January 4, 2016

MEMORANDUM

TO: **Council members**

FROM: **Karl Weist**

SUBJECT: **The Distribution and Use of Cold Water Refuges in the Willamette Basin**

BACKGROUND:

Presenters:

Dr Stan Gregory received his BS in Zoology from the University of Tennessee and his MS and PhD. From Oregon State. He was a Professor of Fisheries at Oregon State University (now retired) and recently joined the Independent Science Advisory Board.

Professor David Hulse of the University of Oregon is a graduate of Harvard University's Graduate School of Design, a Fulbright Scholar, and a recipient of the US Chapter of the International Association for Landscape Ecology's Distinguished Landscape Practitioner Award.

Summary

Dr. Gregory and Professor Hulse have collaborated for years on data gathering designed to understand the river processes in the Willamette and its tributaries and what the future may portend for those processes. Dr. Gregory and his team at OSU gathered temperature and dissolved oxygen data from 2008-2015 in the mainstem Willamette, side channels and sloughs between Eugene and Corvallis.

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Relevance:

Please see attached document.

Workplan:

Pertains to floodplain restoration, an emerging priority within the Council's program, and water quality.

Background:

Please see attached document

More Info:

https://nwcouncil.box.com/s/j262ftcgf1ezsz3ebp0t2h8cyi1nrjj5

Distribution and Use of Cold Water Refuges in the Willamette River
Briefing Notes for Presentation to the Northwest Power and Conservation Council
January 12, 2016

Stan Gregory, Emeritus Professor, Department of Fisheries & Wildlife, Oregon State University
David Hulse, Professor, Department of Landscape Architecture, University of Oregon

Our studies of trajectories of change and alternative futures for the Willamette River basin have highlighted the critical social and environmental value of the mainstem Willamette River. Through funding by the Meyer Memorial Trust and the Oregon Watershed Enhancement Board, we monitored native and non-native fish communities and river and floodplain habitat, documenting the distribution and abundance of 22 native fish species and 19 non-native species in the mainstem Willamette River. Many of these non-native fish are warm-water species that may outcompete native species in warm habitats of the Willamette River.

Over the last decade, the Willamette River has exceeded the state temperature standard each year during summer for the entire length of the mainstem. Longitudinal dataloggers documented a warming of 2 - 3^{o}C from Eugene to Corvallis.

All of the mainstem sampling sites exhibited complete thermal mixing in the water column and contained no cold water refuges within the main channel.

Between 2008 to 2015, we sampled more than 80 sloughs along the mainstem river.

72% of the 81 floodplain sloughs in the Willamette River were colder than the mainstem, and 40% were more than 2^{o}C colder than the maximum mainstream temperature at the site (ODEQ cold water refuge standard). The majority of the cold water sloughs had conductivity values that were similar to the mainstem river, indicating hyporheic flow as the major source of cold water rather than groundwater.

Dissolved oxygen concentrations can be low in some sloughs. 80% of the sloughs that were more than 2^{o}C colder than the mainstream also contained adequate concentrations of dissolved oxygen to support native fish (4.0 mg/L) at the depths where cold water was detected.

Fish communities differed substantially between sloughs with cold water and warm water habitats.

- Numbers of native fish species were greater than non-native species in cold water habitats, but numbers of non-native species exceeded numbers of native species in warm water habitats.
- Abundances of native fish were greater than non-native fish in cold water habitats, but abundance of non-native fish exceeded abundance of native fish in warm water habitats.
- Native fish made up more than 60% of the individuals captured in cold water sloughs, but non-native fish comprised more than 85% of the fish captured in warm water sloughs.
- Salmonids were approximately 10 times more abundant in cold water sloughs than in warm water sloughs.
- Chinook juveniles were found in two of the ten cold water sloughs and were not observed in warm water sloughs.

Radio telemetry studies of cutthroat and rainbow trout indicated that more than half of the fish released in reaches with cold water sloughs moved into these thermal refuges during summer 2008 and 2009.

- In one slough with lower dissolved oxygen concentrations, only 33% moved into the cold water slough.
- When cutthroat trout were randomly released every mile along the mainstem for 15 miles, a third of the fish moved into cold water sloughs even though the mainstem river provided far greater area of habitat.

We implanted temperature dataloggers in fish in the Willamette River to determine the thermal environment used by cutthroat and rainbow trout. We surgically implanted dataloggers in 102 trout and recovered loggers from 14 fish.

- All fish were captured in the same reach of the river where they were released with the exception of one fish from a slough upstream into the mainstem.
- All trout occupied temperatures between 13-16°C even though source water was as cold as 10°C and mainstem water reached more than 19°C.
- We also tested the method on 23 carp and recovered 4 fish, all of which exhibited internal temperatures that ranged from 2-8°C warmer than the maximum mainstem temperatures.

Field mapping of thermal regimes provided a spatial framework for known cold water habitats in the Willamette River. David Hulse and his research team at the University of Oregon are integrating the cold water refuge information into the SLICES framework, a spatially explicit floodplain framework for the Willamette based on 100-m "slices" of the floodplain (Hulse and Gregory 2004, Hulse et al. 2010). The database provides a spatial, quantitative context to predict dynamic geomorphic features that exhibit cold water refuges as a basis for designing a linked network of floodplain and river restoration actions to create cold water habitats through the SLICES framework (http://ise.uoregon.edu/slices/Main.html).

We developed a framework for assessing the distribution of cold water refuges and restoring linkages between them for the Willamette Partnership (Hulse and Gregory 2007).The SLICES framework has been used to identify critical reaches for conservation efforts (e.g., maintain existing cold water stepping stones) and critical reaches for restoration projects (e.g., restore distributions of cold water habitats). OWEB and Meyer Memorial Trust have used data from this project to develop the anchor habitats framework for the Willamette Special Investments Partnership, and the Slices are part of both Willamette proposals to the new OWEB Focused Investment Partnership program. We also provide information on fish communities, thermal habitats, and floodplain characteristics to the Willamette Partnership, watershed councils, Cascade Pacific RC&D, McKenzie River Trust, Greenbelt Land Trust, and Willamette Riverkeeper to assist in developing conservation and restoration actions. The cold water refuge data have been used in major OWEB restoration projects, including at Green Island, Harkens Lake, Middle Fork Willamette TNC, Blue Ruin Island, Waggle/Stellmacher Oxbow, Luckiamute Landing, and others.

References

Hulse, D., and S. Gregory. 2004. Integrating resilience into floodplain restoration. Journal of Urban Ecology. Special Issue on Large Scale Ecosystem Studies: Emerging trends in urban and regional ecology, vol. 7, pp. 295-314.

Hulse, D., S.V. Gregory. 2007. Linking cold-water refuges into a biologically effective network in the southern Willamette River floodplain: outlining key locations and knowledge gaps. Report to Willamette Partnership. April 2007.

Hulse, D.H., A. Branscomb, C. Enright, and C. Brehm. 2010. Linking cold-water refuges into a biologically effective network in the Willamette River floodplain. Final Report on OWEB Research Grant, 208-8006-5780 (in partnership with Dr. Stan Gregory, Oregon State University).

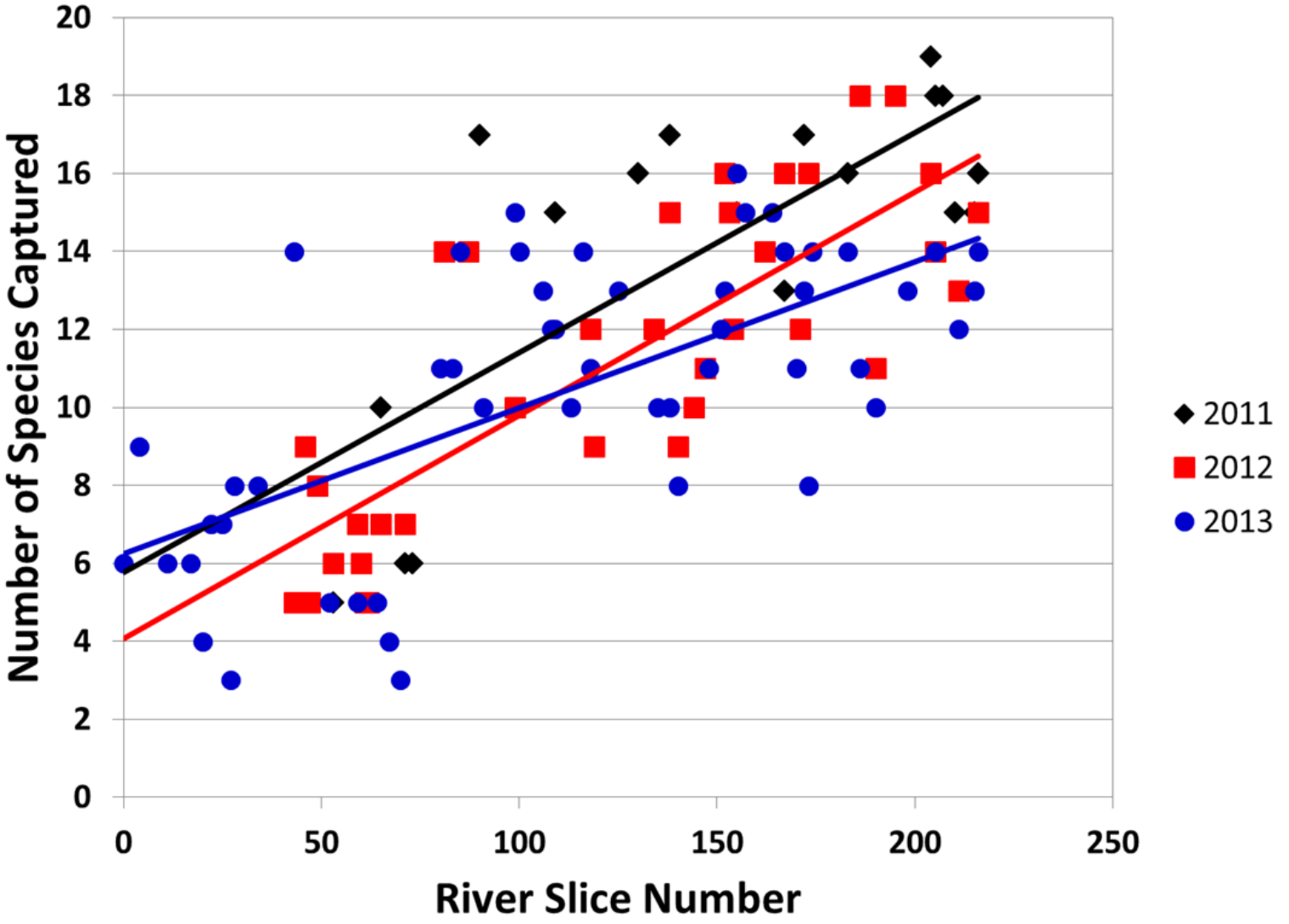
Cold Water Refuges in the Willamette River

