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

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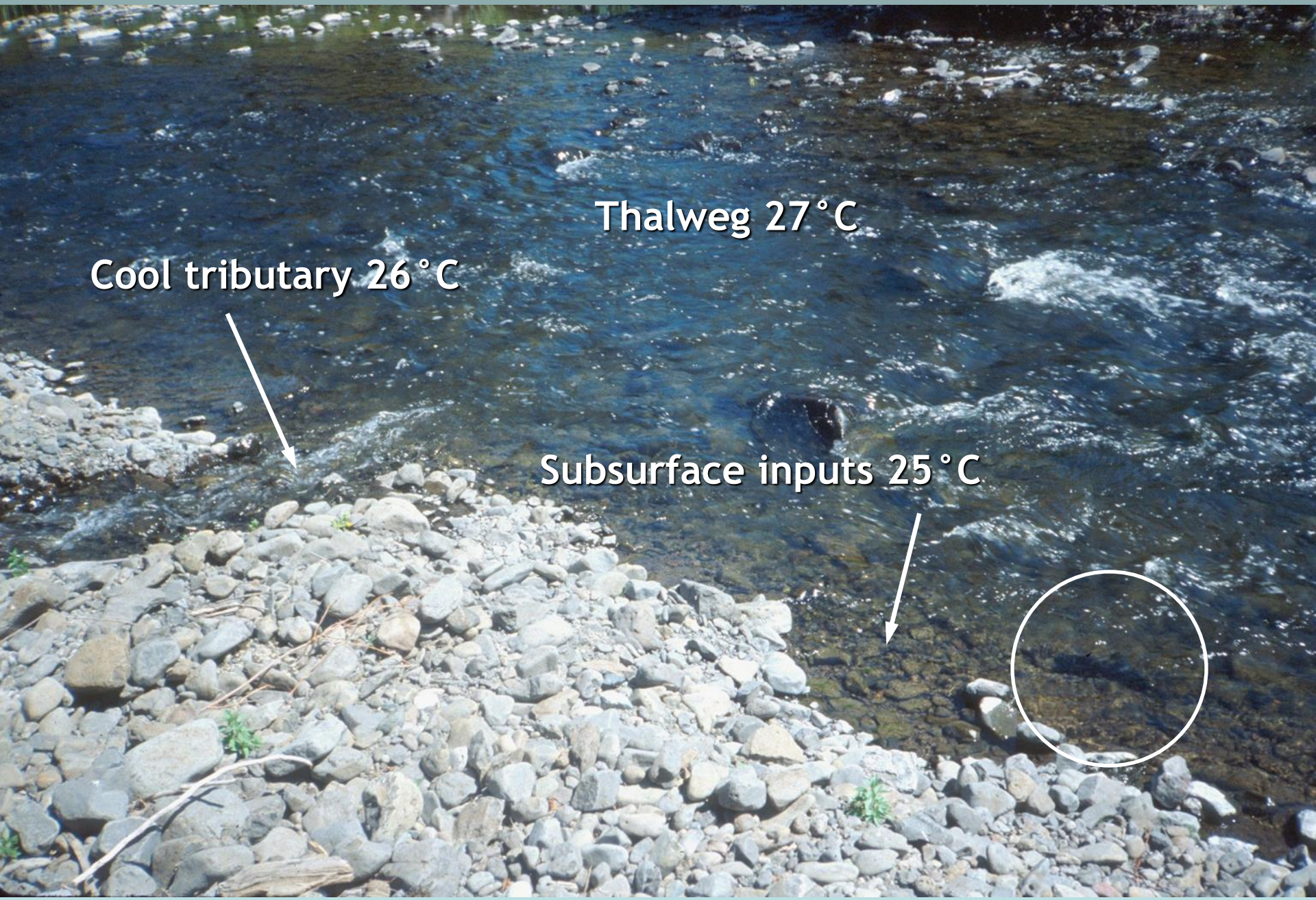
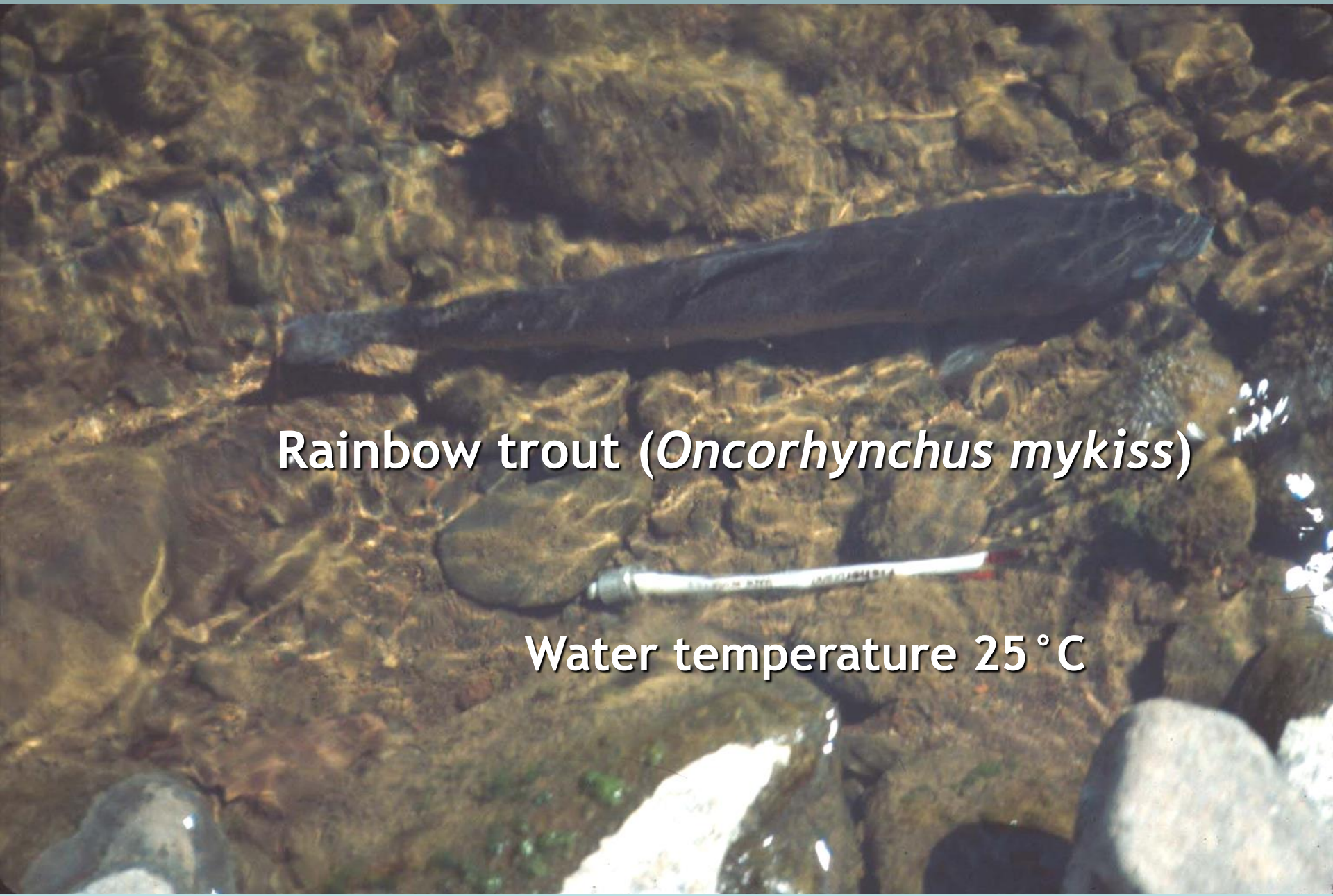
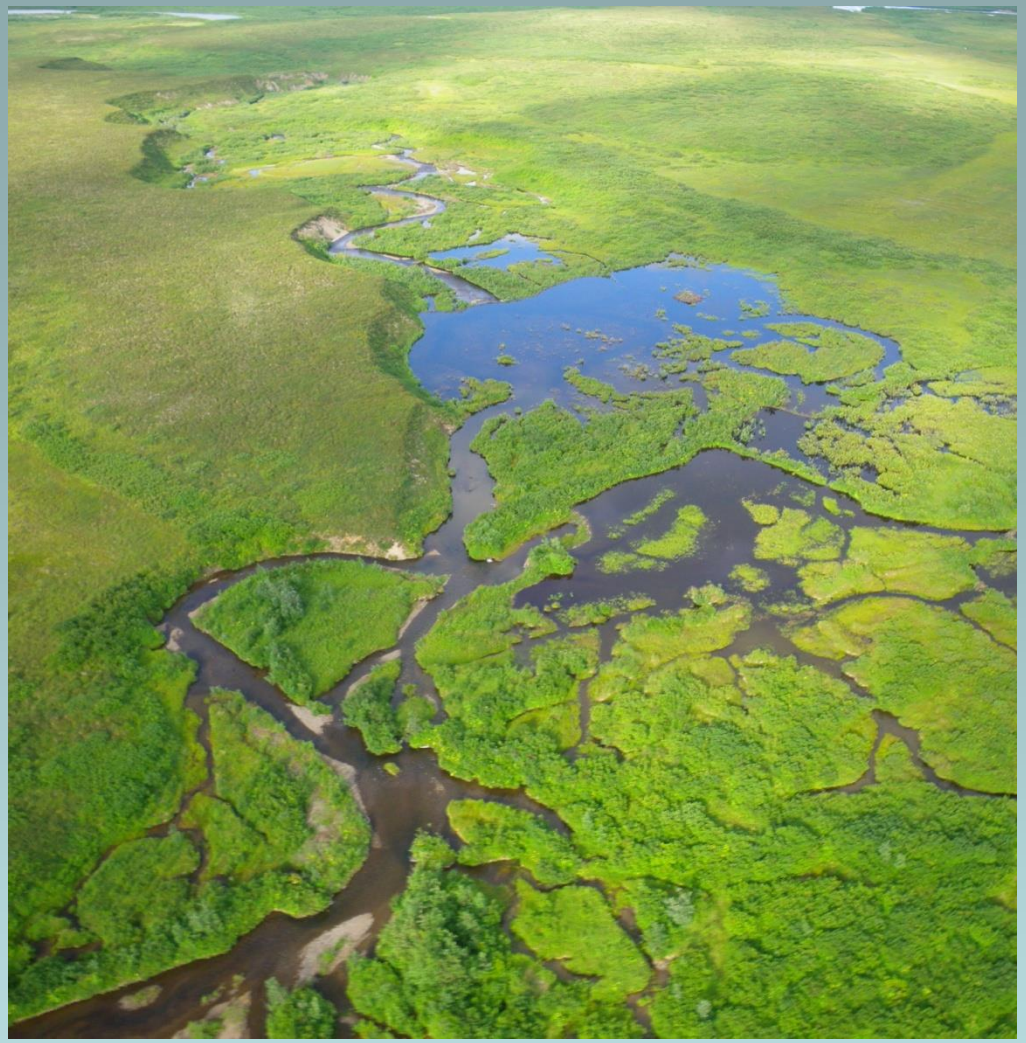

