Using growth models to explain Coho Salmon numbers in the newly accessible habitat of Rock Creek

Charlotte Gerzanics[1]

[1] University of Washington

Cgerz@uw.edu

ABSTRACT

One major part of salmon recovery efforts was the introduction of fish passages, such as fish ladders, to allow salmon to circumnavigate dams and reach historical spawning grounds. While an increasing number of fish passages allow fish to access historical spawning grounds, we cannot expect the fish to immediately take full advantage of this increased habitat. It is unknown how long on average it takes for salmon to fully recolonize the habitat above passages. One such passage is the Landsburg Fish passage which was put in on the Landsburg dam on the Cedar river in 2003. I used data taken in Rock Creek, a tributary of the Cedar River, by the University of Washington to fit growth models to the number of Coho utilizing this newly accessible habitat. I found that both logistic and geometric growth models fit the data almost evenly. While Coho numbers varied largely year to year, the reaches I used as an index reached carrying capacity in five years, likely because of a healthy reproducing population down river of the dam.

Keywords: Salmon, Dam, growth model, logistic growth, geometric growth

INTRODUCTION

Salmon have long been an icon of the Pacific Northwest, sustaining native communities and supporting thriving ecosystems. These iconic fish bring nutrients from the ocean, important for aquatic and terrestrial ecosystems. These nutrients speed the growth of trees in riparian zones and support brown bears as they prepare for hibernation and cub production. Salmon carcass abundance has been correlated to average brown bear litter size, average female brown bear body mass and eagle nest activity (Hilderbrand et al, 2004). Historically over 130 terrestrial vertebrates benefitted from nutrients from salmon carcasses (Feddern et al, 2019).

As western settlers moved in during the early 19th century, beaver trappers demolished the beaver population, reducing the amount of ideal salmon habitat, resulting in a decrease from the salmon population. In the 1930s, massive dams were built as public work projects to employ those who had lost their jobs during the Great Depression. As the population of the western United States grew, the demand for energy, land, and water increased drastically, resulting in the damming of many more river systems to produce hydropower. Salmon paid the price. These dams blocked salmon migration, preventing them from reaching their spawning grounds. As salmon could no longer reach suitable habitat to spawn, population numbers in Canada and the western United States declined to as little as 10% of their historical numbers (Lackey, 2009).

As the abundance of salmon continued to decline, our knowledge and understanding of these fish grew. Many individuals and organizations started to push for recovery efforts. In 1985, the governments of Canada and the United States ratified the Pacific Salmon Treaty in an effort to promote research, recovery and understanding of transboundary salmon stocks (Pacific Salmon Commission). In 2000, the Pacific Coastal Salmon Recovery Fund was established to reverse the population declines of Pacific salmon in the western United States (NOAA).

One major part of salmon recovery efforts was the introduction of fish passages, such as fish ladders that allow salmon to circumnavigate dams and reach historical spawning grounds. The National Fish Passage Program (NFPP) is a program funded by the U.S. Fish and Wildlife Service (USFWS) that partners with federal, state and non-governmental organizations, tribes, universities and local communities to provide financial and technical assistance for the reconnection of aquatic habitats (US Fish and Wildlife). This program allows organizations access to funding to build fish passages as part of their recovery efforts.

Since its installation in1901, the Landsburg Diversion Dam on the Cedar River had prevented salmon from reaching spawning grounds in many of the river's tributaries. In 2003, a fish passage was added to the Landsburg Division Dam on the Cedar River in effort to revive salmon population in the area (Landsburg Fish Passage Facilities). Since its installation in 2003, NOAA Fisheries, Seattle Public Utilities and scientists from the University of Washington have been working together to monitor use of the fish passage and collect data to evaluate the effectiveness of the Landsburg fish passage project (Salmon Recolonization). Additionally, scientists from the University of Washington have been monitoring the number of Coho salmon that use the fish passage and reach historical spawning grounds in Rock creek. Looking at this data can provide an understanding of the effectiveness of these recovery efforts and provide useful information as to what recovery efforts might still be needed. While these passages allow fish to access historical spawning grounds, we cannot expect the fish to immediately take full advantage of this increased habitat. It is unknown how long on average it takes for salmon to fully recolonize the habitat above passages.

