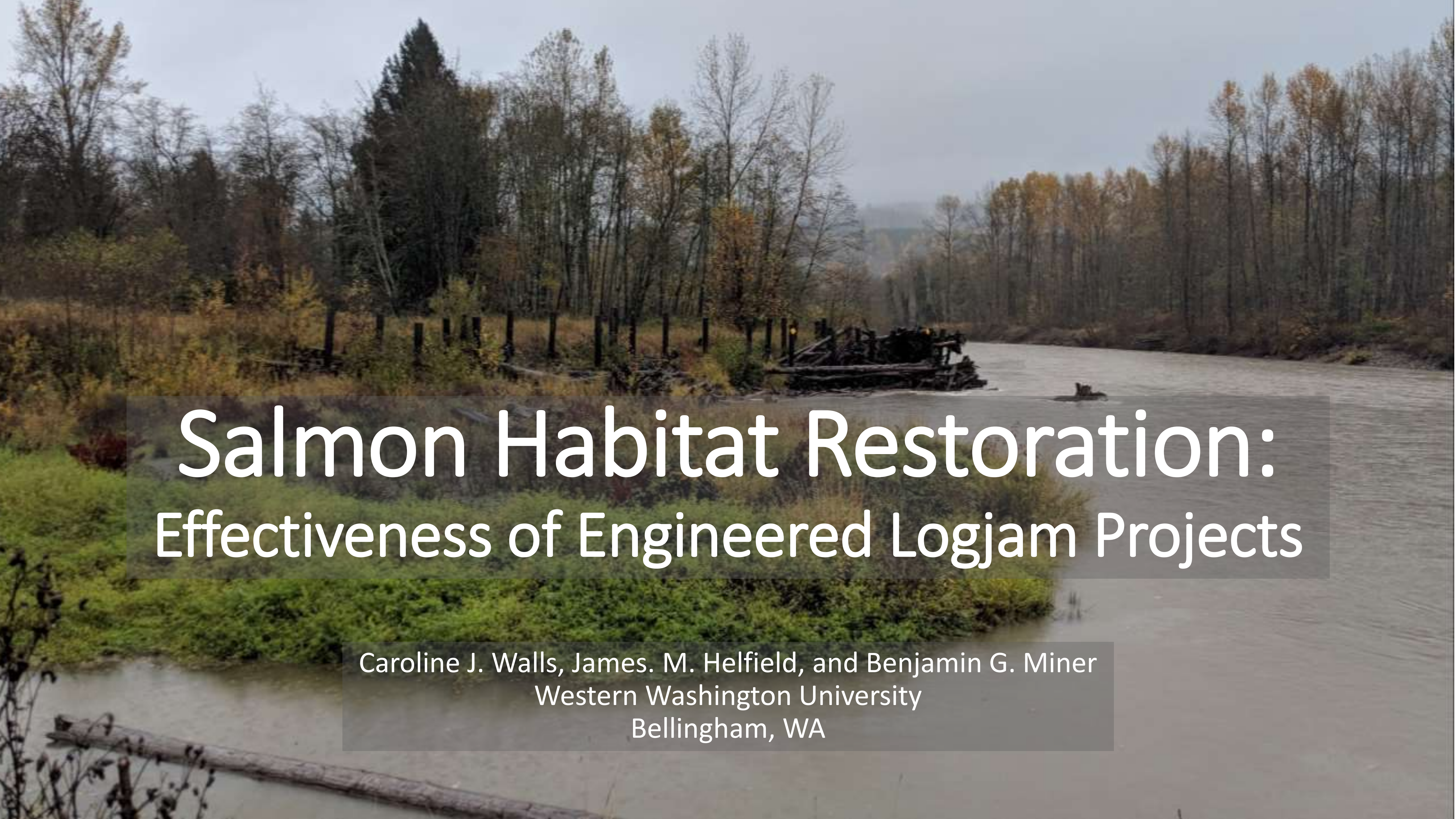

Salmon Habitat Restoration:
Effectiveness of Engineered Logjam Projects

Caroline J. Walls, James. M. Helfield, and Benjamin G. Miner
Western Washington University
Bellingham, WA

Pacific Salmon (*Oncorhynchus* spp.) are Important

Salmon in Decline

1/3 of historical salmon populations in PNW have gone extinct (Gustafson et al. 2007)

