Drought-Driven Water Loss in the Upper Sacramento River and its Effect on Chinook Salmon

Overview

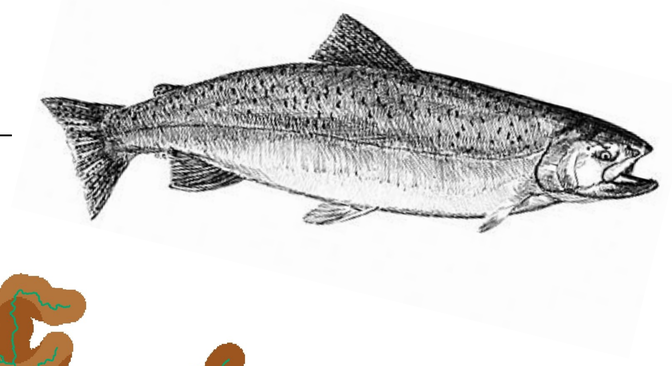
California's river levels have been in a severe decline due to the persistent drought, which began in 2012. This loss in streamflow has been concentrated in the Central and Southern regions of California, although the effect is seen throughout the state. The decreased water levels throughout the state have had serious effects on native ecological systems; however, the extent of these effects is currently unknown. In order to enact effective policy and planning, we need to know both the outlook for California's river systems and what this outlook could mean for local flora and fauna. Given the recent climate and water loss, which populations are most at risk to local extinction? Can we predict what Californian rivers might look like in 5-10 years? These are the questions I set out to answer in this project.

I focused on modelling the river water levels in the Upper Sacramento River in central California, using historical streamflow data, along with precipitation and temperature as streamflow predictors. Additionally, I looked at these changing river levels in relation to the native Chinook salmon populations, which use this river as a major spawning location. Theses salmon have been in the midst of a severe population decline recently, and with a decrease in habitat, the chances of its extinction are getting greater every day.

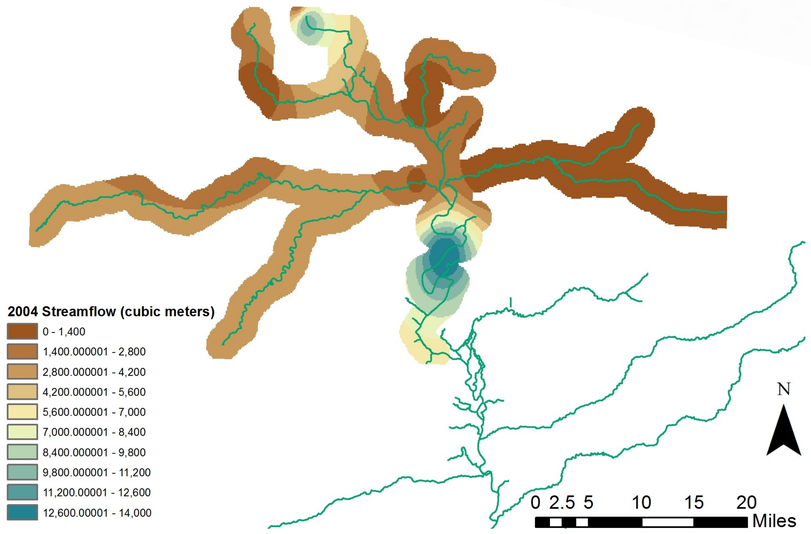
Through a predictive model, I aimed to estimate viable habitat areas for the Chinook, taking into account the continuing drought. The habitat requirements of this taxa are well studied, and by combining these ecological data with spatial data from a water loss model, it is possible to study this population's viability in the coming years.

