Continuous Study: A population study on Chinook Salmon (*Oncorhynchus tshawytscha*) in the Capilano River Hatchery

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Abstract

Over the past few decades, the population of Chinook salmon has been declining in the Pacific Northwest ecosystem, mostly caused by a combination of increasing demand of Chinook in fisheries, a higher predation pressure, and a decrease in survival and reproductive success due to climate change. This species has long been considered a vital player in the Pacific Northwest ecosystem, so a decline in the population will have several serious effects on other species and the environment. In order to recover the Chinook population, hatcheries were built as an additional source for restocking salmon population. However, the recovery efficiency of hatcheries has long been doubted. In order to find the current salmon population recovery of the Pacific Northwest ecosystem, a continuous study was carried following the same procedure is done by Houwelling et al. last year. Our study focused on 1) whether the increase in the number of returning Chinook last year was an outlier or not, and 2) testing if the population of Chinook salmon is still decreasing in terms of the number of salmon returning to the hatchery. Data was collected by counting the number of Chinook returning over one hour period. By averaging the number of five trails and calculating the estimated total number of returning, we compared this year's estimation with the estimation calculated in the previous study. The result showed an increasing returning number ($W = 46$, p-value $= 0.006$) compared to the 2017 returning number. Our result showed a significantly greater return number of Chinook salmon in 2018 than the return number the previous study estimated in 2017.

Introduction

The population of Chinook salmon (*Oncorhynchus tshawytscha*) has been declining in the Pacific Northwest ecosystem over the last few decades (Ohlberger *et al.* 2018). One main reason for this reduction is the high demand for Chinook in fishing, as approximately one million are taken each year in sport fisheries (Healey 1991). In addition, many predators of Chinook salmon have increased in abundance, leaving more Chinook susceptible to predation (Ohlberger *et al.* 2018). Climate change is also a factor in the decline of the salmon population as the stress caused by the increase in temperature decreases adult Chinook survival and reproductive success (Crozier *et al.* 2008).

The declining trend of the Chinook salmon population is of great concern due to the large impact this species has on the Pacific Northwest ecosystem. Most notably, Pacific salmon play a vital role in the transport of nutrients from marine to terrestrial ecosystems (Cederholm *et al*. 1999). After spending 5-7 years in the ocean, the Chinook salmon return to their original spawning site where they are a valuable source of food for bird and mammal species. Furthermore, their decaying carcasses release more nutrients and increase the productivity of other aquatic species (Helfield and Naiman 2006). In attempts to recover the salmon populations, humans have built many hatcheries where they produce large quantities of salmon in hopes of replenishing population numbers, however, the effectiveness of the hatchery system is unclear (Meffe 1992).

In 2017, a study by Houweling *et al*. was conducted to observe the effects of this population recovery system on Pacific Northwest salmon. They determined the number of Chinook salmon that returned to the Capilano River Hatchery (Figure 1) in North Vancouver, British Columbia and found that the number of returns was the largest it has been in the past seven years (Houwling et al. 2017). The objective of this study is to further investigate this outstanding and unexpected result by determining the number of returns in 2018 using the same method. Comparing the return values from both years will provide information as to if this 2017 increase in Chinook returns is indicative of a generally increasing trend in the years to come or is a large outlier in a decreasing trend.

We hypothesize that the number of Chinook returns to the Capilano River Hatchery will decrease from 2017. Seeing as the climate is continuing to warm, fishing practices are still very high, and the abundance of salmon predators is increasing, we think it is likely that the high number of salmon returns in 2017 was an outlier in the generally declining trend. Therefore, we predict that the number of Chinook returns found in 2018 at the Capilano River Hatchery will be lower than the number of returns found in 2017.

