Unintended Consequences: Warming the Deschutes River to Benefit Fall Chinook

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Introduction

Portland General Electric (PGE) and the Confederated Tribes of Warm Springs Reservation of Oregon (CTWS) jointly own the three dam Pelton Round Butte Hydroelectric complex (PRB). The complex consists of the Regulating Reservoir, Pelton Dam which impounds Lake Simtustus and Round Butte Dam which impounds Lake Billy Chinook (LBC), the uppermost feature of PRB. Anadromous fish passage was never successful around PRB and passage was abandoned totally in 1968. Mitigation for the loss of salmon and steelhead above PRB was provided by production at Round Butte Hatchery starting with the release of juvenile steelhead *(Oncorhynchus mykiss*) in 1974 (ODFW, 2019).

The original adult upstream passage scheme was a hybrid affair involving a 2.84 mile-long fish ladder around the Reregulating Reservoir, release into and volitional passage through Lake Simtustus, recapture at a trap at the base of Round Butte Dam and a bucket tramway ride over the dam for release into LBC.

Downstream juvenile passage was originally attempted using a trap or “skimmer” to capture fish near Round Butte Dam as they attempted to find their way out of the reservoir. This failed because of the complex nature of surface currents in LBC caused by different water temperatures in the three tributaries entering the LBC – the Crooked, Deschutes and Metolius rivers. In brief, surface currents in the reservoir went upstream away from the dam and collection facility making it difficult for downstream migrating juvenile to find the collection facility and be captured.

In order to continue operating the complex after 2005, a new Federal Energy Regulatory Commission (FERC) license was required that mandated anadromous fish reintroduction above PRB. Both downstream juvenile passage and upstream adult passage around the project were required.

The new adult fish passage and reintroduction plan relies on trucking returning salmonids from the Pelton Trap at the base of the Reregulation Dam upstream for release directly into LBC.

The centerpiece of the new juvenile fish passage effort is a $135 million structure called the Selective Water Withdrawal Tower (SWW) built in the forebay of LBC and put into operation in late 2009. This structure passes water from LBC either from the surface or through a deeper port (240 feet) and has two purposes: to establish surface currents in LBC to make it possible for migrating juvenile salmonids to find a collection facility on the top of the SWW and to modify the seasonal temperature regime in the lower Deschutes River downstream from the dam complex. Figure 1 displays how the year-long temperature regime in the Deschutes River downstream from the dam complex has been changed under SWW operation. Note how water temperatures have been warmer starting in January most years, warmer (up to 4°C in some cases) in the summer and seasonal peak temperatures have been forward-shifted form about September to about mid-June. Post-SWW temperatures after October that are generally, depending on the year, similar to pre-SWW temperatures (Figure 1).

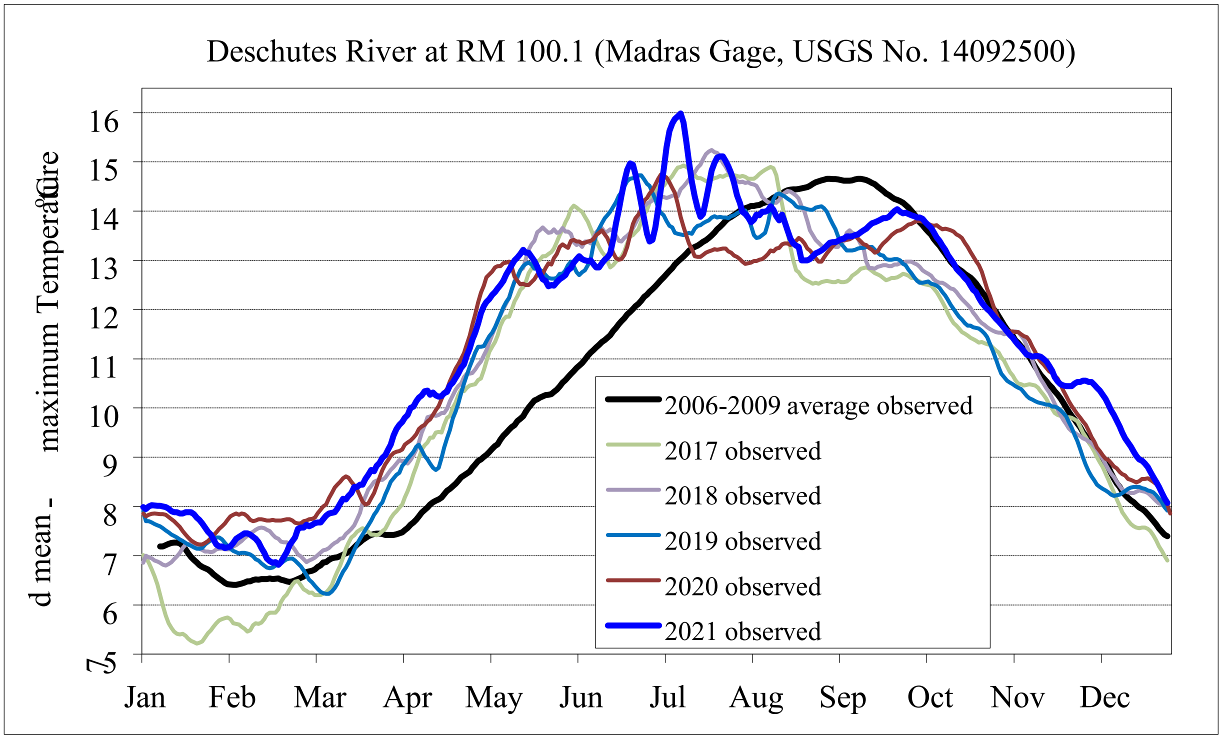


Figure 1. The pre-SWW 3-year average 7dAM (2006-2009) for the Pelton Round Butte Project compared to the observed 2015-2021. 7dAM discharge temperatures as measured at the Madras USGS gage (from Campbell, 2022).

The Deschutes River Alliance (DRA), a science-based advocacy organization seeking collaborative solutions to basin-wide threats to the health of the Deschutes River and its tributaries, have documented a range of negative, damaging effects to the ecology of the lower Deschutes as a result of these temperature changes and nutrient loading in the winter and spring. A detailed discussion of these many issues is beyond the scope of this report although many of them will be mentioned below. This report will examine claims by PGE that their current temperature management in order to benefit fall Chinook (*Oncorhynchus tshawytscha*).

General Discussion of PGE’s Deschutes River Temperature Claims

The principal reason PGE frequently offers to justify post-SWW temperature management of releasing warm, nutrient-laden surface water from LBC during the winter, spring and summer is to save cold water in LBC throughout the year for release in the fall to benefit fall Chinook. That is, they do not release cold water downstream in the Deschutes River in the summer because they want to retain the colder water in the lower levels of LBC for release later in the late summer and fall, claiming a need for cold water in the fall to benefit fall Chinook. In a July 21, 2021 Question and Answer segment on PGE's Deschutes Updates website (portlandgeneral.com/about/rec-fish/deschutes-river/deschutes), fish biologist Megan Hill references cold water in the fall for the benefit of fall Chinook without offering any detail on what that benefit might be. Quoting Ms. Hill when she is answering a question relative to why PGE and the Tribes manage water temperature and flows: "This approach ensures that spring temperatures are conductucive [sic] to fall Chinook growth and helps us save cooler water for the fall when these fish return to spawn."

The nature of this benefit and how fall Chinook will benefit from cold water in the fall has never been specified. The claim that cold water in the depths of LBC must be saved for fall release to benefit fall Chinook has been made by PGE so often that others repeat it as a justification for current temperature management.

PGE has long claimed that they cannot influence water temperatures more than about 55 miles downstream from PRB, particularly during the summer. To support this claim, they cite a theory they call "The Canyon Effect" that says that any attempt on their part to change river temperatures (ie lower summer temperatures by releasing more cold water) will be unsuccessful. The "Canyon Effect" theory postulates that solar radiation, the south to north orientation of the river, general lack of shade and heat absorbed by the canyon's rocky geology all combine to heat the water as it travels downstream despite the water temperature released from the SWW.

This theory is referenced in a 2015 PGE and Confederated Tribes of Warms Springs publication "Temperatures, Insects and Algae on the Deschutes River" in response to public concerns about river temperatures (portlandgeneral.com/about/rec-fish/deschutes-river/deschutes-updates). Quoting from that publication "Many factors affect downstream water temperatures, especially near the mouth of the river. The biggest factor -more so than SWW operation – is solar exposure in the hot summer months when the sun is at its highest over the Deschutes River canyon."

Under the "Canyon Theory" any claim that PGE is cooling downstream water temperature to benefit fall Chinook is somewhat meaningless then since a large section of the lower Deschutes downstream from river mile 55, which is heavily used by fall Chinook would, by this theory, remain unchanged from PGE temperature management strategies.

DRA Studies of Water Temperature and the "Canyon Effect"

DRA has conducted studies and analysis to address PGE's claims of both the "Canyon Effect" and their inability to influence water temperatures in more downstream reaches of the Deschutes. These efforts have demonstrated that neither claim is supported by available data, especially the above referenced claim that solar exposure during the summer months is the biggest factor in increased water temperatures at the mouth of the river.

Airborne Thermal Imaging

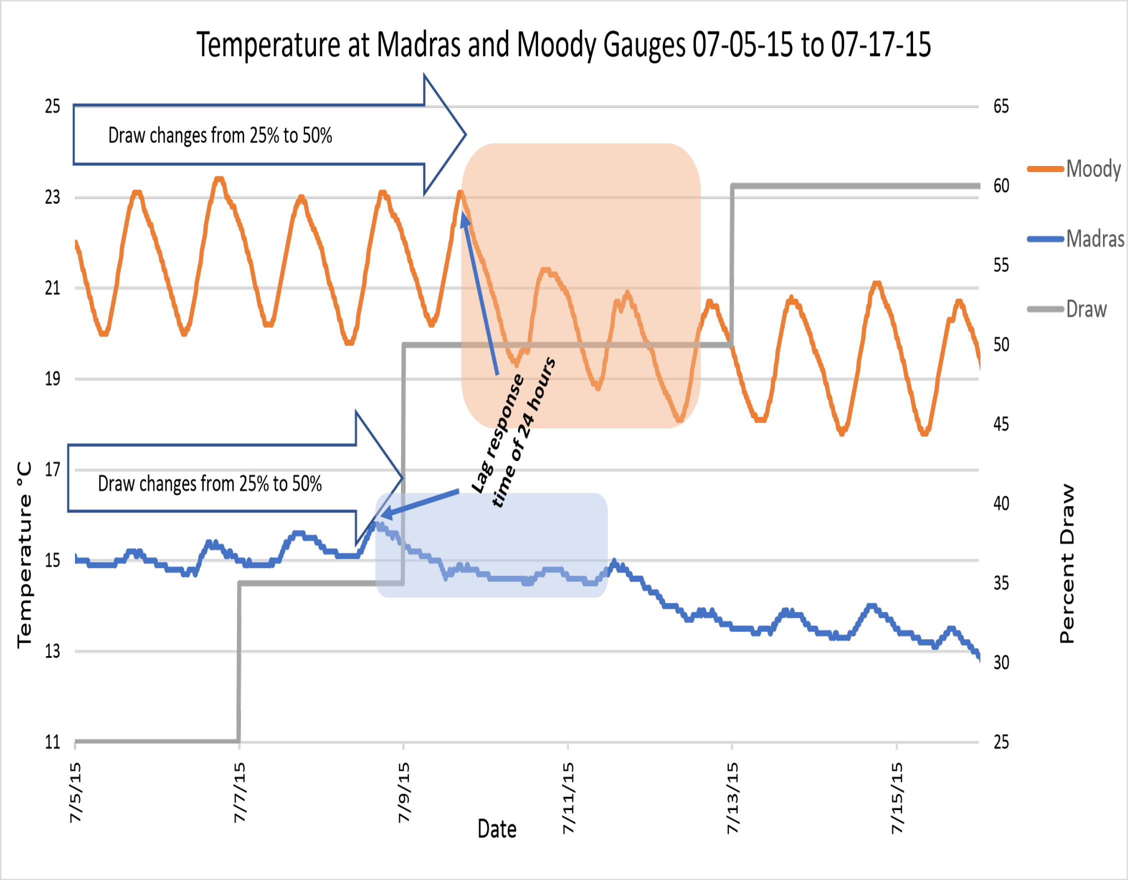
DRA conducted a thermal imaging study of the lower 100 miles of the Deschutes utilizing data from an airborne thermal infrared remote sensing flight on July 26, 2014 and real-time water temperature monitoring during the flight (McMIllan, et al, 2016). This study was done to characterize water temperature changes in real-time through the lower 100 miles of the river in relation to the “Canyon Effect” theory. It is difficult to broadly characterize a river’s thermal behavior from one imaging flight although Fullerton, et al (2015) documented similar thermal profiles of several western rivers despite inter-annual variations in temperature, suggesting that the Deschutes would exhibit a similar thermal profile year on year. McMillian, et al (2016) also points out that SWW temperature discharge temperatures during nighttime hours (cooler) travel down the river as a bolus or mass of colder water that can be tracked downstream by temperature. This results in a what would likely be characterized as a “complex” thermal profile by Fullerton, et al (2015) with temperatures being lowest near the source, highest at the river mouth with a plateau wherever the cold-water bolus was at the time of measurement. At the time of day of the thermal imaging flight, this cold-water bolus appeared to extend to at least Sandy Beach (river mile 47), the end of where PGE has claimed cold water release temperatures are ameliorated due to the “Canyon Effect. As will be shown below, cold water releases from the SWW influence river temperatures to the mouth instead of being negated by the “Canyon Effect”

Additionally, McMillan, et al (2016) found that while downstream warming spatially coincides with tributaries entering the river, no single tributary is shown to have a sustained thermal effect on water temperatures nor were any cold-water plumes (subsurface springs) detected through thermal imaging.

Graphic and Statistical Analysis

DRA also examined water temperatures from the USGS gage (USGS monitoring location 14103000) at Moody Rapids (river mile 0.5) after changes were made in SWW operation to release cold water.

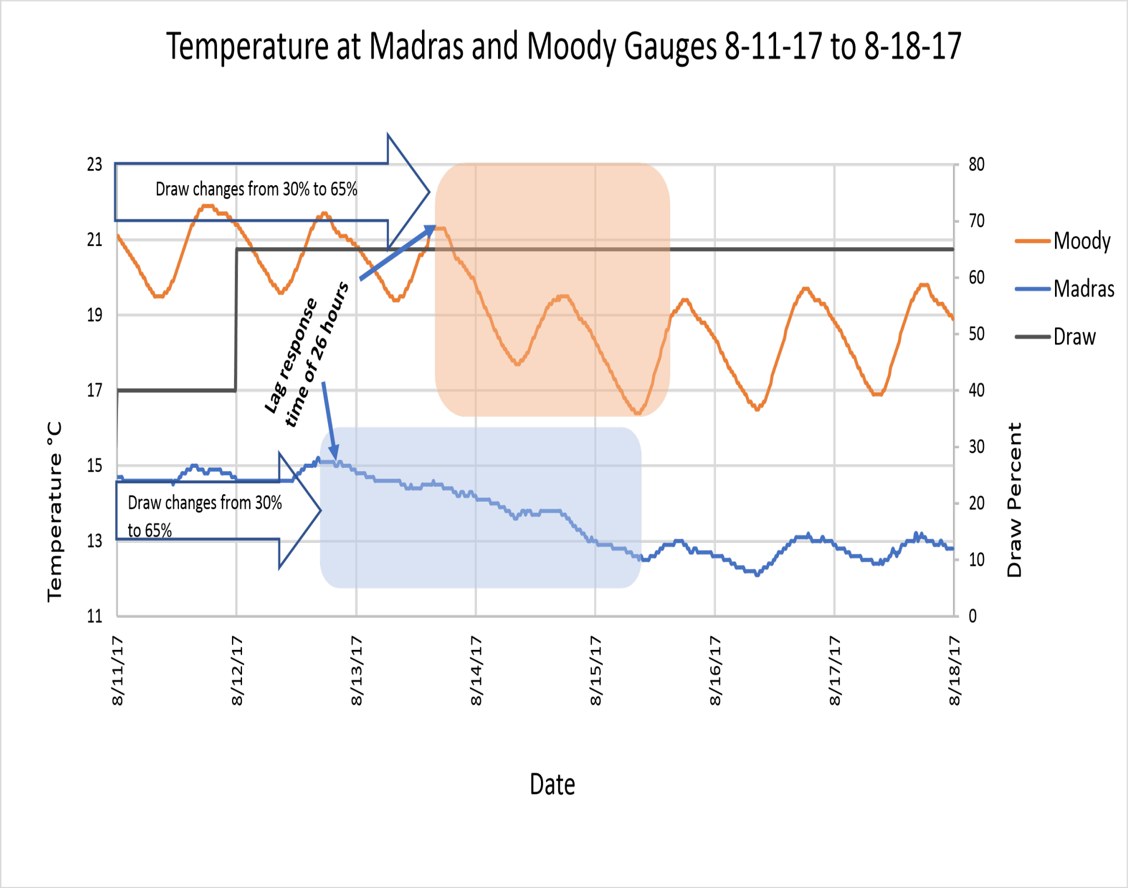
All three time-temperature-location analyses (figures 2,3 and 4) represent changes in SWW operations where the percent bottom draw increased over a short period of time. Changes in temperature resulting from cold water releases through the SWW were measurable 100 miles downriver at the Moody gage (USGW 14103000) after a time-lag. In all three cases, temperatures at the Moody gage showed a strong statistical correlation (Spearman Value at least > 0.6 denoting statistical significance) with the temperatures 100 miles upriver at the Madras gage after accounting for a time-lag that varied among analyzed flows. Time-lags represent the time it takes for cold water release to travel from point of release 100 miles downstream to the Moody gage. Variations in flow account for the different travel time of the cold water between gages between years.



Spearman correlation value for the temperatures at Madras and Moody with 24-hour lag = "Strong correlation" at 0.6

P ≤ 0.05

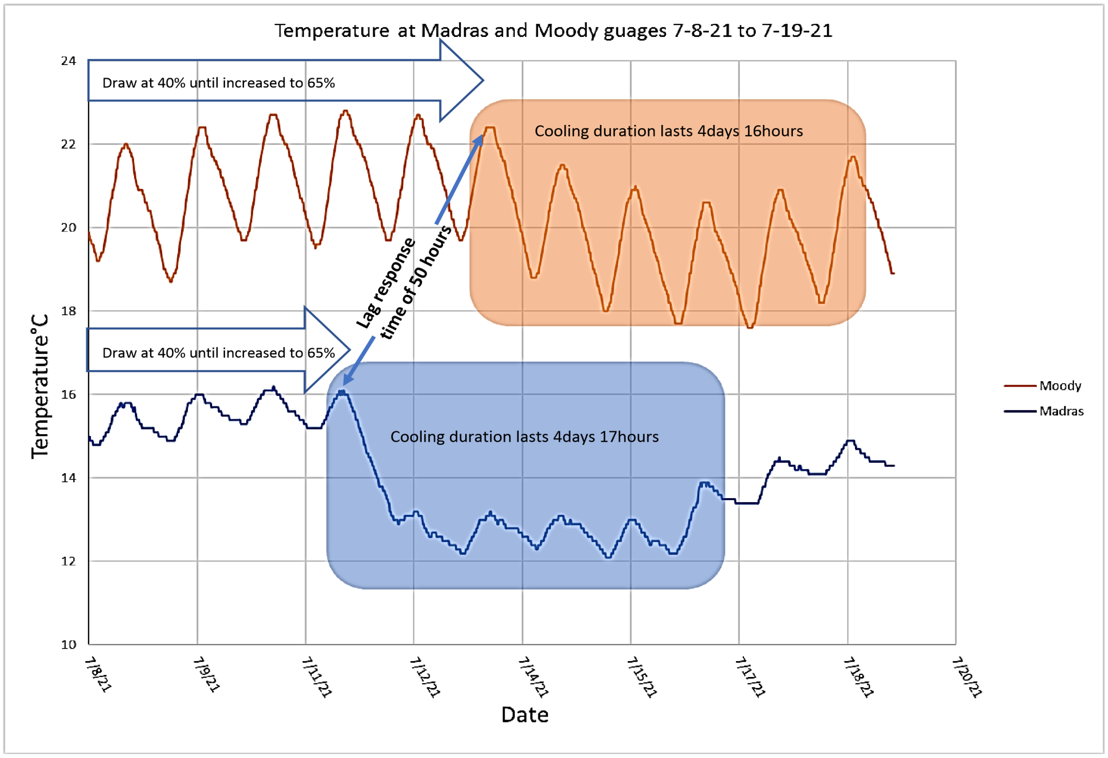
Figure 2. Water temperatures at the Madras gage (USGS gage 14092500 river mile 100), the Moody gage (USGS 14103000, river mile 0.5) overlayed with changes in the amount of cold water released through the SWW, July 5 – 15, 2015. Flow at Madras gage averaged *4,100 for the period. Spearman correlation values indicate a statistically significant correlation (p≤0.05) between Madras and Moody temperatures and a lag-response time of 24 hours between the two gages 100 miles apart.*



Spearman correlation value for the temperatures at Madras and Moody with 26-hour lag = “Strong correlation” at 0.73

P ≤ 0.05

Figure 3. Water temperatures at the Madras gage (USGS 14092500, river mile 100), the Moody gage (USGS 14103000, river mile 0.5) overlayed with changes in the amount of cold water released through the SWW, August 11 – 18, 2017. Flow at Madras gage averaged 4,000 for the period. Spearman correlation values indicate a statistically significant correlation (p≤0.05) between Madras and Moody temperatures and a lag-response time of 26 hours between the two gages 100 miles apart.