Thalweg 27˚C
Cool tributary 26˚C
Subsurface inputs 25˚C


Rainbow trout (*Oncorhynchus mykiss*)
Water temperature 25˚C

Thermal Diversity in Riverine Landscapes

Growth and survival of trout and salmon are higher in pristine "cold" streams when fish can move between relatively cold and warm patches (4-18˚C).



Alaska

(Armstrong et al. 2010, Ruff et al. 2011)

Management and policy

"Critical aspects of the natural thermal regime that should be protected and restored include the **spatial extent of cold-water refugia (generally defined as waters that are 2°C colder than the surrounding water**), the diurnal temperature variation, the seasonal temperature variation (i.e., number of days at or near the maximum temperature), and shifts in the annual temperature pattern." **EPA**

"**Cold-Water Refugia means those portions of a water body where or times during the diel temperature cycle when the water temperature is at least 2°C colder than the daily maximum temperature of the adjacent well-mixed flow of the water body**." **ORDEQ**

Part I.

- What are CWRs and why are they important?
- Road map for addressing water quality standards
- Application to EPA guidance on migration corridors

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

EPA

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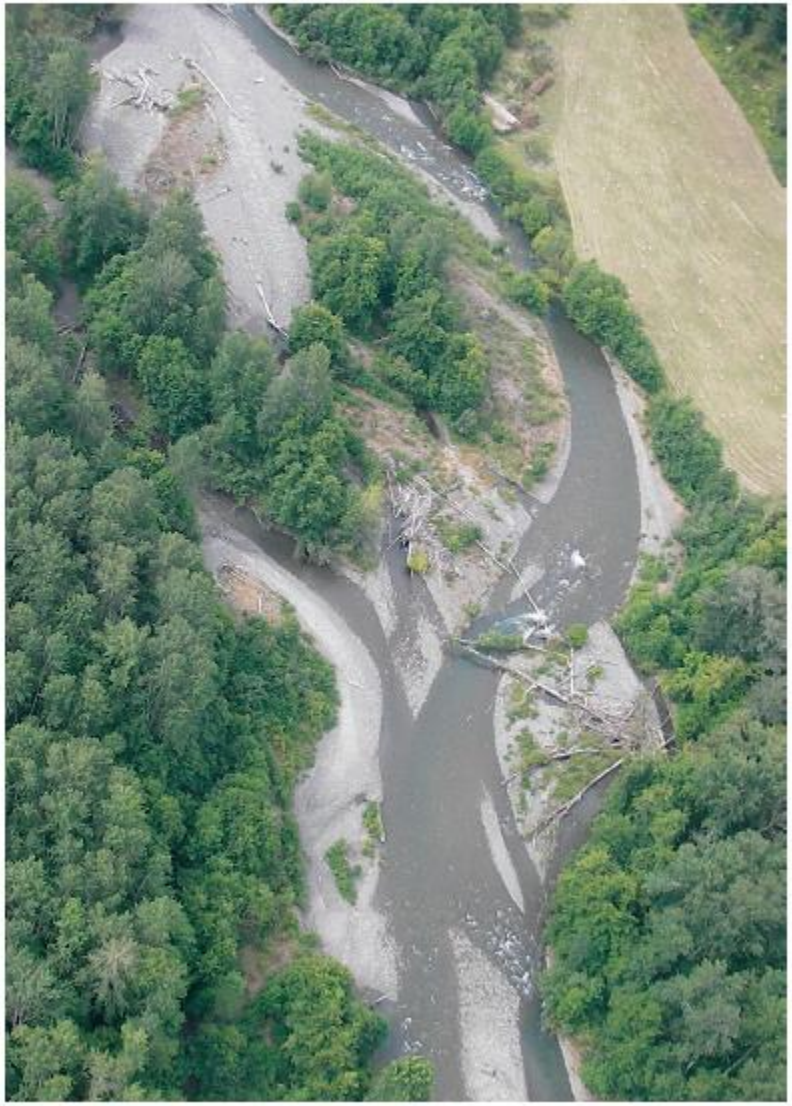


90 pp.

Part II.

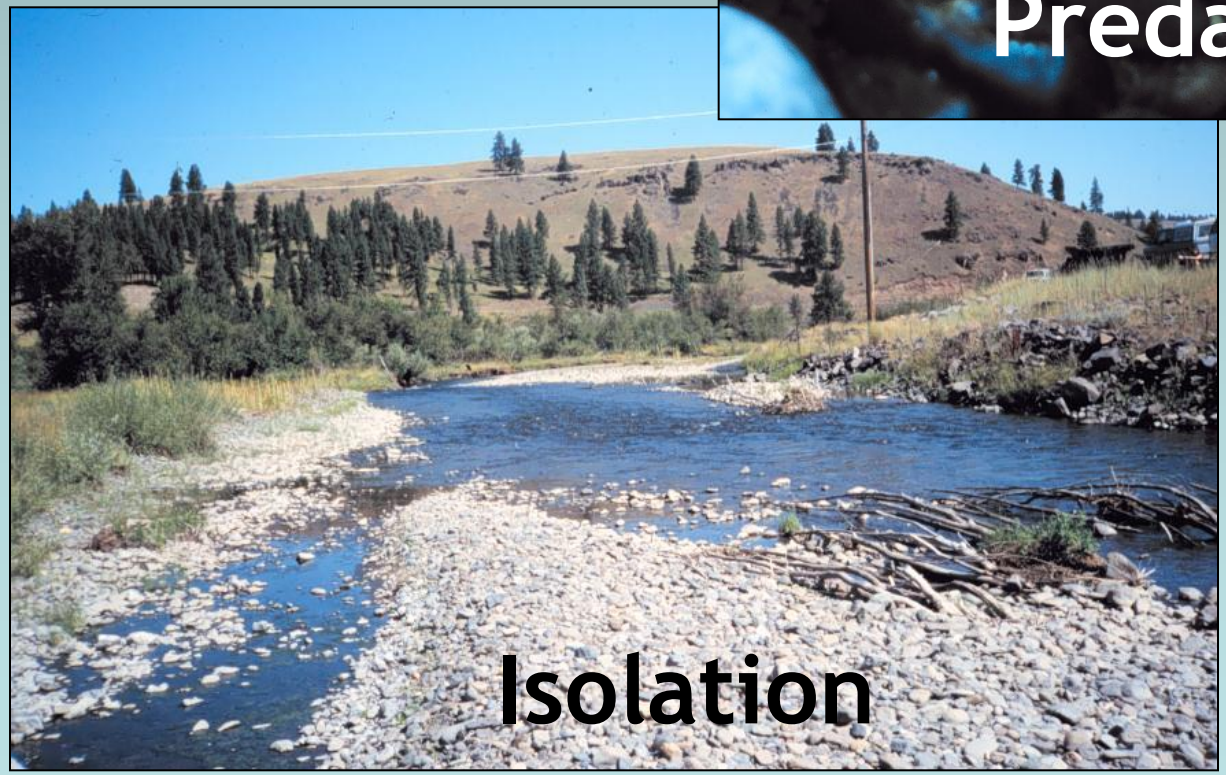
- Classification and characterization
  - Hierarchical organization
- Identification and prediction
- Protection and restoration

