

# Elwha River Dam Removal

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Fall 2025

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Sylvia: discharge, gage height, sediment, fish transport Kaitlyn: invert abundance, fish abundance, fish diet

## I. Introduction

The Elwha River in Washington was the site of one of the largest dam removal projects in United States history. Headwatered in the Olympic Mountains of Washington and flowing to the Strait of Juan de Fuca, the Elwha River originally supported all five Pacific salmon species, steelhead, and other fish populations, along with the Lower Elwha Klallam Tribe. However, the Elwha Dam and Glines Canyon Dam, located 7.9 km and 21.6 km from the river mouth, respectively, blocked fish and sediment passage for more than 100 years (**Figures 1 and 2**).



Figure 1: Elwha Dam approximately one month into removal (NPS 2025)



Figure 2: Glines Canyon Dam approximately one month into removal (NPS 2025)

Alongside the concern for fish populations and ecological balance was the concern of rising sea level and the impacts that dams have on coastal erosion and resilience. To restore the passage of fish, preserve the watershed, and protect the people, the Lower Elwha Klallam Tribe sought to remove the dams. They were instrumental in the passing of the Elwha River Ecosystem and Fisheries Restoration Act in 1992, but it took 20 years for dam removal to begin. Thus, from 2011 to 2014, the two dams were removed and impacts were tracked by a team of federal, state, tribal, academic, and community partners.

Studies were conducted before, during, and after dam removal to understand the shifts in the geomorphology, hydrology, and ecology caused by the removal. Various groups sought to characterize phenomena such as sediment and woody debris dispersion, vegetation growth, invertebrate densities, and fish migration. In this study, we sought to analyze a portion of these impacts and specifically focused on the impacts on streamflow, sediment transport, water quality, invertebrate density, fish migration, and fish diet before, during, and after the dam removal.

Specific questions studied here include:

Question 1. How are river discharge and gage height impacted by dam removal? Question 2. Is there an observable impact on sediment load and concentration following dam removal? Question 3. Is water quality and nutrient availability impacted by the dam removal? Question 4. Is there a shift in the types of taxa consumed by Chinook and Coho salmon before and after the dam removal? —->Sylvia you put your stuff here about the fish movement Question 5. Fish movement?

## II. Dataset Information

We have obtained multiple datasets from the United States Geological Survey (USGS) in regards to the Elwha River dam removals. **For more information on data availability and sources, see Appendix.** These datasets include:

1. Elwha River daily sediment loads and concentrations during and after dam removal
2. Elwha River water quality at the estuary
3. Invertebrate abundance and density at multiple sites in the estuary
4. Chinook and Coho salmon diets, sampled at estuary sites

Additionally, we obtained continuous streamflow data along the Elwha River from USGS's Water Data for the Nation. These data comprised of daily discharge and gage height recorded at USGS monitoring station #12045500 (Elwha River at McDonald Bridge near Port Angeles, WA). For a discussion on data availability from this and other monitoring stations along the Elwha River, see **Section III.A** below.

The relative locations of the Elwha River watershed, communities, USGS monitoring sites, and Elwha and Glines Canyon Dams are depicted in **Figure 3** (map sourced from “Coastal Habitats of the Elwha River, Washington-Biological and Physical Patterns and Processes Prior to Dam Removal”, published 2011 by USGS).

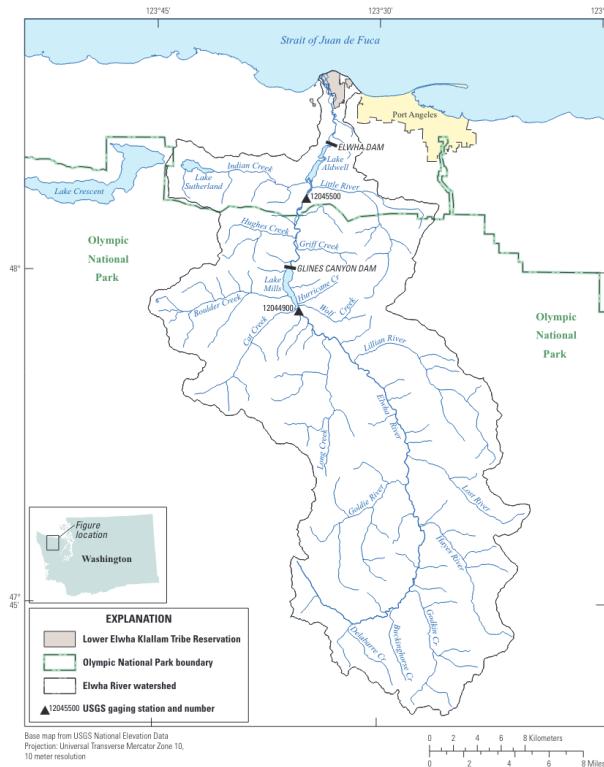


Figure 3: Elwha River watershed, monitoring stations, and dam locations (USGS, 2011)

### III. Exploratory Analysis

#### III.A. Streamflow

Water quality data were obtained from USGS's Water Data for the Nation data repository. Historical water data for three USGS monitoring sites along the Elwha River are available. **Table 1** outlines the availability of river discharge and gage height data at each monitoring site.