Spearman correlation value for the temperatures at Madras and Moody with 50-hour lag = "Strong correlation" at 0.72

P ≤ 0.05

Figure 4. Water temperatures at the Madras gage (14092500, river mile 100), the Moody gage (USGS 14103000, river mile 0.5) overlayed with changes in the amount of cold water released through the SWW, July 8 – 19, 2021. Flow at Madras gage averaged 3,600 for the period. Spearman correlation values indicate a statistically significant correlation (p≤0.05) between Madras and Moody temperatures and a lag-response time of 50 hours between the two gages 100 miles distant. From multiple sources.

These analyses done under different atmospheric, solar radiation and stream flow (travel time) variables demonstrate that the statistically significant relationship between temperature at the Moody gage and subsequent temperature at the Madras gage is durable through time and changing conditions. These analyses clearly show that PGE can lower water temperatures from the dam complex at river mile 100 to river mile 0.5 under summertime conditions despite many claims to the contrary. Further, these analyses demonstrate that a principal driver in water temperature in the lower reaches of the Deschutes – and one that can be controlled – is the water temperature released through the SWW.

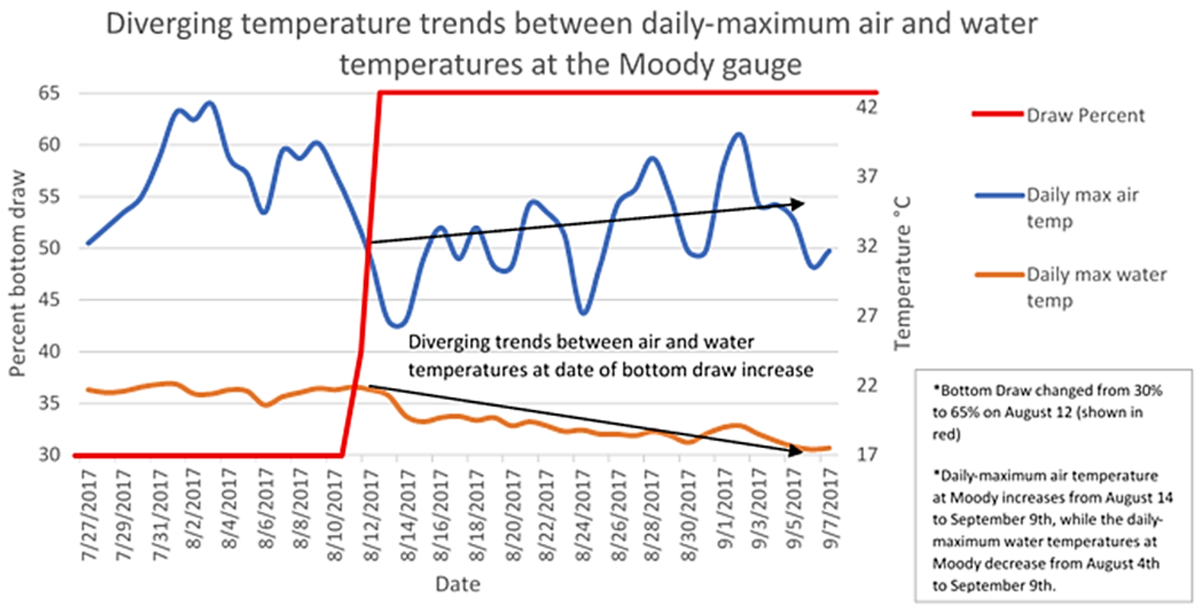


Figure 5. Water temperature at the Moody gage (river mile 0.5) compared to air temperature near the same site and the percent of cold water released through the SWW at river mile 100, July 27 – August 7, 2017. From multiple sources.

To further demonstrate that the "Canyon Effect" theory is not correct in respect to air temperatures being a principal driver of water temperatures, DRA compared water temperatures at the Moody gage (river mile 0.5), the Madras gage (river mile 100) with maximum air temperature and the amount of cold water released through the SWW. Figure 5 shows that water temperature at Moody declined after additional cold water release even though air temperature there showed an increasing trend over the same time period. This is another strong repudiation of the "Canyon Effect" theory and clearly demonstrates that the water temperature released through the SWW can and do influence water temperatures at river mile 0.5 even under an increasing trend in air temperature during peak summer-time conditions.

Interestingly, for all PGE claims about saving cold water in LBC for fall release, the release temperature profile for 2021 shows that release temperatures that year match the pre-SWW temperature profile closely after late September. Rather than providing cooler water in the fall, the 2021 temperatures were cooler in August into early October, equal to the pre-SWW temperature profile for October through early November and warmer the rest of the year (Figure 6). The cause of this change in temperature profile over previous years is unknown but shows that cooler water was not released through the SWW in the fall in 2021.

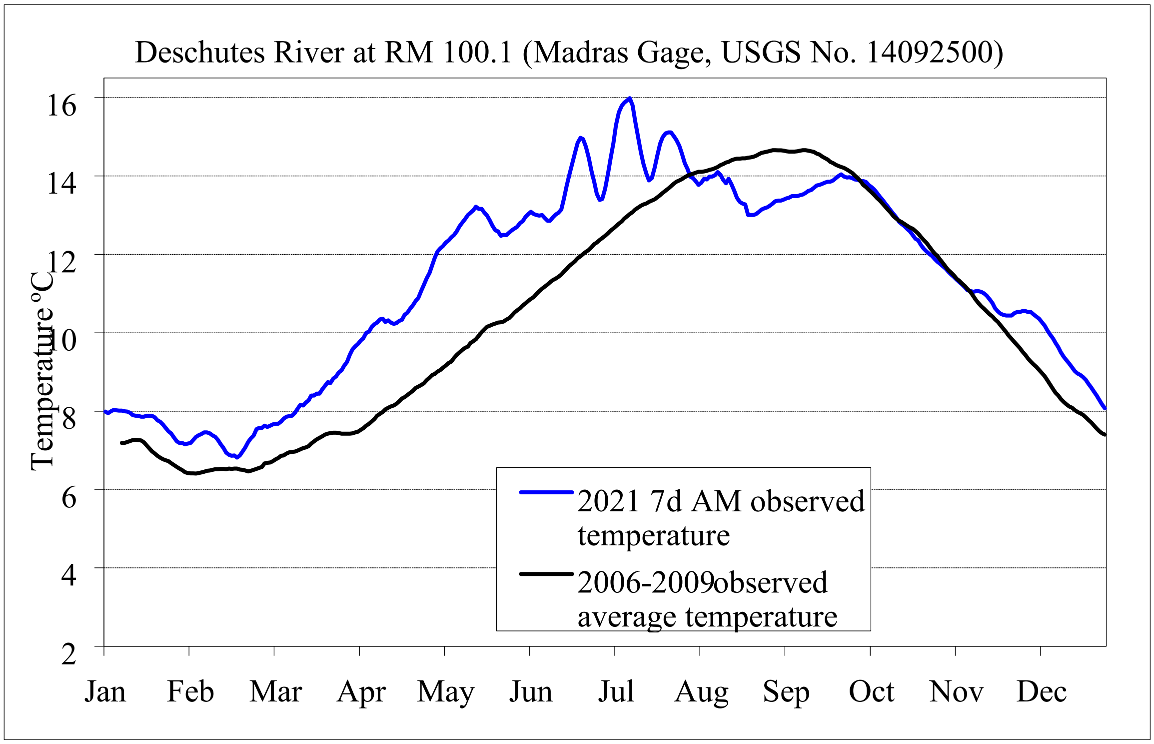


Figure 6. 7dAM temperature for Reregulating Dam tailrace (Site 2) in 2021. From Campbell, 2022.

In summary, PGE's claims that they have no or little control over downstream water temperatures through manipulation of releases through the SWW are not supported by the data above and that they can (and many times have) lower water temperatures at the mouth of the river under peak summer conditions by releasing more cold water through the SWW. Additionally, the data we have presented show that the "Canyon Effect" theory is not supported by the available record and that the principal driver in downstream water temperature is the temperature of water released through the SWW.

Depleting Cold Water in LBC Needed for Fall Release

PGE has frequently claimed that one of the reasons for current temperature management is that LBC will "run out of cold bottom water" if more bottom water is released earlier. They also claim that this retained cold water is conserved for fall release for some unspecified benefit to fall Chinook.

Admittedly, water temperatures in LBC are complex and have changed since SWW operation started (Eilers and Vache, 2091).

Changes in the thermal profile of LBC pre and post SWW are documented by Eilers and Vache (2019). Their report shows that water temperature in the reservoir's hypolimnetic layer is colder after SWW operations started in late 2009 (Figure 7). It should be noted, however, that the pre-Tower bottom water was still cold, just not as cold as post-Tower conditions. The statement that they will run out of cold water is simply not true. More on that later.

An interesting and confounding factor in terms of lower river temperature management is PGE's inability to release more than 60% (also reported variously by PGE as 65%) of the total flow from LBC through the bottom of the SWW Tower (240 feet or about 80 meters below full pool elevation). This prevents them from using the maximum amount cold water available in LBC for downstream release. If PGE could use the full range of 0 % to 100% of the cold water contained in the hypolimnion of Lake Billy Chinook, it would allow more precise control of downstream temperatures as opposed to being constrained to only having 60% or 65% of the cold bottom water available for downstream temperature modification. The other 40% of downstream flows into the lower Deschutes must be released from the surface of LBC under current SWW operations. This means that all cold water released through the lower port in the SWW must now be blended with at least 40% surface water, the warmest water contained in the reservoir.

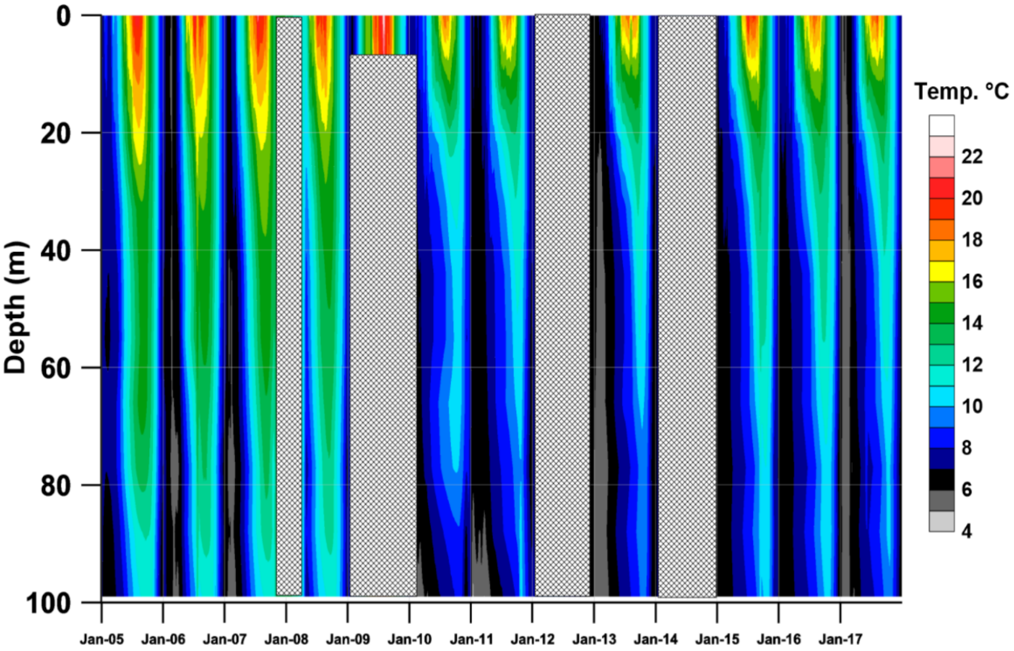


Figure 7. Vertical water temperature profiles in the LBC forebay from January 2015 through 2017. Gaps (gray) in 2007, 2008, 2009 (at depth), 2012 and 2014 represent period where data were not collected (from Eilers and Vache, 2019).

However, in 2006, 100% bottom water was being released. Now, using the SWW Tower, bottom water must be mixed with at least 40% surface water. Using estimated values from Figure 8, we can show the difference between bottom water temperature released in 2006 and the mixed bottom and surface temperature released from LBC in 2016 (Table 1). Table 1 assumes a 60% bottom and 40% blend of water temperatures to calculate the 2016 release temperatures. In 2006 only bottom water was released, and temperatures would reflect that. By blending 40% warm surface water with 60% bottom water, the water released from LBC in 2016 is warmer than in

2006 (by up to 4˚C) for each month except for October. Therefore, despite having colder water present at depth under current operations of the SWW Tower, the water being released from LBC is warmer most of the year. The statement that they will “run out of cold water” is very misleading and misrepresents what actually happens under current operations.

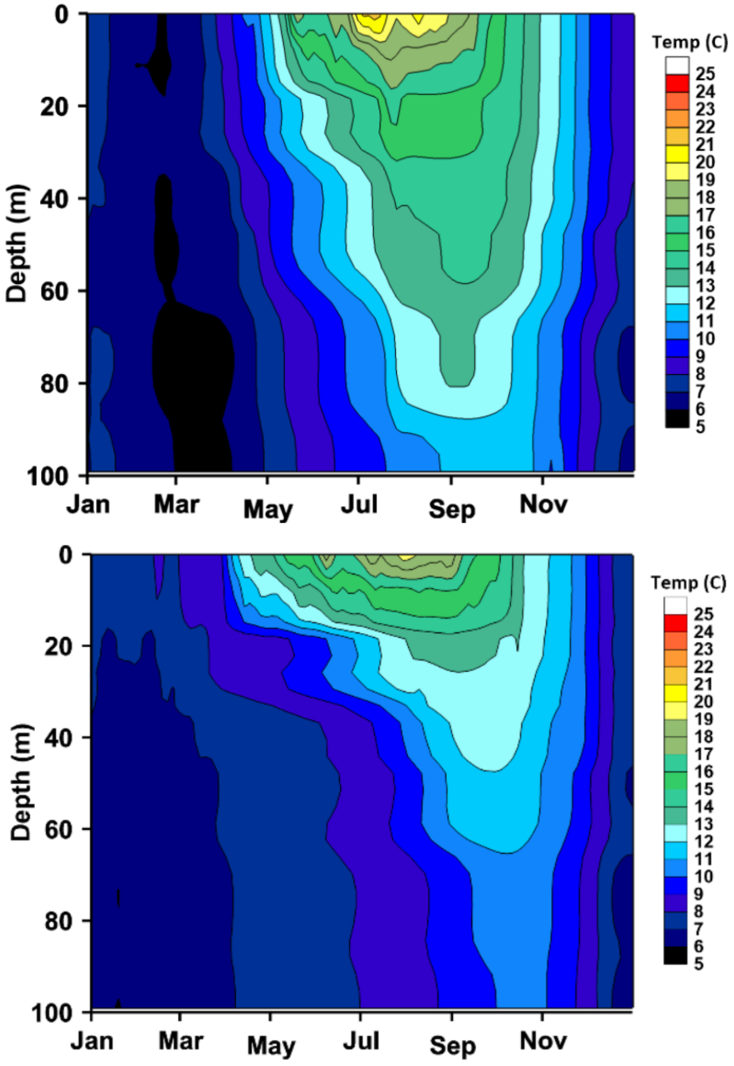


Figure 8. Vertical water temperature profiles in LBC immediately upstream from the dam as measured in 2006 (top) and 2016 (bottom) (from Eilers and Vache, 2019)

Table 1. Estimated water temperatures (˚C.) released from LBC resulting from the current 60% bottom and 40% blending during current SWW operations (2016) compared to pre-Tower temperatures in 2006 (values estimated from Eilers and Vache, 2019).

Month	2006 Bottom	2006 Release	2016 Bottom	2016 Surface	2016 Release
June	9	9	8	17	11.6
July	9	9	8	18	12
August	10	10	8	18	12
September	12	12	9	18	12.6
October	13	13	10	16	12.4
November	10	10	9	10	9.4

Thus, it is apparent that the claim that PGE must not release cold water throughout the summer to benefit the lower Deschutes in order to save cold water for fall release is because of the self-induced inability of the SWW to release more than 60% cold water. If the SWW were, in fact capable of releasing non-blended downstream flow, more precise downstream temperature control would be possible.

Agency and PGE Positions for Releasing Cold Water in the Fall

One way to explore PGE's reasoning for saving cold water in LBC to benefit fall release is to examine statements made and actions taken by the Oregon Department of Fish and Wildlife (ODFW) and the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS) the two entities who -co-manage fishes in the Deschutes as well as PGE who is responsible for operation of PRB and the SWW.

Oregon Department of Fish and Wildlife

DRA contacted Rod French, ODFW District Fish Biologist for the Mid-Columbia Fisheries District in The Dalles (who oversees fish management the lower 100 miles of the Deschutes River and now retired) to seek ODFW's position. An email from French dated December 5, 2018, points out that they have no studies or data to support PGE's contention that cold water in the fall has some benefit to fall Chinook. Rather, ODFW seems to believe something completely different although only opinions are offered and no studies or data.

Quoting French's email directly: "First of all, I actually think the earlier spring warming resulting from SWW [French is referencing the current temperature management of releasing surface water through the SWW] is probably the most beneficial result to Deschutes fall Chinook (CHF). As I understand, the actual temperature difference between pre and post SWW late summer, early fall is considerably less than the difference that now occurs during the spring.

While the temperature benefits are not easy to characterize, I would suggest the cooler temperatures help control disease epizootics, assist in migration (more in thermal preference), providing trigger mechanisms for earlier spawning, amongst other things that a more natural thermal regime may provide but are not easily recognizable."

French continues: "I do think, however, the CHF probably greatly benefit from the warmer spring temperatures resulting from the. Some of these benefits likely include: 1) Early emergence, longer growing period, 2) Increased growth due to warmer temperatures, 3) Increased condition and lipid levels, better food conversion, 4) Earlier migration/smolting triggers, and 5) greater overall juvenile and migrant survival."

French, in his Declaration provided in support of Case: 3:16-cv-01644-SI, Document 85-2 (filed 4-27 2018) Deschutes River Alliance v Portland General Electric, somewhat obliquely refers to post-SWW water temperatures as being beneficial to fall Chinook and generally credits that to warmer spring flows and the belief that those warmer water temperatures benefit fall Chinook juvenile rearing (Declaration of Rod French).

Thus, ODFW's position does not support PGE's contention that they are saving cold water for release in the fall to benefit fall Chinook but rather, the opposite. It is ODFW's position that warmer water in the spring would be more likely to benefit the juvenile life history stage rather than cold water in the fall providing any benefit to adults. This is somewhat of a necessary conclusion since, as will be discussed below, very few juvenile fall Chinook are present in the Deschutes in the fall that would potentially be benefitted by temperature management.

Furthermore, if PGE and ODFW agree that warming the river in the winter is beneficial, they are certainly taking a scattershot approach accomplishing that goal since we are not aware of any modeling to inform that management process (see Modeling section below). Additionally, if warming the river in the winter and spring is their ultimate management objective, then it would be entirely possible to accomplish that goal with modeled SWW surface release in the winter and early spring and release stored cold water in the late spring and summer rather than the fall. This would help considerably with restoring the pre-SWW summer temperature and nutrient regime to the benefit of a wide variety of species. We believe the available science (Eilers and Vache, 2019) supports that conclusion.

Portland General Electric

Bob Spateholts, a PGE biologist (now retired) working on the fish reintroduction project at PRB was contacted by phone in December, 2016 to help understand PGE's position on the fall cold water release. This conversation not only did not provide any clear reasoning but actually added more confusion.

Spateholts related his belief that warmer water in the fall prior to SWW operation, delayed the initiation of adult fall Chinook spawning and that the SWW-driven fall cooling restored the spawn timing that would have occurred under the natural thermal potential (NTP, also called

Without Project Temperature or WPT). This is the exact opposite of findings by Huntington, et all (1999) and counter to generally accepted thoughts on the effects of water temperature on maturing adult salmonids. Briefly, in any hatchery setting where you can control water temperature to alter maturation and spawn timing of adult salmonids, you RAISE the temperature to speed up biochemical processes leading to earlier egg maturation and spawn timing and you LOWER temperature to retard those factors. When asked to explain why this thought to be so, he did not have an answer as to why PGE believes those things.

