The Lower Snake River Reservoirs Generate Significant Amounts of Methane, a Potent Greenhouse Gas

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Contrary to the greenwashing by the hydropower industry and their benefactors that dams are "green" and "carbon free," recent scientific evidence is showing that globally (and locally), dammed rivers are significant contributors of greenhouse gases to the atmosphere. The lower Snake River reservoirs are no exception. The once free-flowing Snake River has been dammed into a slow moving, high temperature, nutrient loaded habitat, prime for growth of the vegetation necessary for methane and carbon dioxide production. Alas, the "green-ness" of the dams has been used for decades to justify the destruction they wreak on salmon spawning and rearing habitat, but not even that defense can hold water any longer.

Introduction

Greenhouse gas emissions created by anthropogenic (human) sources are drawing increasing attention due to their role in overheating the planet. Countries around the world have committed to reducing their greenhouse gas (GHG) emissions in an effort to slow, halt, or reverse the current trend of increasing global temperatures and extreme weather patterns. Developing science is exposing hydropower, once thought to be clean energy, as a significant cause of GHG emissions.

This is important for the Pacific Northwest, since it relies heavily on the hydropower system of the Columbia River Basin for its power needs. Over 50% of the region's consumed electricity comes from 130+ hydropower projects in the Basin. (NPCC doc 2010-18) Hydropower has long been touted as a "green", clean, renewable resource that emits no greenhouse gasses. The "carbon footprint" of hydropower has long been assumed to be zero, as no fossil fuels are combusted (Bonneville Power Administration, 2016) (Northwest Riverpartners, 2013) (Pacific Northwest Waterways Association, 2016). To continue the public's perception that hydropower is green, the US Army Corps of Engineers (USACE) – Walla Walla District published an article in September 2016 entitled "Methane Gas Emissions at dams: why methane production isn't an issue at the lower Snake River dams" (US Army Corps of Engineers, 2016).

Yet recent scientific publications cast doubt on the claims that hydropower has no carbon footprint. It has been known for some time that inland lakes emit GHG's, carbon dioxide (CO_2) and methane (CH_4), as organic matter decomposes. The first study of reservoir GHG emissions was published in 1993 (Rudd JWM, 1993). More recent studies show hydropower reservoirs in tropical zones produce high methane emissions. Mid-latitude reservoirs and boreal hydropower reservoirs are GHG emitters also. One recent study measured the rate of GHG production in the Columbia River Basin which is in a xeric region (Pacific

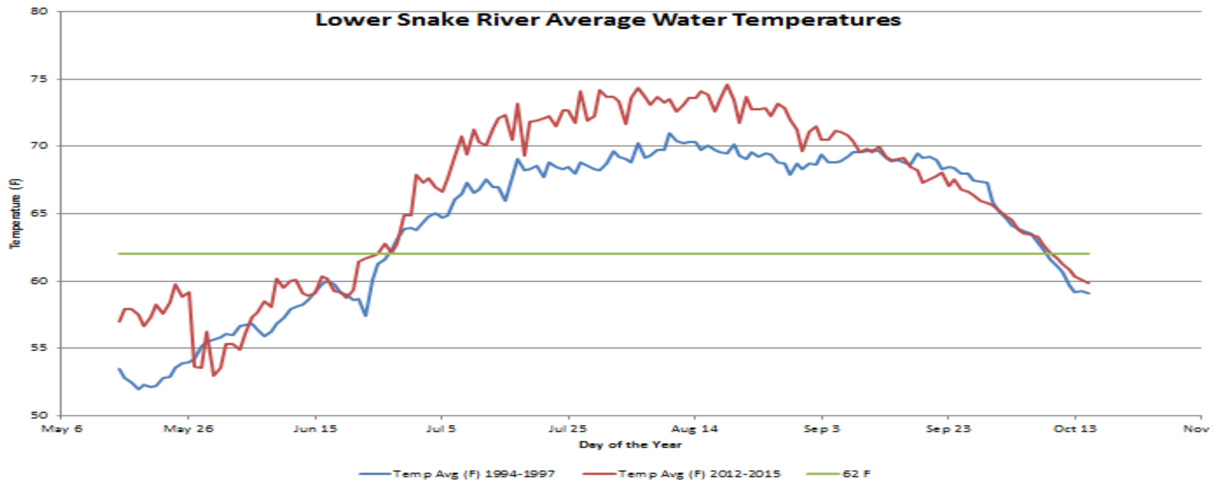
Northwest National Laboratory, 2013), and another attempted to estimate the global GHG production (Deemer BR, 2016). Using the results of several of these recent scientific studies, this paper shows the potential GHG emissions from the reservoirs created by the four lower Snake River dams are significant.