Salmon have been extirpated in 40% of their historical range in the PNW (National Research Council 1996)

28 of the 51 Pacific salmon evolutionary significant units are listed under the Endangered Species Act (NOAA 2015)

Freshwater Habitat Degradation

Decline of Large Woody Debris

- Harvesting of large riparian trees
- Stream clearing for navigation

Source: The History Museum of Hood River County

Property of Museum of History & Industry, Seattle

Large Woody Debris in Streams

1. Flow impediment / Bank armoring
   - Aeration of water
   - Reduces peak flow energy
   - Reduces erosion/siltation

2. Flow deflection
   - Pool creation
   - Meander formation
   - Increased Habitat Complexity

3. Channel aggradation
   - Reduces incision
   - Promote floodplain development

4. Substrate
   - Retention of fine sediments
   - Macroinvertebrate habitat

5. Fish Cover

6. Source of organic material/nutrients
   - Slowly released

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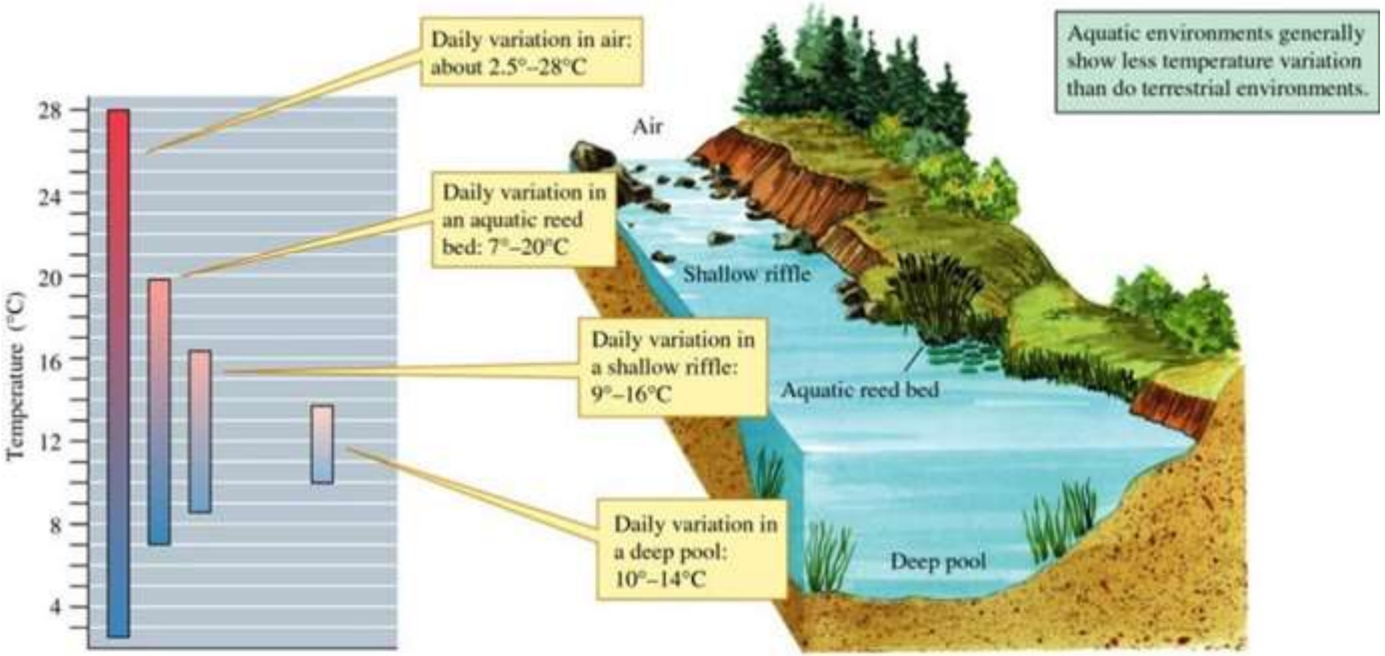
Benefits of Wood Formed Pools for Juvenile Salmon

