Effect of Quasi-Run-of-River Implementation on Roanoke River Discharge and Water Quality

https://github.com/je138/EDA-project.git

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1 Rationale and Research Questions

In June 2016, the US Army Corps of Engineers implemented a new quasi-run-of-river (QRR) flood management regime for the Roanoke River. Kerr Dam, near the North Carolina/Virgina border, is managed for flood control and hydropower generation (Hydro Review 2017). Prior to the QRR, the Army Corps held back floodwaters at the Kerr Dam and released them slowly over time, changing short, intense floods into smaller ones with extended periods of floodplain inundation. Working with The Nature Conservancy, Dominion Energy, and other stakeholders, the Army Corps determined that a quasi-run-of-river management regime would produce environmental and flood control benefits without jeopardizing economic returns (Hydro Review 2017).

Under the new QRR management, the Corp is permitted to increase discharges to 25,000 cubic feet per second on a more frequent basis and can discharge up to 35,000 cubic feet per second during extremely wet periods (Lake Gaston Gazette-Observer 2016).

The purpose of this analysis is to:

1) assess any change in mean daily discharges at the Roanoke Rapids gage station before and after the QRR was implemented, and
2) evaluate whether changes in discharge relate to changes in downstream water quality indicators, specifically dissolved oxygen, temperature, and specific conductance.

2 Dataset Information

Data for this analysis was collected from the United States Geological Survey water data website. The data is from two gage stations: one at Roanoke Rapids (close to Kerr Dam) and the other downstream near Oak City, North Carolina.

The data was scraped from the website using the USGS "dataRetrieval" package in R. The data was processed by changing variables to appropriate data classes, removing extraneous variables, selecting the time frame of interest, and removing non-USGS-approved data points.

The Roanoke Rapids gage data contained values for mean daily discharge (in cubic feet per second), gage height (ft), and the date measured (yy-mm-dd format). The Oak City gage data contained gage height (in feet), dissolved oxygen (mg/L), specific conductance (uS/cm at 25 degrees C), temperature (degrees Celsius), and date measured (yy-mm-dd format). Discharge and water quality values had associated qualification codes with "A" indicating the data was approved by the USGS for publication and "P" indicating provisional data. For the purpose of quality control, provisional measurements were removed from the analysis.

Table 1: Summary of descriptive statistics for discharge and water quality indicators.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
Discharge	1510	2760	5170	7777	9700	35400	1510
Conductance	61	105	115	114	125	156	200
Dissolved_Oxygen	3	7	8	9	11	14	180
Temperature	0	10	18	18	26	32	40