Bioscience Article

In November 2016, *Bioscience* published the article titled "Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis." This paper attempted to accomplish multiple objectives, one of which was to estimate the global production of GHGs by hydropower reservoirs, and another was to identify the best predictors of emissions from reservoirs. To do this, the authors reviewed data from 267 reservoirs, the majority of which are in North America, and several are in the Pacific Northwest. What they found was that methane emissions were best predicted by chlorophyll-a concentrations. Chlorophyll-a is the green pigment found in plants. Its concentration in a body of water is an indicator of phytoplankton abundance and biomass, and can be an effective measure of trophic status and water quality. Bodies of water can be categorized into one of four trophic states, depending generally on the amount of nutrients and primary producers (organisms that produce biomass from inorganic compounds) found within them. In the order of the least to the most nutrients, the states are oligotrophic, mesotrophic, eutrophic, or hypereutrophic. The researchers found that the strong positive correlation between reservoir methane production and chlorophyll-a is reflected in the significantly different methane emissions found in systems with different trophic states. Eutrophic reservoirs emitted an order of magnitude more methane than oligotrophic ones. This pattern is consistent with findings in shallow lakes in controlled environments as well as in North American, Swedish, and Canadian reservoirs, and Finnish lakes and reservoirs.

The Corps of Engineers (USACE) measured chlorophyll-a concentrations in the lower Snake River reservoirs from 1994 to 1997. They are included in the *2002 Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement* (FR/EIS). Samples taken in Ice Harbor, Little Goose, and Lower Granite reservoirs on average fell into the eutrophic or high mesotrophic categories. The chlorophyll-a averages were in the eutrophic range in 13 of 19 locations/years and mesotrophic range in 6 of 19 locations/years. USACE measurements of total phosphorus and total nitrogen also indicate that these reservoirs fell into the eutrophic or high mesotrophic categories.

So while no direct measurements of greenhouse gas emissions from the reservoirs behind the four lower Snake River dams were used in the *Bioscience* paper, the best predictor (chlorophyll-a) for methane gas production has been measured in the reservoirs during past USACE research studies, and in quantities consistent with other reservoirs that are high methane producers. Also, it should be noted that conditions for aquatic plant growth, and thus methane production, have increased since the USACE took measurements in the mid-1990's. Water temperatures in Lower Granite reservoir from 2012-2015 were at or above 62° F for 2 days longer than in 1994-1997, and the average peak temperature was 3.6° F higher. See Graph 1.



Graph 1: Lower Snake River average water temperatures measured at Lower Granite dam (US Army Corps of Engineers, 2016)

This increase in temperature and time at temperature creates a longer growing season for aquatic vegetation and thus an increased potential for methane emission production.

Pacific Northwest National Laboratory Research

In a study published in 2013 titled "Evaluating greenhouse gas emissions from hydropower complexes on large rivers in Eastern Washington" (Pacific Northwest National Laboratory, 2013), the Pacific Northwest National Laboratory (PNNL) compared greenhouse gas emissions from a Columbia River reservoir and a lower Snake River reservoir, against a free flowing section of the river. The laboratory measured methane gas emissions from Lake Herbert G. West (behind Lower Monumental dam on the lower Snake River), Priest Rapids Lake (behind Priest Rapids dam on the Columbia River), and the Hanford Reach, an undammed section of the Columbia, for use as reference.

Measurements at each site included pathways that GHGs can reach the atmosphere through surface flux, degassing through hydroelectric turbines, ebullition (gases bubbling up from bottom sediment), and hyporheic flux (exchange between ground water and surface water) of CO_2/carbon dioxide and CH_4/methane. Emissions were found to be miniscule or slightly negative for all pathways except ebullition. This was consistent with other researchers' findings worldwide, but the magnitude of methane gas emissions measured from ebullition was not expected from the Snake or Columbia Rivers due to their xeric environments.