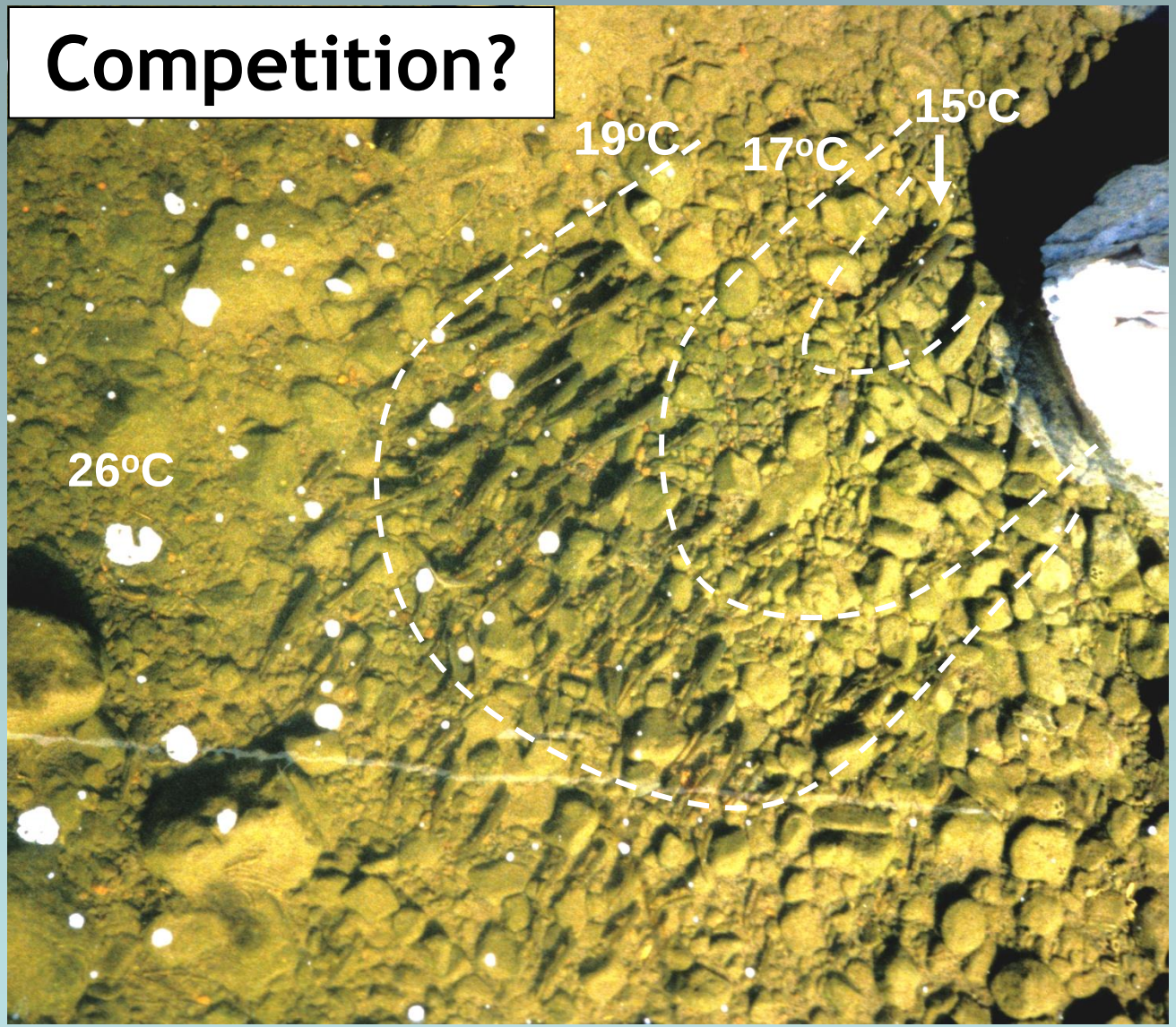
Part III.

- Figures (38)
- References (251)
- Appendices:
  - Video from WDAFS symposium
  - List of rivers and streams surveyed with FLIR (1994-2007)