The goal of this study was to see if basic population growth models could be applied to smooth variability and capture general trends in Coho population recolonizing new habitat north of Landsberg dam as a whole. To do this I used three reaches of Rock Creek as an index. I hypothesize that Coho population will follow a geometric growth pattern.

METHODS

Data for this project was provided by the University of Washington School of Aquatic and Fisheries Sciences. Every year since the input of the fish passage in 2003, members of the University of Washington have taken electrofishing data at rock creek. Each year, three sites on Rock creek were sampled, lower, middle and upper rock creek. At each site, two habitats were sampled, a rifle and a pool. At each habitat site, researchers used a backpack electro-fisher to record the length and species of each fish found. Measurements of water velocity, depth and substrate size were also taken.

With the data in excel I created a graph to plot the number of salmon counted per year. To do this I first filtered the data to only include Coho Salmon. I used a pivot table to find the number of salmon counted in Rock Creek per year, ignoring both site and habitat.

After plotting the data, I fit both a logistic (figure 2) and geometric (Figure 3) growth model. To fit the logistic growth model I used the equation, Nt=K/ (1+ea-rt), where “K” is the maximum value, “a” is the constant of integration, “r” is the growth rate, and “t” is the time in years. To find these parameters I used the solver package in excel to find values for these parameters that minimize the difference between the predictions and the actual data points. For this model r was 2.349.

For the geometric model I used the equation Nt=N0*ert, where N0 is the initial population, "r" is the growth rate and t is the time is years. I again used the solver package on excel to find the value 0.174 for the r parameter. In geometric modeling, initial population must be greater than zero, so this model starts in 2005 with an N0 of 3. To see which model fit the data best, I the sum of squares for each data point in each model. I then totaled the sum of square values for each model. The model with the lowest total sum of squares value fits the data best.

It is important to note that both of these population models assume that the population of a given year is a function of the population of the previous year, however for Coho salmon it takes juveniles three years to mature to reproducing age meaning the population in a given year is determined mainly by the population of juveniles three years prior. That said, these models still give us a good approximation to model salmon population growth.

RESULTS

In this study, the number of Coho salmon captured in Rock Creek varied dramatically over the years since the fish passage was installed at Landsburg Dam. As predicted, salmon were more abundant in 2019 than in 2003, but contrary to my prediction, the population did not slowly increase over time. Instead, the population was highly variable (Figure 1). The first few years of the data, until around 2009 seem to follow the expected pattern. For the first two years in which the Rock Creek habitat was available (i.e., 2003 and 2004), no juvenile salmon were detected. In 2005, the first juvenile Coho salmon were observed in Rock Creek habitat since the early 1900s, when the Landsburg Dam was completed. After that, salmon increased yearly until a sudden drop in 2009. The catch than quadrupled in 2010 to 28, followed by a two-year period where only four salmon were counted in Rock Creek. This two-year low was followed immediately by two years of increasing catch, which was followed by another sharp decrease and increase. In 2017, only one juvenile Coho salmon was captured in Rock Creek, the smallest number of salmon to be caught in Rock Creek since 2004. Surprisingly, this was followed immediately by an increase where numbers rose from one to 53 between 2017 and 2019.

Surprisingly the logistic and geometric growth models were almost equally variable from the actual data (Figure 2). Ultimately, the logistic growth model fit the data better than the geometric growth model, although the difference in the total sum of squares was only 34.

DISCUSSION

When fitting the models, I hypothesized that the geometric growth model would be a closer fit to the actual data than the logistic model, because this is a newly establishing population and therefore I did not think it would be affected by density dependent factors which could cap population growth. Additionally, upon plotting the data, salmon population did increase as time went on, seeming to follow a pattern of geometric growth and did not seem to level out, which would indicate carrying capacity and logistic growth. The logistic model flattened out at a catch of 18 after 5 years, but this leveling out was not seen in the actual catch data, leading me to believe the geometric model would fit the data better. Contrary to my hypothesis, when I ran the sum of squares the logistic growth model better fit the data and captured the general trend of the population as a whole.