Statements by Don Ratliff (Declaration of Dan Ratliff in support of Case: 3:16-cv-01644-SI, Document 85-2 filed 4-27 2018 Deschutes River Alliance v Portland General Electric), a PGE biologist at the PRB complex for more than 40 years, offers opinions that are completely at odds with PGE's currently stated goal of saving cold water for the fall to benefit fall Chinook. Ratliff discusses the effects of water temperature on juvenile fall Chinook growth and concludes that faster growth of juvenile fall Chinook with warmer water (although he does not specify a time frame for benefits from this warmer water nor provide any details relative to claimed benefits) from post-SWW operation is the most likely explanation for increased in adult and jack fall Chinook returns to the Pelton Fish Trap.

Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS)

Robert Brunoe, the CTWS Branch of Natural Resources General Manager, offers his belief that the post-SWW water temperature regime is reducing the impacts of water temperatures in the lower Deschutes River that have impaired juvenile fall Chinook emergence, growth and survival (Declaration of Robert A. Brunoe in support of Case: 3:16-cv-01644-SI, Document 85-2 filed 4-27 2018 Deschutes River Alliance v Portland General Electric).

Bradley Houslet, the CTWS Fisheries Department of the Branch of Natural Resources Manager briefly discussed temperature and fall Chinook (Declaration of Bradley S. Houslet in support of Case: 3:16-cv-01644-SI, Document 85-2 filed 4-27 2018 Deschutes River Alliance v Portland General Electric). He notes that the CTWS has been concerned that delayed emergence and reduced growth rates of juvenile fall Chinook has contributed to their lower survival rates in the lower Deschutes River because they are smaller and more vulnerable to predation. Quoting Houslet's declaration directly: "When water temperatures are too far below optimal levels, development of Fall Chinook salmon eggs is slower, the emergence from the eggs is delayed, and the juveniles suffer reduced growth rates. The Tribe has long been concerned that delayed emergence and reduced growth rates of the juvenile Fall Chinook salmon has contributed to their lower survival rates in the lower Deschutes River because they are smaller and more vulnerable to predation."

Houslet's declaration does not offer any support for saving cold water in PRB for release in the fall to benefit fall Chinook, rather, it suggests that the CTWS believe COLD WATER IN THE FALL WOULD BE A DETRIMENT to growth and subsequent survival of juveniles (even though very few are present), rather the opposite of what PGE is claiming.

The declarations of French, Ratliff, Brunoe and Houslet do not address benefits to fall Chinook from cold water release in the fall. Rather, each assumes benefits to juveniles from warmer winter and spring temperatures. None of these statements are supported by the findings of Huntington et al (1999) that detected no significant difference in fall Chinook emergence timing anywhere in the Deschutes caused by temperature changes from historic operation of PRB. It follows then that juvenile fall Chinook emergence (and likely subsequent juvenile growth) was not different after PRB. Any modification to the contemporary water temperature regime to benefit any juvenile life history stage is not necessary and may, in fact, cause unintended consequences to the lower Deschutes unless carefully modeled and controlled.

So, it appears there is no consistent, data-driven reasoning by ODFW, PGE, or CTWS that supports the contention that saving cold water for release in the fall benefits fall Chinook. Rather, there is not even agreement between those groups on the effects of that management strategy.

Unintended Consequences of Temperature Manipulation and Impacts to other Species

One thing that is certain is that changing historic water temperature regimes regardless of the reason will cause unintended consequence that will ripple widely throughout the aquatic environment. Water temperature is a controlling factor for all biochemical and physiological processes, and exerts strong influence on salmonid behavior (EPA, 2001). Water temperature influences the behavior of fish more than any other nonliving variable (Beitinger and Fitzpatrick, 1979 as cited in EPA, 2001). Changing water temperatures in a managed river system should, therefore, be approached after a great deal of thought and done with an equally large amount of caution.

Any discussion on modifying water temperature for the benefit of one species must consider the impacts to other species and in fact, the whole aquatic ecosystem. To do otherwise would be extremely short-sighted and arrogant. Suitable water temperatures within a somewhat broad range are obviously needed to facilitate the well-being of both juvenile and adult fall Chinook. It is interesting in that regard, though, to note their short freshwater residency as both juvenile and adult. Fall Chinook generally spend the great majority of their lives in the ocean rearing phase and they may well be tolerant of freshwater temperature regimes that are not "optimum" (Beacham and Withler 1991 as cited in EPA 1999). This is true for fall Chinook where the adult exposure to freshwater temperatures (especially once they reach their natal stream, in this case the Deschutes River) may be relatively minor and they are likely and necessarily tolerant of a broad range of temperatures. Thus, any attempt to alter freshwater temperature regimes to benefit fall Chinook may be yield relatively minor survival advantages relative to any unintended consequences from that action. Similarly, fall Chinook juveniles have a very short freshwater residence period relative to most other anadromous salmonids with pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) being notable exceptions. Deschutes River fall juvenile fall Chinook juveniles, at least during pre-SWW temperature regimes, were in the Deschutes for less than 7 or 8 months prior to migration (Jonasson and Lindsay, 1988).

Changes to resident trout spawn timing

Resident redband trout (*Oncorhynchus mykiss*), are, by definition, resident and spend their entire lives in the Deschutes and are exposed to the totality of the annual temperature cycle. Any changes to water temperature will affect them vastly more than fall Chinook given their short freshwater residence. For example, increases water temperatures in the winter and early spring may be changing redband spawn timing in the Deschutes. Several years after water temperatures in the Deschutes changed post SWW temperatures, anglers started to notice that Deschutes redbands caught in later November and December appeared to be either in late stages of maturity or completely mature. This is months earlier than the most common pre-SWW spawn timing of late April through July (Schroeder and Smith, 1989). Although redband spawning in the Deschutes is very protracted and spawning activity can be observed any month of the year, the historic pre-SWW peak was, as noted above, was in the April to June period.

DRA thought these observations of very early maturing redbands was concerning enough that we asked ODFW for their opinion in a letter dated February 15, 2019. In their response letter of February 27, 2019, Rod French noted that ODFW had recently seen redband spawning as early as December in several locations and attribute that as a response to a more "natural temperature regime" resulting from post-SWW water temperature changes. To support this, French cites a USGS and Oregon Water Resources Department study of groundwater contribution to the mean annual flow of the Deschutes upstream from PRB and theorizes that these groundwater inputs are cold water. Intra-gravel water temperatures may not be well reflected by the surface water temperature measurement (Zimmerman and Finn, 2012) showing that just saying they are cooling the Deschutes with SWW operation leaves much to be desired in terms of thoughtful science.

Black Spot Disease

Deschutes redband trout, by virtue of their resident status, have been subjected to increased post-SWW exposure to a previously very uncommon condition known as Black Spot Disease (BSD). BSD is a disease of freshwater fish caused by a flatworm larva of the genus *Neascus or Uvulifer* burrowing into the skin, fins or flesh of the fish. The life cycle of this parasite typically involves a fish-eating bird, an aquatic snail and a fish. The adult form of the parasite, an intestinal fluke, resides in the intestine of the infected bird. The adult fluke passes eggs via the bird's droppings into the water where they hatch into a free-swimming larva that infect the aquatic snail. After a period of growth, the larvae pass out of the snail to burrow into the skin of a fish when the pigmented cyst is formed - the black spot. If the infected fish is eaten by a bird, the cycle then starts over (Kirse, 2010)

The increased prevalence of BSD in Deschutes resident redbands has been documented by ODFW (Declaration of Rod French in support of Case: 3:16-cv-01644-SI, Document 85-2 filed

4-27 2018 Deschutes River Alliance v Portland General Electric). This increased frequency may well be due to large increased in the host snail in the Deschutes (Noone, et al 2019), likely in response to both a changed temperature regime from SWW operation and the addition of nutrients from long periods of surface water withdrawal (Eilers and Vache, 2019).

Redband trout are but one of many aquatic organisms that live year around in the Deschutes River, all of which are exposed to and affected by water temperature changes resulting from SWW operation.

Increase in *Ceratonova shasta*

Another unintended consequence of changing the thermal regime and nutrient load in the Deschutes River (Eilers and Vache, 2019) may be increases in *Ceratonova shasta*. *C. shasta* is a freshwater myxozoan parasite native to the Pacific Northwest that is known to causes mortality in both juvenile and adult salmonids. *C. shasta* has a complex life cycle involving infection of a polychaeta worm, *Manayukia speciosa*, by a myxospore and subsequent infection of a salmonid by the actinospore life stage which is shed by *M. speciosa*. The infected salmonid sheds the myxospore which is consumed by *M. speciosa* and the cycle starts over (Hurst, et al, 2014).

Numbers of *M. speciosa* in the Deschutes have increased since SWW operation started in late 2009. While there were difficulties in comparing pre-SWW results with post-SWW results due to differences in sample preservation, Nightengale, et al (2016) showed large increases in *M. speciosa* post-SWW (Table 2). DRA's own macroinvertebrate sampling also found large numbers of *M. speciosa* immediately below PRB with decreasing but still large numbers in more downstream locations (Noone, et al, 2019).

Table 2. Number of Manayunkia speciosia by data source, sample period, location and sample type, Deschutes River, Oregon. Data reported as a range of individuals sampled at multiple sample sites. From Nightengale, et al (2016).

Data Source	Sample Date	Sample Location	Sample Type Pre-SWW	Post-SWW
Nightengale	Oct, 1999	a/	0	
Nightengale	May, 2000	a/	0	
Nightengale	May, 2001	a/	0	
Nightengale	Oct, 2001	a/	0	
Nightengale	Oct, 2013	a/		35-4161
Nightengale	May, 2014	a/		14-479
Nightengale	Oct, 2014	a/		254-1670
Nightengale	Apr, 2015	a/		64-498
DRA	Oct,2015	rm 99		2139
DRA	Oct, 2015	rm 79		780
DRA	Mar, 2016	rm 99		2657
DRA	Mar, 2016	rm 79		535
DRA	May, 2016	rm 99		4261
DRA	May, 2016	rm 79		261
DRA	Jul, 2016	rm 99		1711
DRA	Jul, 2016	rm 79		750
DRA	Sep, 2016	rm 99		8285
DRA	Sep, 2016	rm 79		1318

a/ Multiple sample sites form rm 99.9 to 23.9

Ceratomyxosis, the disease caused by the organism *C. shasta*, has resulted in high mortality of juvenile salmon at Round Butte and Warm Springs National hatcheries in the Deschutes basin and is known to cause mortality of salmonids in the wild throughout the Pacific Northwest.

An unpublished ODFW Fellowship Report, Myxozoan Disease Risks in the Willamette and Deschutes Rivers, 2015-2016, (https://microbiology.oregonstate.edu/content/monitoring-studies) used in-river *C. shasta* spore counts and sentinel fish exposures in several locations in the Deschutes River to determine disease severity in different fish stocks and river sites. Although counts of *C. shasta* spores were variable between time and location, spore densities greater than 100 spores per liter of water were common throughout. Additionally, prevalence of infection and mortality in sentinel fish was over 90% in some sentinel groups in the Deschutes portion of this study. A lethality threshold of 40% mortality was reached for Chinook salmon at spore densities of 10 spores/liter in the Klamath River (Hallett, et al, 2012). Thus, spore counts greater than 100/liter in the Deschutes is very concerning.

Most wild spring Chinook adults returning to the Deschutes River spawn in the Warm Springs River and tributaries (Lindsay, et al, 1989). Spring Chinook adults reaching Warm Springs National Fish Hatchery (WSNFH) (river mile 5.5) are all captured and can be counted there prior to either being spawned as broodstock or released upstream to spawn naturally.

Starting in 2010, the number of redds counted upstream from WSNFH started to decline in relation to the number of adults that were passed upstream to spawn. High fish/redd ratios may indicate adult pre-spawning mortality. Fish/redd ratios exceeded 22 fish/redd in 2016 indicating very high pre-spawning mortality, raising alarm among basin fish managers. CTWS biologists speculated at the time that a combination of high concentrations of *C. shasta* spores in the Deschutes contacted by adults on their upstream migration and highwater temperatures in the Warm Springs River prior to spawning were causing this high pre-spawning mortality (Baker and Boostrom, 2019). It is known that *C. shasta* becomes more virulent with increasing water temperatures. If water temperatures reach 18^o C (64^o F) then the probability of pre-spawning mortality from *C. shasta* is approximately 40% (Bowerman et al, 2018 as cited in Baker and Boostrom, 2019).

The increased prevalence of *C. shasta* in the Deschutes River is disturbing. As referenced above, *C. shasta* increases in virulence with increasing water temperatures and the probability for fish mortality subsequently increases with increasing water temperatures. PGE's current temperature management scheme of releasing warm, surface water from LBC at the exact time spring Chinook adults are migrating upstream likely increases their exposure to and potential from mortality from *C. shasta.*

Changes in water temperature in the lower Deschutes as the result of SWW operation may have caused increases in *M. speciosa*. An additional component of this increase may well be an increase in nutrients, primarily nitrates, contained in the surface layers of LBC and passed downstream in surface flow. Eilers and Vache (2019) note that spill surface of LBC surface water has resulted in downstream increases in pH, nutrients and plankton in the Deschutes. They further note concentrations of nitrates have increased in downstream samples by a factor of two in pre-versus post-SWW sampling. This likely makes increases in periphyton biomass like *M. speciosa* possible. Increases in pH and dissolved oxygen measured in the river would be consistent with increases in periphyton. Eilers and Vache (2019) further note the post-SWW Deschutes River as being rich enough in nutrients to be classified as mesotrophic to eutrophic and suggest that this nutrient enrichment is being caused by nitrate transfer from LBC into the Deschutes via SWW surface spill.

Cladophora sp., a macroscopic, filamentous green algae known to grow in colonies or mats, is one component of the periphyton community of the lower Deschutes. Unfortunately, due to a suite of problems involving pre-SWW sample treatment and differences in taxonomic grouping between laboratory results, Eilers and Vache (2019) were unable to compare pre- and post-SWW densities of *Cladophora sp.* in the Deschutes. Anecdotally however, river users have noted very large increases in *Cladophora sp.* post-SWW. Fishermen notice large enough volumes of drifting *Cladophora sp.* most late summers that biofouling of deployed fishing gear is common, a condition never encountered pre-SWW.

Increases in *Cladophora sp.* and the proliferation of *M. speciosa* in the Deschutes may be linked and can partially explain post-SWW increases in *C. shasta* in the Deschutes. Stocking and Bartholomew (2007) found that M. speciosa in the Klamath River tended to occur within a protective microhabitat such as within beds of *Cladophora sp.* and speculated that protective habitats such as that may allow M. speciosa to persist in the face of high flow events.
If PGE wants to modify water temperatures to benefit salmon, it might be beneficial to cool the river in the spring to benefit spring Chinook rather than cooling in the fall for some vague and unspecified benefit to fall Chinook. This may decrease virulence of *C. shasta* and decrease mortality of both downstream migrating juvenile and upstream migrating adult spring Chinook. Beacham and Withler (1991 as cited in EPA 1999) compared both spring and fall Chinook to temperature challenges and found fall Chinook better adapted than spring Chinook to warmer water. They speculated this is due to the shorter period of freshwater residence for fall Chinook as compared to spring Chinook and being better adapted to warmer waters as found in the ocean and in their freshwater habitats. Consequently, fall Chinook are better adapted to short term exposure to high water temperatures than the spring Chinook and would be unlikely to benefit from cold water in the fall.

Non-native, Invasive Predators

Smallmouth bass (*Micropterus dolomieu*) and walleye pike (*Stizostedion vitreum*) are introduced, warm water, predatory, piscivorous spiny-ray fish that are common in the Columbia River near the mouth of the Deschutes. Except for 1996, when it was believed that significant numbers of smallmouth bass washed downstream during large volume, prolonged spill from LBC (where smallmouth bass were abundant at the time), they were uncommon and rarely observed in the Deschutes. Walleye had never been documented pre-SWW.

Starting in 2014, anglers fishing for summer steelhead in the lower reaches of the Deschutes started to catch increasing numbers of smallmouth bass. By summer, 2016 smallmouth were so numerous that it was possible to catch 20 or more per day. Abundant numbers of smallmouth bass have been present each summer since. The first known capture of walleye in the Deschutes was in summer, 2017 and it was common to catch them below river mile 6 that summer but walleye have only occasionally been observed since.

Deschutes fish managers had long speculated why smallmouth bass and walleye, which are very abundant in the Columbia River near the mouth of the Deschutes, had not colonized that river more extensively. Two possible explanations for the this have been offered: first, water velocity and stream gradient in the lower three or four miles of the Deschutes were too great for smallmouth bass with their more limited swimming ability to overcome or second, the temperature regime in the Deschutes was colder than they preferred, being, by definition, a warm-water loving fish. Since stream gradient and water velocity have not changed post SWW, the likely explanation for colonization of warm water species in the Deschutes is that increased early summer temperatures due to SWW operation has made it possible for smallmouth bass and walleye to swim up the Deschutes to take advantage of habitat and resources present there. While both appear to be only seasonally present in the Deschutes, this should be a source of concern for Deschutes fish managers. Resident redband trout as well as rearing steelhead juveniles are present year around in the areas where smallmouth bass, an enthusiastic and efficient predator, are now found in large numbers. Fritts and Pearsons (2006) concluded from studies of smallmouth bass predation in the Yakima River that the introduction of non-native piscivores like smallmouth bass can clearly have unintended consequences for native fishes, particularly native salmonids.

Maximum daily temperatures in the Deschutes and the Columbia suggest a potential reason warm water species like walleye and smallmouth bass are invading the lower Deschutes under post-SWW water temperatures (Figure 9). Winter, spring and early summer water temperatures in the Deschutes are several degrees Centigrade warmer than the Columbia post-SWW and it is likely these elevated temperatures are an enticement for them to enter the Deschutes when it is warmer than the Columbia.

Consistent pre SWW temperature records are not available from the Moody gage for a direct of pre vs post temperature analysis. This temperature differential is a situation that likely did not exist prior to SWW operations so it is somewhat speculative but the available record supports the contention that the ongoing invasion of non-native, invasive, warm water predators is a result of current temperature management.

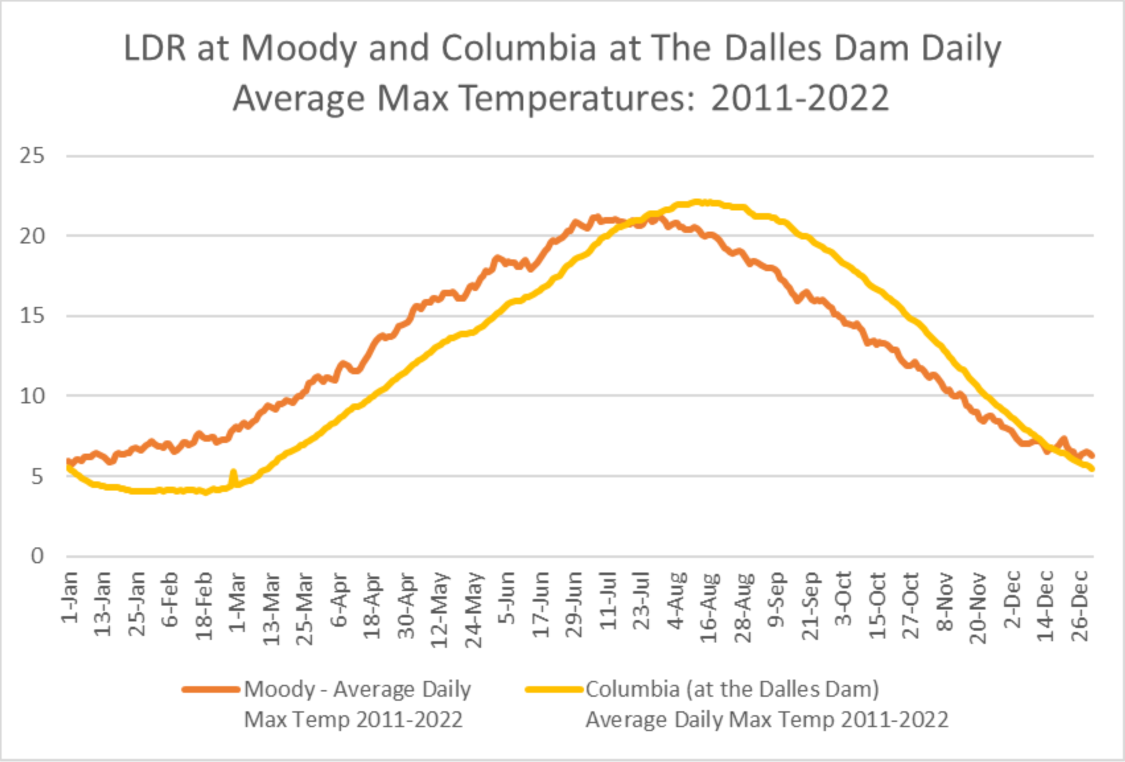


Figure 9. Average daily maximum water temperatures at the Moody gage in the Deschutes (USGS gage 14103000) and The Dalles Dam gage in the Columbia (14105700). 2011 – 2022.