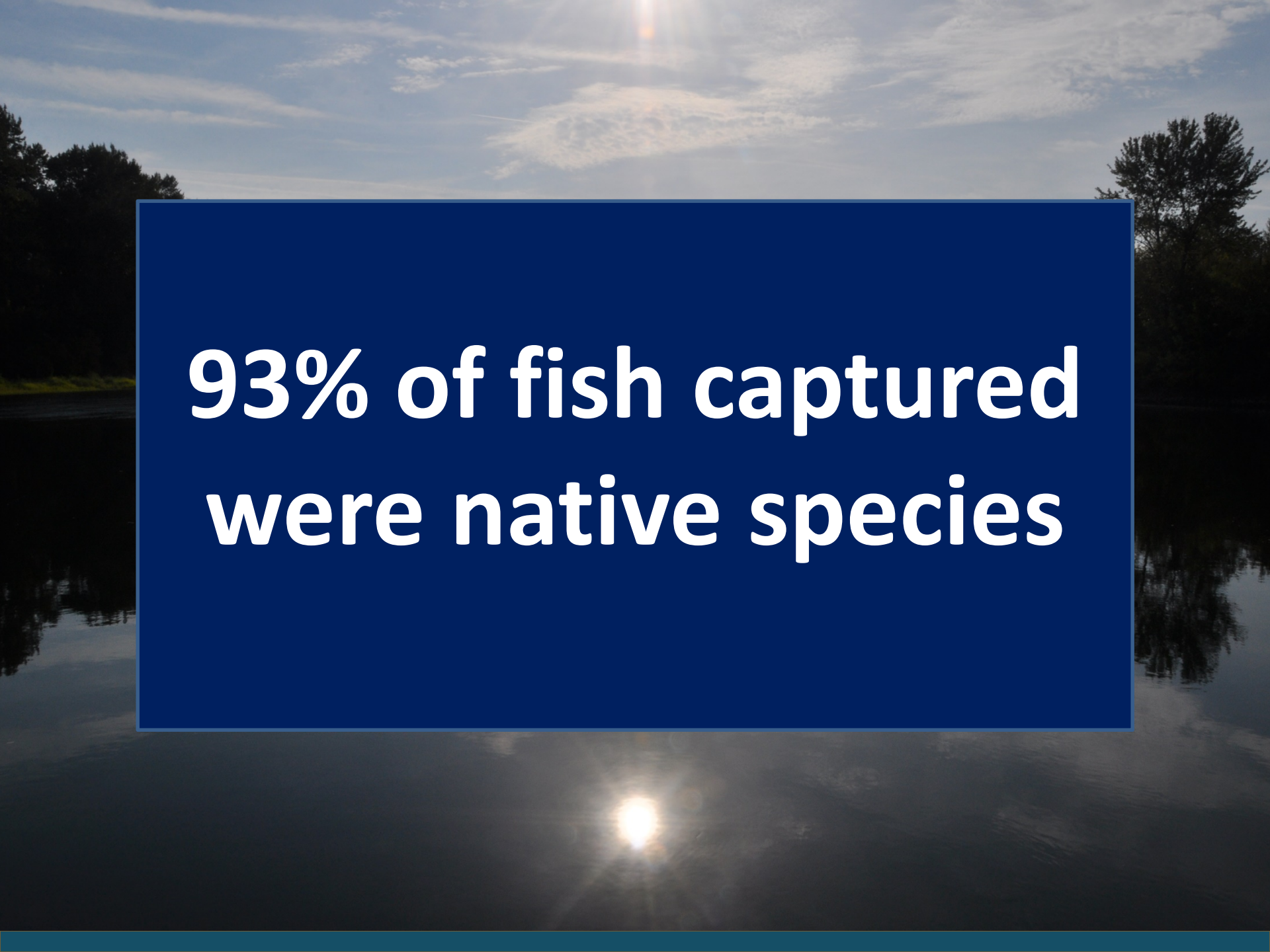
Stan Gregory
Oregon State University

Dave Hulse
University of Oregon

Presentation to the Northwest Power and Conservation Council **Jan. 12, 2016**

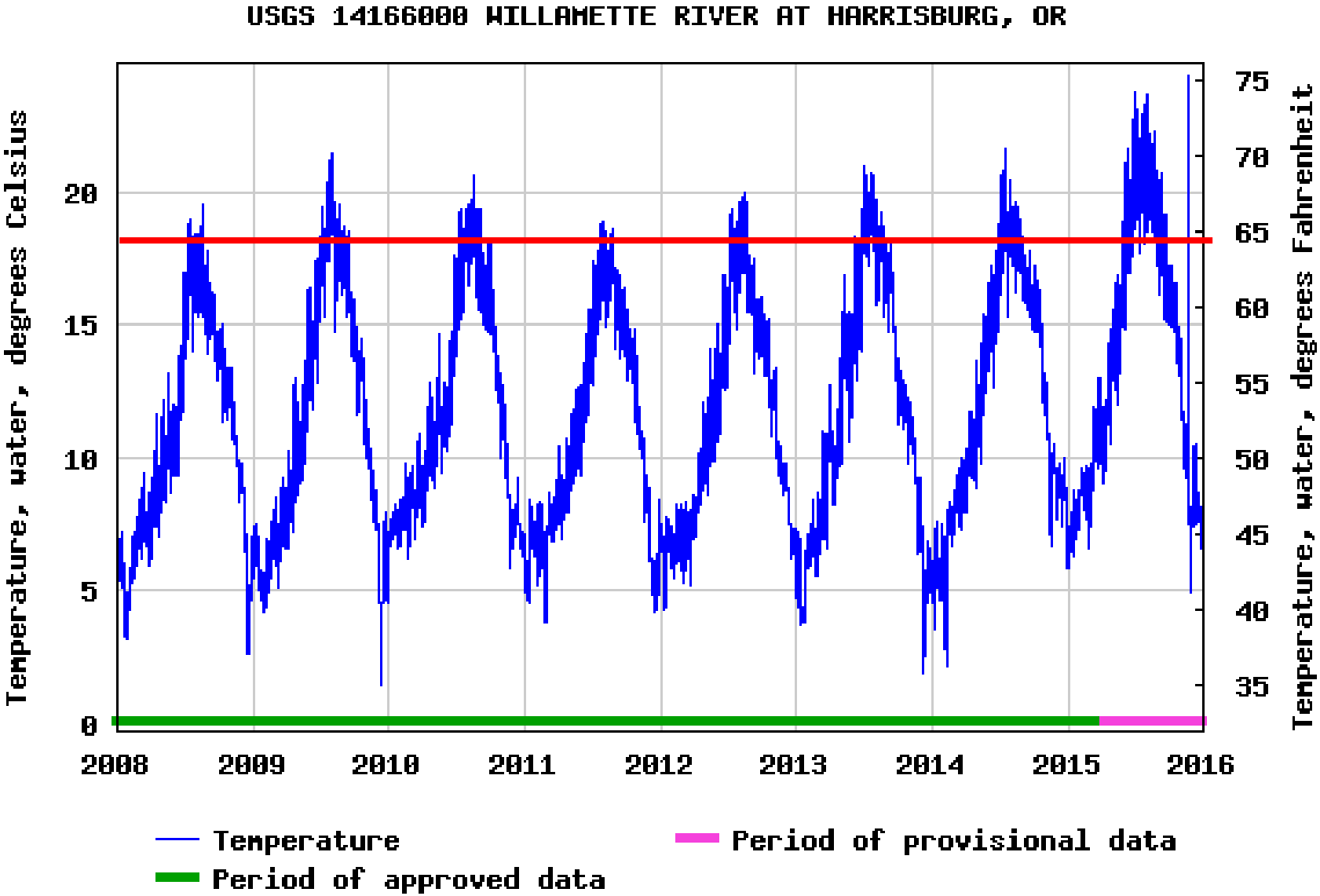
Number of Species




93% of fish captured were native species

Willamette River Thermal Regime

2008 to 2015



Cold Water Refuges

- **Those portions of a water body where, or times during the day when, the water temperature is at least 2 degrees Celsius colder than the daily maximum temperature of the adjacent well-mixed flow of the water body.**

OAR 340-041-0002(10)

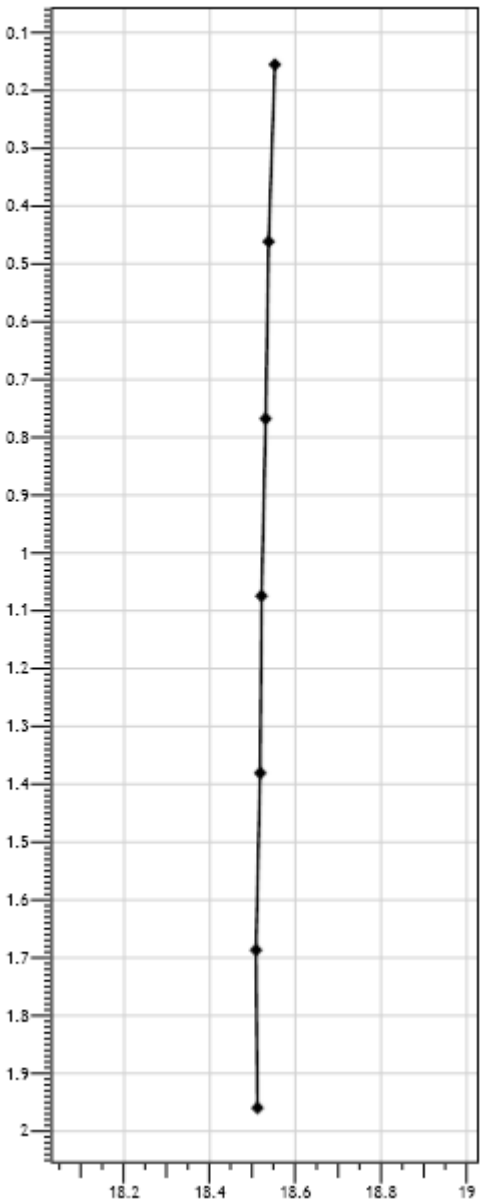
EPA 910-C-12-001

United States Environmental Protection Agency	Region 10 1200 Sixth Ave. Seattle, WA 98101	Alaska Idaho Oregon Washington
Water Division	Office of Water and Watersheds	February 2012

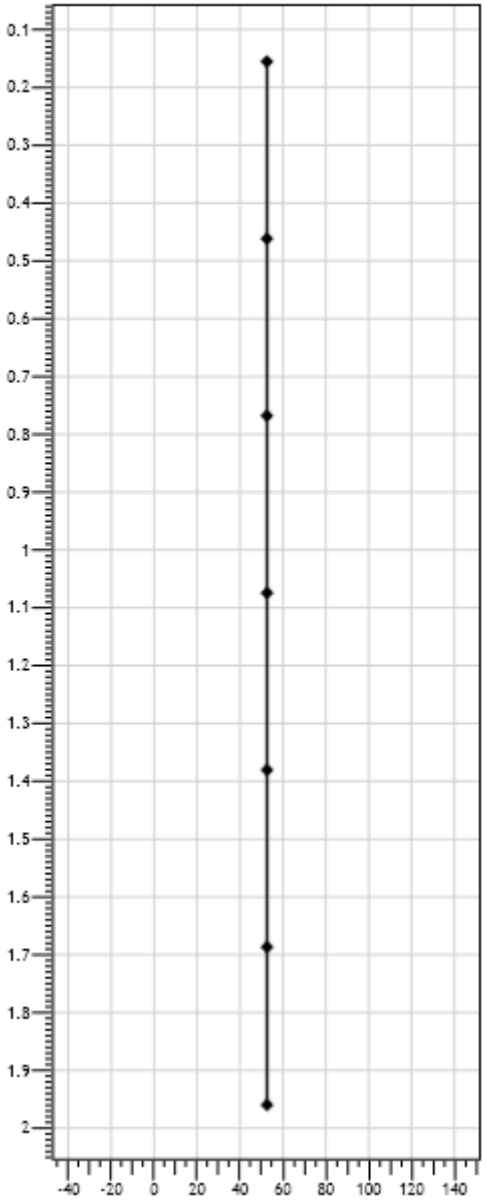
Primer for Identifying Cold-Water Refuges to Protect and Restore Thermal Diversity in Riverine Landscapes

Beginning in 2010, the Meyer Memorial Trust and OWEB supported a study of thermal patterns of 200 miles of the mainstem Willamette River and more than 100 sloughs, side channels, and tributary mouths.

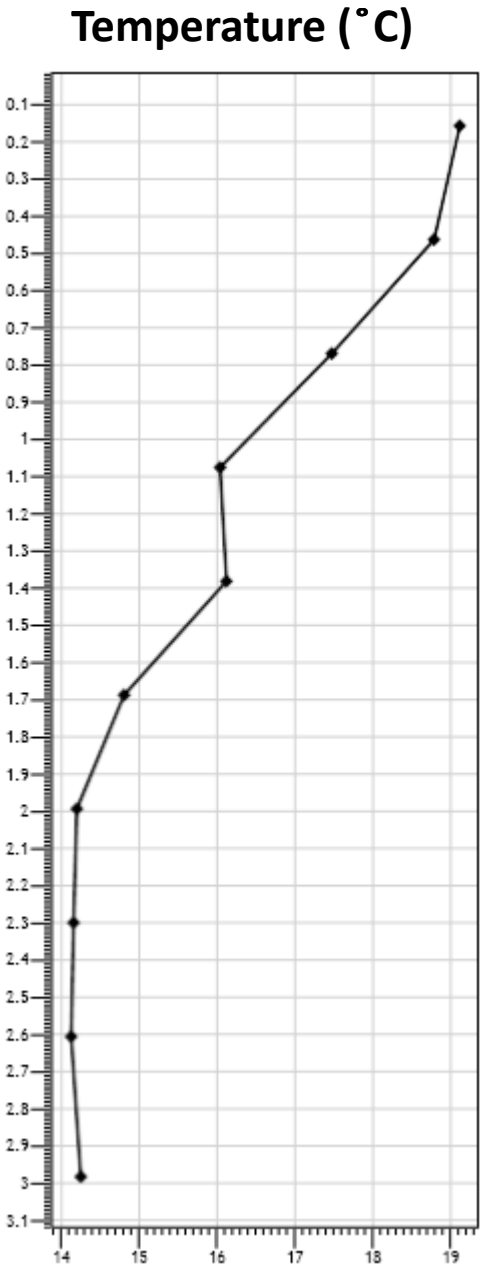
Temperature (˚C)