Table 1: Availability of USGS Streamflow Data

| Site No. | Relative Location                    | Dates Available    |                   |
|----------|--------------------------------------|--------------------|-------------------|
|          |                                      | Discharge          | Gage Height       |
| 12044900 | Above Glines Canyon Dam              | Mar 1994–Sept 2011 | Oct 2007–Nov 2015 |
| 12045500 | Between Glines Canyon and Elwha Dams | Oct 1989–Present   | Oct 2007–Present  |
| 12046260 | Below Elwha Dam                      | Unavailable        | Unavailable       |

Because our goal is to analyze Elwha River streamflow before, during, and after the dam removal that occurred over the period 2011–2014, we focused on discharge data obtained from USGS site #12045500 and gage height data from USGS sites #12044900 and #12045500. We pulled continuous data over the period 2008–2017 (as available) to capture a 10-year window surrounding the dam removal.

**Figure 4** and **Figure 5** show

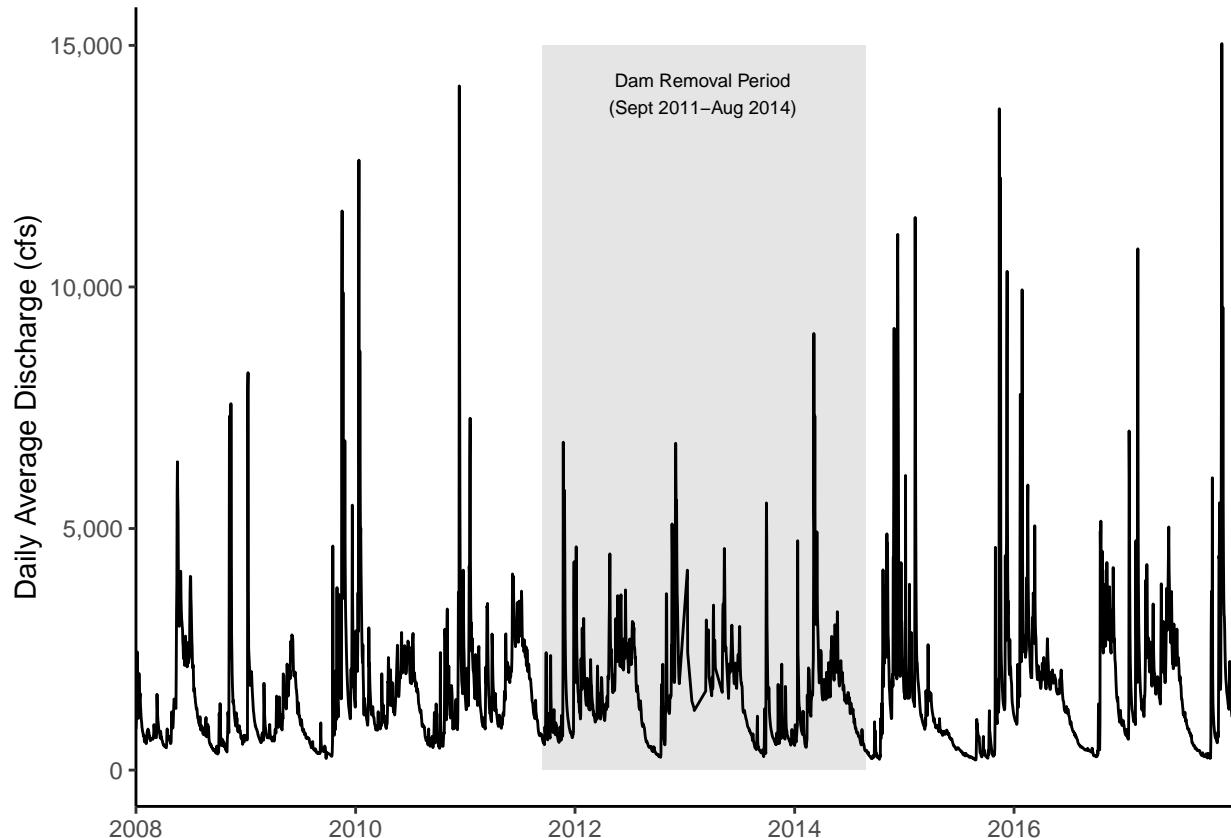


Figure 4: Elwha River Average Daily Discharge, USGS Site 12045500

*# Figure: Gage Height Data Sites 12045500 and 12044900*

### **III.B. Sediment**

### **III.C. Water quality**

————-> THIS PARAGRAPH HAS A FIGURE NUMBER THAT NEEDS FILLING IN!! This dataset contains information of nitrate/nitrile, ammonium, and phosphate concentrations, salinity, temperature, turbidity, dissolved oxygen, and pH at five sites in the Elwha River Estuary. To better understand the individual trends and suitability of this data for analysis, each parameter was plotted against time (plots not shown - for final plot of parameters see Figure #). —————-> THIS PARAGRAPH HAS A FIGURE NUMBER THAT NEEDS FILLING IN!!