The most interesting aspect of the logistic model is that it shows the salmon in the three reaches of Rock Creek, reaching carrying capacity within 5 years. One potential reason for this speedy recolonization of new habitat could be the healthy population of Coho that spawned below Landsberg Dam before the input of the fish passage. According to the Washington State Department of Fish and Wildlife, there were 74,507 downstream juvenile Coho salmon migrations in the Cedar river in 2003, meaning there was a large and healthy population in the river that were available to recolonize Rock Creek. It is likely that this large source population is what allowed Rock Creek salmon to reach carrying capacity so quickly (Volkhardt, 2005). Although while looking at the actual fish catches, it may not seem like the population has reached carrying capacity, it is normal for populations to increase and decrease around carrying capacity. These fluctuations can be extremely large in a new population but tend to level out over time, a process referred to as damping oscillation. The large fluctuations we see in the catch data are likely because the population is so new, and it is too soon to see the "leveling out".

While the logistic model was closer to the actual data, the closeness of the geometric model is important. In 2012, similar research was published about salmon recolonization of the Cedar River, which found the number of natural origin Coho recruits to follow a geometric pattern (Anderson, 2012). This shows that while the geometric model was slightly less accurate in this case, it may be far more accurate in other cases.

Plotting the data showed many increases and decreases in the numbers of salmon caught in Rock Creek between 2003 and 2019. While some of the drops and spikes in numbers seem sudden, especially the drop in 2009, this is not unusual considering environmental stochasticity has a larger effect on smaller populations. While this variation is normal, it does make it harder to see general population trends. Although this data seems promising for future salmon recolonization after barrier removal, salmon's long-life cycle means it can often take up to 20 years of monitoring to determine the success of recolonization after barrier removal (Weiser, 2008).

While these models are by no means perfect because they do not account for the semelparous life cycle, my results show that they can still be used to "smooth" variability and understand general population trends. These general models are incredibly easy to make and can be applied to virtually any recolonization effort, proving their usefulness. Overall, more time is needed to assess the effectiveness of the Landsburg fish passage and salmon recolonization of Rock Creek, but these models are promising tools for management.

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Table 1.

