Synthesizing the State of the Science for Coldwater Refuges in the Willamette River Basin

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Summary

Several regulatory, management, and conservation agencies and organizations want to protect and enhance coldwater and thermal diversity for Chinook salmon, steelhead, and other natives fishes in the Willamette River basin.

This study is synthesizing current and emerging science related to coldwater refuges and thermal diversity. It is also developing conceptual frameworks for understanding the variation in coldwater refuges and thermal conditions and how that variation relates to the abundance and composition of the native fish community.

This information will be used to identify strategic actions to protect, enhance, and restore, where possible, thermal diversity and coldwater refuges.

Emerging Stories

Here are some examples of the stories related to thermal diversity and coldwater refuges that are emerging from existing and new science in the Willamette River basin:

(1) The types and numbers of features supporting coldwater refuges are greatest in the Upper Willamette River, but then decrease downstream (figure 1 and maps).

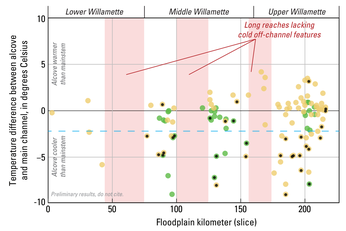

Figure 1. Plot of temperature and dissolved oxygen synoptic measurements in off-channel features along the length of the Willamette River, Oregon. Some cool water features lack adaquate dissolved oxygen for certain fish (black dots).

(2) Habitats provide important ecological functions regardless of whether or not they provide coldwater refuges.

(3) Temperature conditions vary greatly both seasonally and spatially (figure 6 and maps).

(4) Temperature and dissolved oxygen conditions are influenced by many factors, such as groundwater inputs (figures 3 and 6), tributary inputs (figure 14), hyporheic inputs (figure 11), shade, aspect, geology (figure 9), and channel dynamism (figures 4 and 5).

(5) Dam operations directly influence thermal conditions only within a short distance of the dams. Dam operations can indirectly influence temperature and dissolved oxygen conditions further downstream by changing river stage and connecting or disconnecting side channel features from the mainstem.

(6) Fish sampling by ODFW and OSU show that Chinook salmon and other natives fishes are dependent on habitats along the Willamette River all year long.

(7) Coldwater refuges and thermal diversity are driven by natural factors, but are also influenced by large scale human alterations to the basin (such as dam operations and gravel trapping by the dams) and along the river corridor (such as revetments, deforestation, gravel mining, and groundwater pumping). The degree to which the habitat restoration community can maintain, protect, and enhance coldwater refuges and thermal diversity will be nested within these basin and river corridor alterations.

Acknowledgements

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U.S. Department of the Interior
U.S. Geological Survey

Upper Willamette River from Eugene to Corvallis

The Upper Willamette River historically had multiple channels, but today is mostly a single channel with smaller, remnant multi-thread sections. Historically and today, this reach is the most dynamic of the three reaches because the river commonly displays meander migration, channel abandonment, and floodplain erosion. These geomorphic processes create or modify a diverse suite of off-channel features that have the potential to function as coldwater refuges.