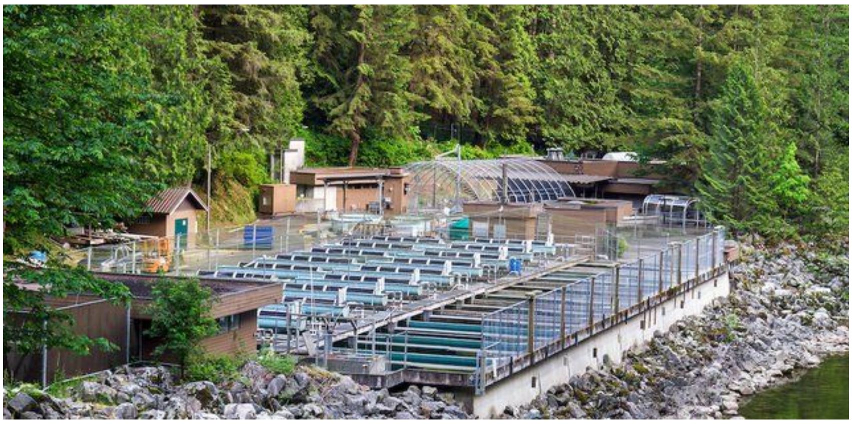

Figure 1. A photo of the Capilano hatchery located near the Capilano river taken by TripExpert.

Materials and Methods

Study site

Our study was conducted on site at the Capilano Salmon Hatchery located in North Vancouver. The hatchery is located upstream of the Capilano suspension bridge and downstream from the Cleveland Dam. Several salmon populations return to Capilano Hatchery at different times of the year but for the duration of our study the majority of returning salmon were adult Chinook.

Juvenile salmon are released from the salmon hatchery into the Capilano river which flows into the Burrard Inlet. After approximately five to seven years the salmon return to Capilano River and the Capilano salmon hatchery where they release their eggs and then die. At the hatchery, there is a series of steps called a salmon ladder that the fish climb in order to enter the hatchery. This ladder is consists of a series of small pools of water that increase in height by approximately one foot each for each step. The current of the water is strong (although it varies day to day) and is traveling downstream meaning the salmon have to fight against both the current and the increasing height in the ladder.

One problem associated with the area that we experienced is the presence of fishermen intercepting the salmon on their journey to the hatchery. At any time during the day you can find dozens of fisherman catching Chinook. Fishing during November is supposed to be prohibited but no law enforcement was observed. Our team spoke to a few fishermen in the area who declined to comment on how fishing might negatively affect the efforts of the hatchery. This makes obtaining accurate measurements at the hatchery challenging because there is this built-in systematic error in that more fisherman are present when the weather is nice or when it is a convenient time of day. The more fishing occurring downstream of the hatchery, the slower the rate of salmon returning will be since some salmon are getting removed.

Data collection

Since our research is a continuation of research conducted in 2017 by a previous group of students, we had perform identical data collection in order obtain numbers that can be compared to last year to get meaningful information.

Our observations were taken from the second rightmost window of the Capilano Salmon Hatchery observation room. This is because it gives the best view of the final step of the salmon ladder which is arbitrarily chosen as the threshold for salmon entering the hatchery. We counted the salmon for one hour using a smartphone timer to keep track of time and a combination of handheld counters and the "Tally Counter" app on the apple app store. From this we calculated the overall number of salmon into the hatchery as the difference between salmon entering and salmon leaving.

One major challenge that we experienced with this data collection style which will be touched on more in the discussion is the relatively large source of human error. The salmon are difficult to count since they travel through very rapid and turbulent water that is not entirely transparent. The salmon also ascend the ladder in different ways. Some make a dramatic leap between the steps which is really easy to observe and count while others slip up the ladder while staying under the water's surface. The latter type is much more difficult to count since it happens so quickly and with so frequently. The other issue that we encountered was the fact that the windows of the hatchery are not very clean. This further impeded our image of the salmon making counting more challenging.