To create the plots desired for analysis, the legend and title were assigned to unique variables.

Based on this data exploration, the parameters with useful data are nitrate/nitrile concentration, phosphate concentration, ammonium concentration, and dissolved oxygen. The other parameters had significant missing data or displayed no trend.

### **III.D. Salmon Diet**

In this dataset, the composition of Chinook and Coho salmon diets are made available. The authors sampled 12 times before the dam removal (across 2006 and 2007), and 23 times after the dam removal (across 2013 and 2014). 193 unique taxa were screened for. To assess the different taxa that comprised the diet, a dataset that contained the sum of each taxa count in each was created. For each year, the top 10 taxa more commonly observed taxa were plotted on a histogram (Figures # and #). A limitation of this study is that the number of fish surveyed was not used to normalize the data, so this dataset does not contain relative abundance.

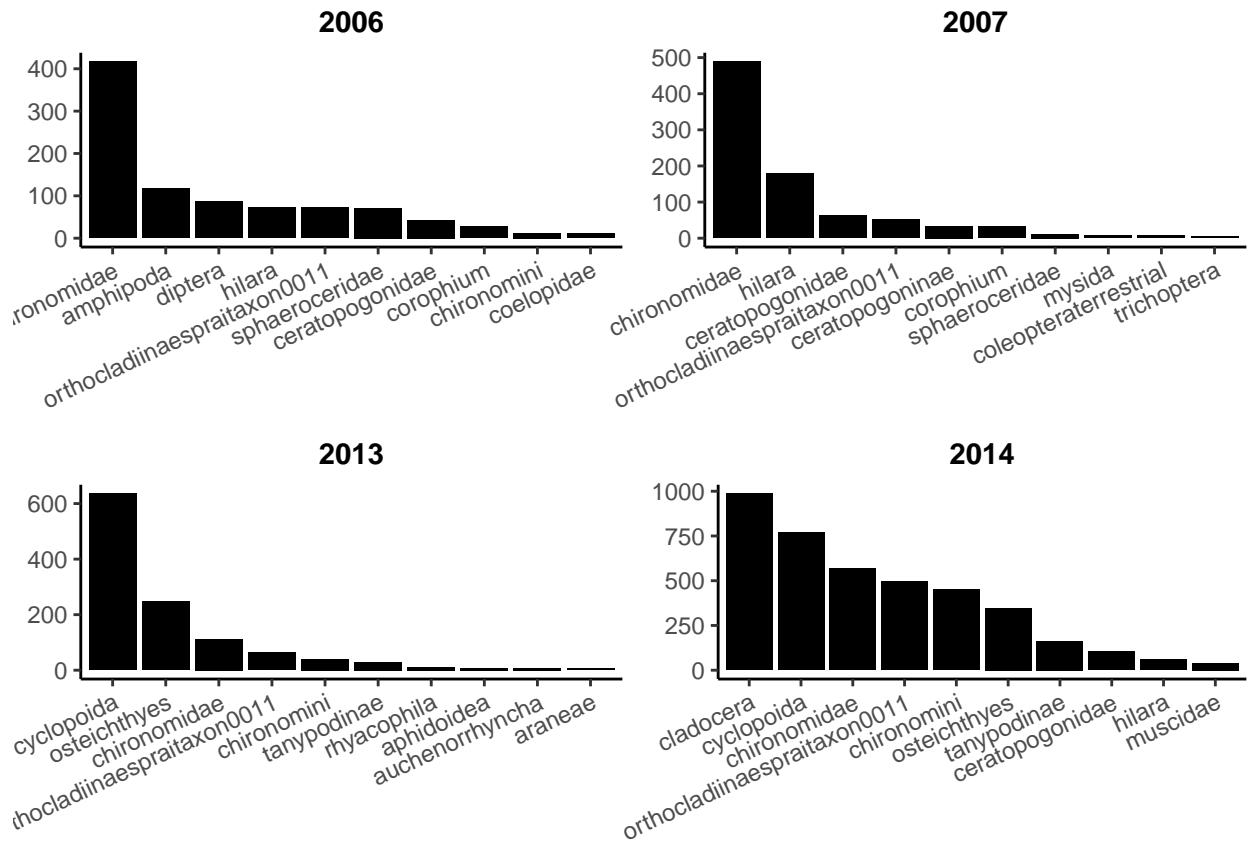


Figure 5: Total counts of the 10 most common dietary taxa each year in Chinook salmon

Upon initial investigation, it is clear that the diet of Chinook salmon has diversified by 2014, and it is possible that the salmon are consuming more food (however, normalizing the data based on the number of fish and time points would be required to substantiate this claim).