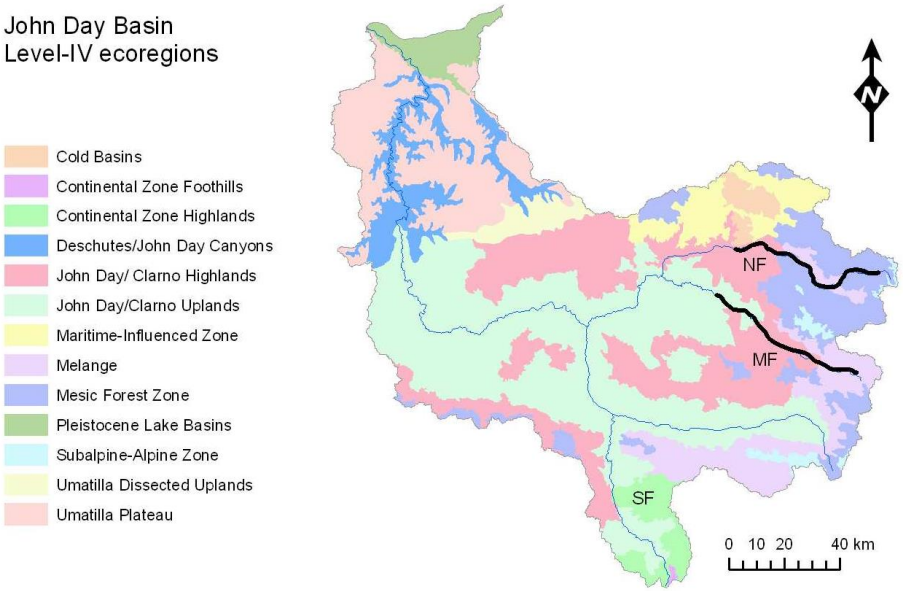
Behavioral thermoregulation

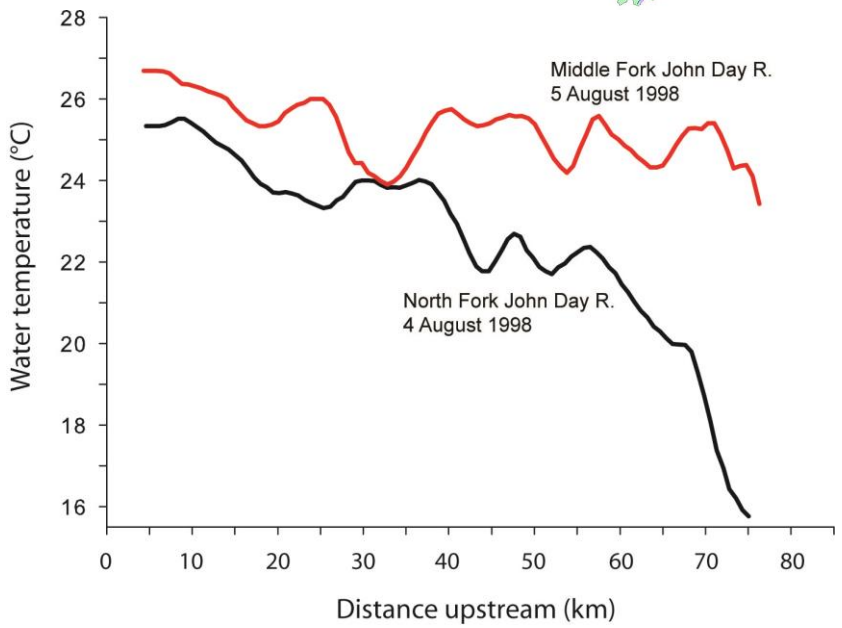
Potential tradeoffs




Competition?
19°C
17°C
15°C
26°C

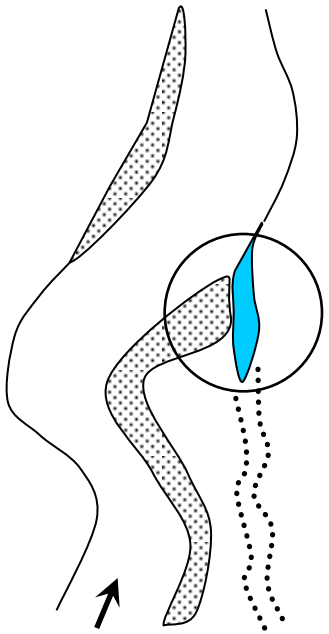
Classification and characterization



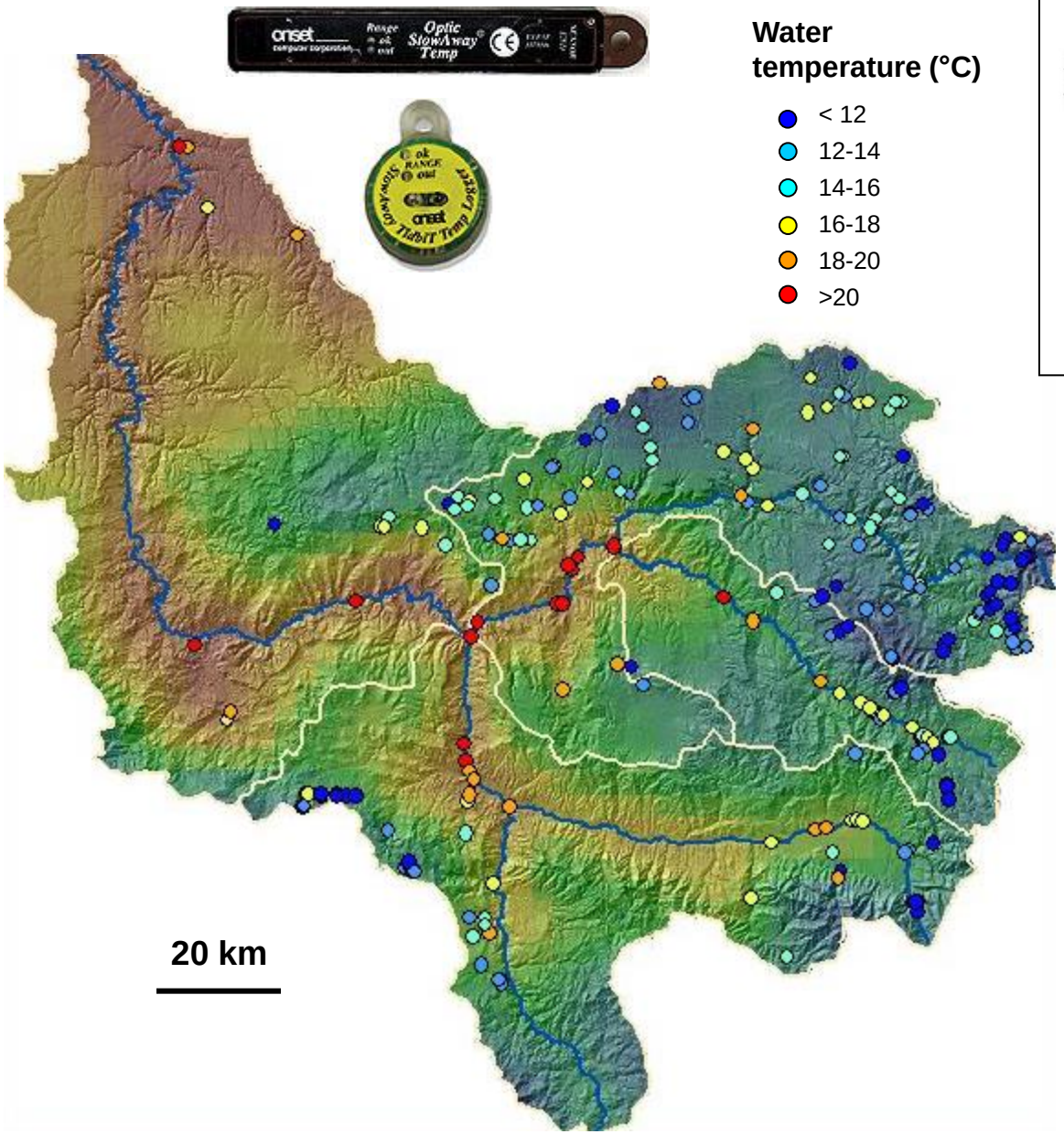