3 Exploratory Analysis

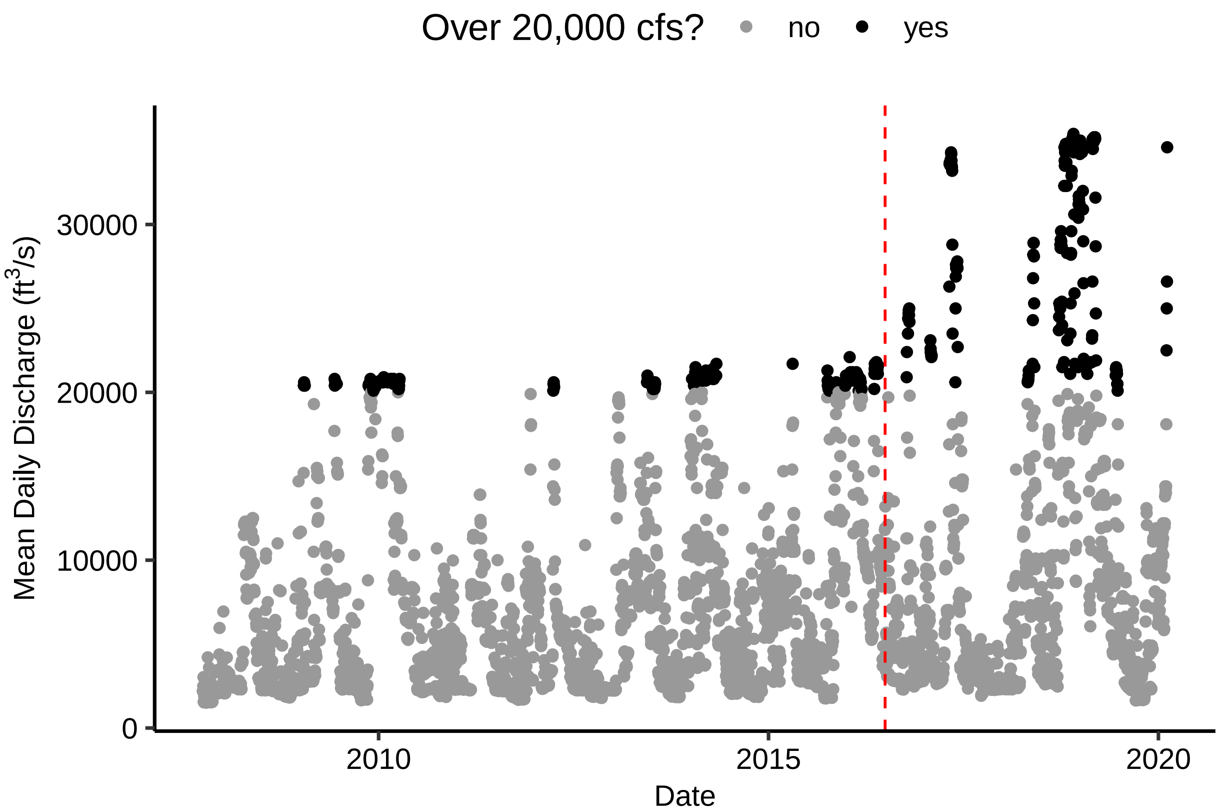


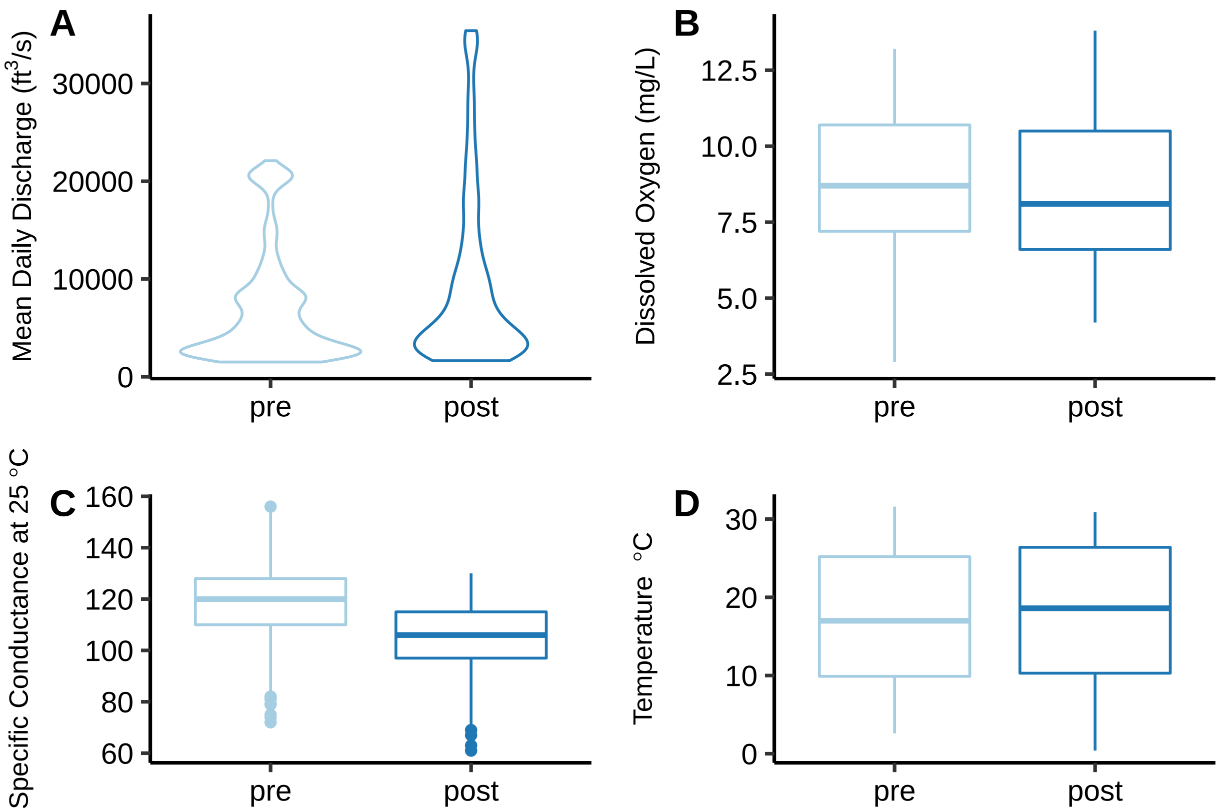
Figure 1: Point plot of mean daily discharge with color coding emphasizing discharges above 20,000 cubic feet per second. The red, vertical dashed line illustrates the date at which the QRR was implemented.

The above plot shows an increase in observed mean daily discharges following the QRR implementation. The number of days where mean daily discharge exceeds 20,000 cfs increases markedly after June 2016.