Data analysis

The number of the Chinook salmon counted in each trail was then divided by the number of trails to get an average number of salmon successfully returning per hour. The estimated number of the 2018 Chinook salmon returning population was calculated using the same formula as what the previous group did in 2017 (Houwelling et al., 2017):

*Estimated total returning number of salmon = averaged number of returned salmon per hour * 9 hours/day * 7 days/week * 8 weeks*

According to a study done by Uittenbogaard, the majority of the Chinook salmon are determined to be active during the day time, so the nine hours in the equation represents the estimated average daylight hours in the period from October (ten hours) to December (eight hours) when the most Chinook salmon was observed to return to the Capilano hatchery site. Eight weeks represents the estimated duration of the Chinook salmon run based on the results from the hatchery's record in 2016, which the previous study used when they first addressed this calculation of the estimation.

In addition, annual return number of Chinook salmon over the past five years was obtained from the hatchery. This data was used to compare our estimation of the return number in 2018 with the records over the past five years.

Statistical analysis

To visualize the difference of the population returning this year compared to the number from last year, a bar chart was plotted with the two calculated means located side by side. In addition, a comparison of the return number of Chinook during 2013 to 2018 can be visualized by a horizontal bar chart.

Due to the limited number of trails we've done, we fail to test the normality of our data. Therefore, we decided to do a non-parametric Wilcoxon rank and sum test instead of a two-sample independent t test. The test was performed by R studio to compare the number of the Chinook salmon returning this year with the population number returned last year. This test was carried with a significance level of 5%.

Results

The averaged number of the Chinook salmon returning per hour was 233.2, which was larger than the average population of 16.6 per hour calculated last year (Figure 2). Our data indicated that 2018 had a higher number of the Chinook salmon returning compared to the previous year. Also, the horizontal bar chart of the annual return number of Chinook (Figure 4) shows an unexpectedly large number of Chinook salmon returns this year, which is approximately 127.2 times more than the averaged number of returns over the past five years.

For statistical analysis, a Wilcoxon rank sum test was carried. The test statistics calculated was W = 46, and the p-value was equal to 0.005986. With a significance level of 0.05. we would conclude that the total estimated number of Chinook returning this year is greater compared to the total estimated population last year.

Among all the five trails we have done this year, the highest number observed was in the second observation (Oct 29th) while the lowest number observed was in the last observation (Nov 11th) (see Appendix Table 1).

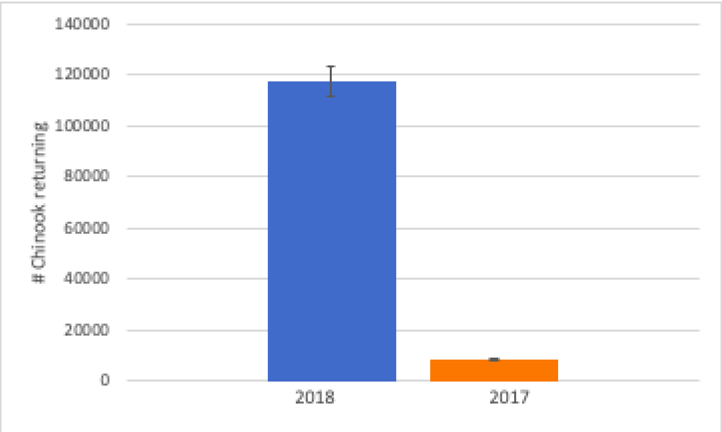

Figure 2. The estimation of the total number of Chinook returning calculated by the above formula in 2018 compared to the estimated number of Chinook returned in 2017. The 2018 data was collected during October 24th to November 11th, 2018. The 2017 data was from the previous study (Houwelling et al., 2017). The error bars represent 95 percent confidence interval of the estimated means of Chinook return numbers.