Aquatic Insects

Saving cold water for fall release or more generally, changing the temperature regime due to SWW operation., may be changing the species composition and density of aquatic insects and other organisms that juvenile fall Chinook to feed on, negating any benefit to them from changing temperature in the first place to say nothing about affects to the broader collection of fishes.

Changes to aquatic insects in the Deschutes from SWW operations have been the subject of much study. While this topic is very important to assess the ecological effects of changing temperatures to the Deschutes, a detailed review is beyond the scope of this document. A brief summary of the issue is necessary to better understand the question of saving cold water to benefit fall Chinook, however.

The Water Quality Management and Monitoring Plan (WQMMP) incorporated into the Oregon Department of Environmental Quality (ODEQ) section Clean Water Act 401 certification is the portion of the Section 401 Water Quality Certificate required by the FERC license to operate the PRB complex. The WQMMP requires that studies of the macroinvertebrate and periphyton communities be conducted such that changes due to SWW operation can be determined. To that end, PGE commissioned both pre-SWW studies (Kvam et al, 2001 and Kvam et al, 2002 as cited in Nightengale, et al, 2016) and post-SWW studies by R2 Resource Consultants (Nightengale, et al, 2016, Nightengale and Shelly, 2017).

The conclusions of the post-SWW study by R2 Resource Consultants (Nightengale, et al 2016) were the subject of much discussion and additional analysis. ODEQ reviewed the study and in a May 23, 2016 letter to Megan Hill of PGE requested that PGE address what they believed were shortcomings in both sample analysis and data interpretations. The result of this request for additional review and reanalysis was a draft addendum addressing the concerns raised by ODEQ. While this report is available to the public on PGE's website it remains in draft form and has never been finalized. (assets.ctfassets.net/416ywc1laqmd/7pLjxWfvWdjKoZRqdgHt8S/aad4bf10c8b124f45e92cbcf665692c4/deschutes-macroinvertebrate-study-addendum.pdf).

DRA was also skeptical of the post-SWW findings of Nightengale, et al, 2016 and sought outside experts to review and reanalyze these data. DRA consulted with Dr. Patrick Edwards, a professor of Environmental Science at Portland State University, to reassess the data using what he believed to be more appropriate statistical methods. The DRA also consulted Dr. John Van Sickle to review the statistical methods used by Nightengale, et al, 2016. Dr. Edwards' report and Dr. Van Sickel's technical review are available on the DRA website at www.deschutesriveralliance.org/reports.

The analyses completed by Dr. Edwards confirmed that there have been significant changes in the aquatic invertebrate community post-SWW. These changes include significant shifts in species composition with a greater percentage of pollution tolerant species present post-SWW compared to more pollution sensitive species. Such changes are indicative of nutrient enrichment in aquatic ecosystems.

Quoting Dr. Edwards: "The results of my analysis indicate that the macroinvertebrate community below the Dams changed significantly after surface water withdrawal was implemented (samples collected 2013-2015) when compared to the macroinvertebrate community before surface water withdrawal operations began (samples collected 1999-2001). The macroinvertebrate community present after surface water withdrawal contained more non-insect taxa, such as worms and snails, and other taxa that are tolerant to poor stream conditions and less mayfly, stonefly and caddisfly taxa that are sensitive to poor stream conditions."

PGE's data are clear and there is no dispute that SWW operations have changed water temperatures in the Deschutes (Campbell, 2022). A seasonal change in temperature often acts as an environmental cue for emergence in aquatic insects, increasing the water temperature can result in earlier emergence while decreasing it delays emergence (Williams and Feltmate 1992 as cited in Nightengale, et al 2016). Early emergence of several species was noted by Nightengale, et al, (2016) during spring sampling, with observations of emerging giant salmon flies (*Pteronarcys californica*) in late April. According to Schollmeyer (1994 as cited in Nightengale, et al 2016), the hatch for this species on the lower Deschutes River takes place in May-June, suggesting that emergence is earlier than it was during the pre-SWW period. DRA (2020) noted that changes in seasonal water temperature and annual water quality have led to changes in the abundance, distribution, and emergence timing of aquatic insects in the lower Deschutes River.

Even a brief review of the subject of changes to the lower Deschutes aquatic insect community points out that changing the temperature regime for the claimed benefit of fall Chinook has far reaching and potentially negative consequences for aquatic insects and many other life forms.

The Deschutes as a Thermal Refuge

An additional but important negative consequence of saving cold water for fall release is that summer water temperatures in the lower Deschutes are now higher than pre-SWW operation. This may negatively impact the effectiveness of the lower Deschutes as a thermal refuge for anadromous fish migrating up the Columbia.

Warmer summer temperatures post-SWW make the Deschutes less attractive as a thermal refuge for upstream migrating salmonids, particularly sockeye salmon (*Oncorhynchus nerka*), that migrate past the Deschutes in June and July. The USGS gage near the mouth of the Deschutes (USGE Moody gage 141030000) started recording temperatures on July 29, 2011, several years post-SWW temperature modifications, so it is not possible to make direct pre- and post-SWW comparisons to fully parse out what effects SWW operation may have on temperature changes near the river's mouth.

Huntington, el al (1999) used the relatively limited temperature data available to him near the mouth of the Deschutes as well as results from the SNTEMP model (Theurer et al. 1984 as cited in Huntington, et al 1999) to plot observed temperatures and model potential changes at the same location. Comparing those post-PRB but pre-SWW temperatures with the same period for post-SWW years 2021-22 (Figure 10), it is apparent that Deschutes temperatures are now warmer during the summer months than pre-SWW and considerably warmer than modeled values (Figure 11). This appears to be especially true during the early and mid-summer period when the thermal refuge offered by colder Deschutes water may be important for sockeye on their migration up the Columbia.

Figure 10. Daily maximum and minimum water temperatures at the USGS Moody gage (14103000), July 1, 2021 to April 02, 2022. Red lines correspond to Huntington data periods below.

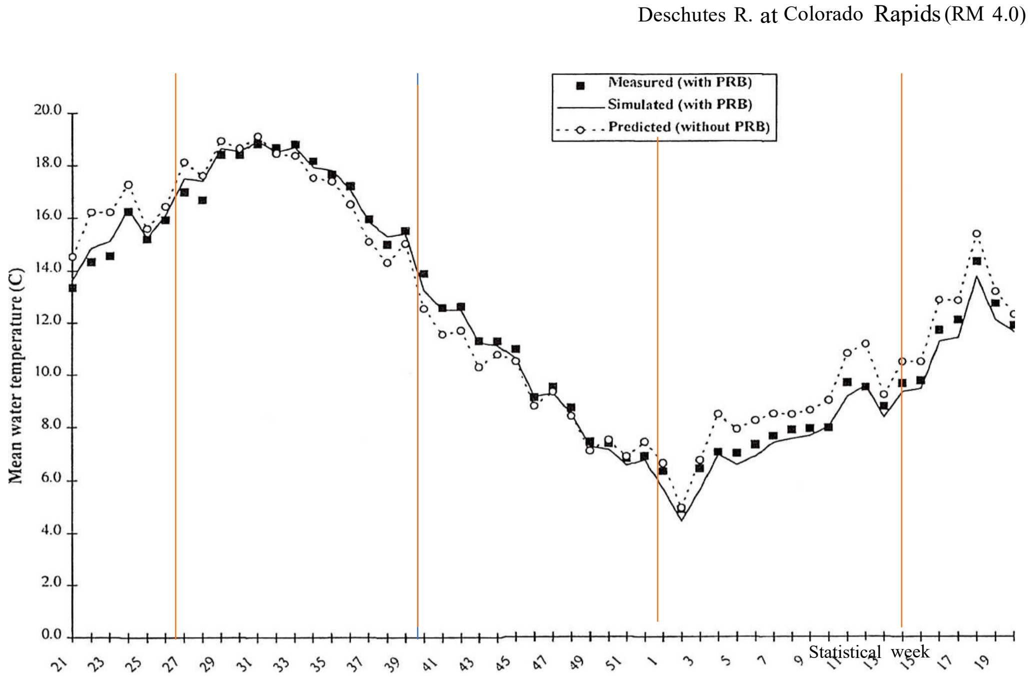


Figure 11. Measured and SNTEMP-simulated mean water temperatures for the Deschutes River at Colorado Rapids (RM4.0) for statistical week 21 in 1997 through statistical week 20 in 1998. Statistical weeks 27, 40, 01 and 14 begin on 02 July, 01 October, 01 January, and 02 April, respectively. (From Huntington, et al, 1999)

Keefer et al (2016) and others have documented extensive use of thermal refuges either in or near colder tributaries to the Columbia by adult salmonids. It is especially important to note that the Deschutes River is the only significant thermal refuge in the >250 km reach of the Columbia River from The Dalles Dam to Lower Monumental Dam. The recent recognition of the importance of these thermal refuges has resulted in actions by fish managers to regulate sport fishing in these areas to limit exposure of upstream migrating adults potentially congregated there to angling mortality. Concerns about the general importance of thermal refuges ultimately culminated in an effort by the US Environmental Protection Agency to adopt a Columbia River Cold Water Refuges Plan (EPA, 2021). Goals of this project are to identify the cold-water refuges currently available for use by migrating salmonids, assess the sufficiency of the refuges for current and future salmonid populations and to identify strategies to restore, enhance, and protect high quality refuges for the future (EPA, 2021).

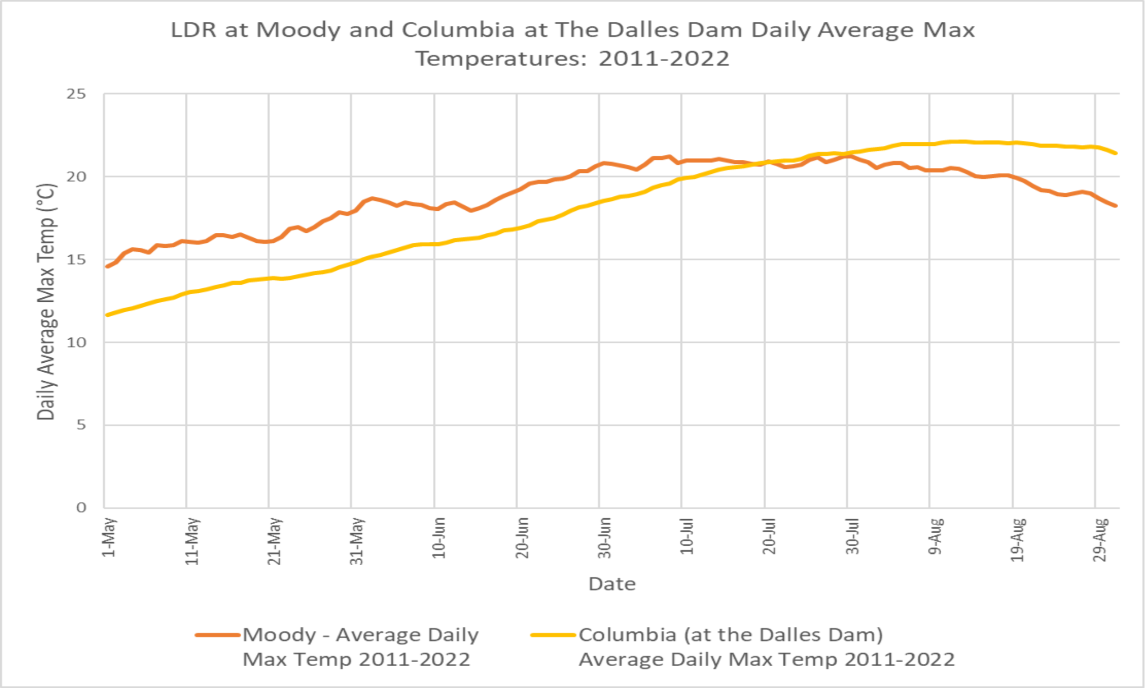


Figure 12. Average daily maximum water temperatures at the Moody gage in the Deschutes (USGS gage 14103000) and The Dalles Dam gage in the Columbia (14105700), May 1 to August 31, 2011 – 2022.

Figure 12 demonstrates that the Deschutes plume into the Columbia shows no substantial cooling of the Deschutes plume as measured at the Moody gage (USGW gage 14103000) at river mile 0.5 taking place until early August. Earlier and more substantial cooling could take place earlier in the summer months to benefit upstream migrating sockeye, summer Chinook and summer steelhead if more cold water was released from the SWW earlier in the summer.

The DRA aerial thermal imaging flight conducted on July, 26 2014 provides a graphic display of the differences between the temperature of the cooler Deschutes as it enters the warmer Columbia on that date. This is an example of the thermal conditions that should exist much longer during the summer months as called for by the EPA (see below discussion) (Figure 13).

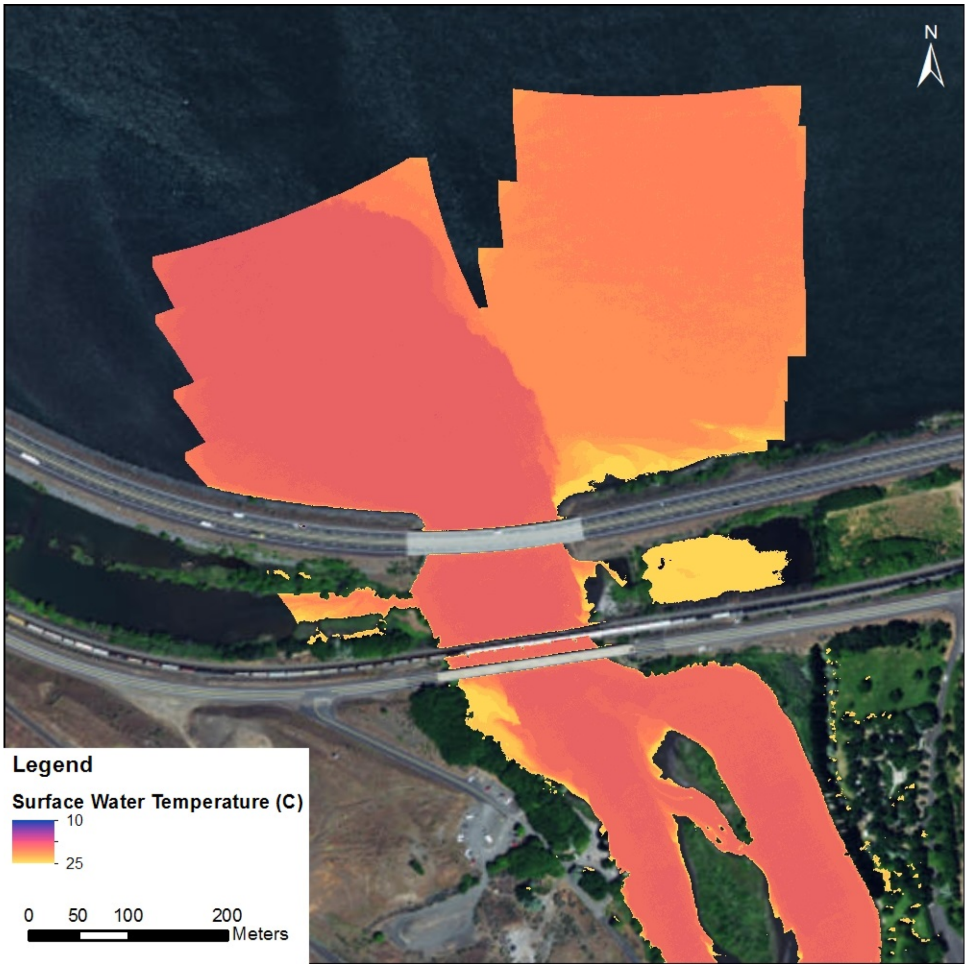


Figure 13. Mouth of the Deschutes River as it enters the Columbia River. Highway structures (lower to upper) are Highway 30, the Burlington Northern Santa Fe railroad trestle and Interstate-84. Color display shows ambient Columbia River temperature is warmer than the Deschutes River thermal plume.

Clearly, from the standpoint of maintaining the Deschutes as an effective and important thermal refuge, the available record suggests that PGE should be releasing more bottom water earlier in the summer and transitioning to full bottom draw earlier. The EPA Cold Water Refuge Plan (EPA, 2021) analysis suggests that some potential exists to consistently provide 60% of cooler water from early August through September to help cool the Deschutes cold water refuge over existing conditions. They further note the Deschutes River both above and below the Pelton Round Butte Project exceeds temperature water quality standards and is listed on the State of Oregon's 303(d) list of impaired waters.

EPA (2021) lists a specific action to protect and enhance the Deschutes cold water refuge:

"As part of the Pelton Round Butte Project water quality management and monitoring plan, consider the temperature effects of the selective water withdrawal operations on the Deschutes

River CWR. Specifically, consider maximum sub-surface cool water blend (60% percent) in August and September to help maintain temperatures below 18° C when CWR use is highest."

Saving cold water to allegedly benefit Deschutes fall Chinook is likely less a meaningful biological benefit as opposed to enhancing the thermal refuge benefits of the lower Deschutes earlier in and more fully throughout the entire summer period. The clear implication is that current SWW operations result in higher Deschutes water temperatures in the critical summer months which is ill advised as regards the value of the Columbia River cold water refuge values it provided pre SWW temperature management.

Benefit to Adults or Juveniles Fall Chinook

Faced with this lack of any clear, consistent, and unified rational by the relevant ODFW and CTWS to support PGE's claim that colder water temperatures in the fall somehow benefit fall Chinook, an extensive search of the scientific literature was done to identify possible reasons for this position.

Juvenile Life History Stages

In the early phases of the FERC relicensing process, PGE commissioned a study to describe changes in the temperature regime of the lower 100 miles of the Deschutes from PRB operation. This study, led by Charles Huntington of Clearwater BioStudies, Inc. culminated in the report "Water Temperatures in the Lower Deschutes River, Oregon" (Huntington et al, 1999). The intent of this study was to inform PGE on past temperature changes caused by PRB, how these changes may have affected fishes and how to ameliorate these changes during future operations. In the context of PGE's temperature management claims benefitting fall Chinook, Huntington et al (1999) makes some interesting and specific statements about how historic operation of PRB may have influenced egg incubation and alevin emergence timing of both fall Chinook and summer steelhead. Their analysis showed that the mean date for emergence for fall Chinook alevins from the gravel under historic PRB temperature management may have been later for redds very near the dam complex and slightly earlier near Moody (river mile 0). These changes were not statistically significant, however, and well within the range of natural variation at both sites (Huntington, et al 1999). No other analysis of potential temperature-induced changes in any aspect of adult fall Chinook or juvenile life history such as impacts to egg or alevin survival, changes in juvenile residence time, juvenile growth, adult pre spawning mortality, adult migration impacts or smolt migration timing were addressed.

Huntington et al (1999) findings related to PGE's claims about temperature management and supposed benefits to fall Chinook are very telling. That is, there has been no demonstrated harm to fall Chinook from historic PRB operation and PGE offers no amplification beyond that when claiming otherwise. Conversely, there is no benefit expected to accrue to any life stage of fall

Chinook from releasing cold water in the fall because no damage has been demonstrated from historic operation and there would be no benefit from changes. So, at least as far as making claims to support current temperature management to benefit fall Chinook, PGE is ignoring their own science and making claims about benefits to fall Chinook that appear wholly unsupported.

Egg Deposition and Incubation

Egg incubation is a biologically sensitive developmental period requiring accumulation of specific degree-days for proper hatching and emergence timing (Alderdice and Velsen 1978, Crisp 1981, Beacham and Murray 1990 all as cited by EPA, 1999). Too low a cumulative degree-day total, even if egg incubation occurs within the zone of providing high egg survival rates, would result in delayed fry emergence. Likewise, too high a cumulative degree-day total would result in early emergence, which could lead to fry having to cope with adverse flow conditions (Hartman et al 1984 as cited in EPA, 2001). Early or late emergence could lead to mortality from excessive flows, predation or insufficient food resources (Jensen and Johnsen 1999, Einum and Fleming 2000, both as cited in EPA, 2001).