Table 2: Summary of descriptive statistics for mean daily discharge, before and after QRR implementation.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
preQRR_Discharge	1510	2560	4990	7019	8715	22100
postQRR_Discharge	1640	3000	5680	9610	12600	35400

Comparing the descriptive statistics for discharge before and after the QRR implemented, it is observed that discharge is greater in the later period for each measure of central tendency as well as the maximum and minimum values.



In plot A, we can observe a clustering of discharge values around 20,000 cfs, which is consistent with what is known about Army Corps management of the Kerr Dam before the QRR implementation. In comparison, the distribution of mean daily discharge post-QRR has a longer right tail as floodwater managers were permitted to release waters up to 35,000 cfs for extreme wet conditions. From boxplots B and D, it is difficult to distinguish whether dissolved oxygen readings or temperature measurements have increased or decreased significantly. The boxplots in plot C suggest that conductance may have decreased from the early period to the post-QRR period.

Table 3: Descriptive statistics of water quality indicators pre- and post-QRR implementation.

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
preQRR_DissolvedOxygen	2.9	7.2	8.7	8.9	10.7	13.2	161
postQRR_DissolvedOxygen	4.2	6.6	8.1	8.5	10.5	13.8	19
preQRR_Temperature	2.6	9.9	17.0	17.4	25.2	31.6	24
postQRR_Temperature	0.4	10.3	18.6	18.4	26.4	30.9	16
preQRR_Conductance	72.0	110.0	120.0	118.5	128.0	156.0	183
postQRR_Conductance	61.0	97.0	106.0	104.8	115.0	130.0	17

Between the two periods, average dissolved oxygen decreased slightly, average temperature increased by 1 degree, and conductance decreased by over 10%.

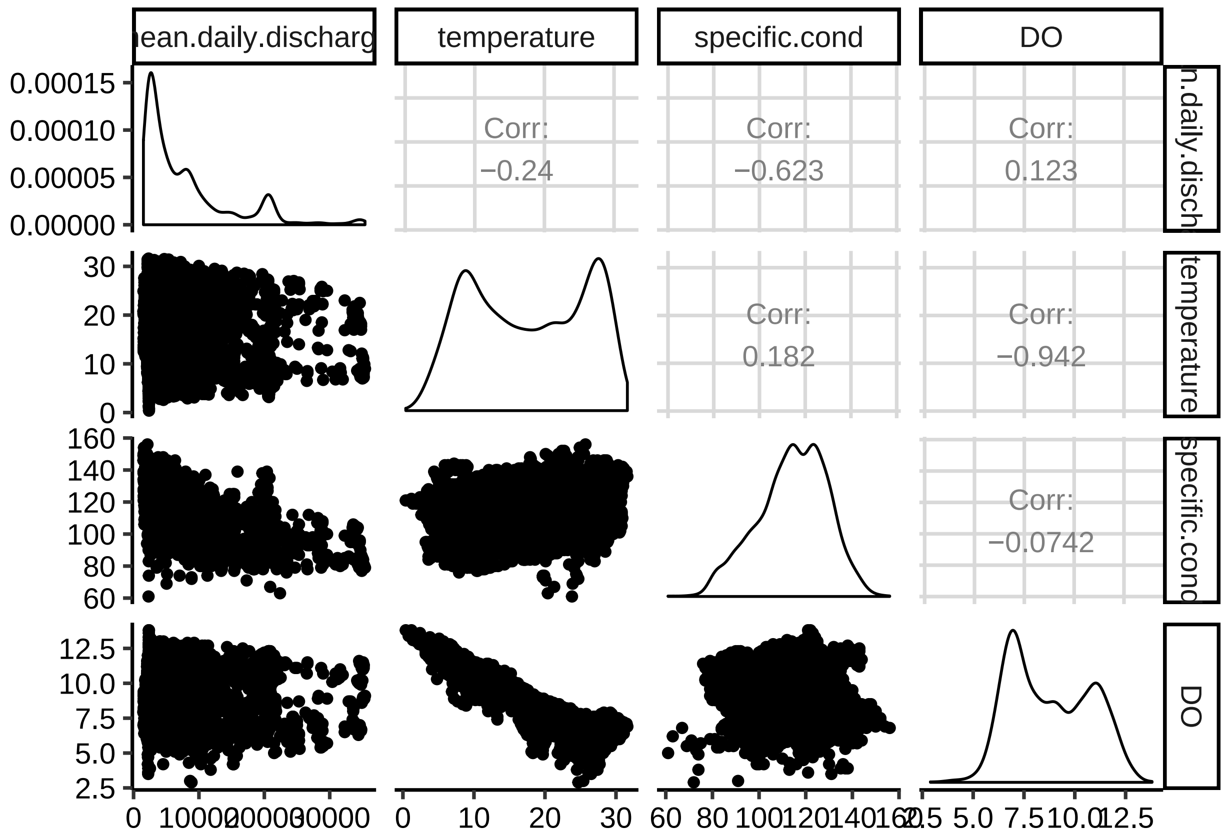


Figure 2: Scatterplot/correlation matrix of discharge and downstream water quality indicators.