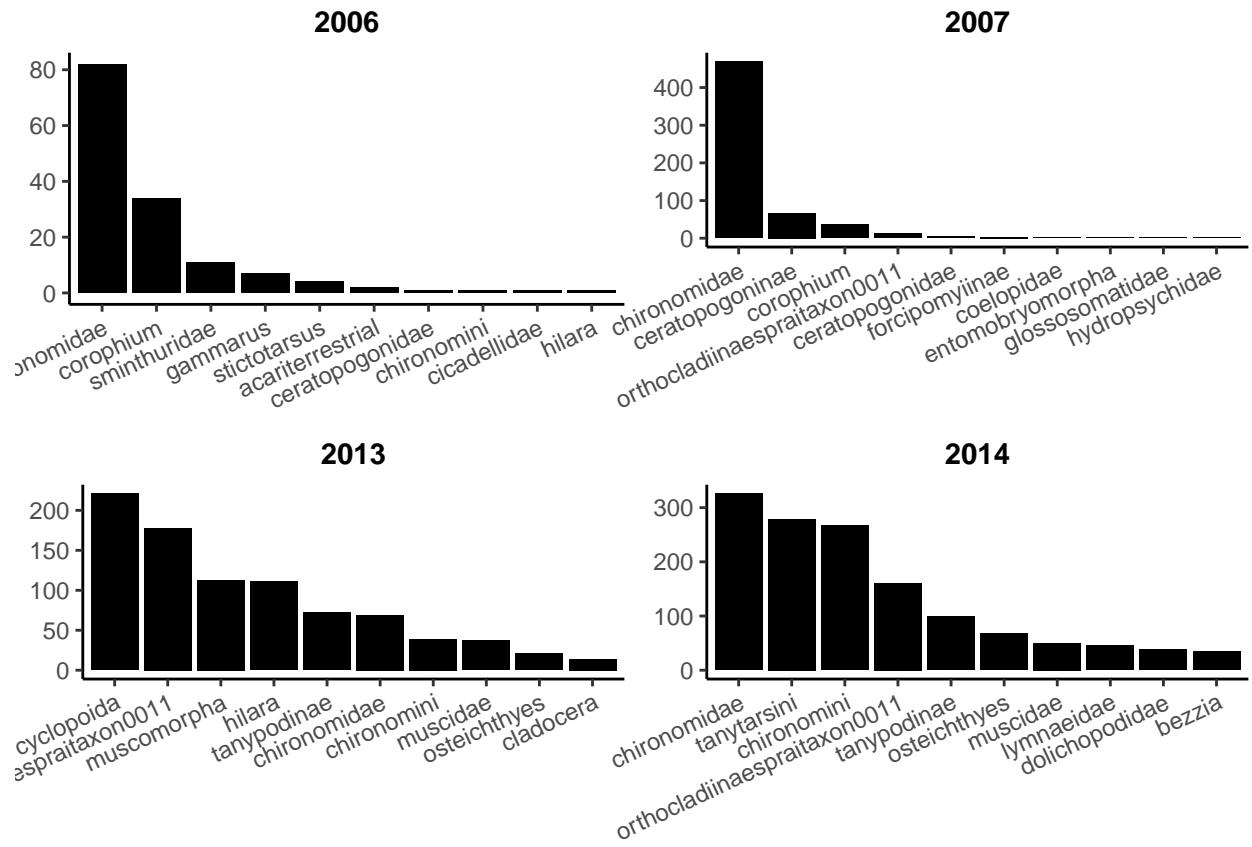


Figure 6: Total counts of the 10 most common dietary taxa each year in Coho salmon

In Coho, similar trends in diversification are seen, however they begin earlier. Unlike Chinook, it is less clear that Coho are consuming more after the dam removal.

## **IV. Analysis**

**IV.A. Question 1. How are river discharge and gage height impacted by dam removal?**

**IV.B. Question 2. Is there an observable impact on sediment load and concentration following dam removal?**

**IV.C. Question 3. Is water quality and nutrient availability impacted by the dam removal?**

Based on the exploratory analysis, only nitrate/nitrile, phosphate, ammonium, and dissolved oxygen concentrations were considered in this water quality analysis (Figure #). Because each datapoint is based on one reported measurement with no error attached, no statistical analyses were run. Thus, all analysis of this data is based on visual evaluation.