Findings

PNNL researchers found mean methane gas emissions in slow moving shallow sections of Lake Herbert G. West to be 324 mg $m^{-2}d^{-1}$ which was 80 times higher than the undammed Hanford Reach. Emissions on Priest Rapids Lake were measured with a mean methane gas emissions of 482 mg $m^{-2}d^{-}1$ (120 times the undammed Hanford Reach).

Mean carbon dioxide ebullition from Lake Herbert G. West was measured at 342 mg $m^{-2}d^{-1}$ whereas the undammed Hanford Reach emitted a mean flux of 10.9 mg CO_2 $m^{-2}d^{-1}$.

Calculations

The PNNL paper did not attempt to quantify the yearly GHG emissions, but stated that it could be calculated with further investigation. This can be done by determining what percentage of the total surface area of the four lower Snake River reservoirs exhibits the conditions where the greatest methane emissions were measured in the PNNL study, and by estimating what percentage of the calendar year these conditions exist. This calculation creates a conservative estimate of the total yearly GHG productions of the reservoirs.

The authors noted that the greatest effluxes (or outward flow) were measured in areas with:

1. Water depth <10 m (33 ft.)
2. Low water velocity (near zero)
3. Water temperatures that exceeded 17 C (62 F)
4. The surrounding land used for agriculture and therefore likely not nutrient (nitrogen and phosphorus) limited.

They also noted that the sites studied were not unique and that a substantial quantity of similar habitat exists within the reservoirs of the Snake and Columbia.

Surface Area

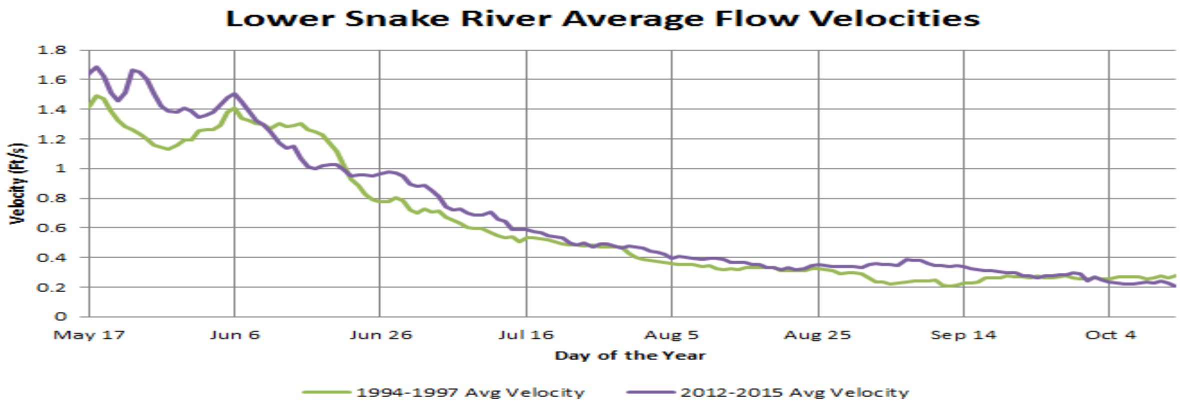
To estimate the surface area of the reservoirs that exists with depth less than 10 m, an estimate by the Fish Passage Center was used (Columbia Basin Fishery Agencies and Tribes, 2016). They referenced diagrams from the USACE 1992 Reservoir Drawdown Test Report (US Army Corps of Engineers, 1992) to conclude that 30% of the reservoir bottom would be exposed if Lower Granite reservoir was drained 10 m. From the USACE Walla Walla Division website (US Army Corps of Engineers) "project pertinent data," the total acreage of the four reservoirs is 34,715 acres. Thirty percent of that is 10,415 acres.

Reservoir Water Temperature

Water temperatures in the lower Snake River were at or above 62° F an average of 106 days annually in the period 2012-2015. This occurred between June 26th and October 9th (see Graph 1). Temperatures above 62° F are ideal for vegetation growth.

