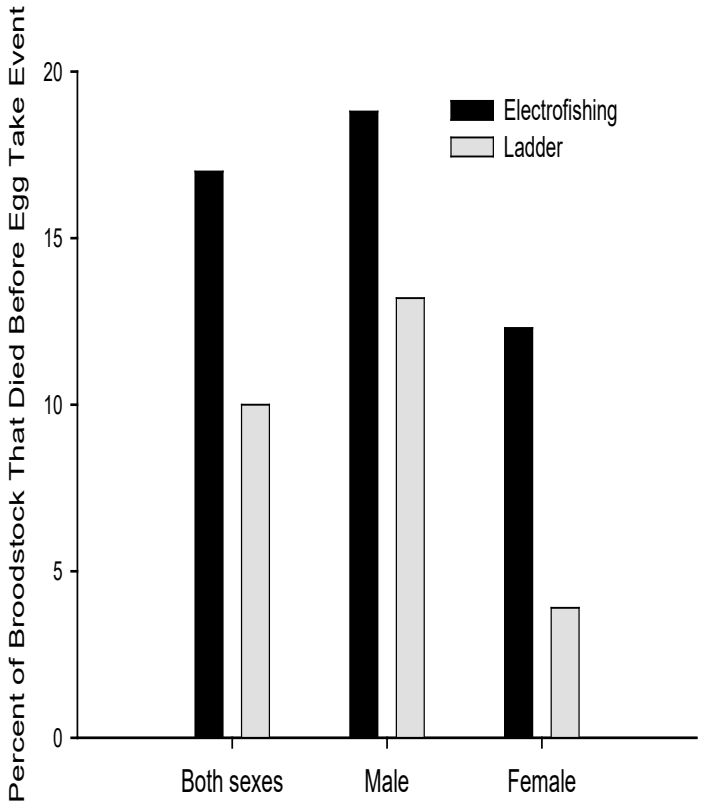


**Figure 2:** Percent of Chinook salmon broodstock captured by electrofishing (black bars) or a fish ladder (gray bars) that died before an egg collection event at the Whitlock Spawning Station, Lake Oahe, South Dakota during typical operations in October, 2017.

The mean (SE) time to mortality for salmon that ascended the ladder and those that were electroshocked was not significantly different at 8.2 (0.4) days and 7.5 (0.5) days, respectively (Figure 3; $\chi^2 = 1.559$, d.f. = 1, p-value = 0.212). There was also no significant difference in the mean

(SE) number of days to mortality for females obtained by either method ($\chi^2 = 0.316$, d.f. = 1, p-value = 0.574) or males ($\chi^2 = 0.606$, d.f. = 1, p-value = 0.4363).

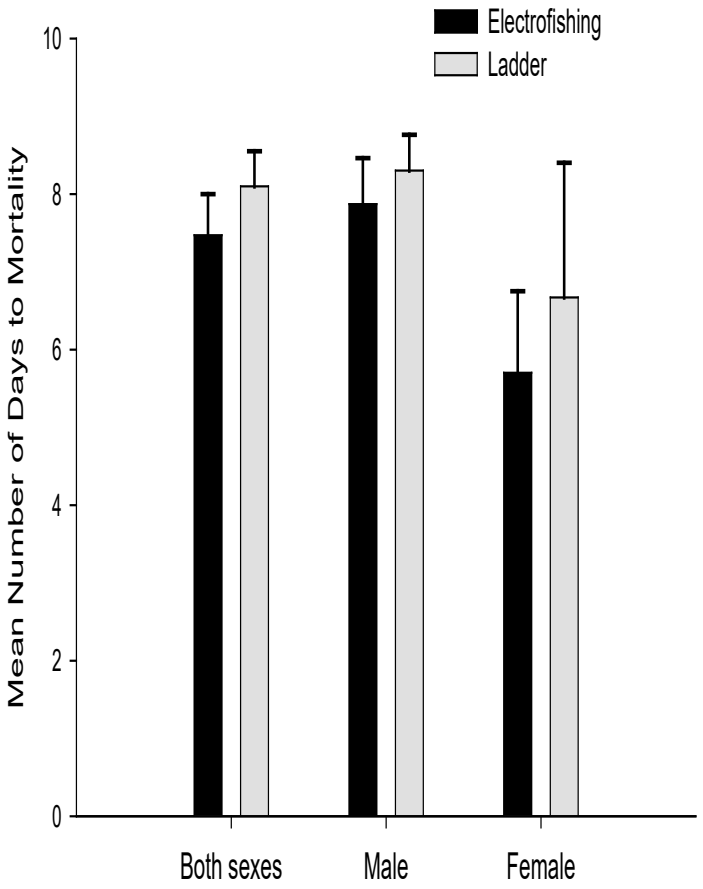


**Figure 3:** Mean number of days to mortality for Chinook salmon broodstock captured by electrofishing (black bars) or a fish ladder (gray bars), that died before an egg collection event at the Whitlock Spawning Station, Lake Oahe, South Dakota during typical operations in October, 2017. Error bars represent Standard Error.

## Discussion

The increase in broodfish mortality associated with electrofishing is not surprising. Although electroshock itself can cause injury and death [13, 14], the increased netting and handling occurring during electrofishing is particularly problematic. As described by Huysman et al. [15], electrofished females were subjected to electroshock, netted, placed into a small boatbased livewell, netted again, placed into a truck-based tank for transfer to the spawning station, and then netted again before release into a holding raceway at the station. All of this netting and handling typically occurred within a relatively short time-frame of two to six hours.

The numerous loading and unloading events very likely created considerable stress on the broodfish [16]. Davis and Schreck [17] showed that handling and confinement in a transfer tank increased fish respiration and energetic costs. Davis and Parker [18] also showed that fish that were electroshocked and confined in transfer tanks for two hours experienced significantly elevated stress hormone levels. Although fish densities were not measured in this study, high confinement densities have been reported to result in fish death [19]. In addition to the afore-mentioned stressors, the landlocked fall Chinook salmon electrofished in this study also likely experienced chase-induced stress [20]. In contrast, none of these stressful or potentially-injurious events were experienced by the salmon broodstock ascending the fish ladder at the station prior to spawning.

It is unfortunate that the number of electrofished broodstock that died during transportation to the station was not recorded. Adding this mortality to the number of electrofished salmon that died at the station prior to spawning would further accentuate the mortality differences between electrofished and ladder-run broodfish. This large increase in mortality of electrofished salmon makes electrofishing broodstock very inefficient. During this study, three staff were required for each of three boats for each day of electrofishing effort. Not only are the labor requirements high, but electrofishing also has substantial additional equipment, maintenance, and transportation costs, none of which are incurred using broodfish passively obtained using a fish ladder.

## Conclusion

The ultimate goal of electrofishing salmon is to collect eggs to produce progeny for restocking. Thus, combining the higher mortality rates of electrofished salmon (in comparison to those ascending the ladder), with the elevated mortality of eggs obtained from electrofished landlocked fall Chinook salmon reported by Huysman et al. [15] and Barnes et al. [2], strongly suggests that electrofishing salm-

on broodstock should only be done when absolutely necessary. Methods to maximize the number of salmon ascending the fish ladder, such as changes to stocking locations, stocking timing, and possible imprinting strategies, should be thoroughly investigated.

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