## Water Quality at the Elwha River Estuary Before and During Dam Removal

Dam removal: 2011 – 2014

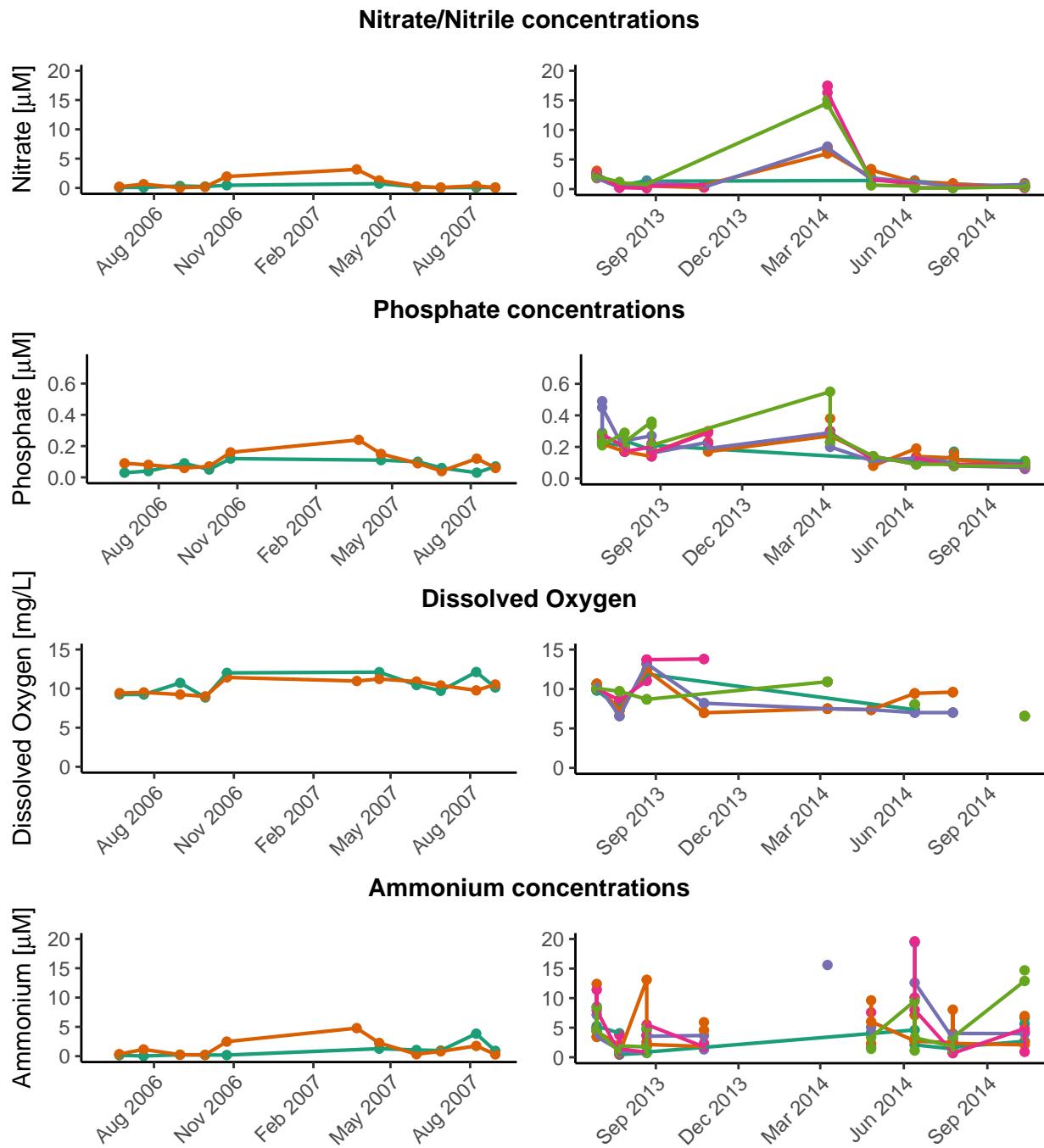
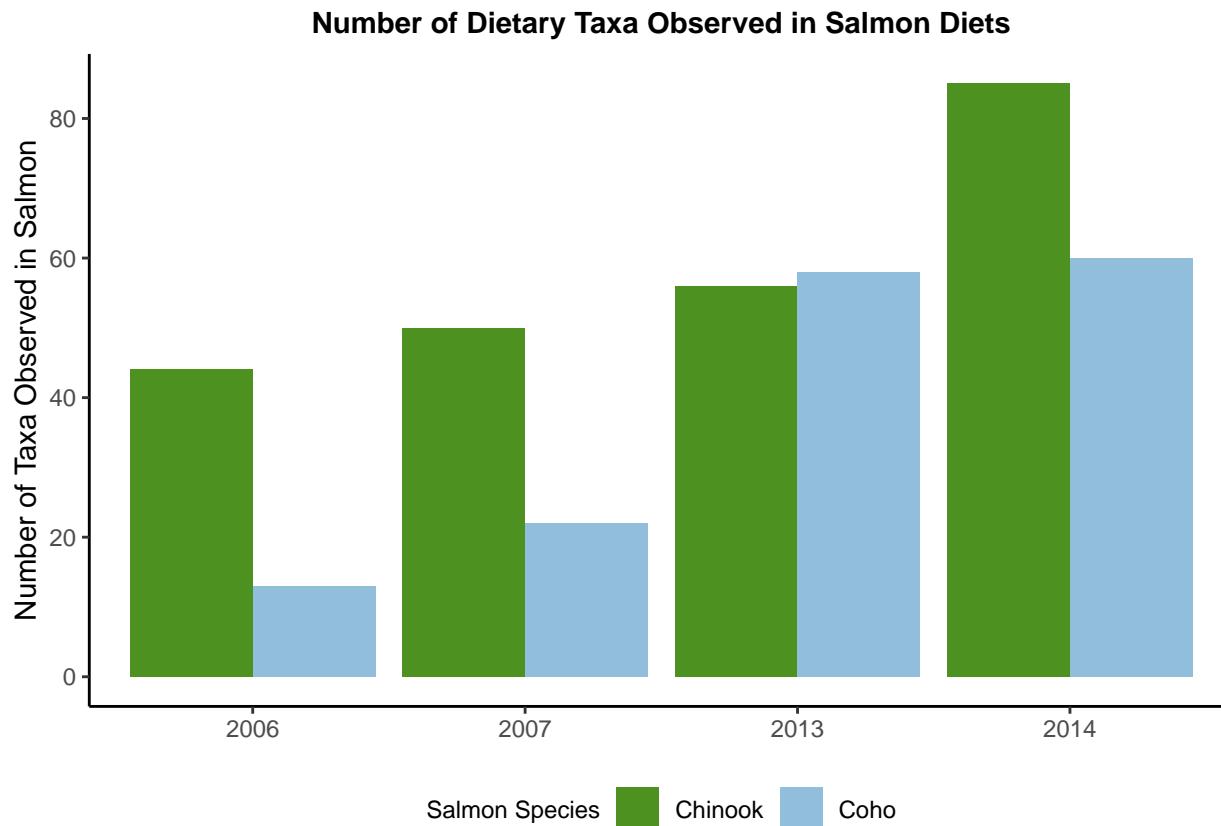