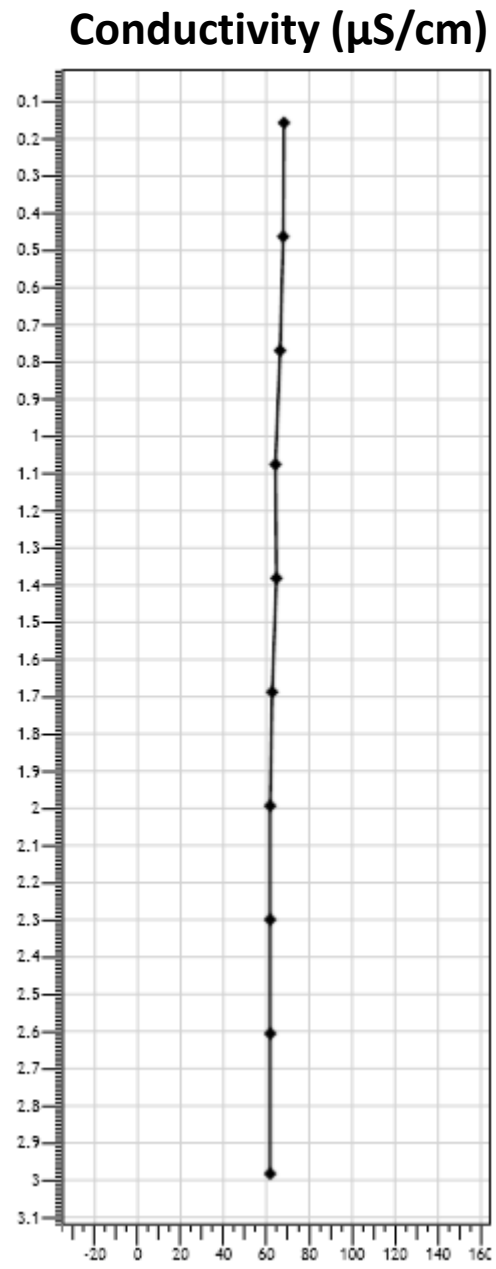


Conductivity (µS/cm)



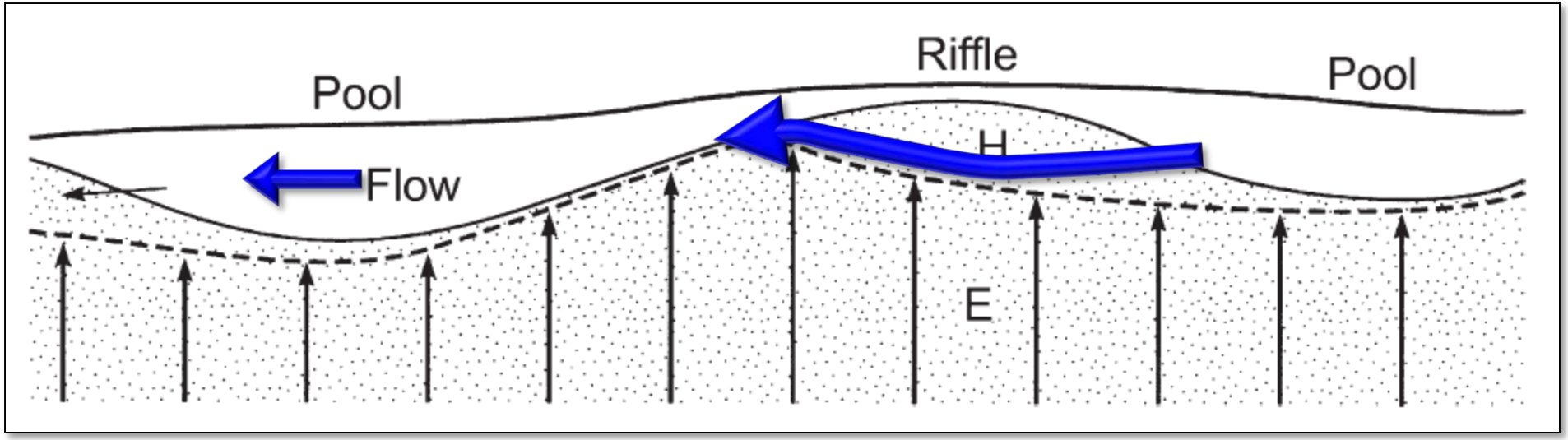
Green Island Mainstem- data shown are depth profiles