Modeling suggests that the warming caused by dams likely imposes little direct thermal stress on embryos or fry. Nevertheless, the winter warming caused by dams could have indirect effects on survival, such as those believed to stem from early emergence (Braun, et al, 2013)

One potential negative consequence of saving cold water for fall release thus raising spring temperatures may be that of disrupting fall Chinook as well as summer steelhead and redband trout fry development. Water temperatures of 14° C were found to negatively impact initial development of salmonid fry (EPA, 2001). This temperature as a daily maximum has been reached or exceeded in the Deschutes River in all of May, June, and July most years of SWW operation (Figure 1), a period that initial fry development would likely still be occurring (EPA, 2001). Rainbow trout are known to have one of the shortest periods of time from fertilization to emergence (Quinn, 2005). This suggests that fall Chinook and redband trout emergence may overlap more now than under pre-SWW temperatures to the potential detriment to early emerging fall Chinook due to competition for resources.

Effects of changing temperature regime on other species and not just fall Chinook must be considered. For example, after the occurrence of ovulation in females and sperm maturation in males, the effects of elevated water temperatures on rainbow trout egg and sperm viability becomes a concern (Billard, 1985). Obviously, if PGE is reserving cold water for fall release, they are releasing warmer water than they otherwise would at some other time of year. Holding temperatures of 20° C (68° F) experienced a for 70 hours caused reduction in viability of eggs held in the body cavity, compared with females holding at 10° C (Billard and Breton 1978 as cited by Billard, 1985). This is another example of a poorly thought-out strategy for saving cold water for the fall release. Resident species in the river are subjected to the same temperature regime which may be harmful.

Eilers and Vache (2019) state that warmer spring temperatures support optimal emergence timing and growth conditions for fall Chinook and trout but offer no data or studies to support that statement.

They also make several references to the effects of temperature change on fish and specifically on fall Chinook. They note a potential result of their Night Blend model would be cooler tailrace water in the spring and early summer followed by warmer water in the late summer as cold water available for release is consumed. This is opposite the current temperature management scenario of warm, surface water in the spring and cooler water in the late summer and fall. They speculate that their Night Blend model would result in temperature changes that might have a critical effect on Deschutes fall Chinook. Oddly, they do not speculate on what that change might be or whether it would be beneficial or detrimental to fall Chinook. This study, voluminous as it is, does nothing to offer support for PGE's frequent statement that cold water needs to be saved in LBC for release in the fall to benefit fall Chinook.

At 5° C incubation temperatures, Chinook achieved a greater fry length than at other temps of 2°, 8°,11°,14° C. The smallest alevins were produced at 14° C (Murry and McPhail 1988, as cited in EPA, 1999), suggesting that careful modeling should be done to guide any temperature modification scheme intended to benefit any fish species.

The timing of water temperature modification can cause issues for egg/alevin development during the pre-spawning phase. Berman (1990) and Berman and Quinn (1990) determined that holding temps of 17.5° to 19° C caused females to produce smaller alevins than females held at 14° C. Higher adult holding temps also produced abnormalities during egg development stages.

Juvenile Growth, Smoltification and Migration

There are two possible water temperature scenarios to examine when considering the effect of changing water temperatures on juvenile salmonids: cooling the river or warming the river.

Cooling the River

PGE has insisted they need to preserve cold water at the bottom of the thermally stratified reservoir through the summer so that colder water is available for fall release for unspecified benefits to fall Chinook.

This is an interesting claim for benefiting fall Chinook juveniles if you examine the timing of downstream temperature change taking place from intentional temperature modification. Figure 14 shows the amount and direction of water temperature change immediately downstream from the dam complex under pre- and post-Tower releases. Of particular importance is the period when water temperatures are cooler under post-Tower temperature management (blue highlight). Based on observations of adult spawning, Jonasson and Lindsay (1988) note that adult fall Chinook spawning taking place from late September, peaks in November and is completed in December. Additionally, the magnitude of cooling from early October on is minor, approximating less than 0.5˚ C (Figure 14). This suggests that any cooling of water temperatures due to SWW operation is not timed correctly to coincide with the peak of spawning.

Further examination of Figure 14 shows that most incubating fall Chinook eggs are only marginally influenced by cooler water temperatures under present conditions. Quinn (2005) citing aggregated data from several studies, estimates 98 to 124 days from fertilization to hatching for Chinook salmon eggs at temperatures that would be encountered in the Deschutes. Given the timing of adult spawning and the length of egg incubation both cited above, very few incubating fall Chinook eggs are in the gravel when cooling takes place and no benefit would be provided them even if it were needed.

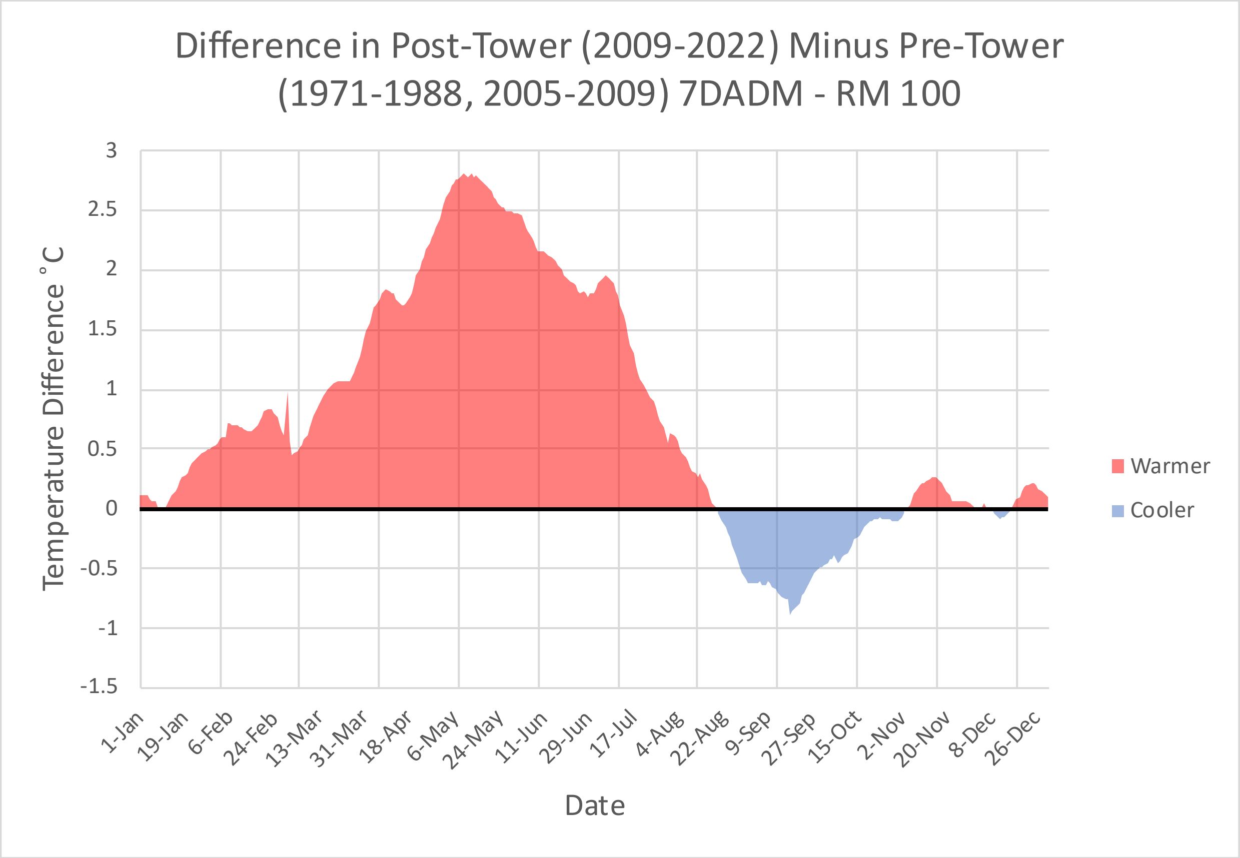


Figure 14. Graphed values depict difference between (1) the average 7DADM calculated from 13 years during Tower operations (2009-2021) and (2) the average 7DADM into the lower during four years before Tower operations (2006-2009) at RM 100). 2006-2009 temperature data source: PGE's annual Water Quality Monitoring Reports, post-Tower temperature data source: USGS (monitoring location 14092500). From DRA 2022 Water Quality Report.

Additionally, it is apparent from Figure 14 that both the duration and magnitude of cooling provided by SWW Tower manipulation is minor in comparison to the amount of warming that takes place the rest of the year. Cooling basically takes place during the months of September and October and the maximum cooling is less than 1°C. Since there are very, very few juvenile fall Chinook present during those months and few eggs in the gravel, it is difficult to quantify any benefit to fall Chinook juveniles from the post SWW temperature management strategy.

Figure 14 presents data from river mile 100 (Madras) and near the mouth (Moody). Unfortunately, there is no comparable pre-SWW temperature data set from the Moody site to compare pre vs post temperatures prior to that time or unmodified temperature prior to SWW manipulation.

Any cooling caused by temperature manipulation at RM 100 is ameliorated to some degree in more downstream locations (Figure 15). As pointed out above, these data also clearly show that increasing the amount of cold-water release through the SWW does, in fact, result in temperature decreases downstream to the river mouth.

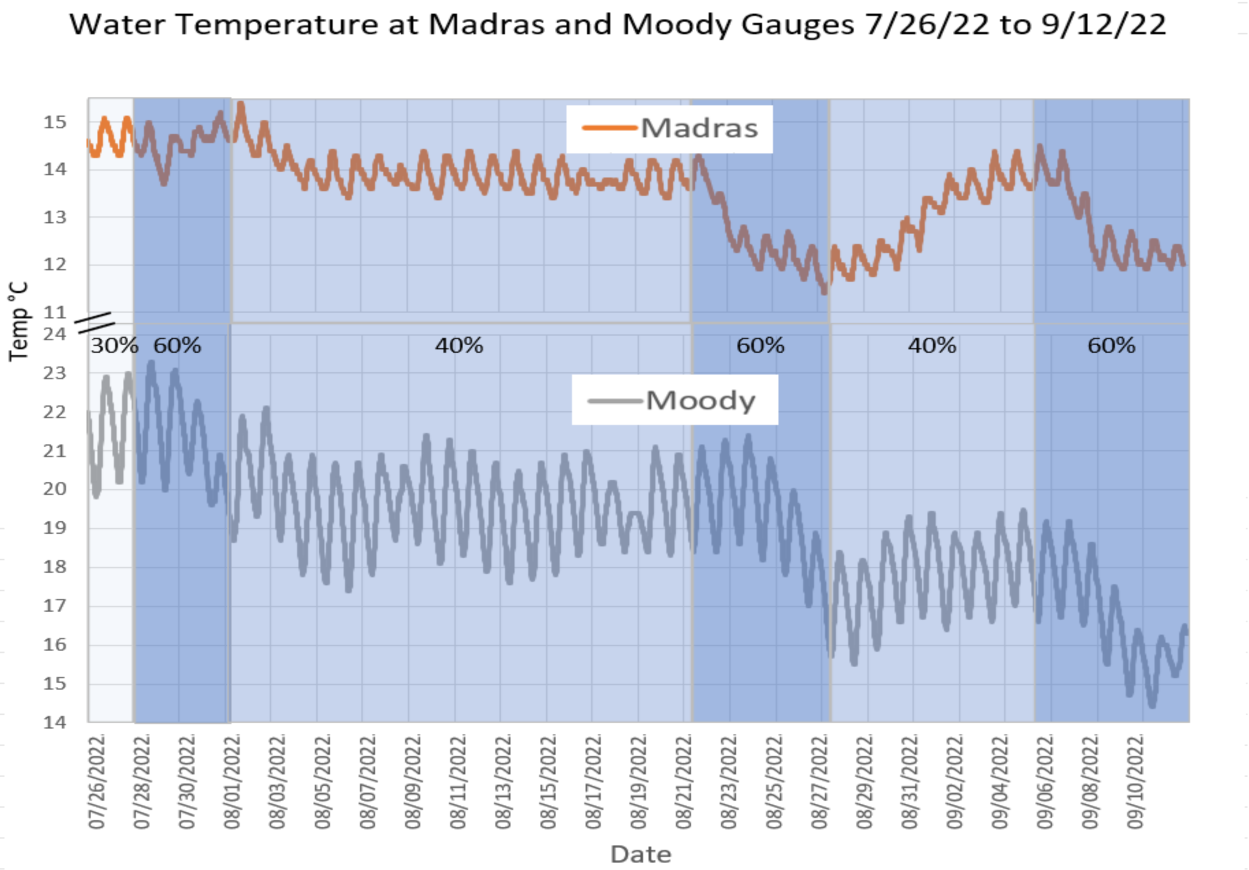


Figure 15. Deschutes River water temperatures measured near the mouth (river mile 0.5) and, immediately downstream from the PRB complex (River mile 100), 7-26-22 to 9-12-22. Blue overlays indicate the percentage of bottom release of cooler water with the percentage centered in each overlay bar.

Jensen (1990, as cited in EPA 1999) noted that a decreasing autumn temperature trend caused juvenile growth of multiple species to be less at a given temperature than at the same temperature under a generally increasing temperature trend in spring, suggesting that intentionally lowering fall temperatures beyond what would otherwise take place may not be beneficial for juvenile growth.

Laboratory experiments conducted by Beacham and Murry (1990 as cited in EPA, 1999) showed that not only was initial size strongly correlated with final juvenile size but also that the largest juveniles and the highest rates of survival occurred at intermediate temperatures. Further, they found that emergence timing, which is a critical life stage where juveniles switch from using their yolk for energy to feeding was strongly determined by temperature. Higher temperatures led to faster development and earlier emergence, as one would expect. This could have consequences for the success of individuals during this transition from yolk to feeding, countering assertions that warmer late winter/spring temperatures, not cooler fall temperatures, could be beneficial to fall Chinook.

Literature exists to support the thought that current temperature management may not be beneficial for incubating fall Chinook eggs. Murray and Beacham (1986) and Alderdice and Velsen (1987), both as cited in EPA, 1999, providing data showing best survival at between 7.2^{o} C and 9.6^{o} C. These temperatures are higher than those observed in the Deschutes during December, 2021 through March, 2022 (Figure 10) when fall Chinook eggs are incubating. Full surface spill is being released through the SWW during this time of year which may be the coldest water available. While it is somewhat difficult to parse out, it appears that LBC is at least weakly reverse-stratified during this time with warmer water at the lower levels of the reservoir (Figure 16). PGE could warm river temperatures in the winter to the potential benefit of incubating fall Chinook eggs by releasing water from the lower levels of the reservoir if that were a goal.

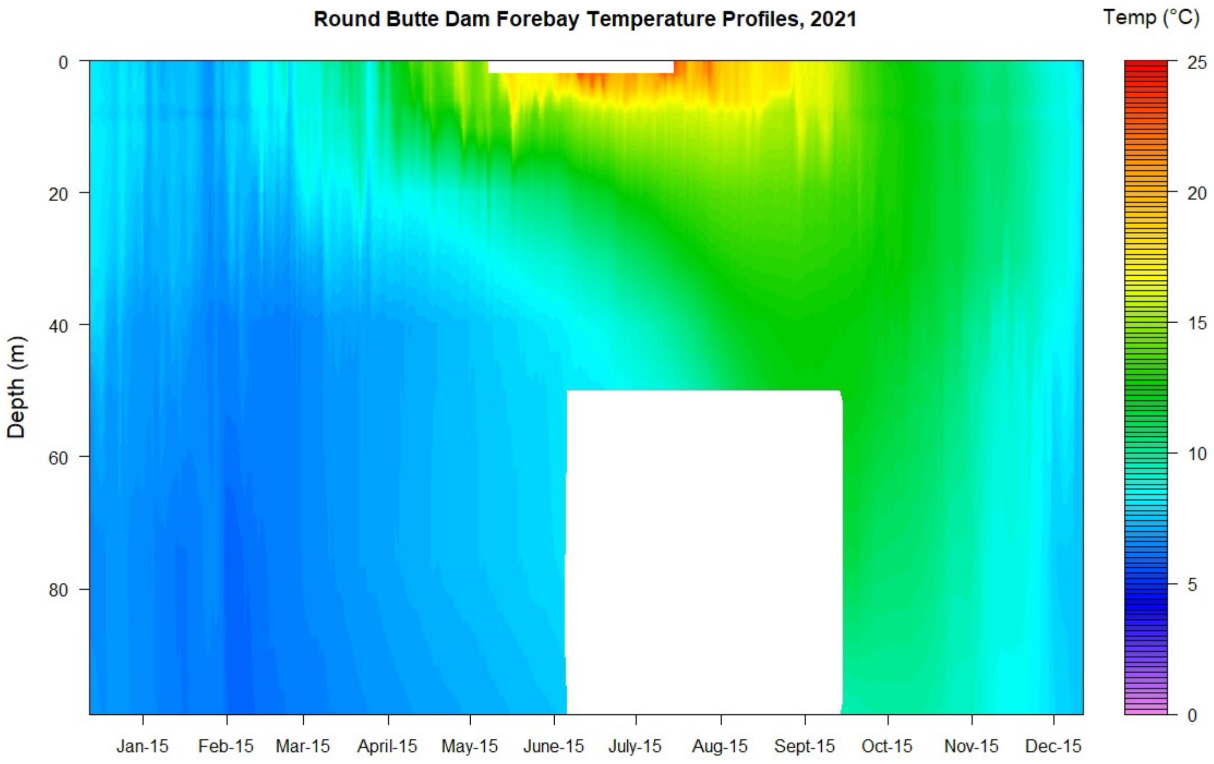


Figure 16. Temperature profile in the forebay of Lake Billy Chinook, 2021. Gaps in color represent periods of equipment malfunction. From Campbell, 2022. Blank area represents period of no data.

If PGE is trying to lower water temperatures in the fall to benefit fall Chinook, these observations on juvenile response to changing temperatures suggest that modeling (see Modeling section below) must be done to help identify what actual benefits may accrue to which fall Chinook life stage from temperature management. Based on a review of relevant literature, lowering river temperatures in fall has little actual benefit for juvenile fishes and potentially have negative consequences.

Warming the River

Whatever PGE's goal is for modifying water temperatures through SWW operation, they have succeeded in making the Deschutes warmer from early spring through mid-summer (figures 1 and 14).

The claim that cold water in the fall benefits returning adults specifically is considerably different than PGE and others claim that warm water in the winter and spring water benefits fall Chinook juveniles. In a July 21, 2021 interview with PGE fish biologist Megan Hill (https;//Portlandgeneral.com/about/rec-fish/deschutes-updates), PGE raises the issue of juvenile benefits from warmer water in the spring. Quoting here: "This approach ensures that spring temperatures are conducive [sic] to fall Chinook growth and helps us save cooler water for the fall when these fish return to spawn. Fall Chinook are hugely important to the ecosystem and runs in the Lower Deschutes…..” ODFW has made similar claims without the benefit of data. In a December 5, 2016 letter mentioned above, French expresses the view that juvenile fall Chinook benefit greatly from warmer spring temperatures.

This statement and the opinions of Hill, French, Ratliff, Bruneo and Houslett (declarations as cited above) that increased winter/spring temperatures may aid in growth and development of fall Chinook juveniles are fraught.

The Confederated Tribes of Warm Springs Reservation of Oregon Branch of Natural Resources has done considerable monitoring, evaluation and tagging (both coded wire tags and passive integrated transponders) of juvenile fall Chinook in the Deschutes. Data gathered during these studies should help answer questions relative to increased growth and growth rates of juvenile fall Chinook during post-SWW temperature manipulation although these studies have limitations that generally prevent any clear answer relative to benefits to fall Chinook juveniles from temperature manipulation.

From 2002 to 2009 (during pre-SWW temperature manipulation conditions), juvenile fall Chinook were collected between river kilometer 87-93 for coded wire tagging and these fish averaged 63.9mm fork length. Juvenile fall chinook collected in 2016 (post-SWW temperature manipulation) averaged 69.0mm fork length although the two sample sizes differed by two orders of magnitude making any statistical comparison between time periods not possible (Combs, et al, 2017).

Juvenile fall Chinook bio-interrogated during tagging in 2011 were smaller than expected with average fork length of 59mm in May and 61mm in June (CTWSRO, 2012). Fall Chinook juveniles sampled in the same general area during years 2002 to 2009 averaged 62mm fork length in May and 67mm fork length in June. It should be noted that in this case, average fork length of juvenile fall Chinook was larger under pre-SWW conditions than after post-SWW temperature manipulation although CTWSRO (2012) offer two possible explanations for this neither involving changes in water temperature. First, a faulty measuring board was used to collect at least part of the length data and which may have resulted in under measuring fish. Second, they speculate that later adult spawning during the 2010/2011 spawning season resulted in later emergence and smaller juveniles.