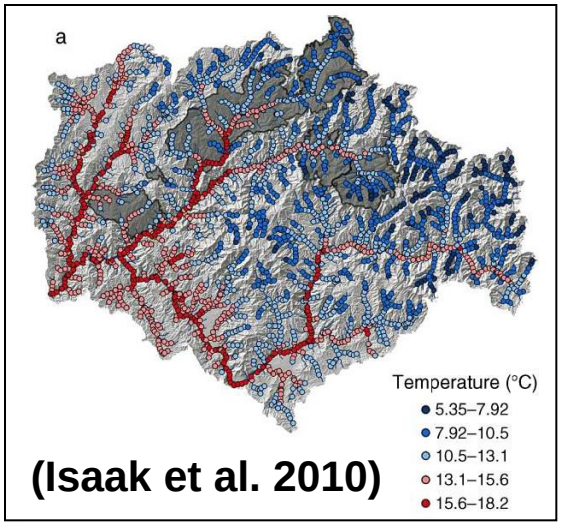
Basin and subbasin scale

Cold alcove



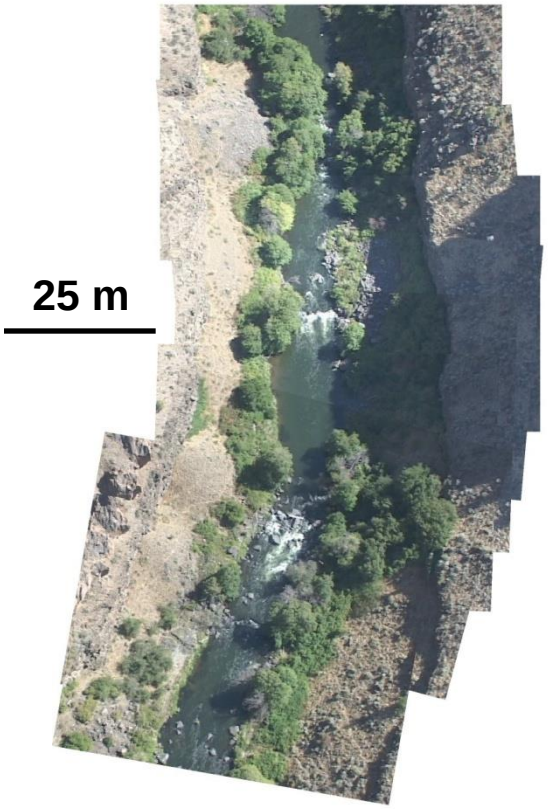
Identification and prediction

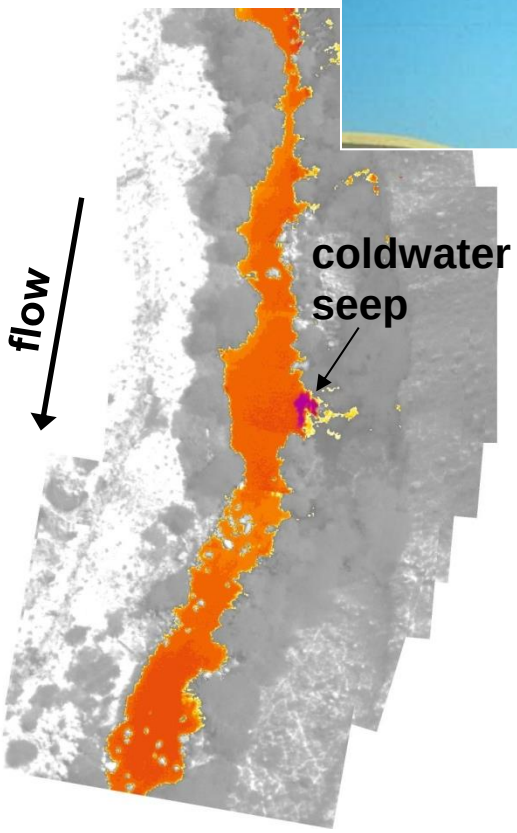




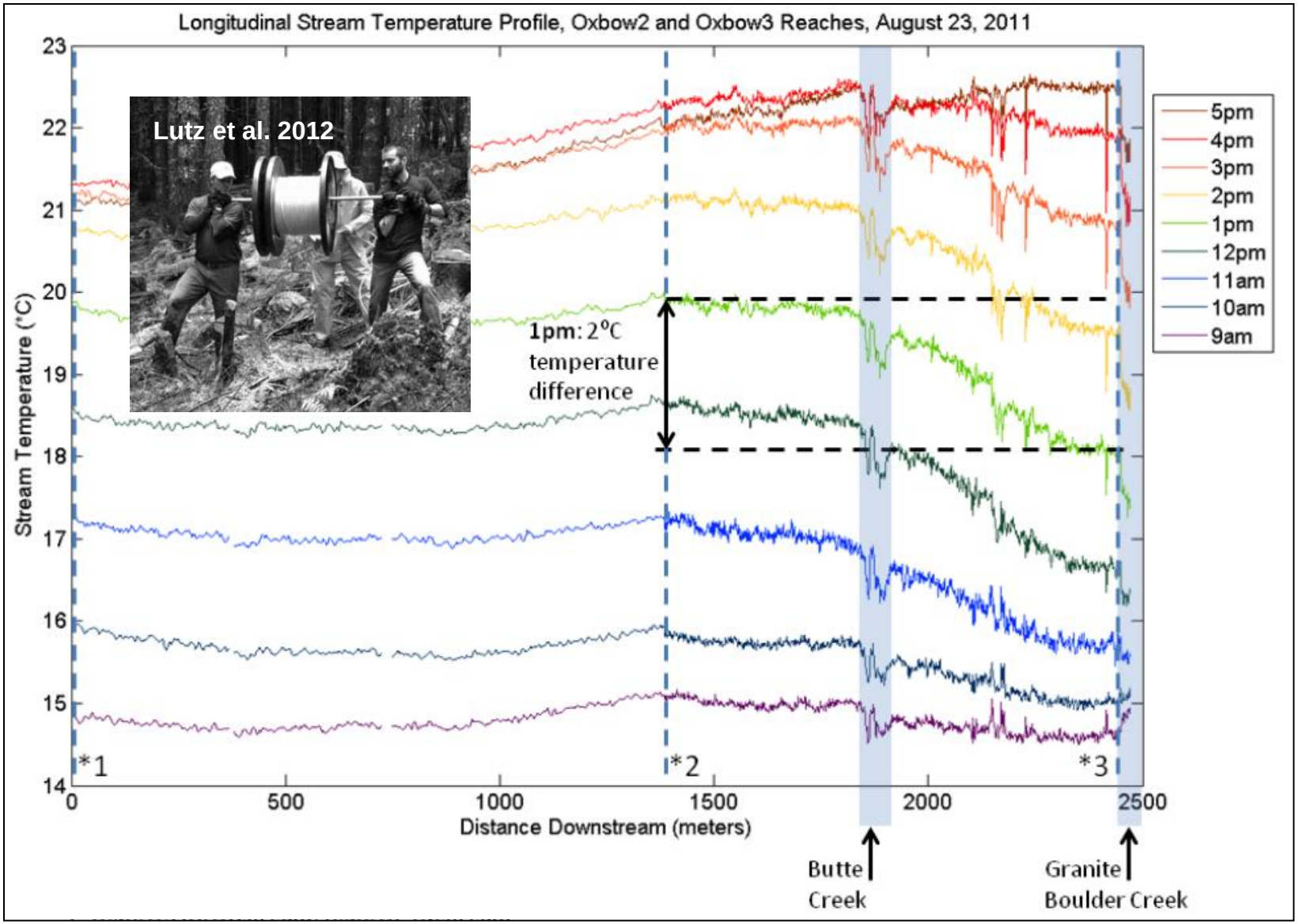
(Isaak et al. 2010)