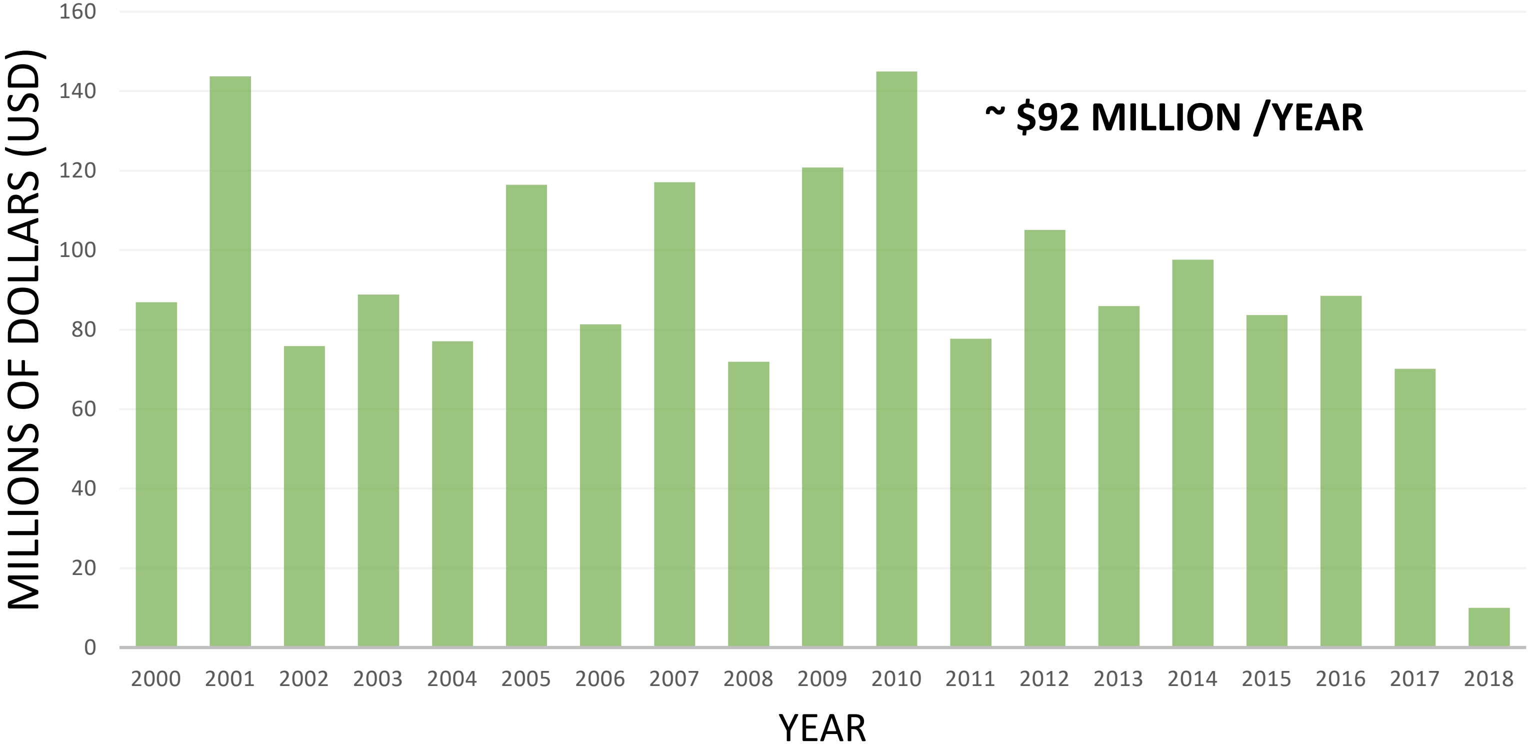
- Pools = Essential Habitat
  - ➢Energetically efficient holding water
  - ➢Thermal refuge
  - ➢Cover