Short-term growth rates of juvenile fall Chinook recaptured after passive integrated transponder (PIT) tagging in 2012 was lower than in 2011, both years post-SWW temperature manipulation. Average growth rate of recaptured fish in 2012 was 0.37mm/day compared to 0.54 mm/day in 2012 (Baker and Jim, 2013). This inter-year variation in growth rates under post-SWW temperature conditions is somewhat confounding and did not match expectations of the workers. Baker and Jim (2013) opine that they would expect higher growth rates under warmer post-SWW conditions that are closer to the optimal stream temperatures for growth of juvenile Chinook of 14.9C (citing McCullough, 1999) which suggests no benefit for warmer stream temperature in the Deschutes.

Increased stream temperatures have been shown to result in decreased food availability and salmonid growth rates (EPA, 1999). Increasing stream temperatures do not necessarily lead to increases in abundance of drifting macroinvertebrates, the foods normally comprising the diet of salmonids. Increased temperatures can result in increased metabolic demand, increased competition for a limited food base, leading to displacement of rearing juveniles to habitats in which they are more exposed to warmer water tolerant predators or competitors.

Warmer water temperatures in the winter and spring may contribute to early emergence of fall Chinook juveniles. They may emerge at less than optimum size and could be subject to competitive disadvantage relative to other early emerging salmonids. For example, resident redband trout in the Deschutes are known to spawn earlier post-SWW (letter from ODFW Rod French to the Deschutes River Alliance, 02-27-2019), presumably as a result of warmer water temperatures in the winter. Rainbow trout are known to have one of the shortest periods of time from fertilization to emergence (Quinn, 2005), suggesting that fall Chinook and redband trout emergence may overlapping more now than pre-SWW operation to the potential detriment to early emerging fall Chinook.

Warmer temperatures during winter and spring may not be optimum for juvenile fall Chinook growth. EPA (2003) provided a single guidance temperature of 16° C as the 7-day average daily maximum temperature that should not be exceeded in areas designated as core rearing locations. Using their definition for fall Chinook core habitat, the entire lower 100 miles of the lower Deschutes would qualify. Using temperature from the Moody gage, the 16° C temperature limit was exceeded from late May through mid-September (Figure 10), the period fall Chinook juveniles are present in or migrating from the lower Deschutes (Combs et al, 2018). This suggests that more cold water should be released during this period to benefit fall Chinook juveniles rather than saving it for fall release.

Increased water temperatures in the spring as a result of saving cold water for fall release may have unintended consequences on feeding and growth for both rearing anadromous and resident salmonids. Linton, et al (1998, as cited in EPA, 2001) noted that a +3.6° F (2.0° C) increase in annual water temperature regime increased the feeding rate of rainbow trout in the winter and spring months, but significantly decreased feeding rate at peak summer temperatures of 68° F (20° C), leading to an overall decline in growth rate.

Beacham and Murray (1990), noted compensation in rate of embryo development at different stream temperatures. That is, more thermal units are required for completion of development from egg to fry emergency when incubation occurs at high temperatures compared to low temperatures. This mechanism moderates development rate at high temperatures and tends to stabilize time of emergence under annual temperature variations. Thus, differences in emergence timing may well not be solely controlled by spawn timing or temperature manipulation.

From application of laboratory studies on smoltification in relation to temperature, it appears that an accelerated temperature regime during springtime results in either earlier emigration or less successful smoltification. Spring water temperatures over 12° C inhibit smoltification due to decreasing gill ATPase activity (Zaugg and Wagner, 1973 as cited in EPA, 1999).

Anadromous salmonids at the time of smoltification experienced reduced ATPase levels at temperatures greater than 11°-13° C. Reduced ATPase levels may result in delayed or ineffective transition to the marine environment. Temperatures above 18° C may inhibit feeding in smolts and temperatures of 14-15° C may cause cessation of seaward migration (EPA, 2001).

Transformation from parr to smolt during fall Chinook seaward migration can be blocked by temperatures in the range 15-20° C. (Adams et al, 1973, as cited in EPA, 1999). Temperatures greater than 17-20° C place smolts under either lethal or loading stresses and can impair metabolic activity, reduce swimming performance or lead to death (Brett 1958, as cited in EPA, 1999).

Post-SWW spring temperatures may be warm enough to exceed the optimum range for fall Chinook juvenile smoltation. Deschutes fall Chinook juvenile emergence is largely completed in April through May and they leave the Deschutes River from May to July, depending on location in the river (Jonasson and Lindsay, 1988). Using water temperatures from 2019, PGE transitioned from 100% warm surface water withdrawal on May 16, 2019 to an 85%:15% ratio of surface water to colder bottom water in order to cool lower river temperatures, slightly later than previous years (Campbell, 2020). Water temperatures at that time routinely exceeded 15° C as a daily maximum at the Moody gage (Figure 17), suggesting that a higher percentage of bottom release to cool temperatures in the spring could benefit juvenile fall Chinook smoltation.

Figure 17. Deschutes River water temperatures at the Moody gage (USGS 14103000), January 1, 2019 to December 31, 2019.

Literature reviews suggest that current temperature management is generally achieving acceptable temperatures for egg fertilization through fry development in the 4° C to 12° C range (Carter, 2005) until about mid-March but temperatures after that period are generally greater than that range using 2019 Moody gage data as representative (Figure 10).

Finally, any discussion of temperature effects on juvenile fall Chinook egg and alevin development should be tempered with the knowledge that water column temperatures that are so heavily discussed here may not accurately describe reality. McCullough (1999) notes that intra-gravel water temperatures do not reflect the surface or water column temperatures perfectly. Intra-gravel water temperatures are somewhat challenging to collect over longer time periods but are certainly more meaningful in the discussion of temperature-driven egg and alevin development. We therefore lack a significant set of data to accurately frame this discussion and what we think is happening may not be reality. Further, water temperatures are known to show spatial variation within a stream reach so widely spaced temperature measurements may not perfectly represent water column temperatures in the stream in total let alone intra-gravel water temperatures. The DRA airborne thermal imaging flight of the lower Deschutes is a pertinent example of stream reach temperature variation (McMillan, et al, 2016).

Benefits to Adult Fall Chinook

Egg to smolt or smolt to adult survival data would be the gold standard to measure fall Chinook response to SWW operation in the Deschutes. If these data were available for a significant time period, they would inform us more completely on potential effects of saving cold water in the fall, allegedly to benefit fall Chinook. However, these data are not widely available. Studies by the CTWS using juveniles fall Chinook PIT tagged in the Deschutes yielded a smolt to adult survival rate of 0.7% for the 2011 brood year, the only brood year this data is available for (Combs, et al, 2018). This estimated smolt to adult survival rate is low compared to Northwest Power Coordinating Council's consistently stated goal of 2% to 6% and the greater than 2% smolt to adult survival figure values cited in the 2020 Columbia River System Operational Environmental Impact System Record of Decision (2020) and by Marmorek et al (1998). While the available Deschutes data are limited to a single data point, SWW-driven temperature modifications do not appear beneficial to smolt to adult survival in the Deschutes.

Combs, et al (2018) describe juvenile survival rates of PIT-tagged juvenile fall Chinook to several measuring points and these do offer potential clues for the low smolt to adult survival rate. They estimated a 57% mortality of PIT-tagged juveniles from tagging at various locations to the mouth of the Deschutes. Additionally, they estimated a mortality rate of 79% after release at Dry Creek (river mile 94) in the Deschutes downstream to Bonneville Dam. They note that these survival rates are lower than expected and offer various environmental or biological factors that include lower water velocities and warmer water temperatures in the Columbia as well as avian and piscivorous fish predation (see invasive non-native predator discussion above).

PGE's Claim of Increases in Adult Numbers Post SWW

Representatives of ODFW and PGE point to some yearly increases in adult fall Chinook returns and claim those increases are the result of SWW-induced temperature manipulations. No explanations or evidence is offered to inform this claim, however. Without applicable data, contentions that warmer water in the spring— as ODFW claims—or colder water in the fall—as PGE claims—are conjectural at best.

A closer look at fall Chinook life history, age class structure and adult returns is needed to better examine claims that cold water releases in the fall benefit adult fall Chinook.

Deschutes fall Chinook juveniles, typical of many other fall Chinook stocks, have a short freshwater residency period. Approximately 96% or all fall Chinook returning as adults migrated to the ocean as age 0 smolts (Jonasson and Lindsay, 1988).

Adults, however, return to freshwater from the ocean each run year at different ages and periods of ocean residency. In this way, any negative effect on one brood year's juvenile survival is dampened in successive return years since multiple brood years (age classes) are already in the ocean and will return to freshwater to spawn in different years. For example, Deschutes fall Chinook return after one year in the ocean (age 2 jacks) and adults after 2 to 5 years in the ocean (age 3 through age 6), thus spreading the risk of unfavorable survival conditions through multiple brood years.

Salmonids age can by examining their scales which exhibit a tree-ring like pattern that is formed due to variations in the fish's growth from summer to winter. Fall Chinook age data derived from reading scales is commonly displayed using two numbers in a super script, subscript fashion. The super script number represents the total age of the individual in years and the subscript number describes the number of years the individual spent rearing in freshwater. This is the widely used Gilbert-Rich method of denoting Chinook age. (Steelhead age, because of their more variable freshwater age and generally shorter ocean residency is displayed by a different notation system called the European system.) An example of the Gilbert-Rich age notation for a returning adult that was 4 years total age and had spent 1 year in freshwater and 3 years in the ocean would be 4_1. For Deschutes fall Chinook, the 1 year in freshwater is somewhat misleading since 96% of the juveniles that migrate to the ocean do so at less than a full year of age, having spent only about 6 months in freshwater. This is, however, the common reporting convention for fall Chinook age classification.

Deschutes fall Chinook, typical of Chinook stocks, exhibit what is called a jack life history pattern. Jack is a term used to describe an individual, nearly always a male, that returns from the ocean to its natal stream after spending a single year in the ocean. A jack fall Chinook jack age notation in the Gilbert-Rich system would be age 2_1. Jonasson and Lindsay (1988) found that using a length-based criteria of 54 centimeters folk length to differentiate between jacks and adults is adequate because only 2% of age 2_1 fish are greater than 54 centimeters and 15% of age 3_1 fish are less than 54 centimeters. Jacks are sexually mature and fully functional and contribute to successful fertilization of females.

With that as background, Jonasson and Lindsay (1988) present a table of percent-age composition of Deschutes River fall Chinook salmon by brood year and is illustrative of age at return (Table 3)

Table 3. Percent age composition of Deschutes River fall Chinook salmon that returned to the mouth of the Columbia River, 1975-80 broods (from Jonasson and Lindsay, 1988).

Brood Year	% return Age 2_1	% return Age 3_1	% return Age 3_2	% return Age 4_1	% return Age 4_2	% return Age 5_1	% return Age 5_2	% return Age 6_1
1975	29.0	28.4	1.4	34.4	3.0	0.0	0.0	0.1
1976	37.8	28.2	2.0	26.8	0.6	0.8	0.8	0.0
1977	39.7	27.3	0.4	26.7	1.1	0.6	0.6	0.0
1978	24.2	27.2	2.2	39.5	0.7	1.8	1.8	0.1
1979	28.7	42.7	0.4	22.0	2.9	0.7	0.7	<0.1
1980	44.4	19.8	1.3	27.7	1.4	1.5	1.5	0.2
Mean	34.0	28.9	1.3	29.5	1.6	0.9	0.9	0.1

We can see from these data that for a brood year, there are eight possible age-at-return scenarios during any given run year: one jack age at return (2_1) and seven adult ages (3_1,3_2 4_1,4_2, 5_1, 5_2 and 6_1). These age classes return in successive years so the age 2_1 jacks of the 1975 brood year in the above table would have been migrated from the Deschutes in the spring of 1976, to the ocean in the summer/fall of 1976 would have returned in fall, 1977. Jacks, by definition, from any given brood year all return the same run year. Similarly, the 3_1 adults from the 1975 brood year would return in 1978, 3_2 adults would return in 1979, the 4_1 adults in 1979, 4_2 adults in 1980 and so on. From this example we can see that the return of **adult** fall Chinook to the Deschutes in any given **run year** is comprised of fish from multiple **brood years** of different ages (total age 3 through total age 6).

With that as background, let us examine Don Ratliff's statement (declaration of Don Ratliff as cited above) that there were "huge increases" in the numbers of fall Chinook entering the Pelton Fish Trap starting in 2010. He speculates these increases were the result of warmer water in the spring from SWW operation. Ratliff presents a figure to support his contention, reproduced below (Figure 18).

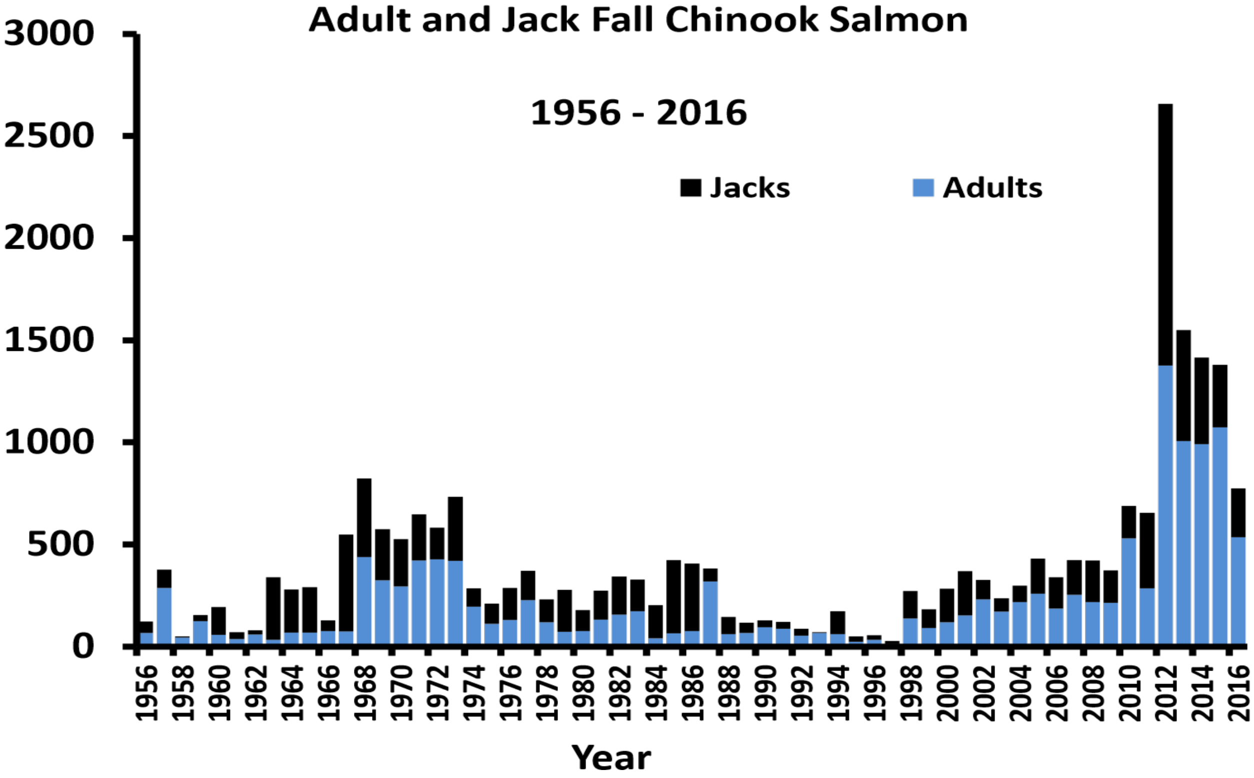


Figure 18. Adult and jack fall Chinook captured at the Pelton Trap (river mile 100), by year. (From the Declaration of Don Ratliff as cited above).

Ratliff's claim of increased fall Chinook numbers as a result of SWW operation is problematic in several ways. First, his inclusion of jack returns confounds the data and biases the viewer. Jacks commonly have a higher smolt to return survival than subsequent adult returns from the same brood year since they are not subject to the continuing mortality factors in the ocean as their longer-lived cohorts are. Adding jacks to adult returns then biases the data high. To eliminate this bias and simplify the discussion, jack fall Chinook will not be considered in the rest of this analysis. Second, Ratliff's statements and figure are based on fall Chinook returns to the Pelton Fish Trap at river mile 100 and not on estimated adult run to the mouth of the Deschutes. In-subbasin harvest and a host of other in-subbasin mortality factors can be variable thus affecting Pelton Trap capture unevenly from year to year. Estimated adult run to the mouth of the Deschutes is a much more accurate measure of fall Chinook trends in the Deschutes. This statistic is generated each year by ODFW to guide subbasin management and is exactly that: an estimate of the number of adult fall Chinook that returned in any given run year (all adult age classes combined) to the mouth of the river. Estimated run to the river is a more accurate measure of true abundance although the methodology used to calculate run to the river does have sources of error (Combs, et al 2018).

The jack component of the 2012 run year that Ratliff cites as the start of the "huge increase", returned at age2_1 and are from the 2010 brood year and did show an increase from previous years. These returning jacks were indeed all influenced in their freshwater life history by post-SWW conditions in 2011. Jack returns in successive run years were also influenced by post SWW operation and stayed relatively high in 2013 through 2016. Whether some post-SWW influence is responsible for the increase in jack numbers in uncertain.

What is certain is that adult returns during the 2012 return year (age 3 and older) were not even in the Deschutes River during any part of their freshwater life history that was influenced by post SWW water conditions! (Remember that a return year is made up of multiple brood years.) Therefore, any suggestion that increases in adult returns in 2012 are the result of SWW operation is not correct.

All adults returning that year were not influenced by SWW conditions as juveniles. Other factors either in the Deschutes subbasin or outside of the Deschutes subbasin are responsible for the increase in adult returns that run year and not any post-SWW influence.

Similarly using age at return data shown in Table 3 (Jonasson and Lindsay, 1988) , of adult fall Chinook returning in run year 2013, only 44% of the total adult during return year were age 3_1 and would have spent their freshwater residency in the Deschutes under post SWW conditions. Therefore, just less than half of any increase in during the 2013 return year could be attributed to post-SWW influence.

Adult fall Chinook returns in 2014 follow a similar scenario but that return year contains age 3_1 (44% of the adult returns on any given return year) as well as age 3_2, (2% of any given return year) and 4_1 adults (59.7% of returns on any given return year) that were in the Deschutes in post-SWW conditions. Therefore, summing these return percentages, about 90% of adults during return year 2014 were in the Deschutes in post-SWW conditions as juveniles.

During return year 2015, adult returns that would have spent their freshwater life history in the Deschutes under post-SWW conditions would span ages 3 through 5 and make up approximately 98% of all ages at return. Age 6_1 fall Chinook during the 2016 run year would be the last age at return that did not spend their freshwater life history in the Deschutes under post-SWW operation, comprising 1.0% of the total return that year (Table 3). Thus, all adult fall Chinook returning to the Deschutes in 2017 and in all subsequent years would have all been influenced in the Deschutes by post-SWW operation and no adjustment to that or subsequent return years is needed.

The analysis presented here considers how adult fall Chinook returning to the Deschutes may have been impacted by SWW operations during their freshwater residence, not the total returns during those years. Adjustments to adult return data are necessary to more accurately estimate how post-SWW conditions influenced subsequent adult returns. These adjusted data are used throughout this analysis. Specifically, adult returns have been adjusted to reflect the fact that only 44% of the adult returns in 2013 were influenced by SWW operation, 90% of adult returns in 2014 and 98% of returns in 2015 and 99% of the adult returns in 2016 and all years after were influenced as juveniles by SWW operations. Appendix A displays the adjusted data used in the following adult return analysis.

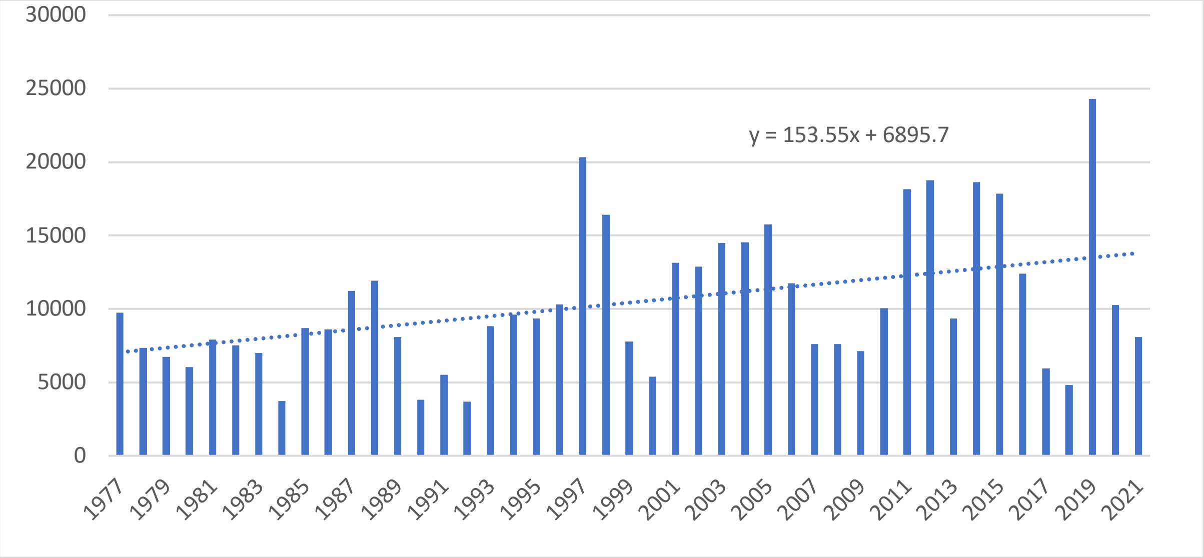


Figure 19. Estimated adult fall Chinook run to the Deschutes, 1977 to 2021, from ODFW data.

