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Research Article

# An Evaluation of Two Rearing Densities During the Initial Rearing of Landlocked Lake Oahe Fall Chinook Salmon

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## Abstract

Landlocked fall Chinook salmon *Oncorhynchus tshawytscha* were at an initial density of either 0.96 or 3.76 kg/m$^3$ shortly after feed training. After 30 days of rearing mean ± SE final rearing densities were 3.26 ± 0.27 and 12.85 ± 0.62 kg/m$^3$. There were no significant differences between percent gain, feed conversion ratio, individual fish length, individual fish weight, specific growth rate, or condition factor between fish reared at either density. Percent mortality was less than 3% in all of the tanks and was not significantly different between the densities. The results of this study indicate that either of the two densities are acceptable for landlocked fall Chinook salmon rearing immediately after initial feeding. However, the results may only apply to the 30-day period evaluated.

**Keywords:** Chinook salmon; Density; Salmon; Salmonid

## Introduction

The density of fish in a rearing unit can have a large impact on aquaculture production. Rearing density is defined as the weight of fish per unit volume of rearing space [1]. High rearing densities are commonly used to maximize fish production but can affect fish health and physiological functioning [2]. In addition, growth, feed conversion efficiency, and fin condition can all be negatively impacted at higher rearing densities [3,4]. High density rearing can also increase use of higher water velocity areas and contribute to elevated activity levels [5]. They can also negatively impact survival of hatchery-reared fish released into natural environments [6-8].

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Individual fish species likely have specific optimal rearing densities that maximize production and minimize any density-induced negative effects [1,9]. Rearing densities for juvenile Chinook salmon *Oncorhynchus tshawytscha* from their native range have been studied extensively [6,9-12]. Barnes et al. [13] is the only published research examining rearing density in completely landlocked fall Chinook salmon located outside of their native range. This entirely freshwater, completely hatchery-maintained population is phenotypically different from native range fall Chinook salmon [13-15].

In addition to varying by species, optimal rearing densities also likely vary by rearing unit type (e.g. rectangular vs. circular tanks) and may even be hatchery specific [1,6,9]. There is a general lack of information on the optimal rearing density for juvenile fish shortly after initial feeding. This is particularly true for small juvenile landlocked fall Chinook salmon reared in circular tanks. Thus, the objective of this study was to evaluate the impacts of a relatively low and relatively high rearing density on landlocked fall Chinook salmon growth and survival during the period immediately after feed training.

## Materials and Methods

This experiment was conducted at McNenny State Fish Hatchery in rural Spearfish, South Dakota, USA, over a 30-day period from January 11, 2021, to February 11, 2021. Approximately 57,000 juvenile Chinook salmon (mean ± SE, total length: 41 ± 1 mm, weight: 0.51 ± 0.01 g, n = 30) were split into six (n = 3) fiberglass circular tanks (1.8 m in diameter, 0.8 m deep, 0.6 m operating depth) at two different densities. The tanks of fish at the lower density of 0.96 kg/m$^3$ had approximately 4,000 fish (1.95 kg) and the tanks of fish at the higher density of 3.76 kg/m$^3$ had approximately 15,000 fish (7.64 kg). Aerated and degassed well water (11° C; total hardness as $CaCO_3$, 360 mg/L; alkalinity as $CaCO_3$, 210 mg/L; pH 7.6; total dissolved solids, 390 mg/L) was used throughout the experiment. The tanks were almost entirely covered with only a small opening present to allow the feeder to dispense feed.

The fish were fed using the hatchery constant method [16] with an expected feed conversion ratio of 1.1 and projected growth of 0.065 cm/day. All the fish were fed automatically with EWOS 505 (Norcolast AS, Sweden) feeders using #0 BioVita Starter (Bio-Oregon, Longview, Washington). Feed was dispersed during daylight hours every 15 minutes for 30 seconds. The low-density tanks received a total of 5.03 kg of feed over the duration of the experiment, and the high-density tanks received 19.72 kg. The tanks were cleaned and moribund fish were removed daily.

After 30 days at the end of the experiment, 10 randomly selected fish from each tank were weighed to the nearest 0.1 g and total length was measured to the nearest 0.01 mm. Total tank weight was obtained by weighing fish in each tank. The following formulas were used:

$$Gain = end\ tank\ weight - start\ tank\ weight$$

$$Percent\ gain\ (\%) = 100 * \frac{gain}{start\ tank\ weight}$$

$$Feed\ conversion\ ratio\ (FCR) = \frac{food\ fed}{gain}$$

$$Percent\ mortality\ (\%) = 100 * \frac{moribund\ fish}{total\ number\ of\ fish}$$

$$Condition\ factor\ (K) = 10^5 * \frac{fish\ weight}{fish\ length^3}$$

$$Specific\ growth\ rate\ (SGR) = 100 * \frac{\ln(end\ weight) - \ln(start\ weight)}{number\ of\ days}$$

Data were analyzed with t-tests using the statistical program SPSS (24.0, IBM, Armonk, New York, USA). Individual tanks were the experimental unit and significance was predetermined at $p < 0.05$.