Engineered Logjams as a Stop Gap

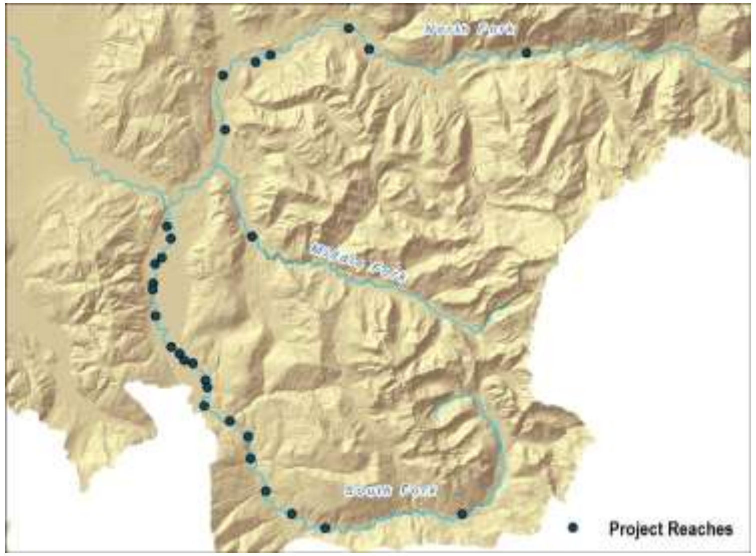
Engineered Logjams are Widely Used

Total Funds for Salmon Habitat Restoration in Millions of $ (includes PCSRF, State, Other, and In-Kind funds)



source: NOAA Fisheries

~240 logjam or instream structures implemented per year in US (Bernhardt et al. 2005)



Example: Nooksack River received 30 logjam projects between 2001-2017

source: Nooksack Indian Tribe

Despite Restoration Efforts, Inconclusive Evidence Regarding Salmon Recovery

- Thompson 2006:
  - “*Little or no demonstrable beneficial influence of the modification [in projects before 1980]*”
  - Proper experimental design and adequate controls needed

- Stewart et al. 2009:
  - “*Effectiveness of in-stream devices is equivocal*”
  - Further research, monitoring and data synthesis required

- Whiteway et al. 2010:
  - 73 % of projects showed increase in salmonid abundance; 27% showed *decrease*
  - More long-term monitoring recommended