Figure 7: Water quality in the Elwha River estuary before and during dam removal

These parameters are all connected such that an increase in nitrates will cause an increase in phosphate, leading to an excess of plant growth and decomposition. As a result, dissolved oxygen will decrease and impact aquatic animals. Optimal ranges for these compounds include 0.16 - 48.38 uM for nitrate with lower being better (Lehigh University), and 0.05 - 0.53 uM (normal ~ 0.32) for phosphate (University of Wisconsin). Concentrations of all analyzed parameters do not breach unsafe thresholds, but it does appear that levels are increased following dam removal. However, lack of data at all sites before the dam removal makes it difficult to assess if these trends are due to the site specifically of the removal of the dam. It is observed that the expected relationships described above are generally represented for nitrate and phosphate, but it is not clear if there is an associated decrease in dissolved oxygen. The data on ammonium are hindered by missing datapoints in the middle of the time period, so it is also difficult to assess effects.

#### **IV.D. Question 4. Is there a shift in the types of taxa consumed by salmon before and after the dam removal?**

The number of unique taxa consumed by each salmon species was assessed (Figure #).



Before removal and into 2013, the number of unique taxa consumed by Chinook salmon appears largely unchanged. However, there was a large increase in 2014, going from 56 taxa to 85 taxa in 2014 and 2014, respectively. Coho salmon saw more consistency in the number of taxa consumed before and after, where levels were generally similar between the years. Between 2007 and 2013, an increase in 36 taxa was observed. These results suggest that dam removal had a positive impact on the diversity of both Chinook and Coho salmon diet.

To assess how the top taxa were impacted by dam removal, the top ten overall taxa were visualized (the top overall taxa reflect the sum of all counts across all years).

```
## Warning in get_plot_component(plot, "guide-box"): Multiple components found;
## returning the first one. To return all, use 'return_all = TRUE'.
```