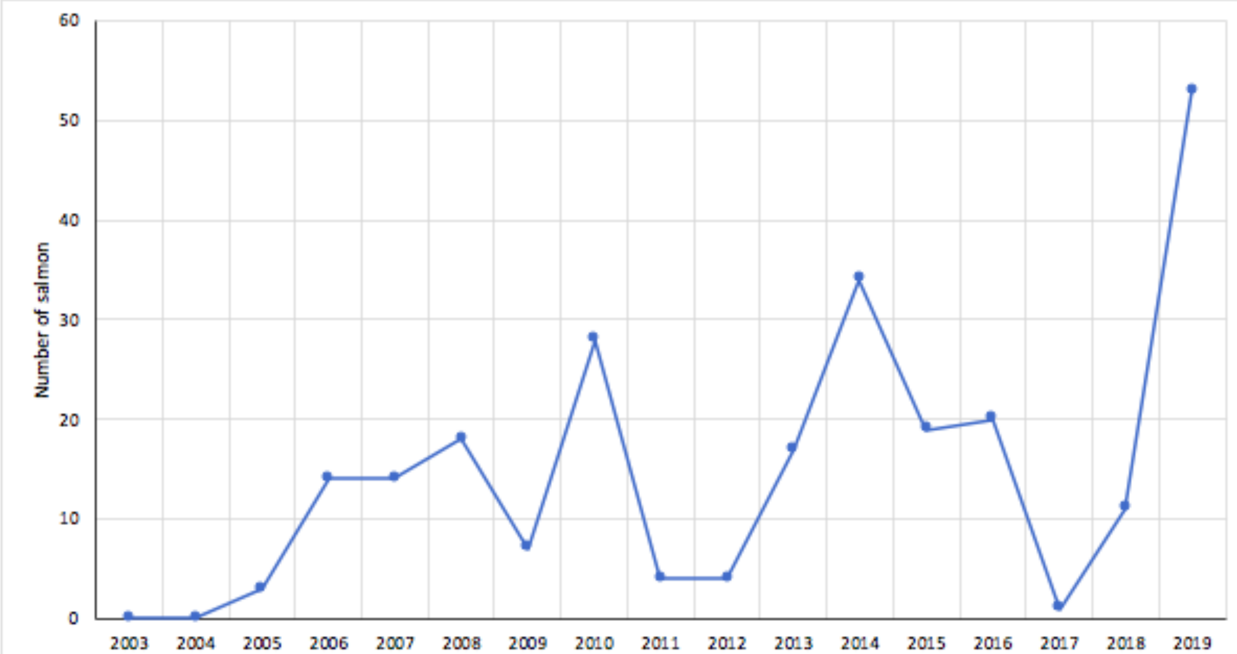

Figure 1: This graph shows the number of Coho salmon counted in Rock Creek every year since the fish passage was put in in Landsburg dam.

Table 2.

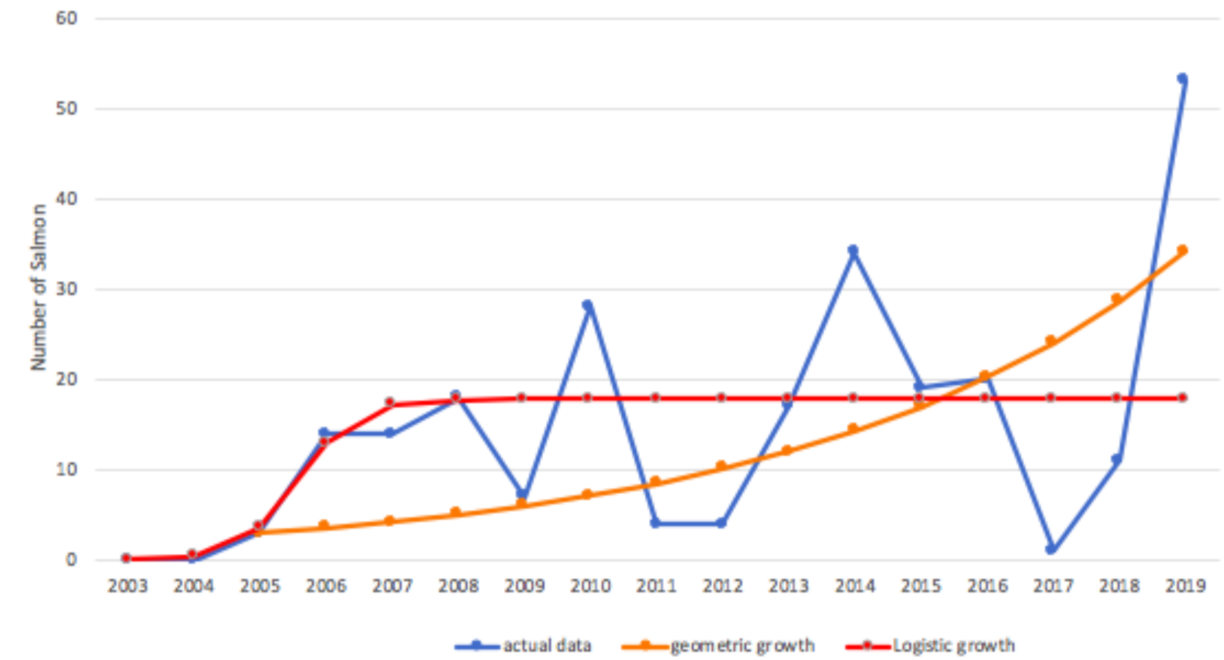

Figure 2: This graph shows the results of the geometric growth model and logistic growth model over the actual data.

Figure captions.

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Fig. 1**.** Locations of 21 receivers used for within-basin analysis; the size of the circle represents the score of that location on the first principal coordinate. Receivers are numbered in order of decreasing site use (1 = most frequently used, see Table 2), with receivers categorized as deep/offshore in white and shallow/onshore in gray.

Fig. 2. Caption here

Fig. 1.

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