Data loggers and modeling

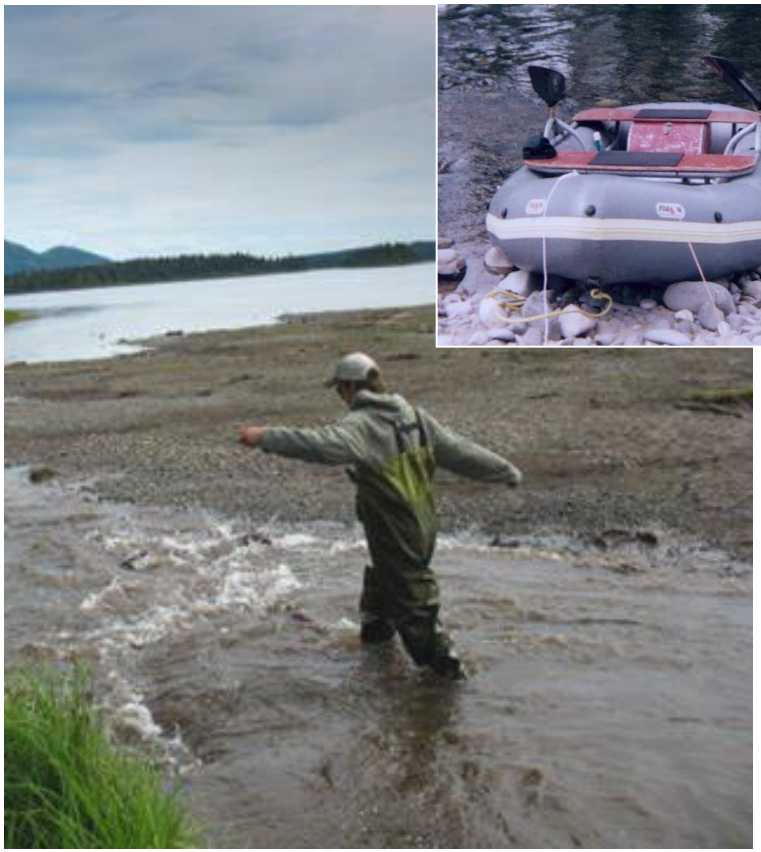

25 m


flow
coldwater
seep

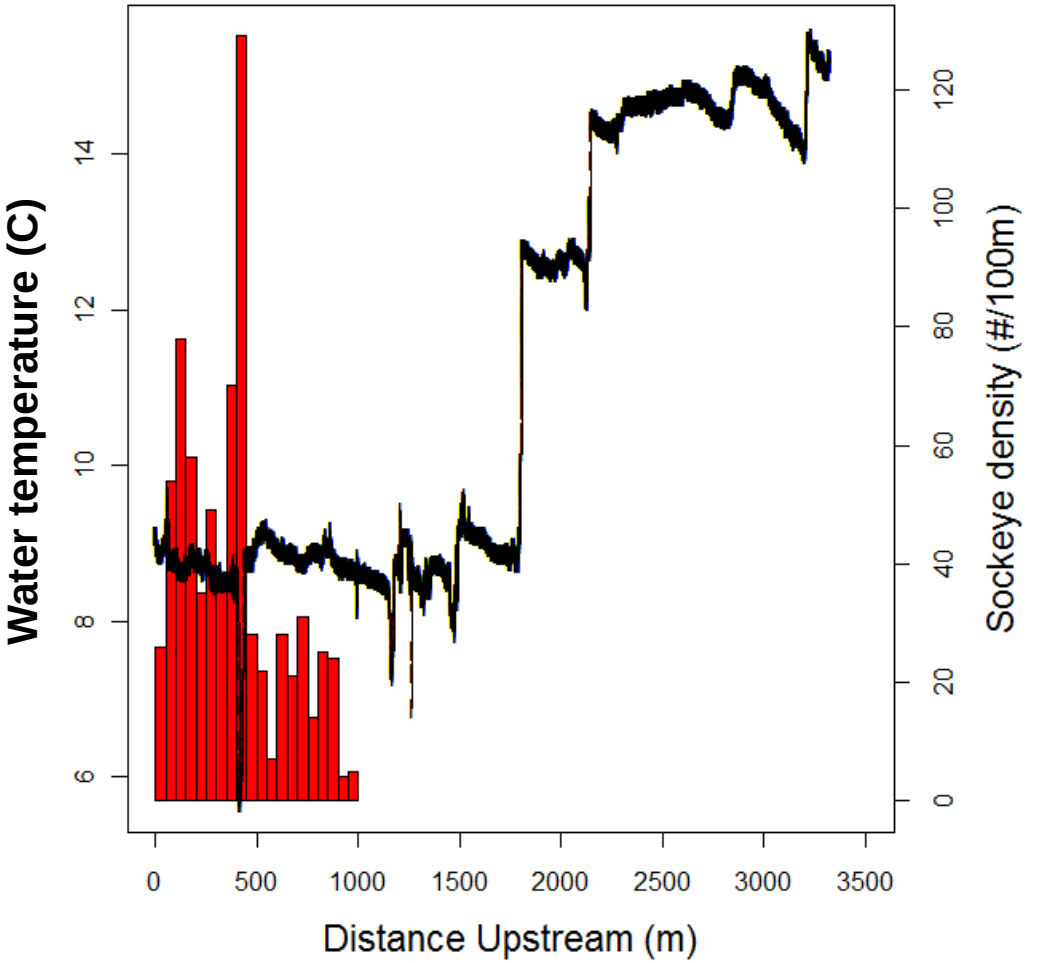

cool
warm
13°C
17°C
20°C



Distributed temperature sensing (DTS) **(O'Donnell 2012)**

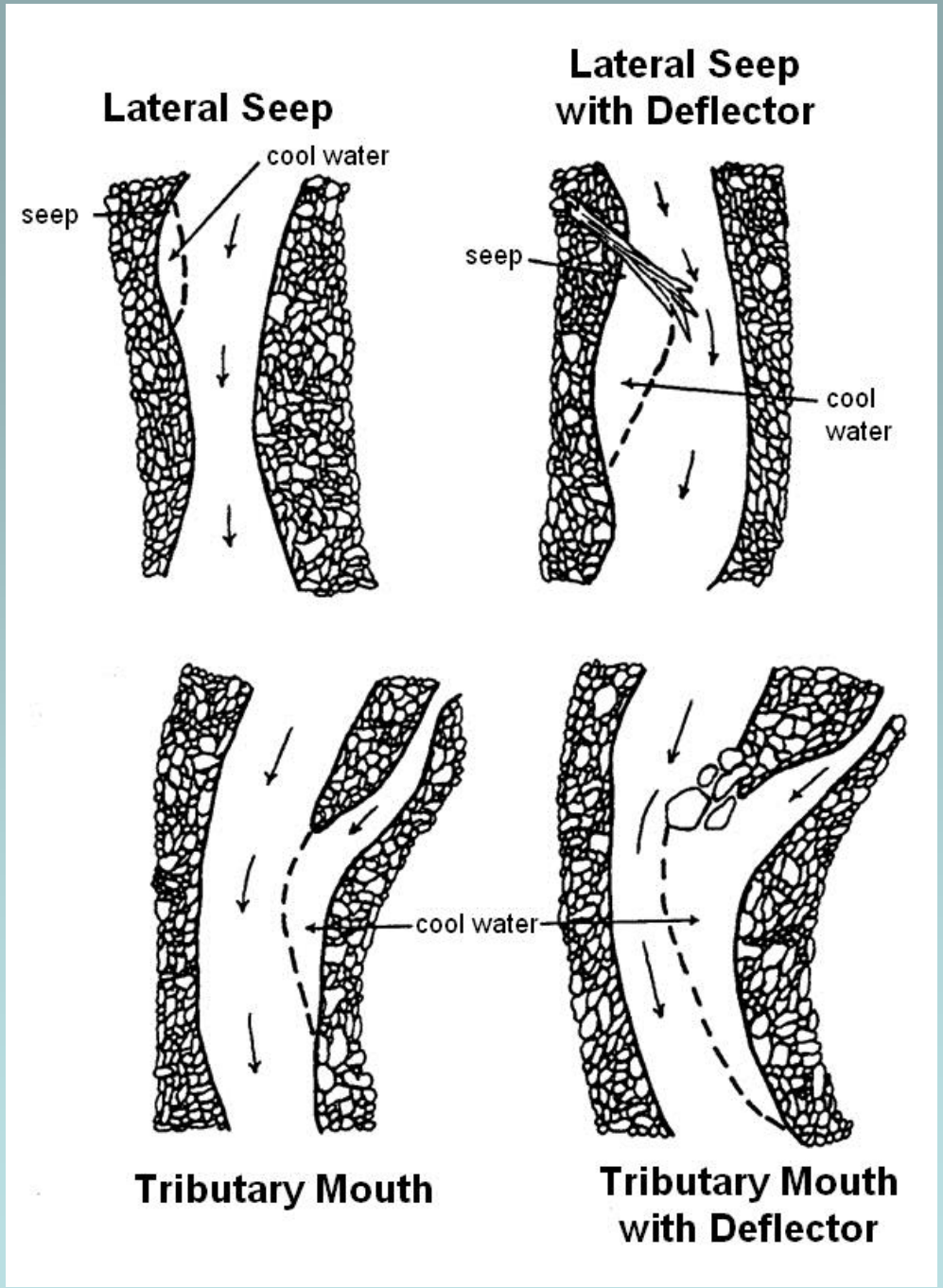



HOBO Pro v2
2 ext temp
onset


Water temperature (C)
6
8
10
12
14
Sockeye density (#/100m)
0
20
40
60
80
100
120
0
500
1000
1500
2000
2500
3000
3500
Distance Upstream (m)

Restoration

Channel unit and microhabitat-scale restoration of cool-water areas



Challenges and research needs

- **What is a thermal refuge?**
  - Provide scientific guidance for **policy definitions**
- **Temperature is not the only factor**
  - Differentiate between thermal anomalies versus refuges based on their **biological effectiveness**
- **Shifting mosaic of thermal landscapes**
  - Consider the full range of complexity in **space and time**
  - Address protection and restoration needs at multiple scales (e.g., microhabitats to the "**Big Cold**")

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Website on EPA Region 10 Water Temperature Guidance:
www.epa.gov/r10earth/temperature.htm

Download report:
http://www.epa.gov/region10/pdf/water/torgersen_etal_2012_cold_water_refuges.pdf

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