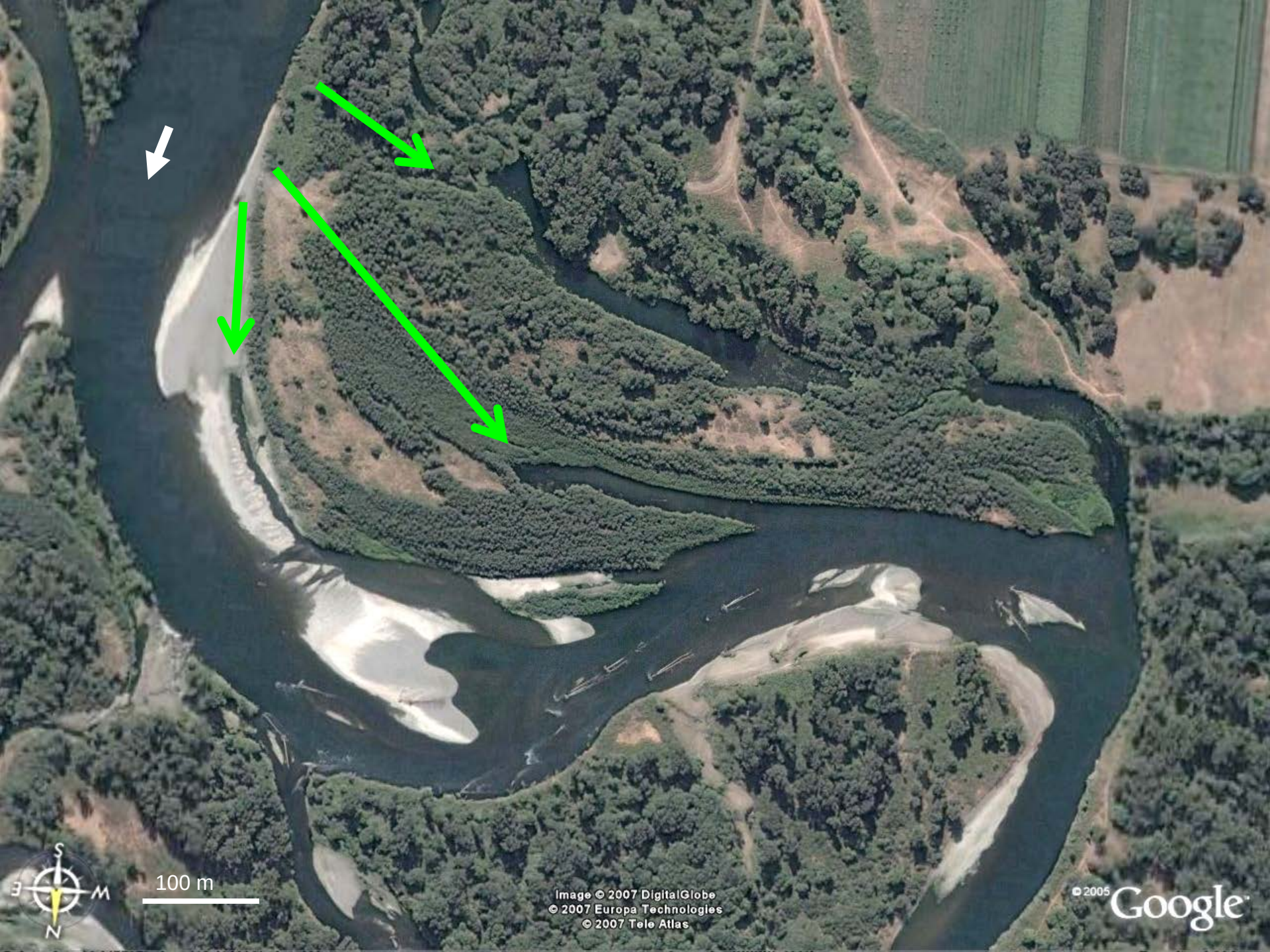


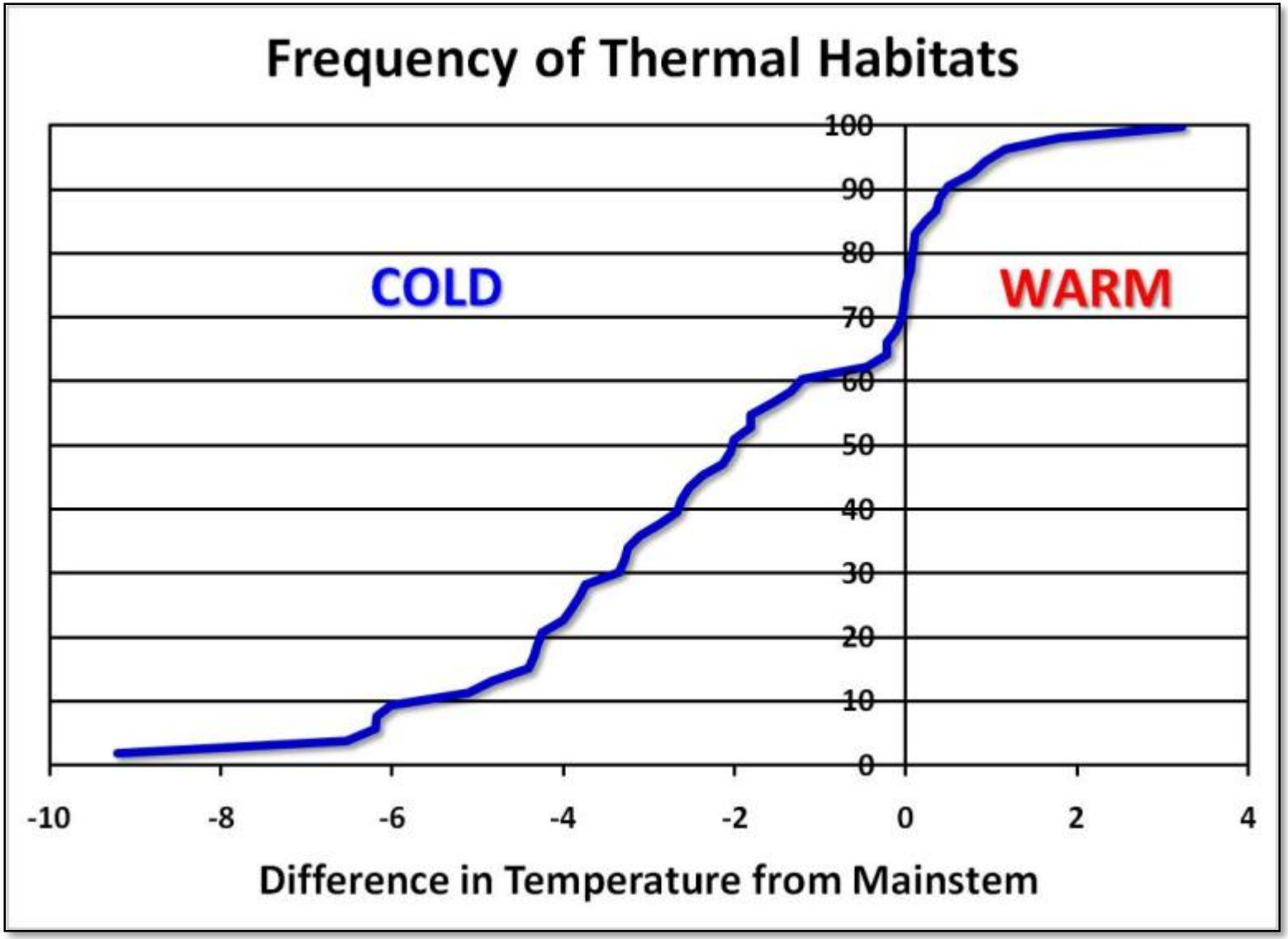


Green Island Alcove- data shown are depth profiles

Hyporheic Flow- side view



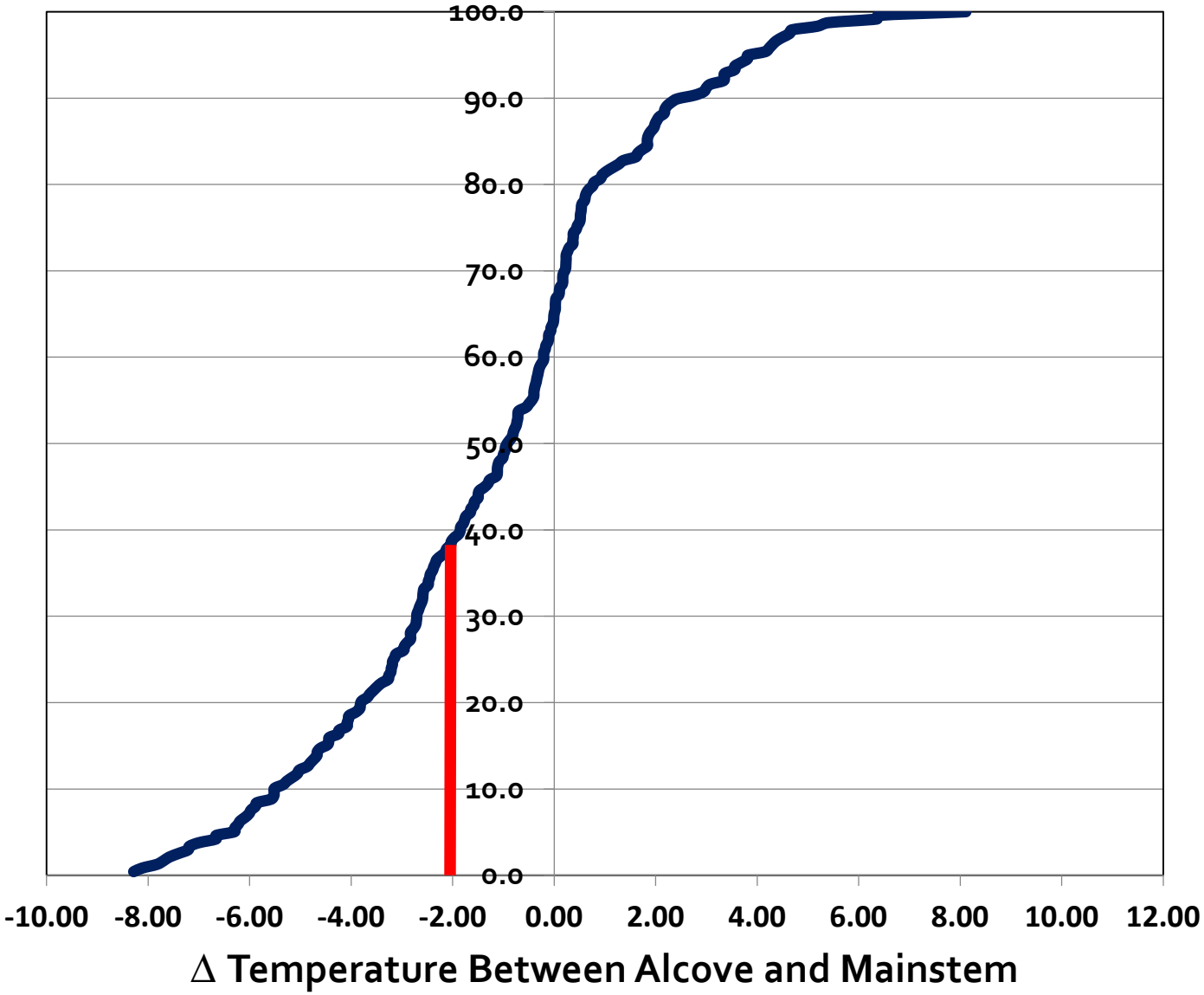

100 m
Image © 2007 DigitalGlobe
© 2007 Europa Technologies
© 2007 Tele Atlas
© 2005 Google


Frequency of Thermal Habitats
COLD
WARM
100
90
80
70
60
50
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
4
Difference in Temperature from Mainstem

Floodplain Alcoves

65% of sites colder than mainstem

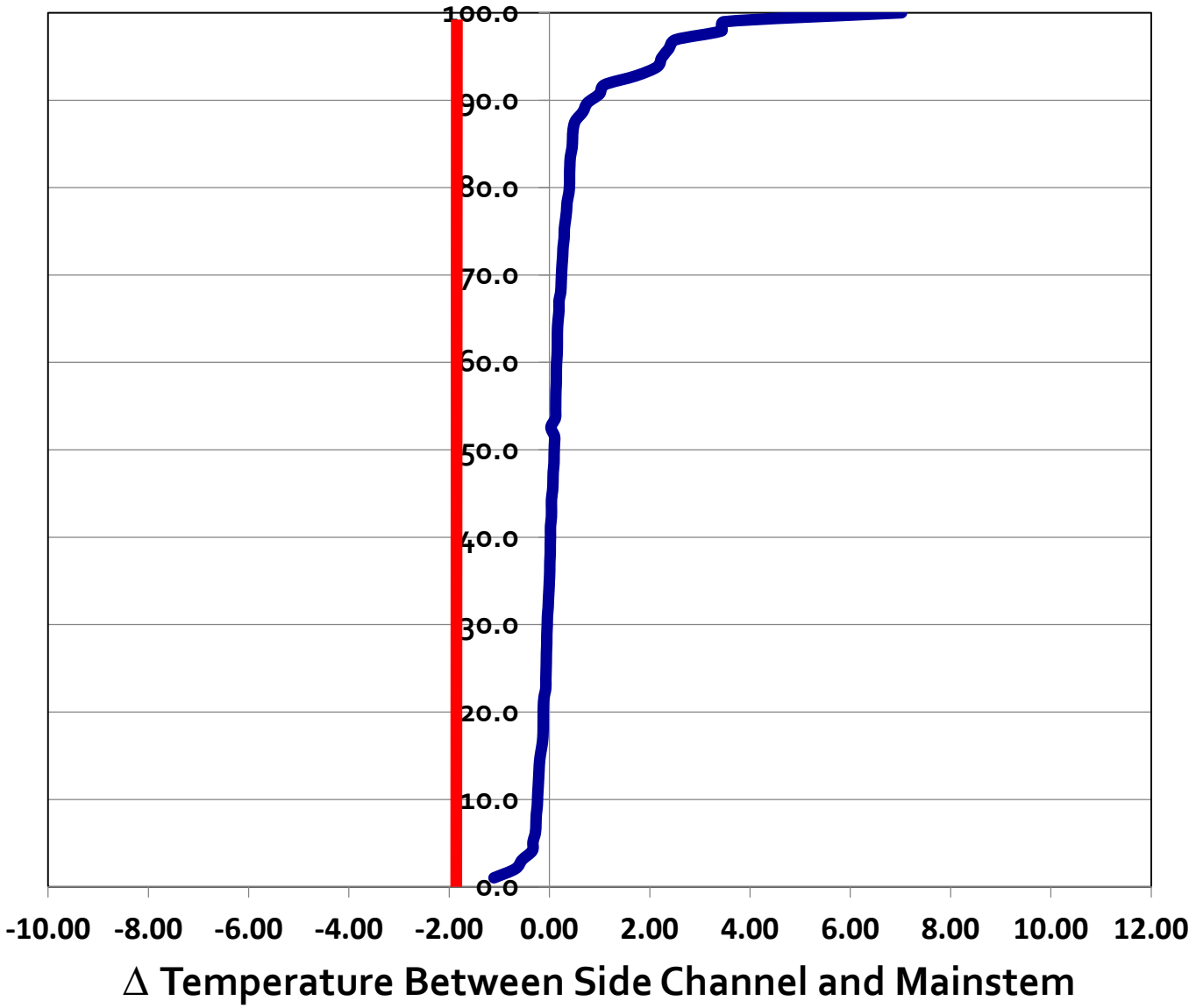
39% more than 2ºC colder than mainstem



Side Channels

25% of side channel sites were colder than mainstem

None of the side channels were >2ºC colder than mainstem



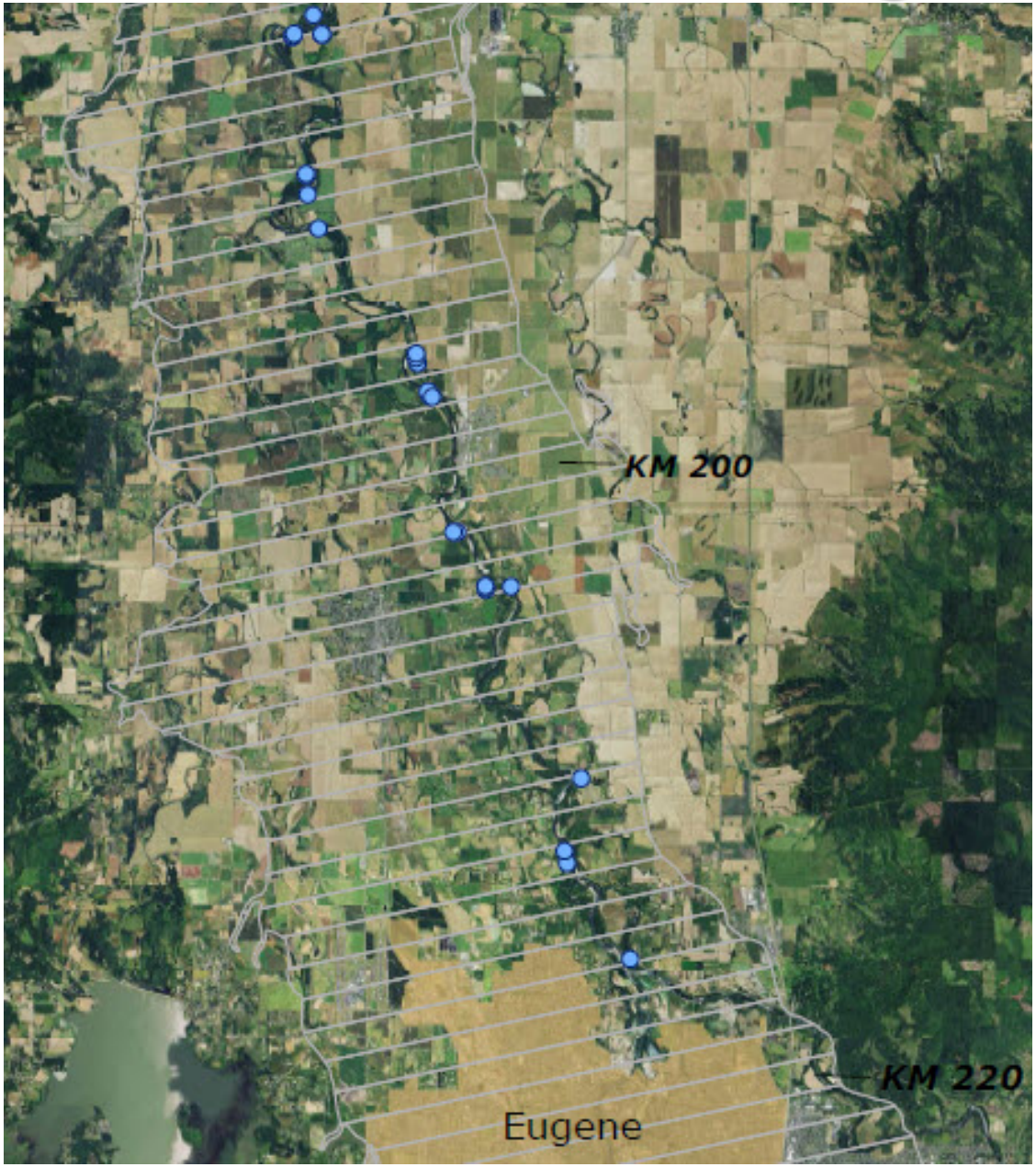
2011 -2015

- **72% of 81 separate floodplain sloughs in the Willamette River were colder than the mainstem maximum temperature**
- **40% of these sloughs were more than $2^{o}C$ colder than the maximum mainstream temperature.**
- **The majority of the cold water sloughs had conductivity values that were similar to the mainstem river, indicating hyporheic flow as the major source of cold water rather than groundwater.**

2011 -2015

- **Dissolved oxygen concentrations can be low in some sloughs.**
- **80% of the sloughs that were more than 2^{o}C colder than the mainstream contained adequate dissolved oxygen to support native fish where cold water was detected.**
- **One-third of the sloughs in the Willamette River meet the definition of cold water refuge and have adequate oxygen for native fish.**