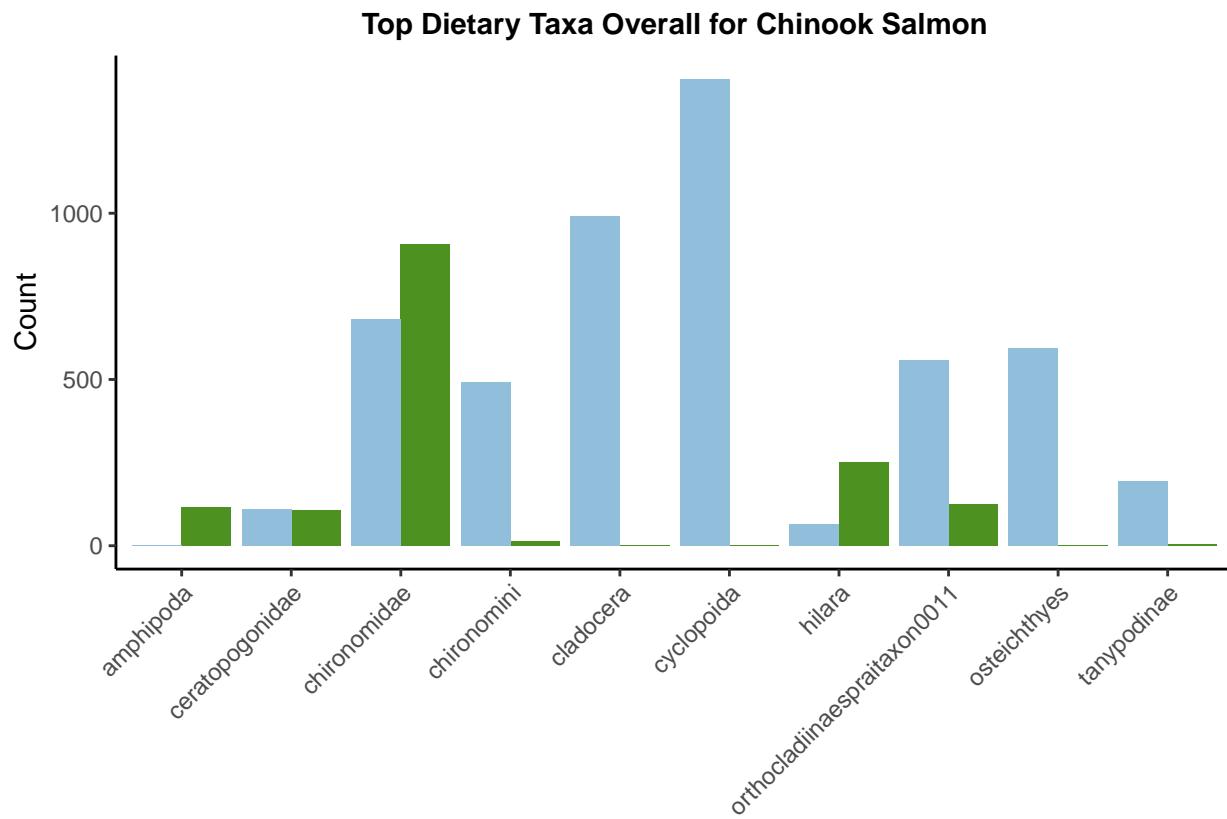


Figure 8: Top overall taxa for Chinook salmon before and after dam removal

For Chinook salmon, the taxa chironomidae (non-biting midges) are dominant before and after removal (Figure #). Other taxa, such as cladocera (water flea), chironomini (within the midge tribe), cyclopoida (order of small crustaceans), and osteichthyes (bony fishes) were present before removal, and either at low counts or not at all after. This could be due to water quality changes that these taxa cannot tolerate or do not prefer, increased choice in dietary foods such that salmon prefer to not eat these taxa, or a number of other reasons. Besides chironomidae, only amphipoda (order of malacostran crustaceans) and Hilara (genus of dance flies) saw increased consumption after dam removal as compared to before. This could be due to the increased diversity in the diet that leads to fewer counts per taxa consumed.

In Coho salmon, chironomidae are the dominant group before and after removal (Figure #). The overall taxa for Coho salmon are certainly dominated by the pre-dam removal state. Few of the taxa identified here have appreciable counts after the removal. This is likely due to the diversification of their diet after removal.