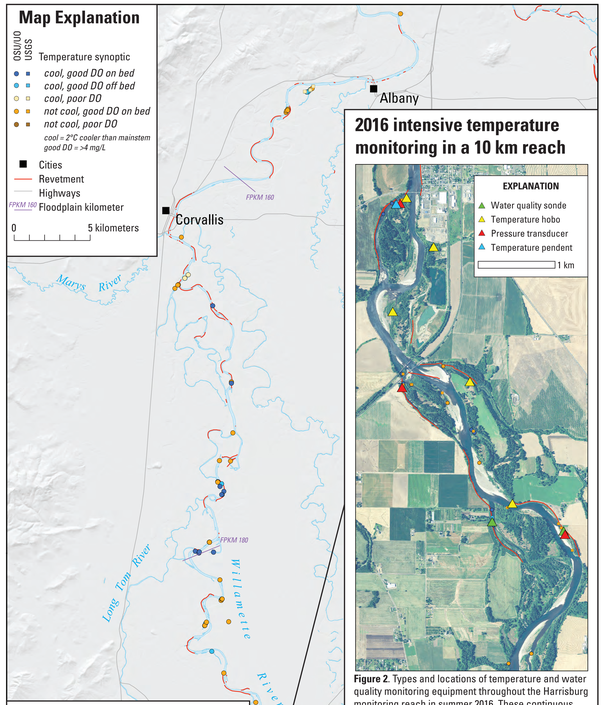

Figure 2. Types and locations of temperature and water quality monitoring equipment throughout the Harrisburg monitoring reach in summer 2016. These continuous sensors help us understand how temperature varies throughout the summer in a variety of off-channel features as discharge and temperature fluctuates in the mainstem Willamette River.

This abandoned channel receives cold groundwater

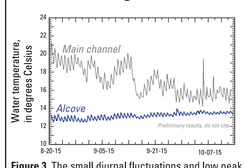

Figure 3. The small diurnal fluctuations and low peak temperatures suggests that this alcove is receiving cold water from groundwater sources. Water quality parameters such as specific conductivity and isotope chemistry can help us determine the source of that water.

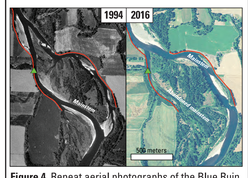

Figure 4. Repeat aerial photographs of the Blue Ruin area shows the history of channel abandonment and dynamic off-channel features.

Geomorphic mapping helps identify off-channel features

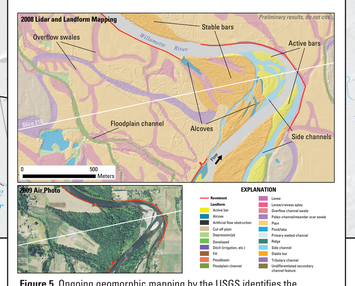

Figure 5. Ongoing geomorphic mapping by the USGS identifies the location and types of off-channel features along the Willamette River from Eugene to Newberg. This mapping helps us identify variability in feature locations and abundance as well as the geomorphic processes associated with the creation and maintenence of these features.

Middle Willamette River from Corvallis to Newberg

The Middle Willamette River is mostly a single thread channel characterized by larger meanders and a lower slope than the Upper Willamette. Several of the meanders are constrained against the bedrock of the Salem Hills or tall Pleistocene terraces. Historically, this reach experienced much channel straightening and dredging for navigation purposes. Today, it is minimally dynamic with geomorphic change limited to slow, large-scale meander migration or changes in individual gravel bars within the active channel.