## Results

Final tank weights and densities (mean ± SE) were 6.6 ± 0.5 kg and 3.26 ± 0.27 kg/m$^3$ respectively in the lower density tanks and 26.1 ± kg and 12.85 ± 0.62 kg/m$^3$ in the higher density tanks. There were no significant differences in percent gain or feed conversion ratio in the tanks of fish reared at either density (Table 1). In addition, individual fish length, weight, specific growth rate, and condition factor were not significantly different between the densities (Table 2). Percent mortality in all tanks was less than 3%, and not significantly different between the densities.

| | Tank Density | | | | | |
|---|---|---|---|---|---|---|
| | Low | | | High | | |
| Initial density (kg/m$^3$) | 0.96 | | | 3.76 | | |
| Initial weight (kg) | 1.95 | | | 7.64 | | |
| Final weight (kg) | 6.63 | ± | 0.55 | 26.13 | ± | 1.27 |
| Final density (kg/m$^3$) | 3.26 | ± | 0.27 | 12.85 | ± | 0.62 |
| Gain (kg) | 4.68 | ± | 0.55 | 18.49 | ± | 1.27 |
| Gain (%) | 240 | ± | 28 | 242 | ± | 17 |
| FCR | 1.16 | ± | 0.14 | 1.13 | ± | 0.07 |
| Mortality (%) | 2.57 | ± | 0.62 | 2.03 | ± | 0.26 |

**Table 1:** Mean (± SE) total tank weights, weight gain, percent gain, feed conversion ratio (FCR[a]), and percent mortality from tanks of landlocked fall Chinook salmon reared at two different densities for thirty days beginning shortly after initial feeding ($n = 3$, $p < 0.05$).

[a] FCR = food fed / gain

## Discussion

The results of this study show that landlocked fall Chinook salmon growth shortly after first-feeding was unaffected by the two densities used in this study. These results are supported by two prior studies, both using larger, more developed, juvenile Chinook salmon. Banks [17] reported rearing density had no significant effect on salmonid growth. Barnes et al. [8] also observed no significant differences in total length, weight, or condition factor in Chinook salmon reared at two different densities.

In contrast, increased rearing density has resulted in growth decrease for Chinook salmon in other studies [3,6,9,18]. However, these studies evaluated densities with larger juvenile salmon in rectangular

| | Tank Density | | | | | |
|---|---|---|---|---|---|---|
| | Low | | | High | | |
| Total length (mm) | 55.96 | ± | 0.78 | 53.57 | ± | 0.99 |
| Weight (g) | 2.18 | ± | 0.24 | 1.74 | ± | 0.04 |
| K | 1.24 | ± | 0.83 | 1.14 | ± | 0.07 |
| SGR | 1.09 | ± | 0.08 | 0.93 | ± | 0.02 |

**Table 2:** Individual fish mean (± SE) total lengths, weights, condition factor (K[a]), and specific growth rate (SGR[b]) of landlocked fall Chinook salmon reared at two different densities for thirty days beginning shortly after initial feeding ($n = 3$, $p < 0.05$).

[a] $K = 10^5$ x (fish weight / fish length$^3$)

[b] SGR = 100 x [(ln(end weight) – ln(start weight)) / number of days]

rearing units, as opposed to the shortly-after-first-feeding salmon and circular tanks used in the present study. Lastly, Olson and Paiya [12] did not observe a density effect on spring Chinook salmon weight gain, but also noted a small, potentially biologically insignificant, effect of rearing density on fork length.

Feed conversion ratio did not differ between the two rearing densities used in this study. In studies with larger Chinook salmon, Ewing et al. [6] and Barnes et al. [8] in one year also observed no density-dependent effects on feed conversion ratio. However, numerous other studies have reported lower feed conversion ratios at lower rearing densities [8,10,18-22].

Ewing and Ewing [1] observed a trend of increasing juvenile Chinook salmon mortality associated with increasing rearing densities over 15 years in multiple hatcheries. However, the similar mortality rates between the two densities used in this study support the absence of density-dependent mortality during Chinook salmon rearing observed by Ewing et al. [6], Banks and LaMotte [9], Barnes et al. [8], and Olson and Paiya [12].

This study was conducted for only 30 days. The timing and duration of fish rearing density studies can impact the results [1,8], with short-term studies particularly problematic [8,23]. Thus, the results of this study, while legitimate for the 30-day duration, may not be indicative of potential density-dependent effects during different periods of landlocked fall Chinook salmon rearing. To fully understand the effects of rearing density, longer duration experiments throughout the entire salmon rearing period are needed.

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