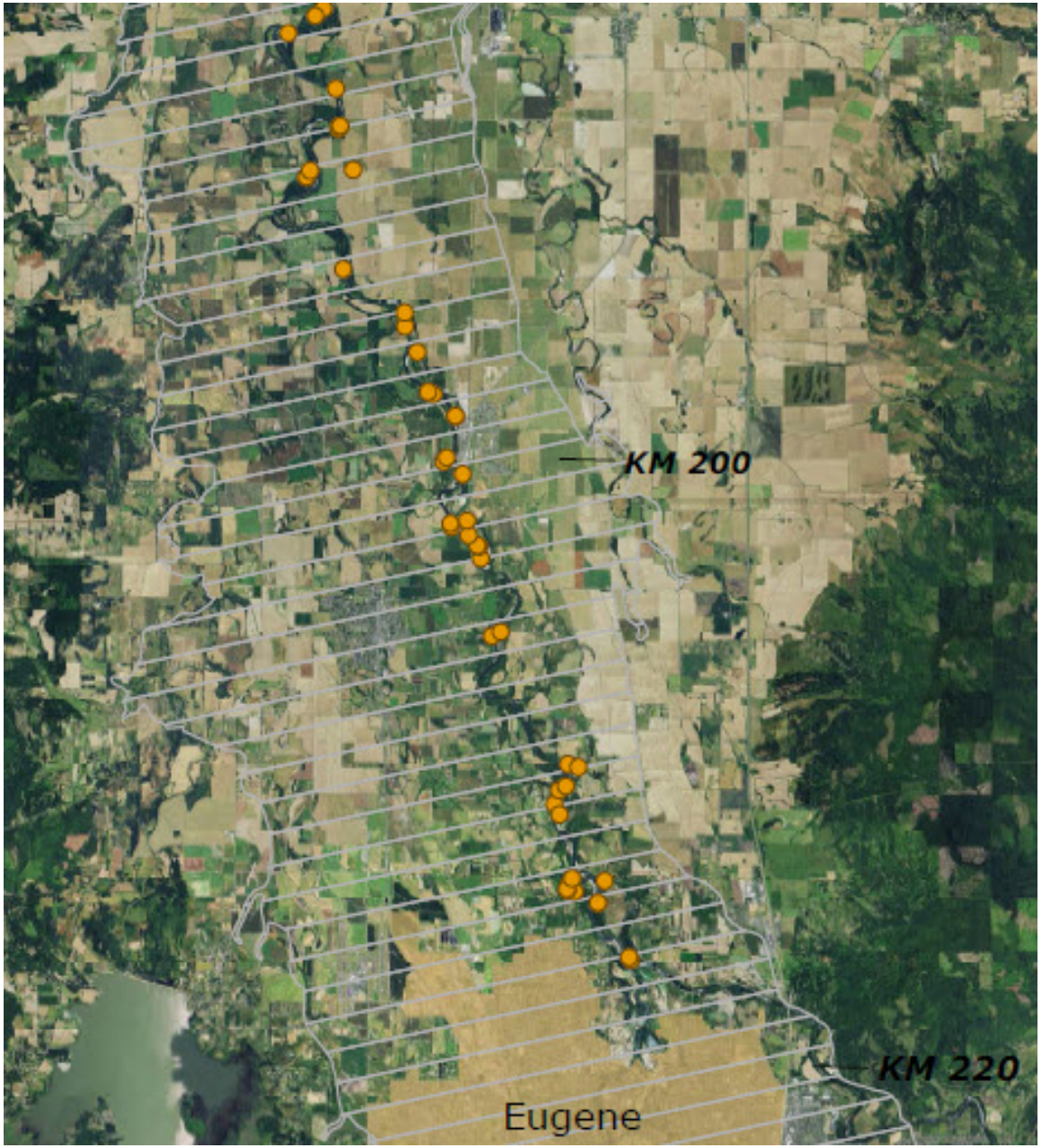
Cold Water Refuges 2011-2015



Cold Water Refuge

1 Km Slice

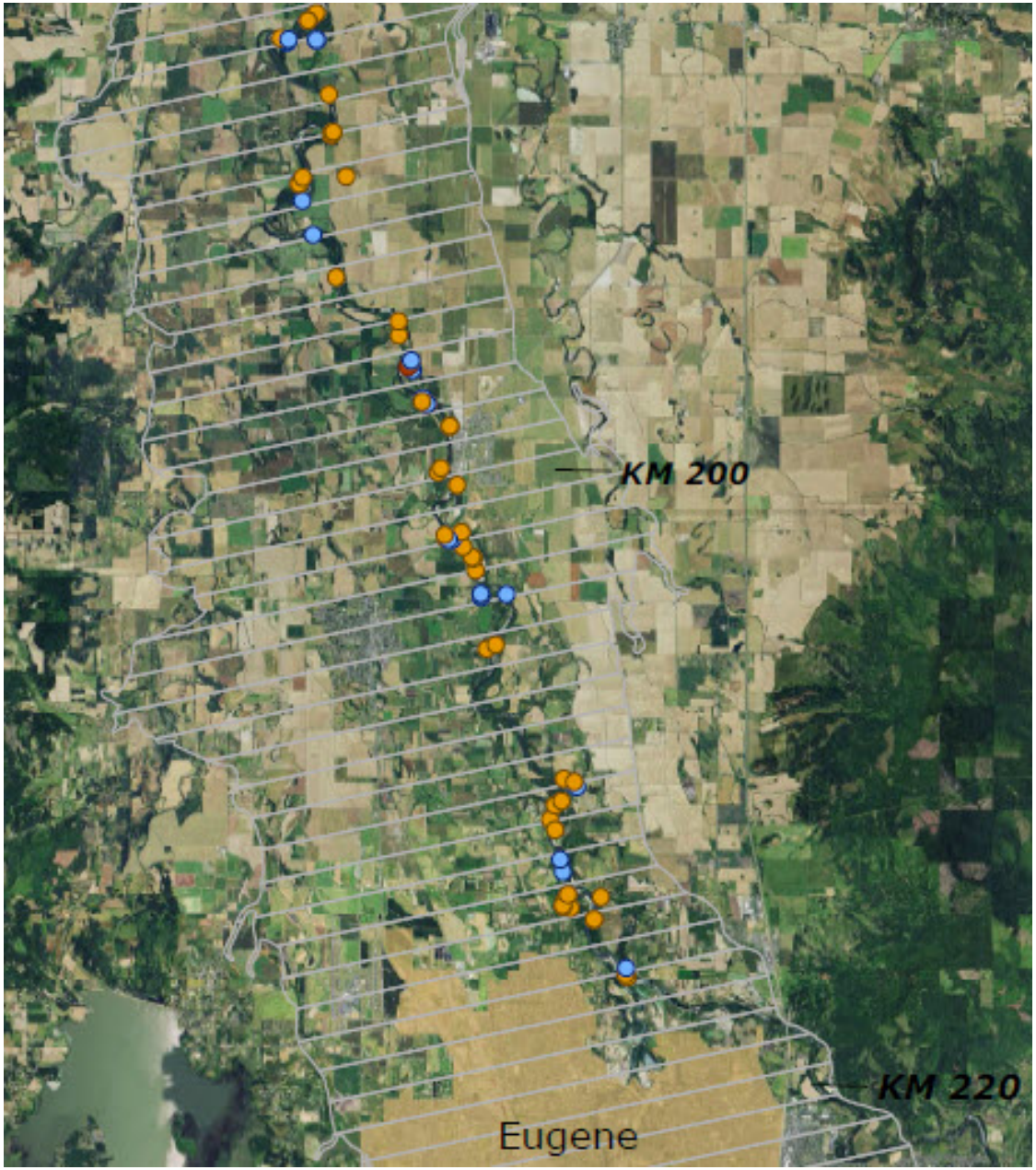
Cold Water Refuges 2011-2015



Not Cold Water Refuge

1 Km Slice

Cold Water Refuges 2011-2015

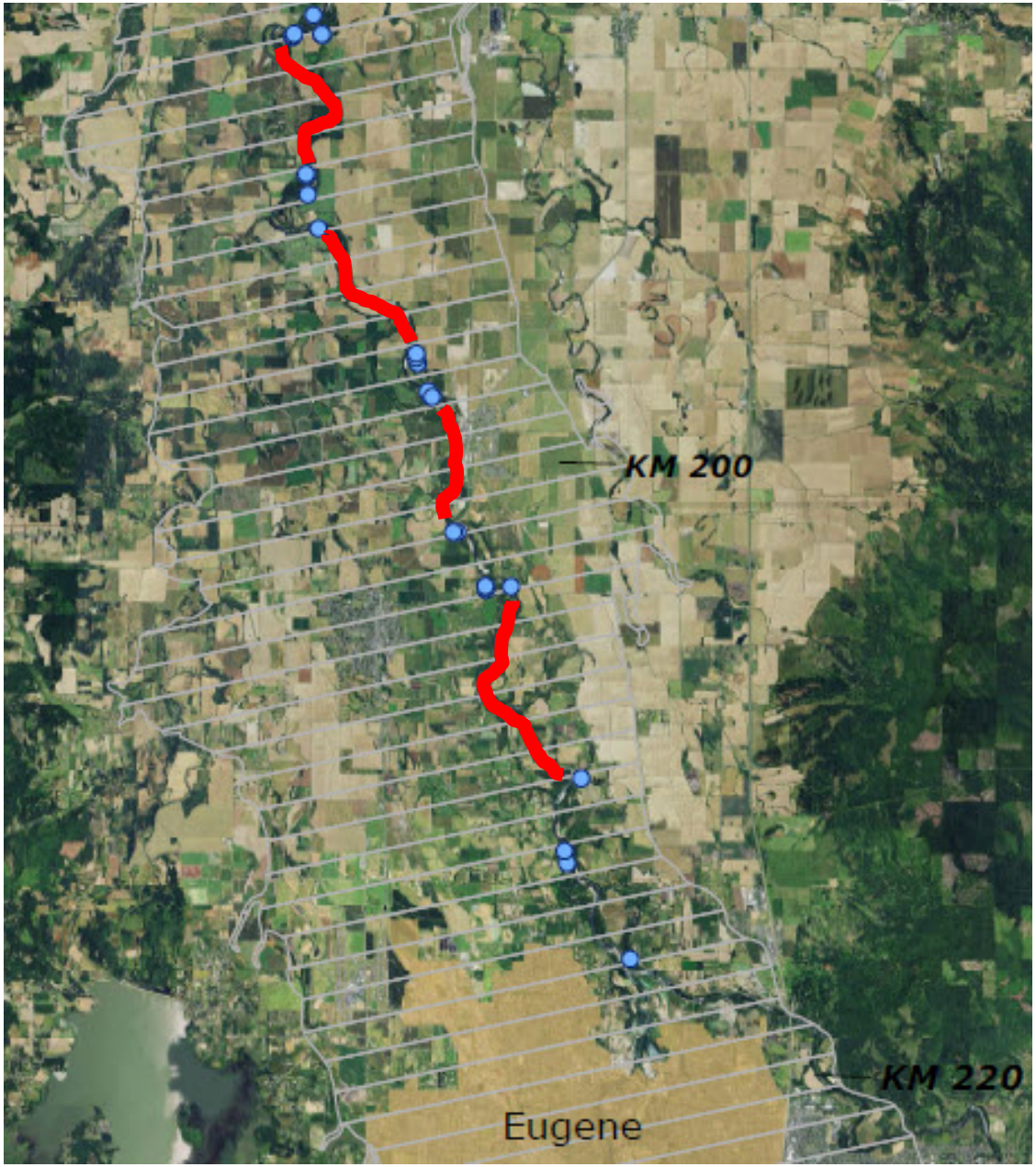


Cold Water Refuge

Not Cold Water Refuge

1 Km Slice

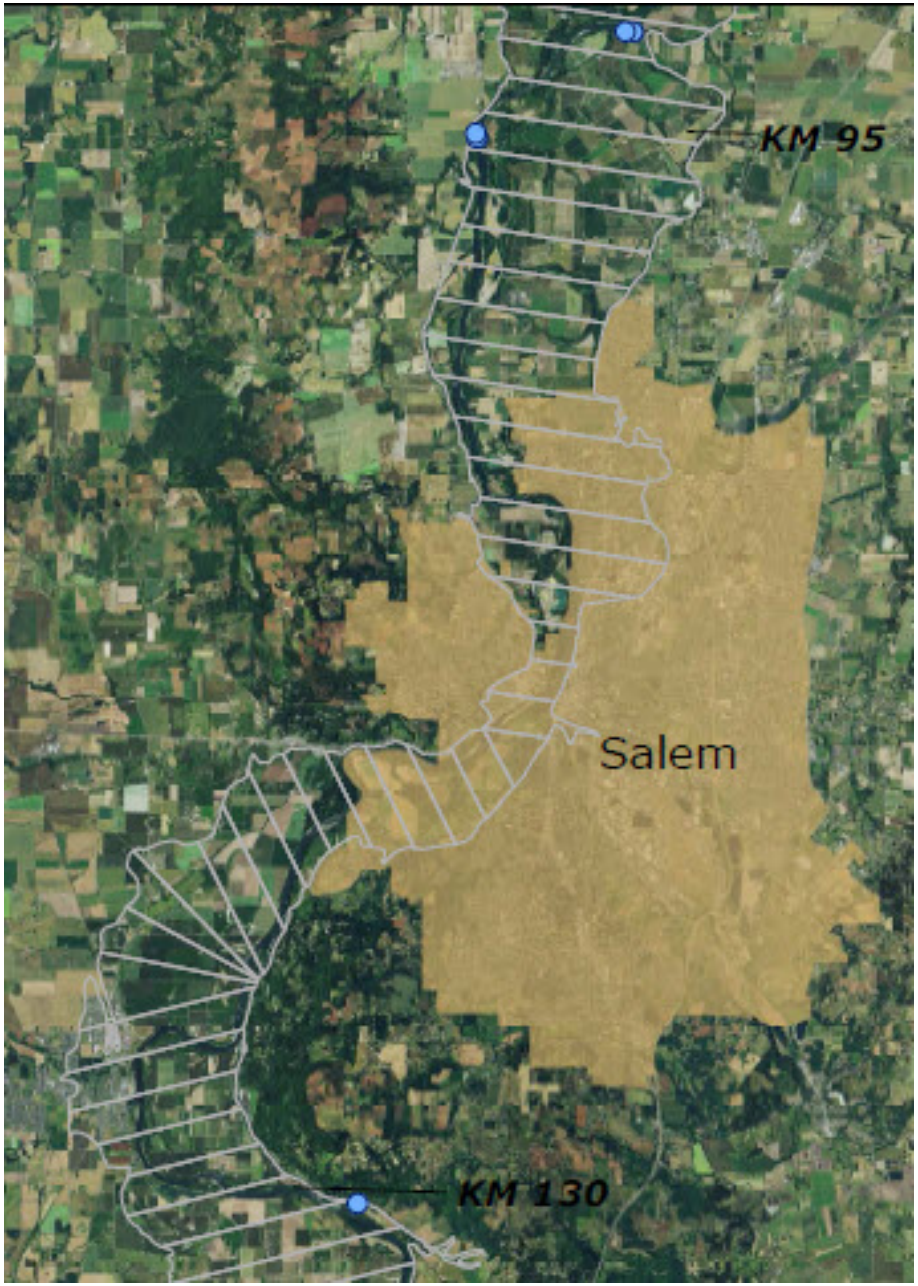
Cold Water Refuges 2011-2015



Cold Water Refuge

1 Km Slice

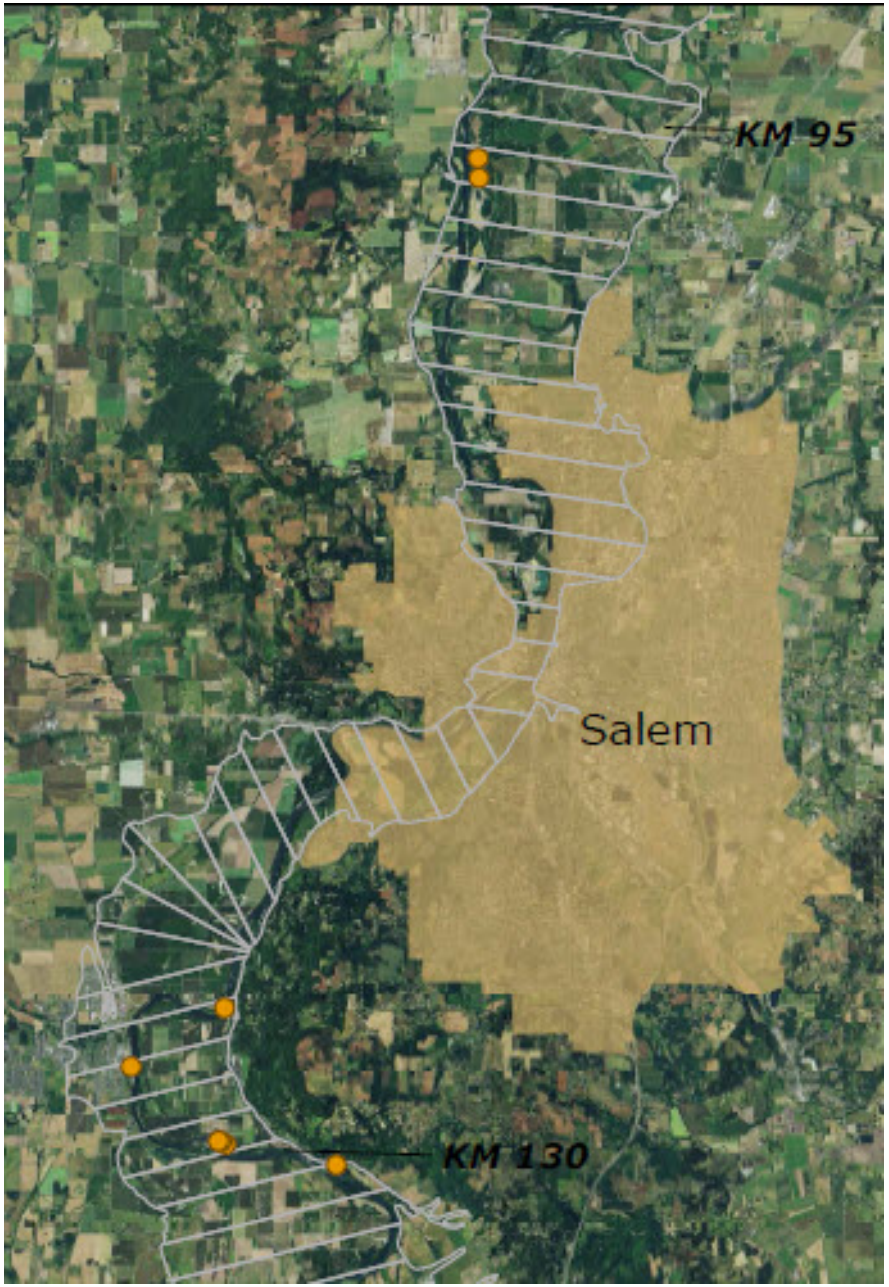
Cold Water Refuges 2011-2015



Cold Water Refuge

1 Km Slice

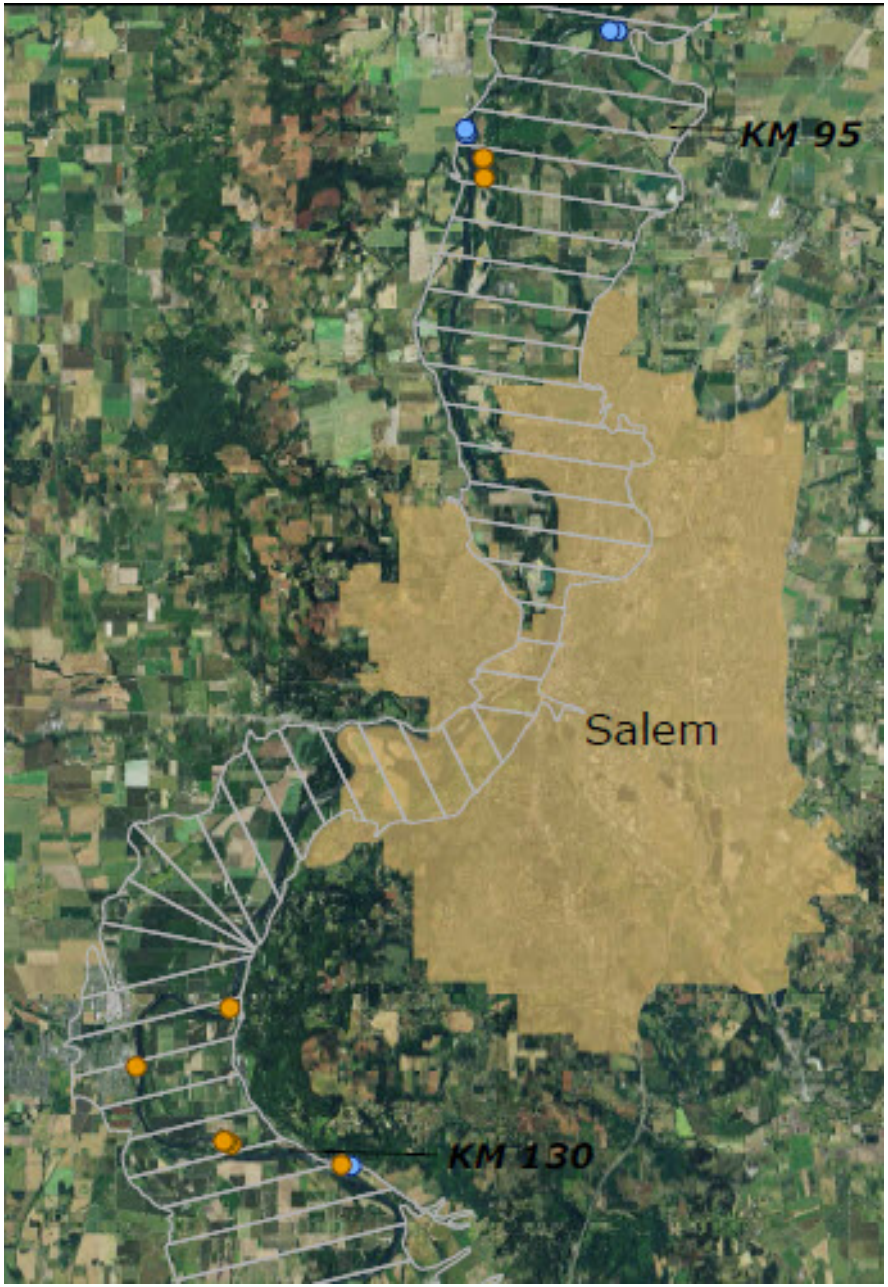
Cold Water Refuges 2011-2015



Not Cold Water Refuge

1 Km Slice

Cold Water Refuges 2011-2015