Reservoir Water Velocity

Water velocity in the lower Snake River varies considerably by location. This is not a measurement that the USACE records, but they do report flow in volume per time (cubic feet per second). By combining this data with the reported volume and length of the reservoirs, an average velocity can be calculated. Data from Lower Granite dam and reservoir was used for these calculations (US Army Corps of Engineers, 2016). The velocity calculated was assumed to be the same for all four reservoirs since these are run-of-river dams without storage capacity. Velocity of the lower Snake River dropped below 1 ft/s after June 21st during both time periods (1994-1997 and 2012-2015) and continued to drop for the rest of the year. This is considered low velocity which is optimal for vegetation growth. See Graph 2.



Graph 2: Lower Snake River Average Flow Velocities (at Lower Granite Dam) (US Army Corps of Engineers, 2016)

Surrounding Land

The vast majority of the land surrounding the lower Snake River is used for agriculture, irrigated and non-irrigated, as shown in Figure 1. Nutrient concentrations in the reservoirs, as discussed earlier (using data from the USACE 2002 FR/EIS), are borderline eutrophic (not nutrient limited), which is essential for vegetation growth.

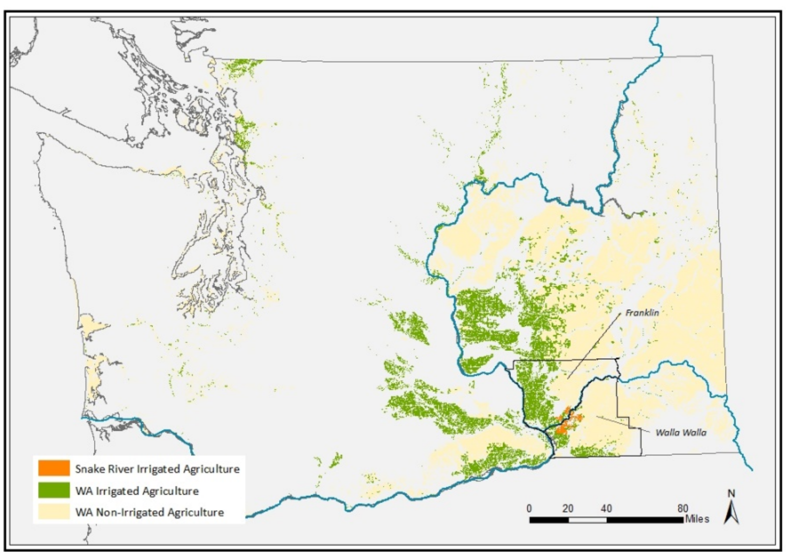


Figure 1: Irrigated and Non-Irrigated Agriculture in Washington State (Earth Economics, 2016)

Results

If the ebullition rates (mg $m^{-2}d^{-1}$) are multiplied by surface area and number of days per year, then the mass of CH_4/methane and CO_2/carbon dioxide generated by the reservoirs can be calculated for the year.

The mean ebullition rate for Lake Herbert G. West was 324 mg CH_4 $m^{-2}d^{-1}$ and 342 mg CO_2 $m^{-2}d^{-1}$. Surface area with depth <10 m was calculated earlier at 10,415 acres (42,148,010 m^2). Number of days with good temperature and velocity for aquatic vegetation growth is 106.

The result is 1,447,531 kg of CH_4 and 1,527,950 kg of CO_2. When CH_4 is converted to equivalent CO_2 using its Global Warming Potential (GWP) factor of 34, the resulting mass is 49,216,054 kg of CO_2. With the addition of the 1,527,950 kg of CO_2 generated, the total greenhouse gas emissions of the lower Snake River are the equivalent of 50,744,004 kg or *50,744 metric tons of* CO_2.

Conclusion

While the estimated yearly greenhouse gas emissions of the dammed lower Snake River reservoirs alone does not approach the GHG emissions of a coal or natural gas fired power plant, the emissions are not trivial and certainly not "0" as many organizations would like the public to believe. The State of Washington currently has 99 dams producing hydropower from the state's total inventory of 1189 dams (State of Washington Department of Ecology, 2016). This means the greenhouse gas production potential for the whole state is massive. It is convenient to apply age-old assumptions about the reservoirs "green-ness," but the mounting pile of evidence against those assumptions cannot be ignored. Eventually, the EPA will require reporting of GHG's from hydropower systems, just as it requires for fossil-fueled power plants.

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