The scatterplot matrix shows that temperature and dissolved oxygen are highly negatively correlated (corr = -0.94), which is consistent with the understanding that cold water can hold more dissolved oxygen. This is important to consider for later regression analysis as there may be an issue of endogeneity when modeling the influence of discharge on dissolved oxygen. Specific conductance and temperature are moderately negatively correlated (corr = 0.182). Also worth noting are the bimodal distributions of temperature and dissolved oxygen.

4 Analysis

4.1 Question 1: Is mean daily discharge at the Roanoke Rapids gage station significantly different between the pre-QRR and post-QRR implementation periods?

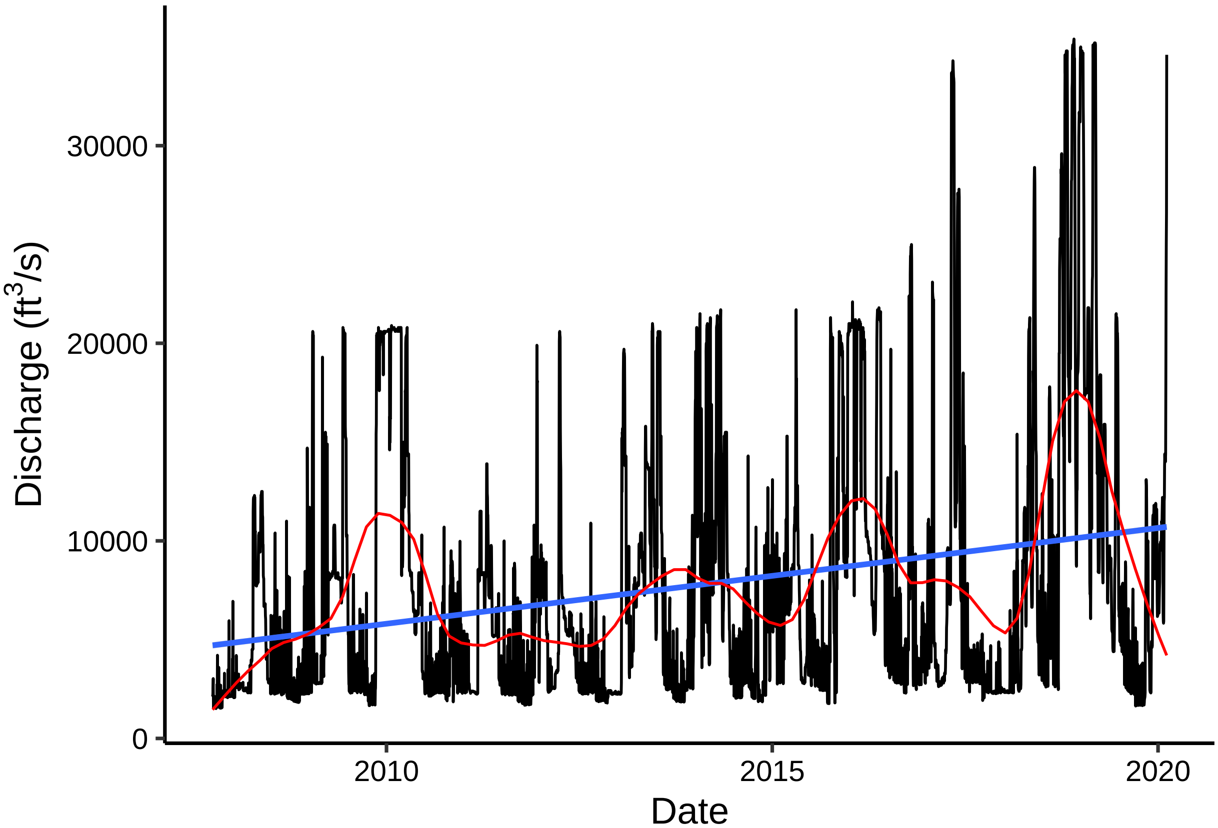


Figure 3: Line graph of mean daily discharge over time with time series trend (red) and line of best fit for trend (blue).

4.2 Question 2: How does discharge relate to downstream water quality indicators?

5 Summary and Conclusions

6 References

https://www.hydroreview.com/2017/12/01/knowledge-is-power/

http://www.lakegastongazette-observer.com/news/article_252eafe2-2d87-11e6-b575-6f234f7cf0ee.html