It is important to remember the period when juveniles in the river could have been influenced by SWW operation. This gives the correct context when considering changes in adult fall Chinook returns and what effects SWW operation may have on their numbers. Adult returns as measured by estimated run to the river were indeed large in 2012, 2013 and 2014 but, as demonstrated above, not all these increases can be attributed to SWW effects to juveniles. Remember as detailed above, that it was not until the 2017 return year that adult returns age 3 through age 6 were all influenced as juveniles by post-SWW operation. Starting in 2015 and continuing through 2018, run to the river of adults started to decrease rapidly to some of the lowest returns during the period of record (Figure 19). This decrease is pronounced, suggesting that if there is some post-SWW mechanism that potentially benefits fall Chinook in the Deschutes (whether it is cold water in the fall or warmer water in the winter and spring) it is not consistent or persistent through time. If that were the case, fall Chinook returns would have remained high through time, which they did not. Note the very large number of estimated adult fall Chinook in 2019 which was a high for the period of record (Figure 19). This was not the case for fall Chinook counts at Bonneville Dam but as will be discussed below, these two counts do not appear well correlated.

Conversely, fall Chinook adult return numbers decreased starting in return year 2017 (apart from the increase in 2019) and declined again in 2021 and 2022 (Figure 19). If there was some mortality factor driven by post-SWW operation – like increased exposure to *Ceratonova shasta* due to huge increases in the host organism for *C. shasta*, the freshwater polychaetae *Manayunkia speciosa* – then 2017 would be the first return year that that mortality factor or any other SWW driven mortality factor would affect all ages of adult return. Note that adult numbers declined considerably until 2019 and continued after that, strongly suggesting that SWW operation conveys no lasting and durable benefit on Deschutes fall Chinook. Rather, it would seem prudent for resource managers to examine water quality changes carefully and diligently in the Deschutes caused by SWW operation for potential **negative** impacts to the freshwater survival of both juvenile and adult fall Chinook.

While the adult return data pre-SWW are presented in Figure 20 suggests that there was a period of increase in estimated adult fall Chinook returns, are these "increases" statistically significant, that is, are these apparent increases real when compared to the following, post -WW years. Comparing the adjusted return data for post SWW years 2013 through 2021 (Figure 21), to the previous 36 years returns (pre-SWW) (Figure 20) indicates that there is no significant difference in estimated adult fall Chinook returns between the pre and post SWW years (p=0.17, 2 tailed t-Test, alpha .05, t=-1.39). Thus, claims that SWW operation, whether from cold water in the fall or warm water in the spring, has significantly changed adult fall Chinook returns in the Deschutes are not statistically valid.

Similarly, examining the trend lines overlayed on the estimated adult fall Chinook run to the run to the river data for years pre-SWW and post-SWW, an interesting dichotomy is apparent.

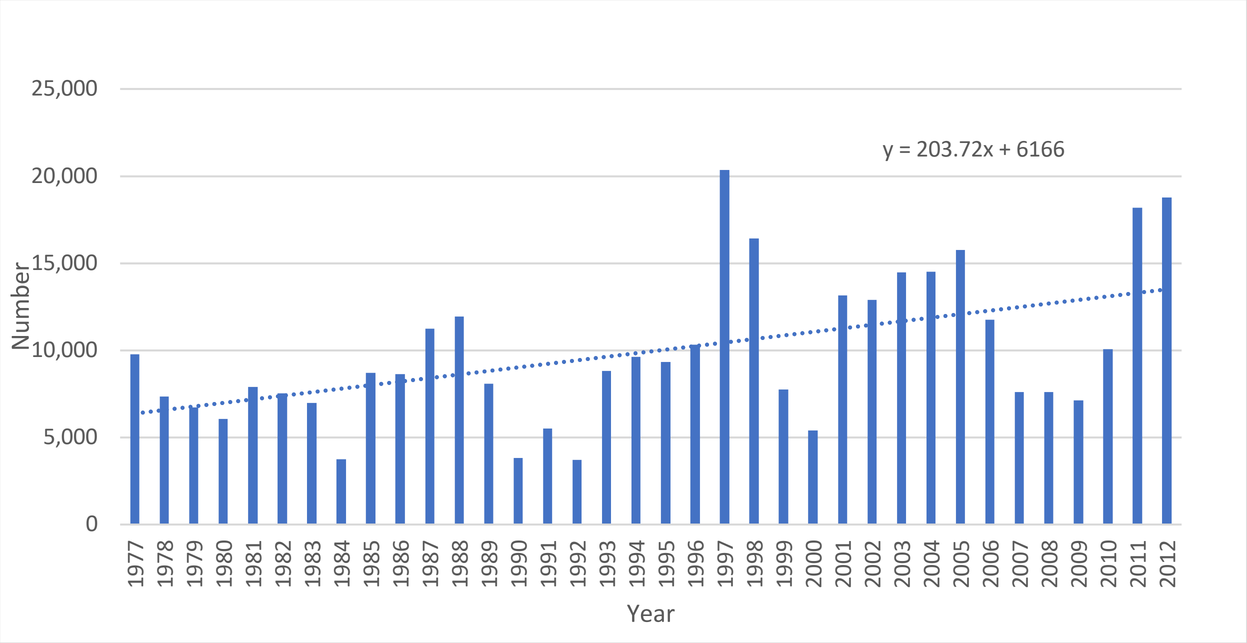


Figure 20. Estimated adult fall Chinook return to the mouth of the Deschutes pre-SWW, 1977 to 2012. ODFW data.

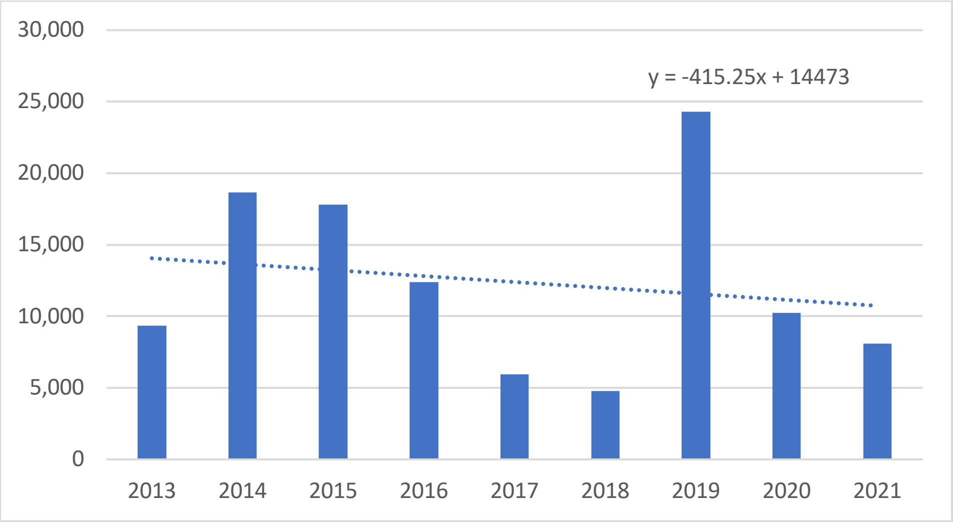


Figure 21. Estimated adult River fall Chinook return to the mouth of the Deschutes post SWW, 2013 to 2021. OFW data.

The trend line for the pre-SWW years 1977 through 2012 (Figure 20) describes a clear, pronounced upward trend. This shows that while adult fall Chinook returns fluctuated around a mean value, the slope of the trend line through time is clearly positive and the population, while showing yearly variation, was on an increasing trend. This suggests that conditions in the Deschutes were positive overall for fall Chinook and the population responded favorably through a long time period.

When a trend line is overlayed on the estimated fall Chinook returns for the post-SWW years 2013 through 2021 (remember that adult return prior to 2013 did not rear as juveniles in the Deschutes under post-SWW conditions), a different result is obtained (Figure 21). The slope of the line is negative, suggesting that the overall numeric trend of the population is decreasing through time. This suggests that conditions for fall Chinook numbers in the Deschutes may be much less favorable for positive population response relative to the pre-SWW period. At the very least, these results clearly show that water temperature manipulation ie, saving cold water for fall release to convey some benefit to fall Chinook, is not effective at increasing the adult population through time.

Is should be noted, however, that there is no statistically significant difference between the slope of the two trend lines (p=0.921, alpha 0.05) or the means of the two data sets (2-tailed t test, t=-1.38, p=.17) likely owing to the small sample size of post-SWW years and relatively large variances in both data sets (coefficient of variation 42.0% pre-SWW and 50.0% post-SWW).

A second way of examining whether adult fall Chinook returns to the Deschutes either have been positively influenced by post-SWW conditions is to compare Deschutes returns to counts at

Bonneville Dam. That is, do Deschutes fall Chinook returns correlate well with Bonneville counts and if so, has that relationship changed pre to post-SWW.

Adult salmonid counts in the Columbia River commonly are cited to Bonneville Dam primarily because it is the first dam of the mainstem dams where such counts are possible. There are a variety of factors influencing counts at subsequent upstream dams that make count data at Bonneville most useful. A host of difficult to measure inter-dam mortality factors including, estimating legal and illegal harvest, numerous natural mortality factors, tributary turnoff, and counting accuracy at subsequent dams all contribute to difficulties with accounting after Bonneville Dam.

Regression analysis of Deschutes and Bonneville adult fall Chinook counts during the pre-SWW period (1977 through 2012) show an R_2=0.35, suggesting only a slightly meaningful predictive relationship between the two (Figure 22). Similarly, regression analysis of post-SWW years (2013 through 2019) show an even lower R_2= 0.10 (Figure 23) also suggesting no meaningful relationship or predictive value, although this sample size is small and with considerable variation in the data. Recall that post SWW data are adjusted for age at return for years 2013 to 2016 as shown in Appendix A.

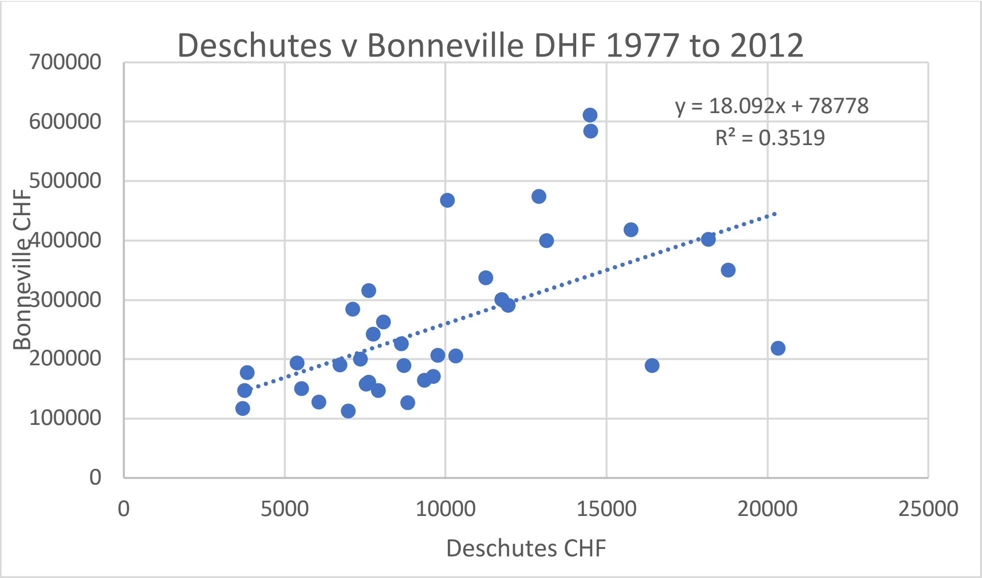


Figure 22. Regression of estimated run to the river of Deschutes fall Chinook and Bonneville Dam fall Chinook counts, 1977 to 2012. ODFW and Fish Passage Center data.

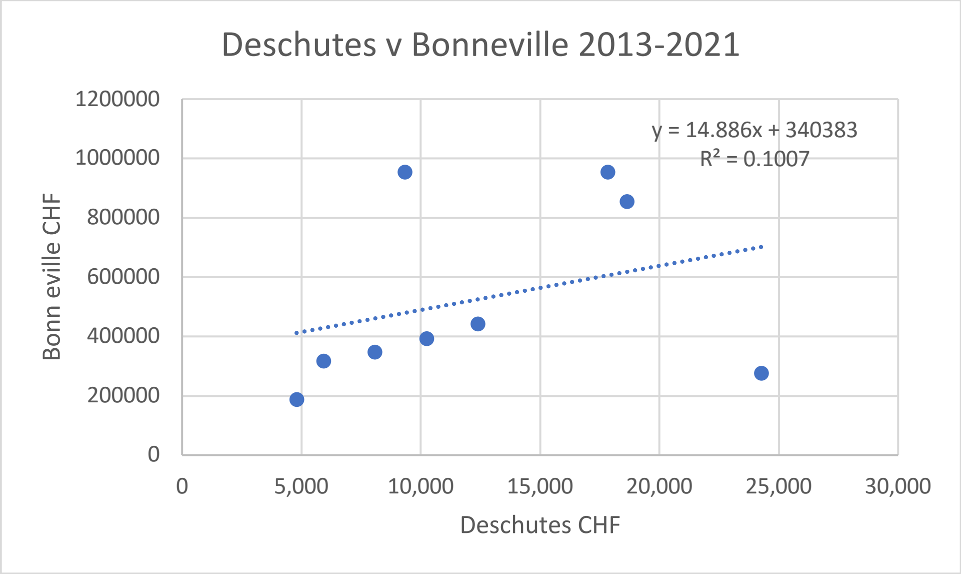


Figure 23. Regression of estimated run to the river of Deschutes fall Chinook and Bonneville Dam fall Chinook counts, 2013 to 2021. ODFW and Fish Passage Center data.

These weak relationships are somewhat unexpected but what do they mean?

First, adult fall Chinook counts at Bonneville Dam are of little value for predicting pre-SWW Deschutes runs and of even less value in post-SWW years with only 35% and 10% of the variation in Deschutes runs being explained by Bonneville counts.

Second, if there was a close statistical relationship between Bonneville counts and adult returns to the Deschutes, it would suggest that Deschutes fall Chinook are affected by the same mortality factors in freshwater and the ocean that all other Columbia basin stocks face. Examples of these mortality factors would include juvenile migration conditions in the Columbia, ocean survival and a host of in-Columbia returning adult mortality factors.

The consistent nature of these poor relationships suggest that whatever is driving the lack of correlation is real and persistent given the relatively large pre-SWW sample size. It is, however, hard to visualize a mortality factor in the ocean environment that effects only the Deschutes population differentially relative to all other above-Bonneville fall Chinook stocks. It is equally difficult to believe that Deschutes returns are subject to stock-specific mortality on their upstream migration, given common migration timing and shared mortality factors acting on all in-Columbia stocks. This lack of correlation in the two Deschutes groups is especially puzzling because of the short freshwater residence time for fall Chinook juveniles and adults and the brief period differential mortality factors could affect Deschutes fall Chinook.

Third, and somewhat conversely, the lack of relationship suggest that Deschutes River fall Chinook are subjected to mortality factors somewhere in their life history that are not shared by other stocks passing Bonneville Dam. Otherwise, one would expect the two groups to exhibit a more statistically-relevant relationship. It is difficult to speculate on what these mortality factors may be, however, although post-SWW temperature manipulation after 2009 is one change that can be identified for the post SWW return years.

Fourth, the Deschutes data presented here are estimated run to the river not Pelton Fish Trap count data so in-Deschutes mortality (harvest or otherwise) is not a confounding factor. This makes the comparison of Bonneville and Deschutes data more of an apples-to-apples comparisons than using Pelton Trap data.

Finally, and importantly for this discussion, both pre and post SWW regressions show low correlations. While the post-SWW regression is lower (as evidenced by R^2 value), although that analysis suffers from a small sample size, the low correlation strongly suggests there is no strong post-SWW benefits overriding long-standing mortality factors affecting Deschutes fall Chinook and may be contributing to a declining trend in the returning adults.

In summary, there are apparently mortality factors specific to Deschutes fall Chinook not shared by other above Bonneville stocks and these have not been ameliorated but are potentially magnified by post-SWW water temperature manipulation.

Effects of Temperature Manipulation on Adult Fall Chinook

Most salmonids have evolved with the temperature regime they historically used for migration and spawning, and deviations from that normal temperature pattern can affect survival (Spence, et al. 1996). Thus, it may be necessary or wise to alter fall temperatures from historic values to benefit Deschutes adult fall Chinook.

It is doubtful that Deschutes fall Chinook have altered their spawn timing post-PRB such that PGE needs to cool the river in the fall for their benefit. Deschutes fall Chinook are thought to spawn river-wide from late September through December as evidenced by recovery of spawned out carcasses (Johnasson and Lindasy, 1988). Recall that Huntington, et al (1999) found no changes to fall Chinook egg emergence from PRB temperature changes. Modeling done by Angilletta, et al (2008) suggest that the mean spawning date for Chinook salmon after a temperature change would approach the new optimum within 20 generation or about 85 years, not much longer than the 66 years since Pelton Dam was constructed in 1954. The question this raises is why would PGE think it necessary to change spawning time for fall Chinook by releasing cold water in the fall since they may be well on their way to adapting to the temperature regime in place pre-SWW and there was no demonstrated change in the first place?

Adult salmon and trout respond to temperatures during their upstream migration (Bjorn and Reiser, 1991 as cited in EPA, 2001). Delays in migration have been observed in response to water temperatures that were either colder or warmer than the fish’s extreme preference. A 7-day average daily maximum temperature of 20^{o} C is recommended for migration during an unspecified summer period. This criterion is believed to prevent migration blockages due to high temperatures. The Deschutes at the Moody gage in 2019, for example (Figure 15) exceeded daily maximums of 20° C during July and August but not after that time despite little temperature modification through SWW spill. For example, spill ratios were 50:50 in late August, 2019 (Campbell, 2020). Fall Chinook adults, while possessed of a protracted time of entry into the Deschutes, generally enter the Deschutes after early September based on Sherars Falls trap capture (Jonasson and Lindsay,1988) and would not be subject to temperature blockage conditions in the Deschutes thus rendering any SWW temperature modification unnecessary (2-2-23 email from ODFW District Fish Biologist Jason Seals to DRA).

Further, adult fall Chinook mortality due to high water temperatures has never been documented in the Deschutes River ((2-2-23 email from ODFW District Fish Biologist Jason Seals to DRA). Grove et al. (2007) reviewed pertinent literature on pre-spawn mortality on fall Chinook based on holding spring or summer Chinook adults in a hatchery setting. This literature review showed no adverse effects from holding adult spring Chinook for 15 days or longer at temperatures near 19C. Huntington, et al (1999) did not document either measured or modeled temperatures in this range or duration suggesting that holding, pre-spawn adult fall Chinook were not adversely affected by high temperatures pre-SWW (Figure 11). Thus, lowering temperatures in the fall to prevent pre-spawning mortality in the Deschutes is not necessary.

Strange (2010) noted that upstream migration of adult fall Chinook in the Klamath River basin was inhibited at temperatures from 21.8°C to 24.0°C (mean = 22.9°C). He further defined the upper thermal limits for migration as maximum daily average of 23° C or a weekly maximum average of 22°C. Huntington, et al (1999) showed that temperatures at river mile 4.0 (Colorado Rapids the lowest point of Huntington's modeling) either as measured with PRB influence, as modeled with PRB influence (SNTEMP) or predicted without PRB influence (SNTEMP) did not approach these temperatures (Figure 11). A site as far downstream as river mile 4 would represent an expected worse-case temperature scenario, suggesting that the Deschutes likely did not reach temperatures that would present thermal block conditions for upstream migrating fall Chinook adults and indeed has never been observed. No delay in upstream migration of fall Chinook has ever been documented in the Deschutes (2-2-23 email from ODFW District Fish Biologist Jason Seals to DRA). Thus, post-SWW temperature modification to prevent thermal block temperatures are not justified by the available data and clearly appear unnecessary.