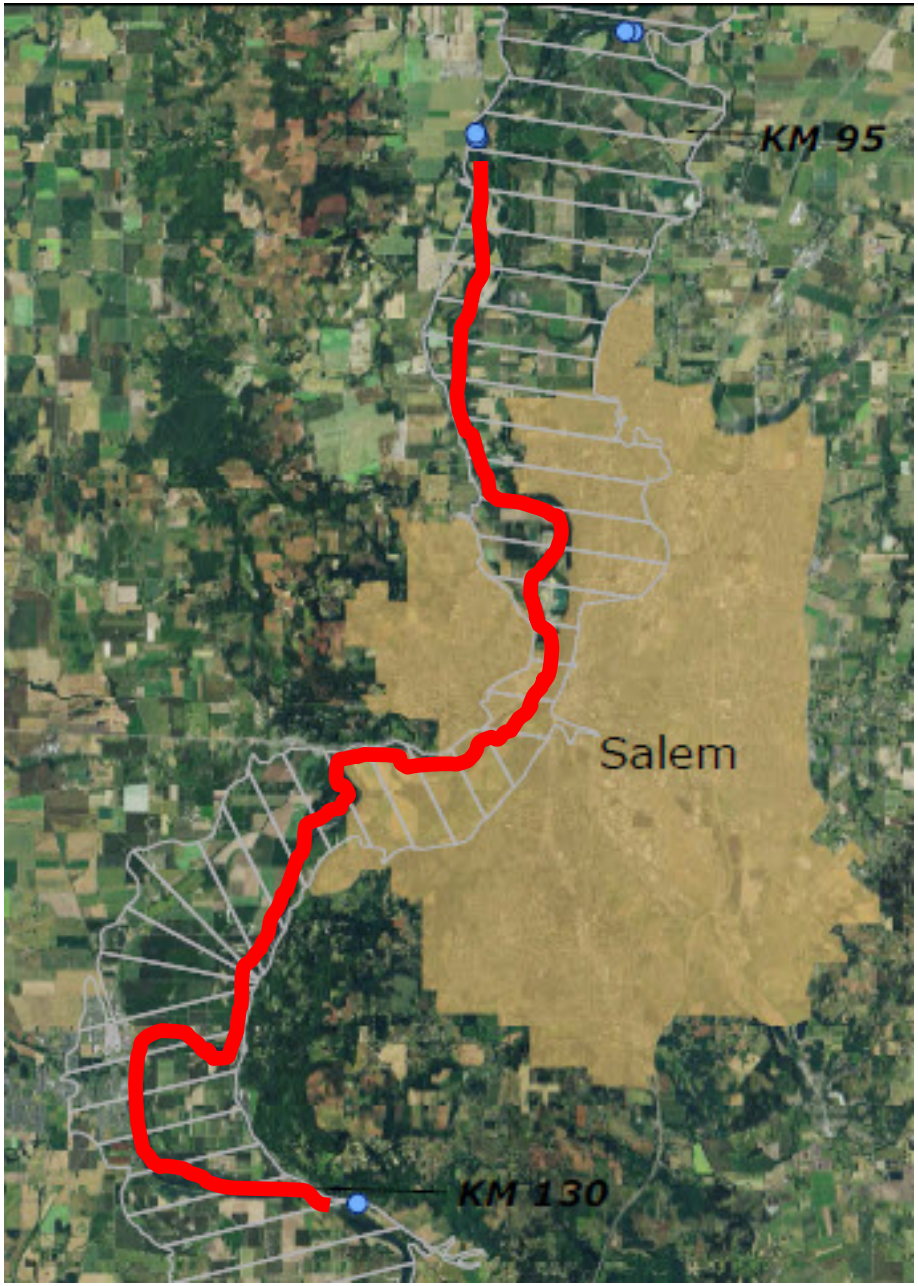


Cold Water Refuge

Not Cold Water Refuge

1 Km Slice

Cold Water Refuges 2011-2015



Cold Water Refuge

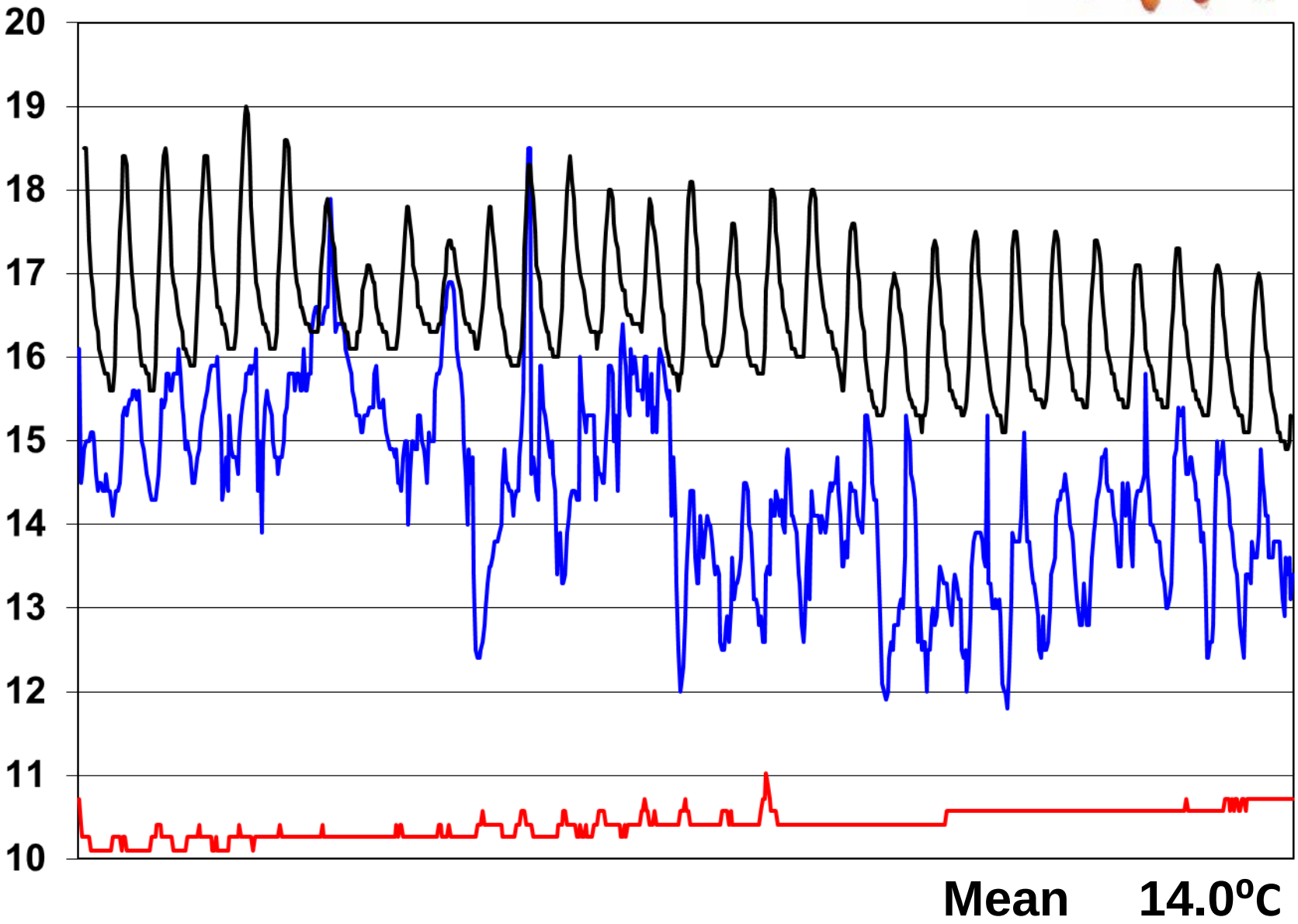
1 Km Slice

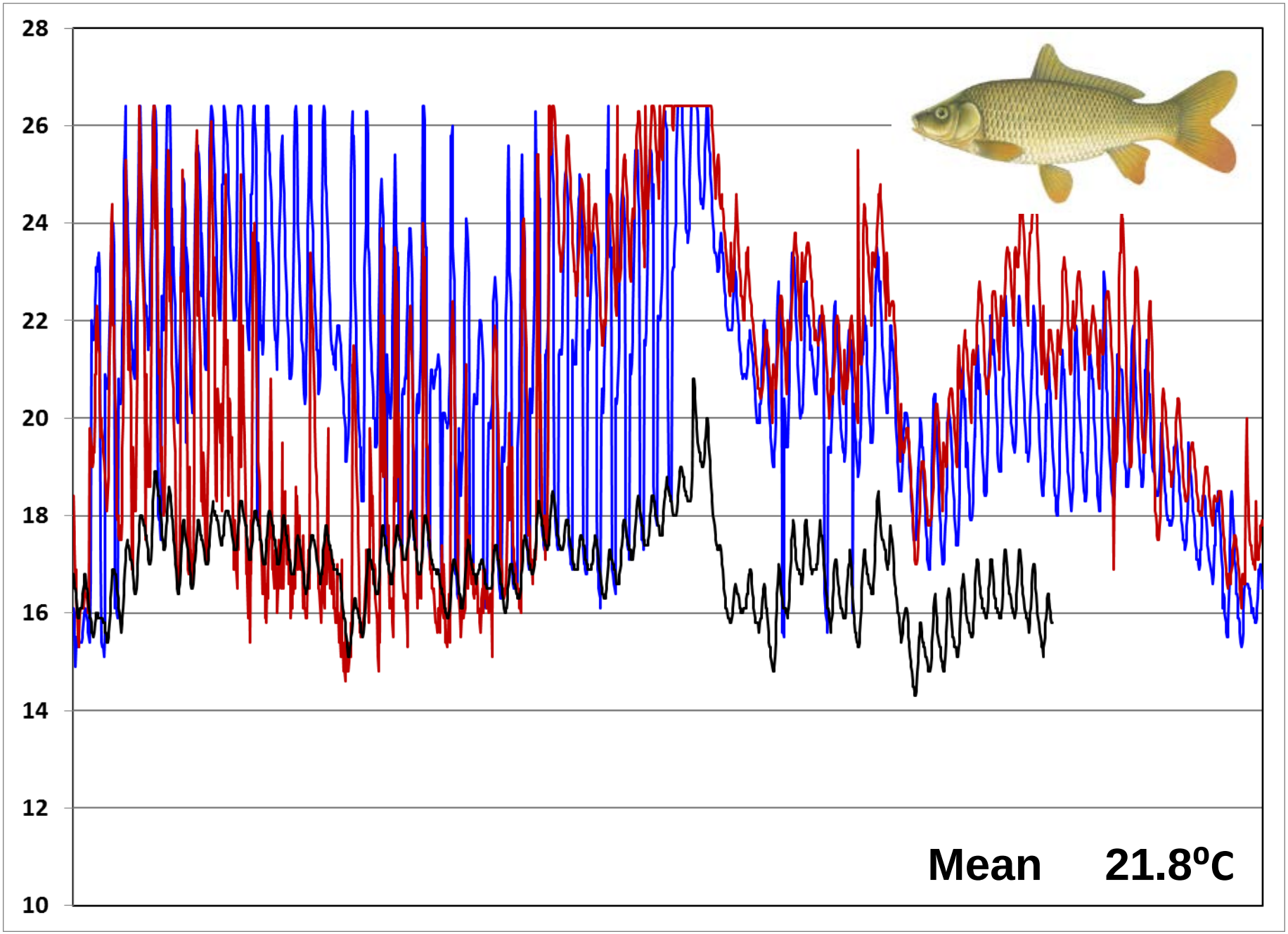
Fish Communities

- **Abundance and number of native fish species were greater than non-native species in cold water habitats,**
- **Native fish made up more than 60% of the individuals captured in cold water sloughs, but non-native fish comprised more than 85% of the fish captured in warm water sloughs.**

Fish Communities

- **Salmonids were 10 times more abundant in cold water sloughs than in warm water sloughs.**
- **Chinook juveniles were found in two of the ten cold water sloughs and were not observed in warm water sloughs.**