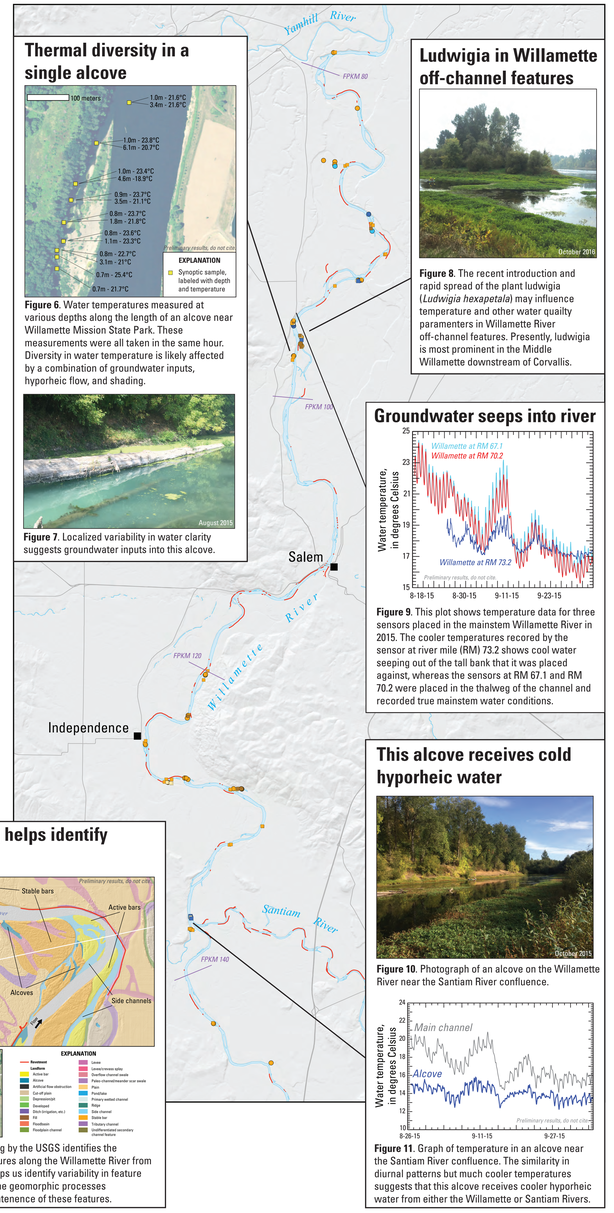

Figure 6. Water temperatures measured at various depths along the length of an alcove near Willamette Mission State Park. These measurements were all taken in the same hour. Diversity in water temperature is likely affected by a combination of groundwater inputs, hyporheic flow, and shading.

Figure 7. Localized variability in water clarity suggests groundwater inputs into this alcove.

Figure 8. The recent introduction and rapid spread of the plant ludwigia (*Ludwigia hexapetala*) may influence temperature and other water quailty paramenters in Willamette River off-channel features. Presently, ludwigia is most prominent in the Middle Willamette downstream of Corvallis.

Figure 9. This plot shows temperature data for three sensors placed in the mainstem Willamette River in 2015. The cooler temperatures recored by the sensor at river mile (RM) 73.2 shows cool water seeping out of the tall bank that it was placed against, whereas the sensors at RM 67.1 and RM 70.2 were placed in the thalweg of the channel and recorded true mainstem water conditions.

Figure 10. Photograph of an alcove on the Willamette River near the Santiam River confluence.

Figure 11. Graph of temperature in an alcove near the Santiam River confluence. The similarity in diurnal patterns but much cooler temperatures suggests that this alcove receives cooler hyporheic water from either the Willamette or Santiam Rivers.

Lower Willamette River from Newberg to the Columbia River

The Lower Willamette River is the least dynamic of the three reaches. After crossing Willamette Falls in Oregon City, the Willamette River is constrained by bedrock to Portland and has been lined almost entirely with revetment downstream of Portland. These constraints limit the channel dynamism and off-channel features in this reach; therefore, coldwater features in the Lower Willamette River are mostly tributary junctions and seeps along bars.

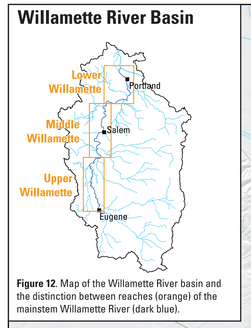

Figure 12. Map of the Willamette River basin and the distinction between reaches (orange) of the mainstem Willamette River (dark blue).

Figure 13. This vertical temperature profile shows that the water temperature only fluctuates within 0.1°C, even as deep as 60 m below the water surface.

Figure 14. This hybrid lidar-bathymetry image shows how the Willamette Rivers flows through a deep, narrow bedrock reach between Oregon City and Portland. This bedrock-controlled setting limits the number of off-channel features. Many of the alcove-shaped features are surrounded by bedrock, minimizing the hyporheic flow into them. Therefore, most coldwater monitoring along the Lower Willamette River focuses on tributary junctions. Lidar makes it easy to locate very small tributaries in this densely vegetated and urbanized reach.

Open Questions

-What types of restoration strategies may help protect or increase coldwater refuges in the different mainstem reaches?
-What are the effects of ludwigia on water temperature and water quality parameters?
-What types of information about coldwater refuges and thermal diversity would help the Willamette restoration community understand the variation in these features and develop strategic restoration strategies?
-How do off-channel features and their thermal diversity benefit natives fishes throughout the year?
-Can off-channel features and thermal diversity be managed to minimize the invasion of non-native, warm water fishes in the basin?

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