Changes in Upstream Migration of Adult Fall Chinook

Upstream migration of adult fall Chinook in the Deschutes can be measured at the ODFW Sherars Falls trap facility located at river mile 43, immediately adjacent to Sherars Falls. The Sherars Trap has been in seasonal operation from 1977 to present except for 2017 when no data was collected. This trap, somewhat unique compared to other trap facilities, relies on water pumped into a steep-pass type fish ladder which fish ascend when the actual Sherars Falls fish ladder is blocked during trap operation. Fish ascend the steep-pass ladder and transition to a holding tank where they are anesthetized and bio-integrated prior to release. The Sherars Trap is an example of an active as opposed to a passive trap and an operator must be on-site when the trap is operating.

Sherars Trap catch data is summarized on two-week intervals. In order to account for varying effort between data periods, the most meaningful statistic to compare trap capture is as catch per unit effort, in this case measured as fish/hour of trap operation. Fall Chinook data reported here were collected at the Sherars Trap by ODFW and were provided by the ODFW Mid-Columbia Fishery District in The Dalles.

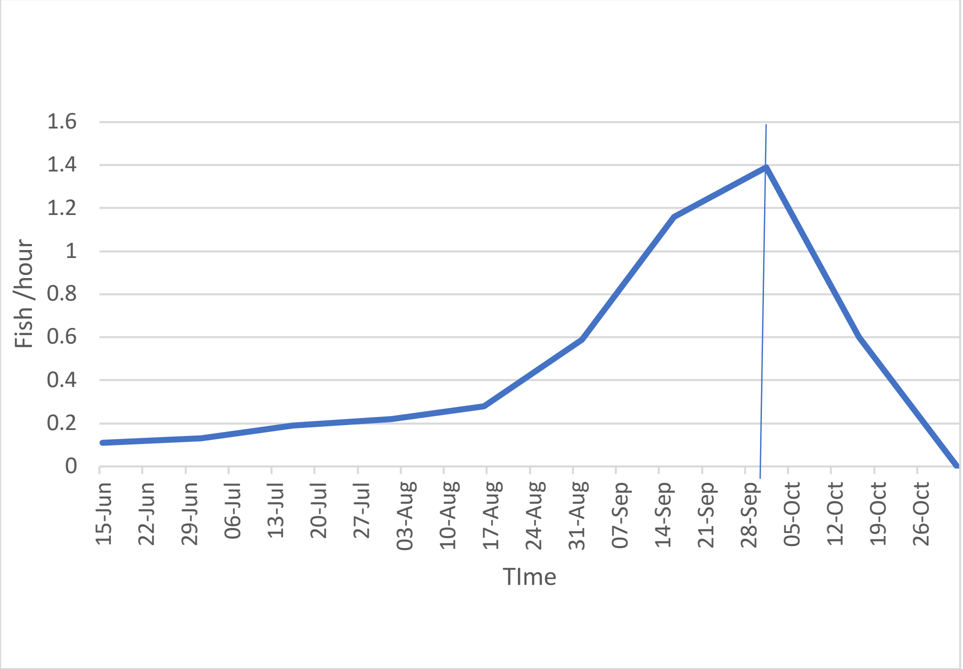


Figure 24. Adult fall Chinook catch per unit effort (fish/hour of trap operation) collected at the ODFW Sherars Falls trap during pre-SWW influenced returns, 1977-2012. ODFW data.

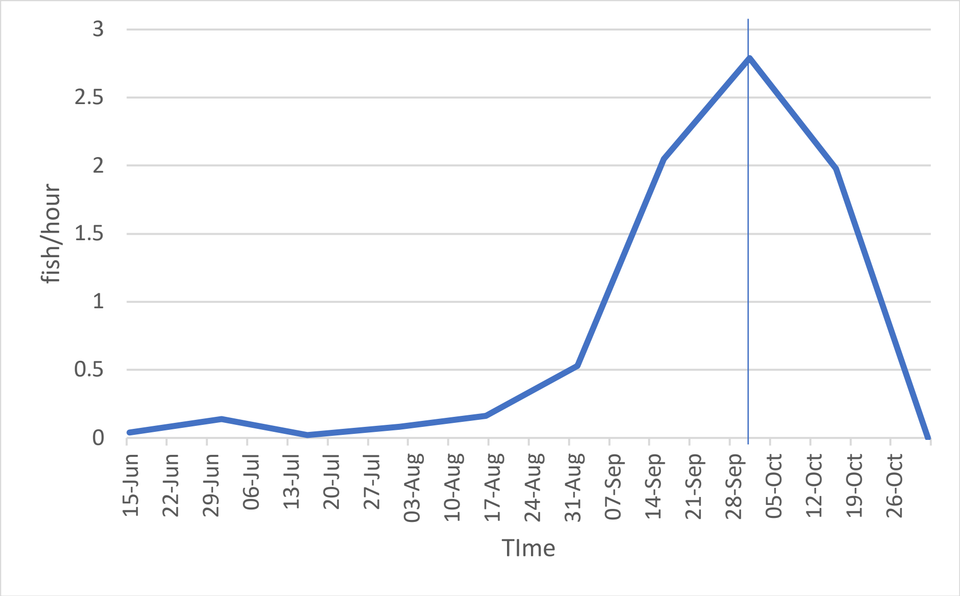


Figure 25. Adult fall Chinook catch per unit effort (fish/hour of trap operation) collected at the ODFW Sherars Falls trap during post--SWW influenced returns, 2013-2022. ODFW data.

Comparing the two figures or pre- and post-SWW data sets (figures 22 and 23, respectively), it is apparent that the peak migration past the Sherars Trap has not changed due to releasing cold water in the fall with the peaks of passage being identical. If releasing cold water in the fall to benefit fall Chinook was intended to modify adult return timing as measured by Sherars Trap passage, it has not been successful.

A change in the timing of peak catch has taken has taken place at the Sherars Trap that is not obvious from figures 24 and 25, however. Figures 26 and 27 display the number of times the peak of fall Chinook capture at the Sherars Trap took place in each two-week data period. Peak trap catch appears to be taking place somewhat later in post-SWW years 2013 to 2022 and the overall peak of trap catch appears to be shifting later. The post-SWW sample size is relatively small (n=9) and it is unknown if this migration timing shift is tied to SWW-induced temperature change, is statistically relevant or what the causal mechanisms may be.

When considering the question of whether SWW-induced temperature changes have affected Deschutes fall Chinook, it is important to look at how much and when temperatures have been changed.

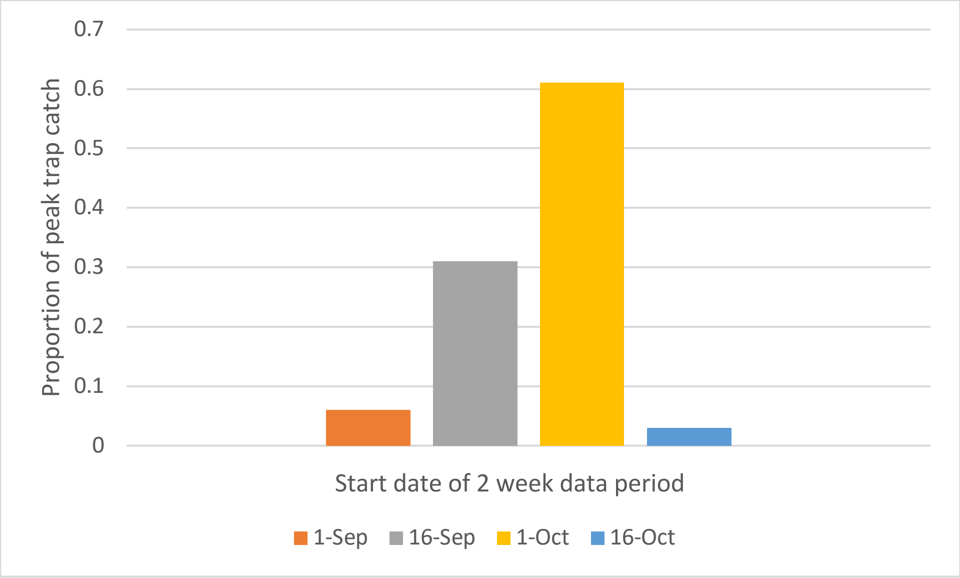


Figure 26. Proportion of times peak adult fall Chinook capture took place in each two-week data period , pre-SWW years 1997-2012. ODFW data.

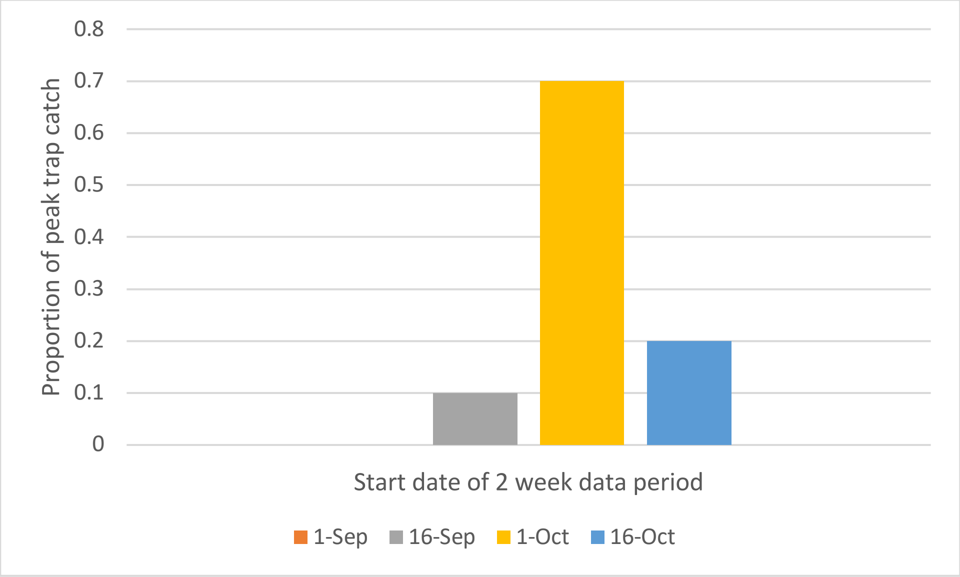


Figure 27. Proportion of times peak adult fall Chinook capture took place in each two-week data period, post-SWW years 2013-2022. ODFW data.

Does either the duration or magnitude of cooling provided by current SWW management suggest that meaningful cooling to benefit adult fall Chinook is taking place? Figure 28 clearly demonstrates that both the magnitude of cooling and length of time the river is cooled by SWW releases are small and little substantive cooling actually takes place. Water temperature is lowered by less than 1^{o} C and, as pointed out above, this cooling effect is lessened in downstream areas resulting in even less cooling. Additionally, by overlaying catch of fall Chinook adults at the Sherars Falls trap on temperature change, it is apparent that the peak date of cooling is not well matched with peak passage at Sherars Falls. The period of cooling does overlap a significant portion of the adult fall Chinook run as measured as passage at Sherars Falls but significant warming is present in the early portion of the run.

The important point from a biological and ecological perspective as regards the lower Deschutes is not the minor cooling that takes place in the fall but the extensive period of warming the rest of the year (figures 14 and 28).

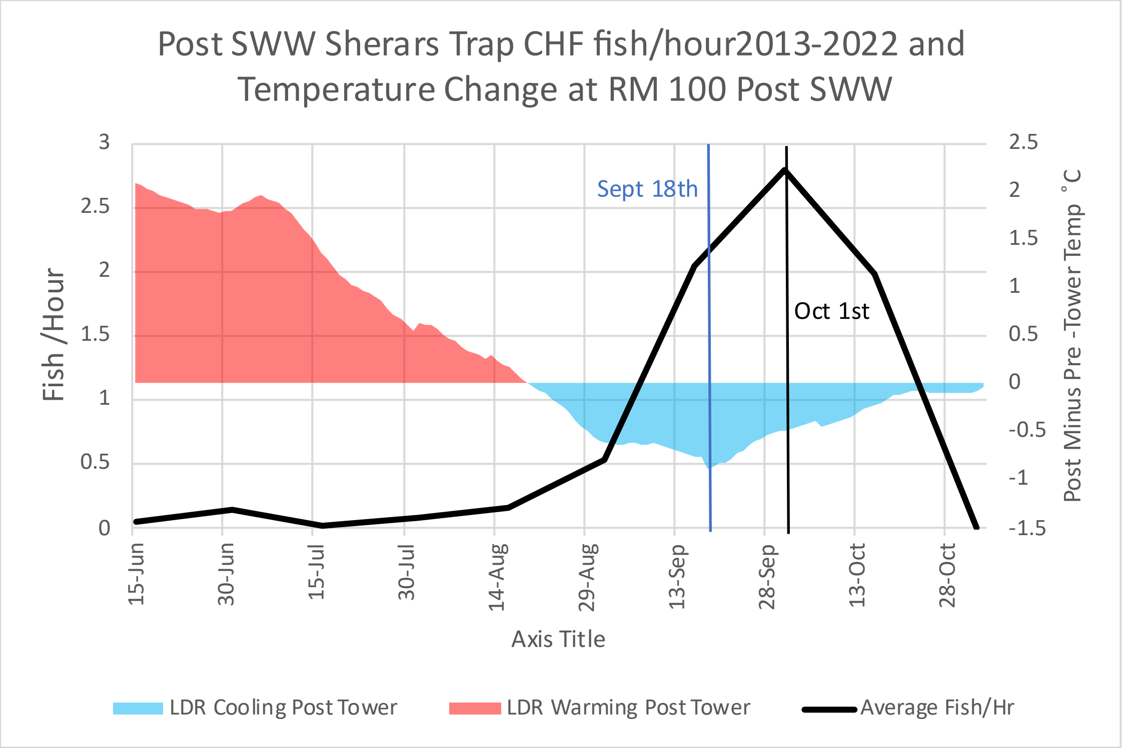


Figure 28. difference between (1) the average 7DADM calculated from 13 years during Tower operations (2009-2021) and (2) the average 7DADM into the lower during four years before Tower operations (2006-2009) at RM 100. 2006-2009 temperature data source: PGE's annual Water Quality Monitoring Reports, post-Tower temperature data source: USGS Madras gage (14092500). Overlay is Sherars Trap adult fall Chinook catch in fish/hour (ODFW data). Note peak cooling on September 18 does not correlate with peak capture at Sherars Falls on October 1.

Modeling

Sophisticated and appropriate models exist to intelligently guide any attempt to modify temperatures in the Deschutes to benefit fall Chinook. PGE does not appear to have been used them, however.

If PGE is operating PRB to save cold water for use in the fall to provide some benefit to fall Chinook, they are not taking a scientific and well-reasoned approach. For example, there seems to be a lack of clarity on whether temperature management is supposed to benefit adult or juvenile fall Chinook. The idea that colder water is needed in the fall to benefit pre-spawning adults appears to be completely without merit. The alternate theory, that warmer water in the winter and spring benefits incubating eggs, alevins and fry, has many potential unintended consequences to the entire aquatic environment. Absent specific pre and post temperature manipulation egg to smolt survival data as well as the low egg to smolt survival rate cited above, temperature manipulation may not be providing any benefit. The intelligent approach to achieving the best possible results from temperature management would be to have clear, well-defined goals and use state of the art modeling to inform the decision makers on the best course of action.

Jager (2011), in support of modeling efforts on the San Joaquin River in California, reviewed and commented on literature pertaining to fall Chinook and water temperature. This review points out that complex and detailed models exist and can be applied to situations where water temperatures can be modified for purposes of altering some life history characteristic. Models exist to predict the effects of temperature change on such life history parameters as distribution of redds in space and time, development, and survival from egg to fry and development from fry to smolt. As we have seen, the concept of modifying stream temperature to benefit one species over others is complex but models exist to better forecast potential outcomes.

There are many temperature models for predicting egg incubation, mean time to hatch and emergence, fry growth and survival as related to temperature for Pacific salmon. Beacham and Murray (1990 as cited in EPA, 1999) examined ten such models, for example.

Modeling done by Plumb (2018) on Snake River fall Chinook supports the conclusion that increases as little as 1° C in the seasonal average river temperature could impose thermal constraints on fish, select against early migrating adults and truncate the start of the spawning migration. This suggest that even small changes in temperature may be consequential and that without careful consideration and modeling unintended consequences could occur.

Eilers and Vache (2019) present 13 models used to predict downstream water quality changes from various operational changes at PRB. How these operational changes would impact fall Chinook is not addressed directly.

Conclusion

Portland General Electric started discharging surface water through the Selective Water Tower in late 2009. This was done to help create currents in the surface of Lake Billy Chinook to facilitate anadromous fish reintroduction upstream from PRB. As a result, the temperature regime in the lower Deschutes has changed being warmer in the winter and spring and slightly colder in the fall.

One reason PGE has advanced to justify the exact way they have modified downstream temperatures is to preserve cold water in LBC for fall release to benefit fall Chinook. PGE has only recently in a July 21, 2021 interview (cited above) with fish biologist Megan Hill speculated that both adult and juvenile fall Chinook benefit from current SWW managed water temperatures and warmer water in the winter benefits juveniles and cold water in the fall benefits adults. They have never specified what these claimed benefits are or whether they expect this temperature change to benefit incubating eggs, alevins, rearing juveniles, or pre-spawning adults.

Based on our analysis and findings, it appears neither claim of benefit are supported by the available record.

The cold water refuge in the Columbia at the mouth of the Deschutes is being negatively impacted by current SWW release strategies but could be enhanced by modifying cold water releases through the SWW.

No compelling reason for saving cold water for fall release to benefit fall Chinook was identified by this analysis and claims to the contrary are not supported by the available data. Neither adult or juvenile life history forms were found to show clear benefit from the release of warm water in the winter and spring. In fact, a variety of negative consequences to the larger aquatic environment were identified as a result of releasing warm, nutrient rich surface water through most of the year in order to save cold water for fall release. These changes are detrimental to the overall ecology of the lower Deschutes.

Despite an abundance of models to guide PGE’s decision making on downstream temperature modifications, none appear to have been used. DRA recommend, that PGE should preform appropriate modeling to result in the best possible outcome for the entire Deschutes aquatic environment.

As detailed above, DRA believes that saving cold water for fall released has not demonstrated any benefit to fall Chinook and rather, that harm may be taking place. Certainly, no documented benefit to fall Chinook appears sufficiently great enough to override well documented negative changes to the overall ecology of the lower Deschutes River from the current temperature management strategy of releasing warm, nutrient-laden surface water the bulk of the year to save cold water for fall release.

Additionally, it is very important to realize that the focus of this paper, water temperature, is but one of a suite of water quality parameters that exert an enormous influence on the aquatic environment of the lower Deschutes River. Changes in pH (as a surrogate for nutrient loading) and dissolved oxygen content are a few water quality parameters have all changed as a result of

SWW operations and not for the better. Temperature changes are but one albeit important factor that determines the health of the lower Deschutes River.

Based on these analyses, DRA recommends that PGE stop making claims that saving cold water for fall release and change SWW operations to release cold water throughout the summer to benefit the ecology and fishes of the lower Deschutes River.

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Appendix A. Estimated Deschutes River adult fall Chinook run to the river, by year (ODFW data) and adult fall Chinook counts, Bonneville Dam, by year (Fish Passage Center data). Highlight indicates adjusted data based on percentage of returning adults by age class that were influenced by post-SWW Tower water temperatures.

PRE-SELECTIVE WATER WITHDRAWAL			POST-SELECTIVE WATER WITHDRAWAL		
YEAR	BONNEVILLE	DESCHUTES	YEAR	BONNEVILLE	DESCHUTES
1977	205637	9764	2013	953222	8934
1978	199997	7364	2014	854826	17489
1979	190127	6718	2015	954886	17830
1980	127718	6057	2016	441171	12266
1981	146876	7907	2017	317313	5931
1982	157617	7529	2018	187079	4799
1983	112486	6987	2019	276066	24284
1984	147278	3749			
1985	188895	8709			
1986	225981	8620			
1987	336537	11244			
1988	290049	11939			
1989	262769	8068			
1990	176935	3834			
1991	149899	5527			
1992	116200	3705			
1993	126181	8820			
1994	170211	9625			
1995	163876	9340			
1996	205358	10311			
1997	218518	20341			
1998	188970	16414			
1999	241867	7762			
2000	192793	5392			
2001	399580	13151			
2002	474165	12899			
2003	610244	14491			
2004	583575	14521			
2005	417152	15771			
2006	299731	11740			
2007	161038	7608			

2008	315086	7614			
2009	283676	7116			
2010	467771	10066			
2011	401746	18168			
2012	350185	18785			

Spearman correlation values:
00-.19 “very weak”

0.20-.39 “weak”

0.40-.59 “moderate”

0.60-.79 “strong”

0 .80-1.0 “very strong”