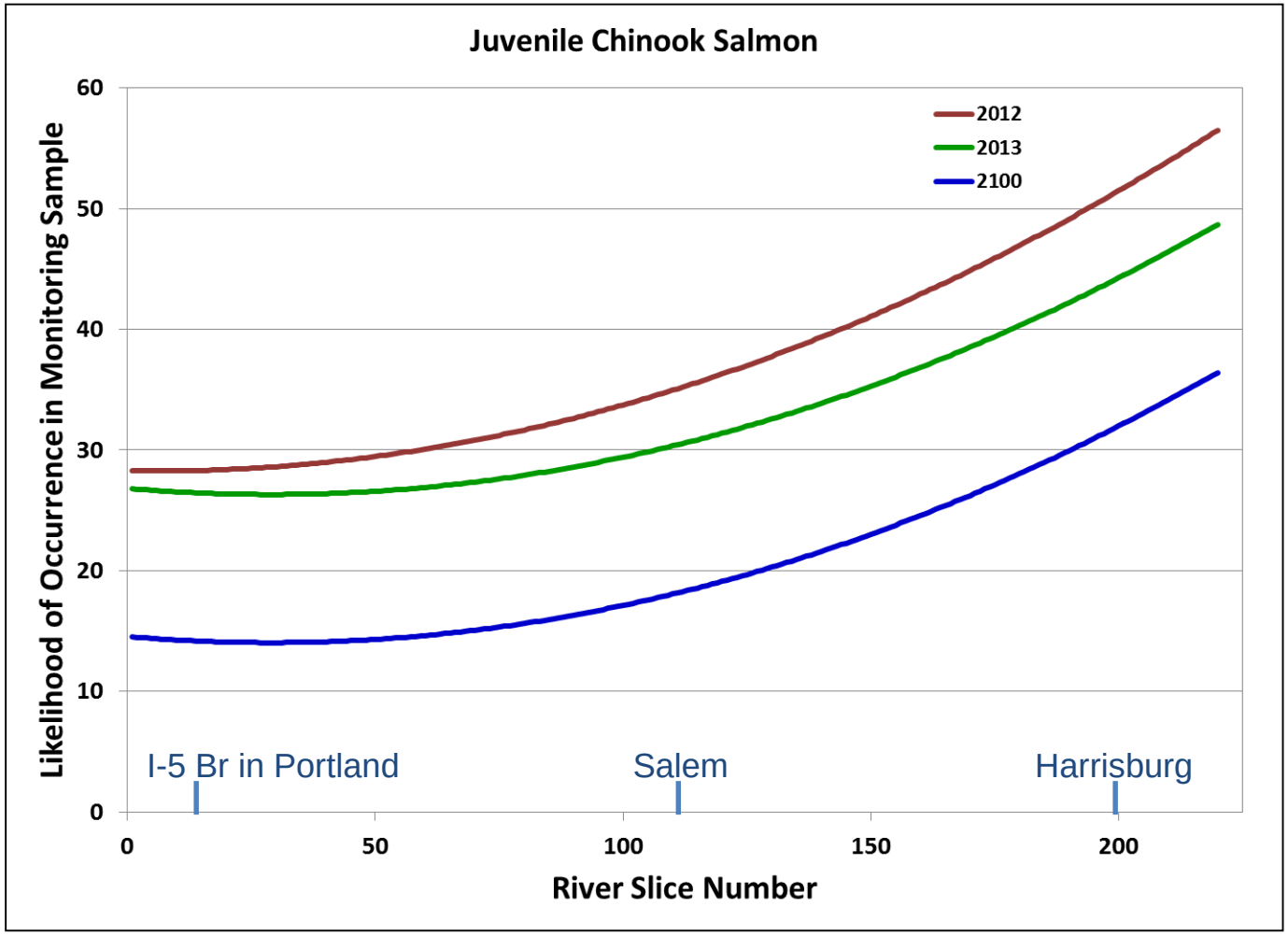

20
19
18
17
16
15
14
13
12
11
10
Mean 14.0°C


28
26
24
22
20
18
16
14
12
10
Mean 21.8ºC

High Confidence Future Projections

- **The likelihood of occurrence for cold-water species along the river is likely to decrease as river temperatures warm in the future.**

- **Cold water habitats associated with the floodplain and active gravel bars provide potential refuges for native fish during periods of high water temperature.**


Juvenile Chinook Salmon
Likelihood of Occurrence in Monitoring Sample
60
50
40
30
20
10
0
2012
2013
2100
I-5 Br in Portland
Salem
Harrisburg
0
50
100
150
200
River Slice Number