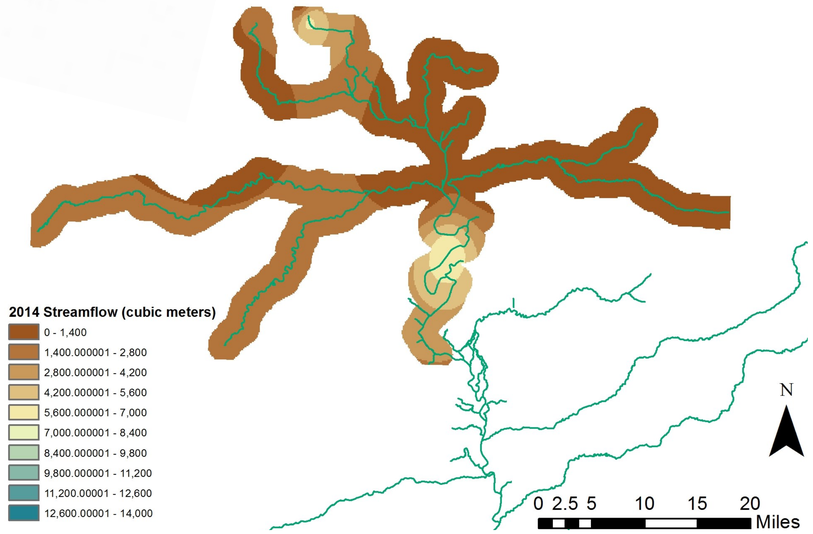
Methods

1. I first performed preliminary analyses to find the most suitable study area. I looked for an area with at least 8 years of salmon population data, at least 10 on-stream gages, and a location which had been affected by the drought. This involved looking at locations of stream gages and analyzing streamflow loss on a wider scale before focusing in on the Upper Sacramento.
2. Organized annual streamflow data in excel table and joined to stream gage locations
3. To make water loss maps, I did an inverse distance weights interpolation of streamflow values for 2004 and 2014 and clipped the raster to a 200m buffer of the Upper Sacramento River.
    a. I based the extent of the "upper" Sacramento River based off of the salmon population data, which counted salmon in the tributaries upstream of Princeton Ferry.
4. I extracted values from the temperature and precipitation rasters of each year to make a table of values that were organized by year and by gage.



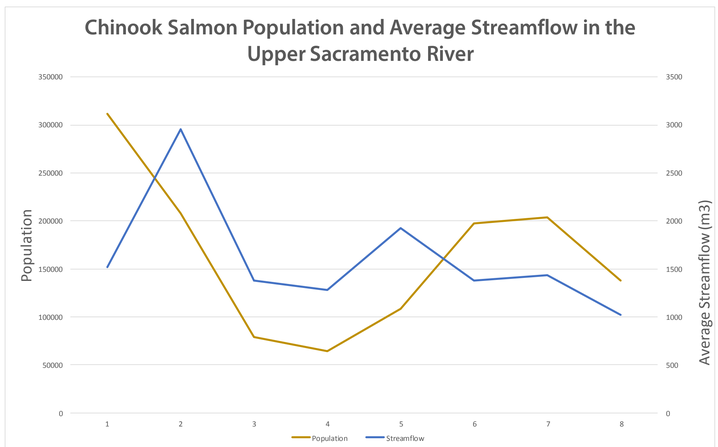
2004 → 2014





5. Ran 3 regressions, using geoda
    1. Did not take spatial or temporal data into account, which meant using all temperature and precipitation data points (330) to predict all streamflow data points (165)
    2. Incorporated a 4-year spatial lag. I used the precipitation, temperature and streamflow data to explain the streamflow 4 years into the future
    3. Another, similar, regression incorporated a 4-year spatial lag, but it only used the temperature and precipitation from more recent years as predictors.

Results & Limitations



This project faced limitations in attempting to create an accurate model to predict streamflow. This is most likely due to the fairly small extent at which I performed the analysis. With more data points to look at, it is likely that the predictor variables would be able to better explain streamflow levels. Because an effective model wasn't created, this limited my analysis of viable Chinook habitat. However, it can be seen by the graph that streamflow loss and salmon population declines in the past 12 years go hand in hand. Additionally, the amount of streamflow loss is clearly demonstrated through the interpolated graphs of 2004 and 2014.

Overview

Overall, this analysis needs to be done over a larger area and with more data points. Additionally in future analyses, it would be valuable to include land use data into the model, which was not relevant at this particular extent. Although these particular models were not able to predict streamflow, it is clear through other studies and data that Chinook salmon populations are at risk, a significant part of which is most likely due to drought-driven habitat loss.

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GIS 102:
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Data Sources: USGS, PRISM, California Department of Fish and Wildlife, CalFish, TuftsGIS, ESRI, Alaska Department of Fish and Game