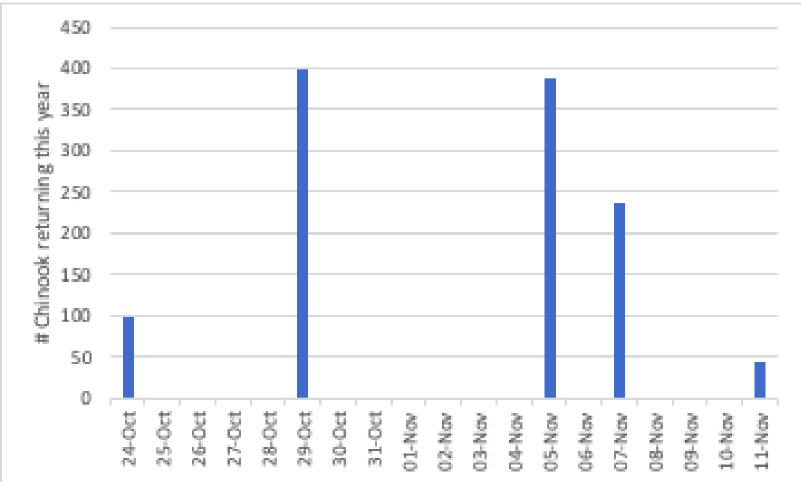

Figure 3. The observed number of Chinook salmon that returned to the Capilano hatchery from October 24th to November 11th, 2018. Each trail represents a one-hour period of data collection.

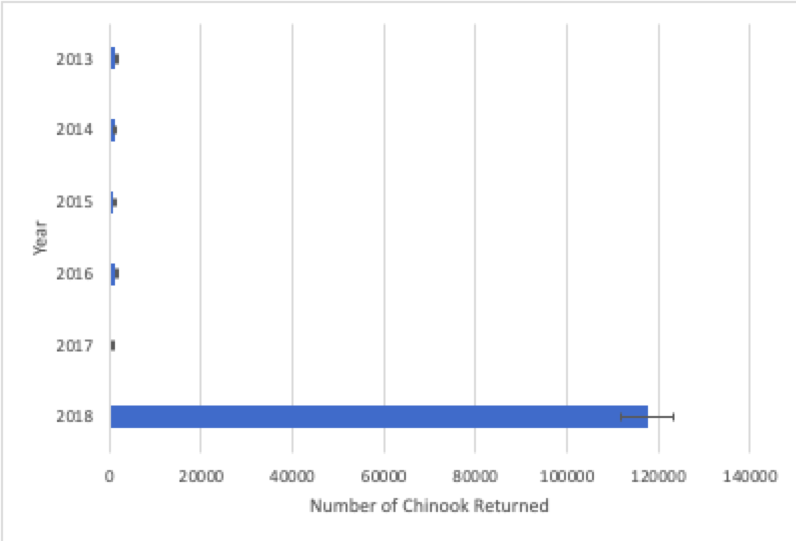

Figure 4. The observed number of Chinook salmon returned over the past 5 years along with the estimated number of Chinook returns in 2018 based on the model above. The 2018 return data was gathered from October 24 to Nov 11, 2018 at Capilano River Hatchery. The 2013 to 2015 return data were obtained from Capilano River Hatchery (Operation Manager). The error bars for 2018 represent the 95 percent confidence interval of the estimation of the number returns.

Discussion

We predicted that the number of adult Chinook salmon returning to the Capilano River Hatchery in 2018 will be lower than the amount that returned in 2017. Our results show an increase in the total estimated returning population and therefore do not support our prediction. According to a study conducted by Houwelling *et al.* (2017), the number of returning Chinook to the Capilano River Hatchery has been increasing since 2015. The results from our study support this claim, continuing the trend of an increasing returning population. Contrary to our results, the general consensus among scientists is that wild Pacific salmon populations have been declining since the 1990s, due to a variety of different stressors (Fresh 1997, Noakes *et al.* 2000, Crozier *et al.* 2008, Nekouei *et al.* 2018). Stressors such as predation, freshwater habitat loss, overfishing, and disease resulting from industrial aquaculture contribute to the population decline, making our results likely an overestimation.