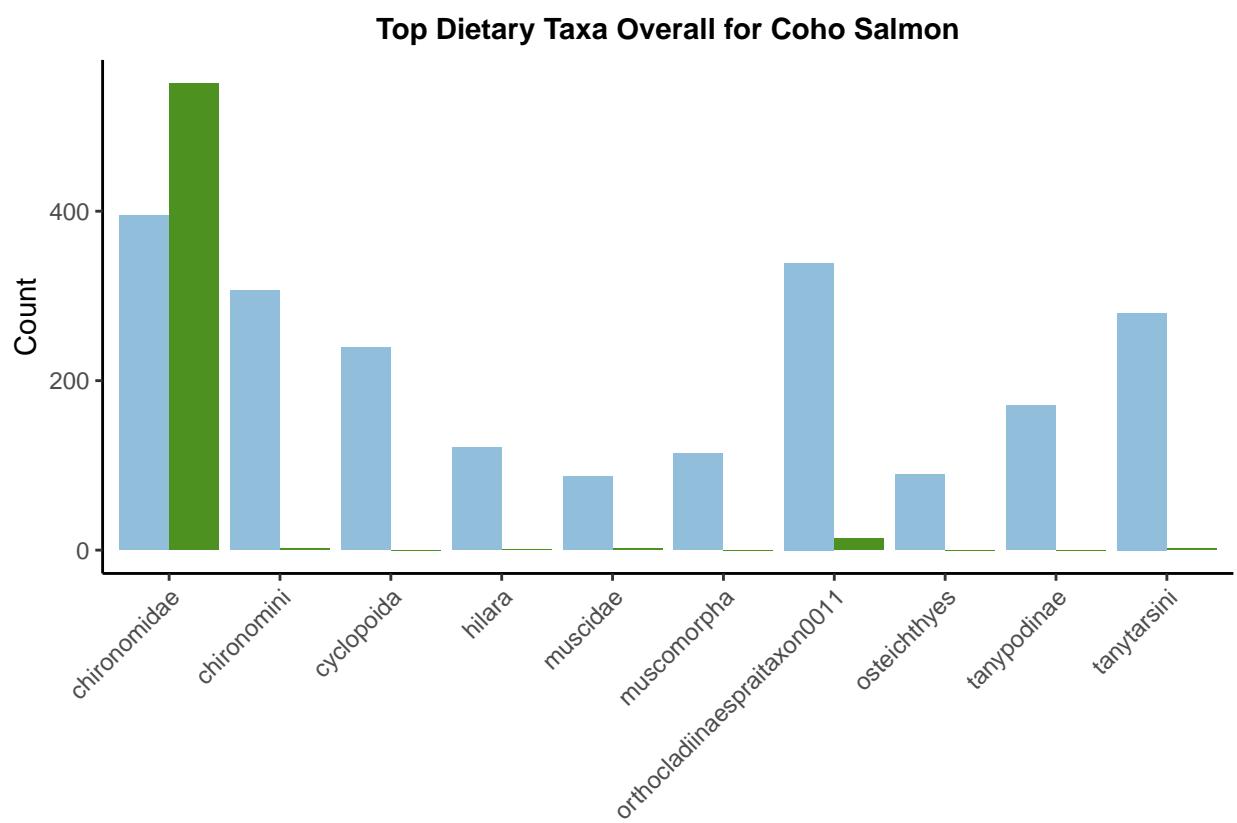


Figure 9: Top overall taxa for Coho salmon before and after dam removal

**IV.E. Question 5. Fish movement**

## V. Summary and Conclusions

The impact of the removal of two dams from the Elwha River was assessed using physical and ecological endpoints. A number of datasets generated by USGS before, during, and after dam removal were utilized. It is clear that the removal of these dams has a profound impact on river characteristics and salmon behaviors.

-> Stuff about the streamflow and sediment and stuff

Water quality was not heavily impacted over the time range analyzed, and levels did not exceed unsafe levels. It does appear that nutrient concentrations were elevated after removal. To fully assess how water quality was impacted by dam removal, significantly more timepoints and locations would have needed to be tested. The diet of two salmon species, Chinook and Coho, was assessed. Although the data were not able to be normalized, it appears that the diet of both species was diversified by 2014. Chinook salmon appear to be consuming more food than before the dam, but the same is cannot be clearly seen in Coho. Further, the taxa consumed by each species saw some overlap before and after removal, however, new groups were introduced after the dam was removed. Some of the top taxa are shared between the species, such as chironomidae, hilara, and tanypodinae, however, more analysis of these variables would better elucidate the similarities and differences in the diet of Chinook and Coho.

## **VI. Appendix**

### **VI.A. Data Sources**

### **VI.B. References**

<https://geonarrative.usgs.gov/elwhariverrestoration/> <https://projects.seattletimes.com/2016/elwha/>

<https://www.nps.gov/olym/learn/nature/dam-removal.htm>

<https://duke.app.box.com/file/2042213070552>

<https://www.nature.com/articles/s41598-018-30817-8>

— Streamflow

[https://waterdata.usgs.gov/blog/gage\\_height/](https://waterdata.usgs.gov/blog/gage_height/)

— Nutrient concentrations

<https://ei.lehigh.edu/envirosci/watershed/wq/wqbackground/nitratesbg.html#:~:text=in%20a%20watershed?,1.,blood%20cells%20to%20carry%20oxygen.>

[chrome-extension://efaidnbmnnibpcajpcglclefindmkaj/https://osse.ssec.wisc.edu/curriculum/earth/Minifact2\\_Phosphorus.pdf](chrome-extension://efaidnbmnnibpcajpcglclefindmkaj/https://osse.ssec.wisc.edu/curriculum/earth/Minifact2_Phosphorus.pdf)