High Confidence Future Projections

- **The river is changing because of human caused changes in hydrology and sediment supply.**
- **A new river is forming and the occurrence of cold water habitats will depend on the dynamics of the channel and floodplain.**
- **We are working to develop a more rigorous and widely shared vision of the new Willamette River.**

SLICES Framework

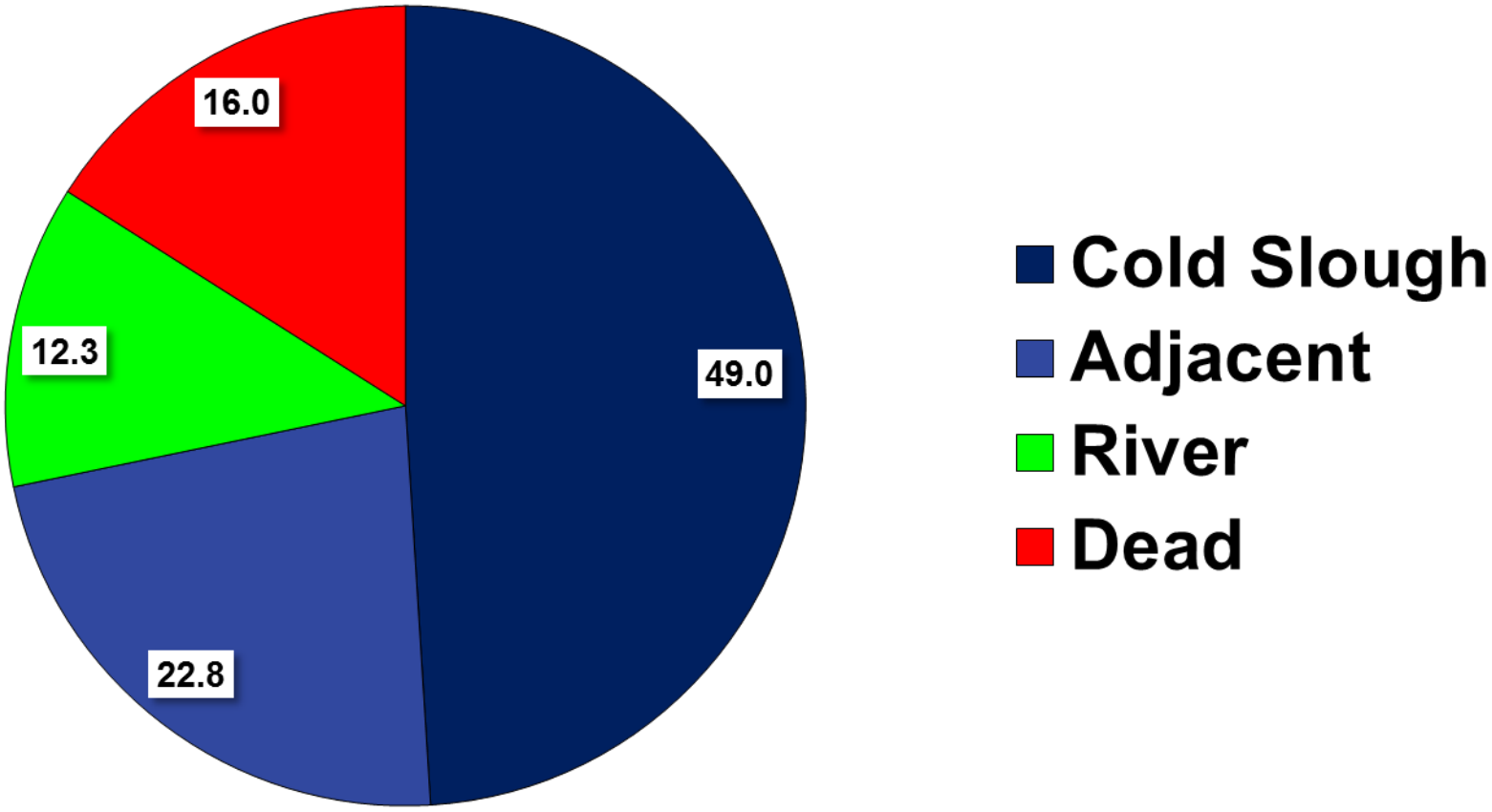
- David Hulse and his research team at the University of Oregon are integrating the cold water refuge information into the SLICES framework, a spatially explicit floodplain framework for the Willamette River.
- The SLICES database provides a context to identify cold water refuges as a basis for designing floodplain and river restoration actions to create cold water habitats (http://ise.uoregon.edu/slices/Main.html).

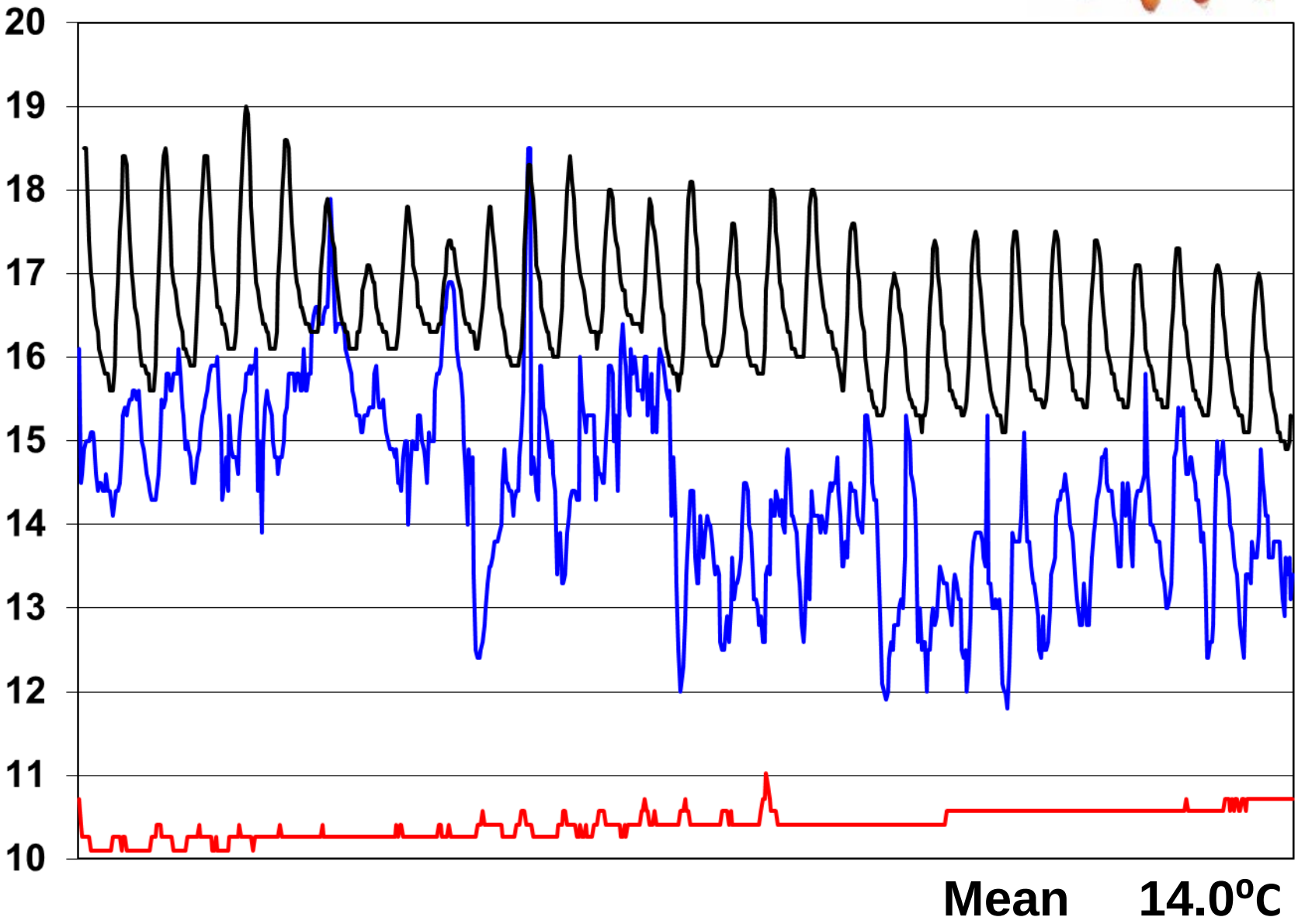
- THE END

- EXTRA SLIDES IF QUESTIONS


BITE ME

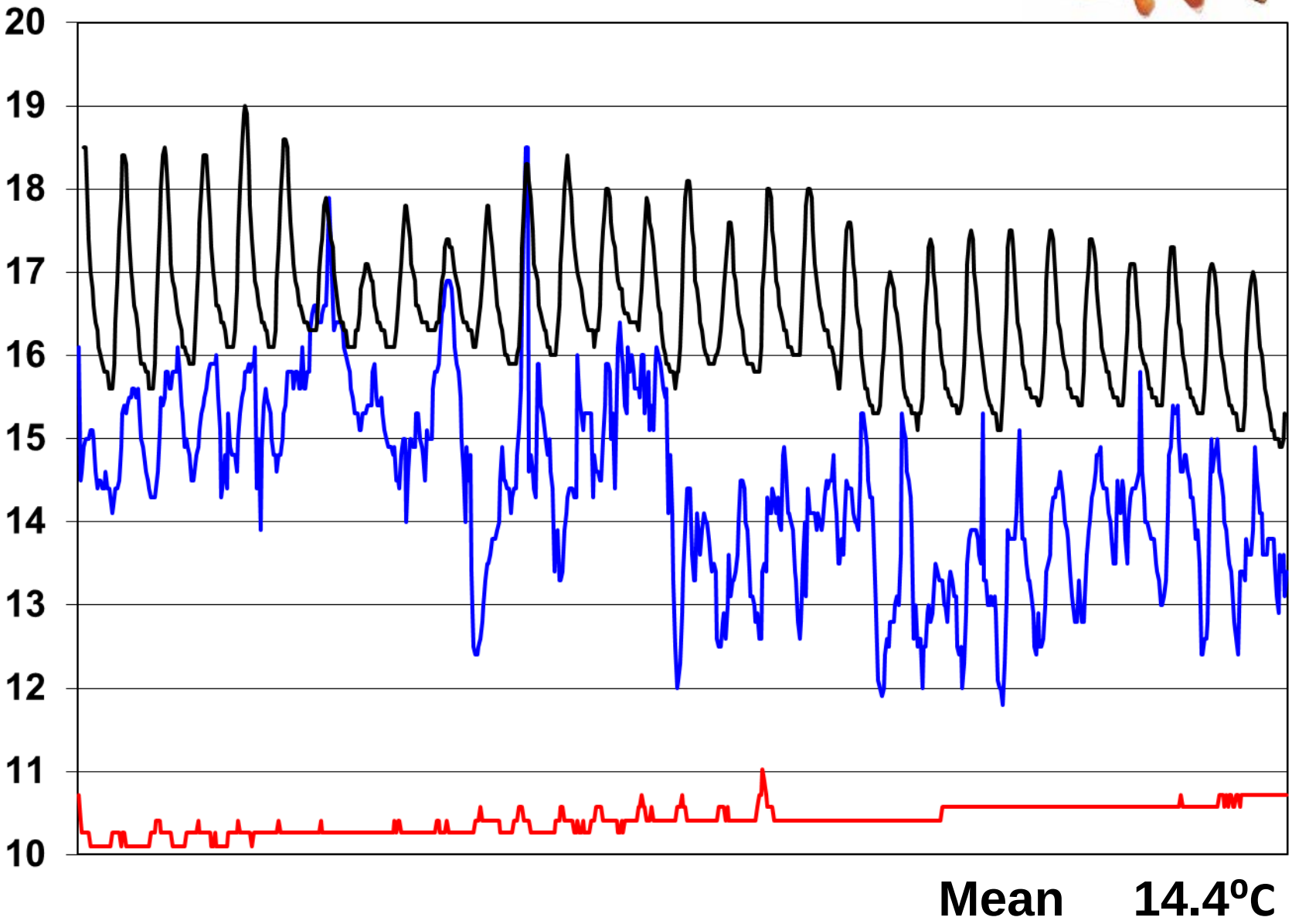
Trout Movement — 2008 and 2009




20
19
18
17
16
15
14
13
12
11
10
Mean 14.0°C

20
19
18
17
16
15
14
13
12
11
10

Mean 13.8ºC


20
19
18
17
16
15
14
13
12
11
10
Mean 14.4ºC


Slice 155
(1 km slices)
Slice 15501
Slice 15505
Slice 15508

SLICES Framework

- **The SLICES framework has been used to identify critical reaches for conservation and restoration projects, including identification of potential cold water refuges.**
- **OWEB and Meyer Memorial Trust have used data from this project to develop the anchor habitats framework for Willamette Partnership.**
- **SLICES information is used in Willamette proposals and the new OWEB Focused Investment Partnership program.**