Salmon are a keystone species which provide essential nutrients to both aquatic and terrestrial ecosystems through the predation by species such as killer whales, bald eagles, bears and humans (Cederholm *et al.* 1999). Destructive logging practices across parts of the Pacific Northwest have destroyed suitable salmon habitat, leading to the extinction of many individual salmon runs (Gustafson *et al.* 2006). Additionally, an estimated one million Chinook salmon are harvested annually (Healey 1991), thus overfishing, including both sport fishing and commercial fisheries lower the odds that an individual will reach maturity and reduce the population (Young 1999). Lastly, sea lice have been identified as a cause for population declines and were introduced to wild Pacific salmon populations via industrial aquaculture (Nekouei *et al.* 2018).

Since the increasing trend in returning Chinook to the Capilano River Hatchery started in 2015, the number of returning individuals has ranged from approximately 900 in 2015, to an estimated 8366 individuals returning in 2017, deemed to be a clear outlier by Houwelling *et al.* (2017). Figure 2 shows a comparison between the data collected by Houwelling *et al.* (2017) and our study. As shown in Figure 2, our study estimates that from 2017 to 2018, the number of returning chinook salmon increased by approximately 14 times the amount estimated to have returned in 2017. This leads us to believe that our data from this study is an outlier when compared to the previous return data.

As our study is a continuation of the study conducted by Houwelling *et al.* (2017), we followed the same methodology used in their study and agree with the 3 assumptions they made about the study that potentially led to our overestimation; (1) a consistent migration rate in Chinook salmon during daylight hours; (2) Chinook salmon run occurs annually for 8 weeks; (3) the individuals observed to make it over the assigned barrier made it to the top of the ladder. Additionally, we added a fourth assumption; (4) all salmon observed to make it over the assigned barrier were adult Chinook salmon.

The fourth assumption may have inflated our hourly counts which were used to calculate the number of returning Chinook. Data provided by the Capilano River Hatchery states that approximately 6000 Coho salmon swam up the ladder between October 1st and November 14th, 2018. This falls directly during our survey time period, therefore we may have misidentified some Coho as Chinook salmon, leading to inflated return counts.

The use of an observational study introduced human error, as the rushing water of the hatchery ladder made it difficult at times to see whether an individual fell back down the ladder. Additionally, Figure 3 shows a large range of returning salmon counted during surveys, leading us to believe that salmon do not return at a consistent rate. By conducting surveys unknowingly during peak and low return times, as well as having a relatively low sample size of 5, our resulting data may be an inaccurate representation of the average return rate. These limitations and assumption may have resulted in our study overestimating the number of adult Chinook salmon that returned to the Capilano River Hatchery in 2018. We suggest that future studies survey the entirety of the run, and develop ways to ensure each individual is counted.

Conclusion

There is a significant increase in Chinook salmon return number to Capilano River Hatchery this year compared to last year, which is opposite to what we hypothesized that this number would decrease. However, according to the evidence shown in other literature focusing on the same topic as ours, Pacific salmon is vulnerable to a variety of stressors and will have a decline in its population. Therefore, we doubted that our result is not representative to the general return numbers of Chinook salmon.

Acknowledgement

First, we would like to thank to BIOL 342 for helping us establish our understanding of one of the most important species - salmon in our local environment. We would like to show our appreciation to Celeste Leander for providing us this opportunity to find out Chinook salmon return in our local ecosystem and Jordan Hamden who helped our statistical analysis. In addition, we would like to thank April Houweling, Juhui Lee, Miji Lee, and Denée Nickel for doing the previous study, so we have this chance for doing a follow-up research on it. Last but not least, we would also like to thank the Capilano River Hatchery and the operation manager for giving us permission to the hatchery as well as providing the reliable data from the past year.

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Appendix

Date	Time	# Chinook jumped up	# Chinook went down	total # returned
24-Oct		112	14	98
29-Oct		517	118	399
05-Nov	1:20 - 2:20	483	96	387
07-Nov	1:50 - 2:50	282	45	237
11-Nov	11:30 - 12:30	81	36	45
Average # Chinook returned/hr				233.2
Average # return/2018 fall run(8 weeks)				117532.8

Table 1. The data table we used in this observational study.