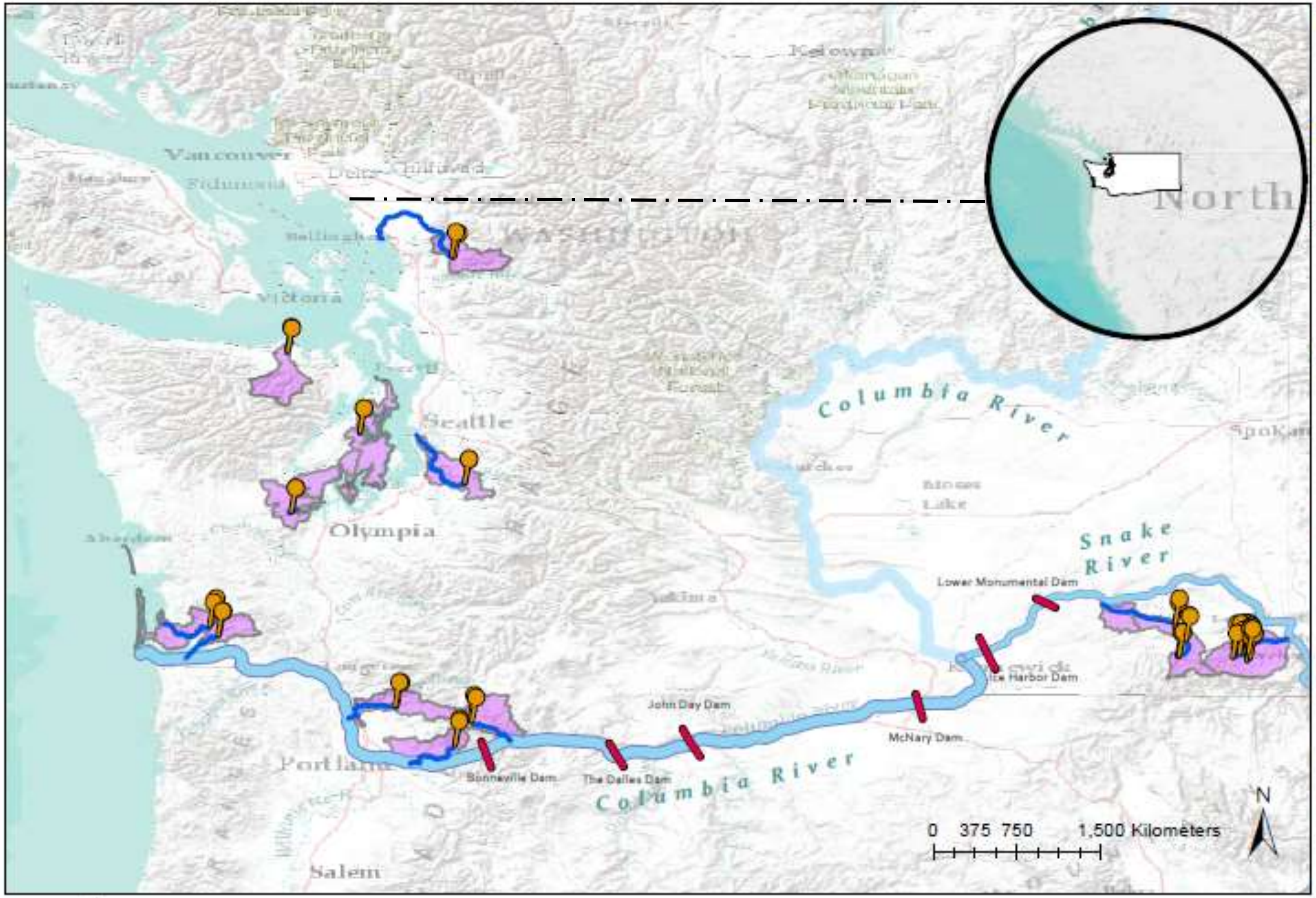
Research Objectives

1. Are engineered logjam restoration projects effective at improving freshwater salmon habitat?

2. Are salmon populations responding to improvements in freshwater habitat?
   - *To be pursued next…*

Engineered Logjam River Restoration Projects in Washington State

Long-Term Monitoring with BACI Study Design



Engineered Logjam Restoration Sites

Stream Pathways to Restoration Sites

Dams Impacting Path to Restoration Sites

HU10 Watershed Boundaries Encompassing Restoration Sites

This map shows the location of each engineered logjam restoration project used in the analysis of their effectiveness at improving salmon habitat. Each restoration site is paired with a nearby "control" site and monitored using a BACI study design.

Map created by: Caroline Walls, WWU

Data Sources: Columbia Habitat Monitoring Program; WA Salmon Recovery Funding Board; USGS; Natural Earth

Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS

Data Sources: SRFB & CHaMP Monitoring Programs

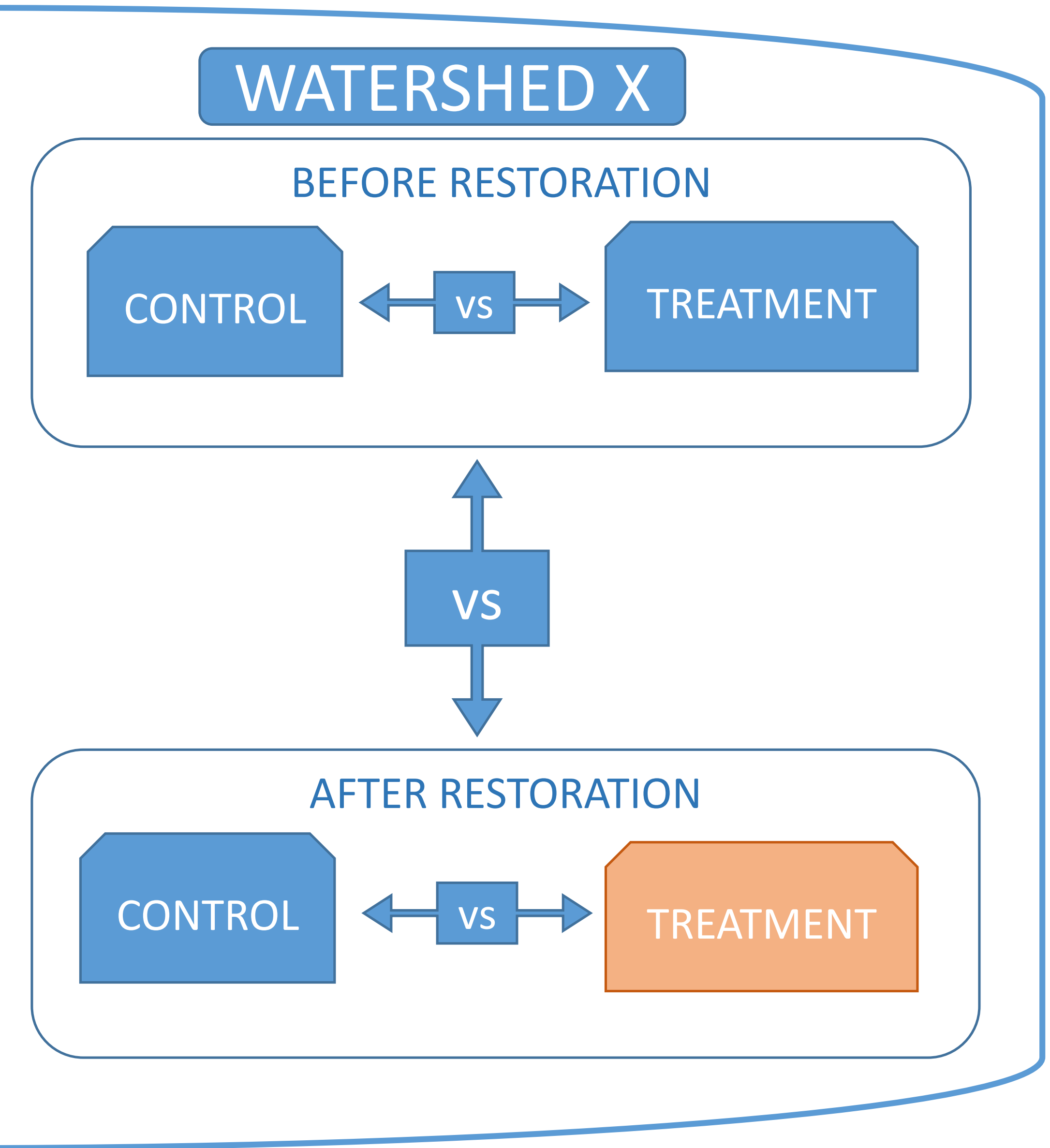
WASHINGTON STATE
RECREATION AND CONSERVATION OFFICE
Salmon Recovery Funding Board

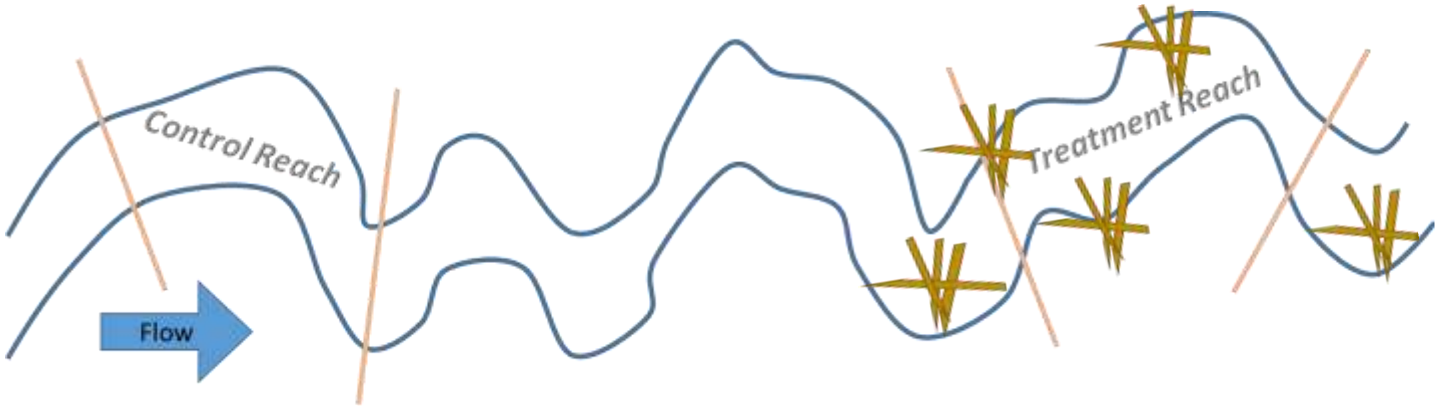
CHaMP
Columbia Habitat Monitoring Program

Study Sample Quick Look (*n* = 26)

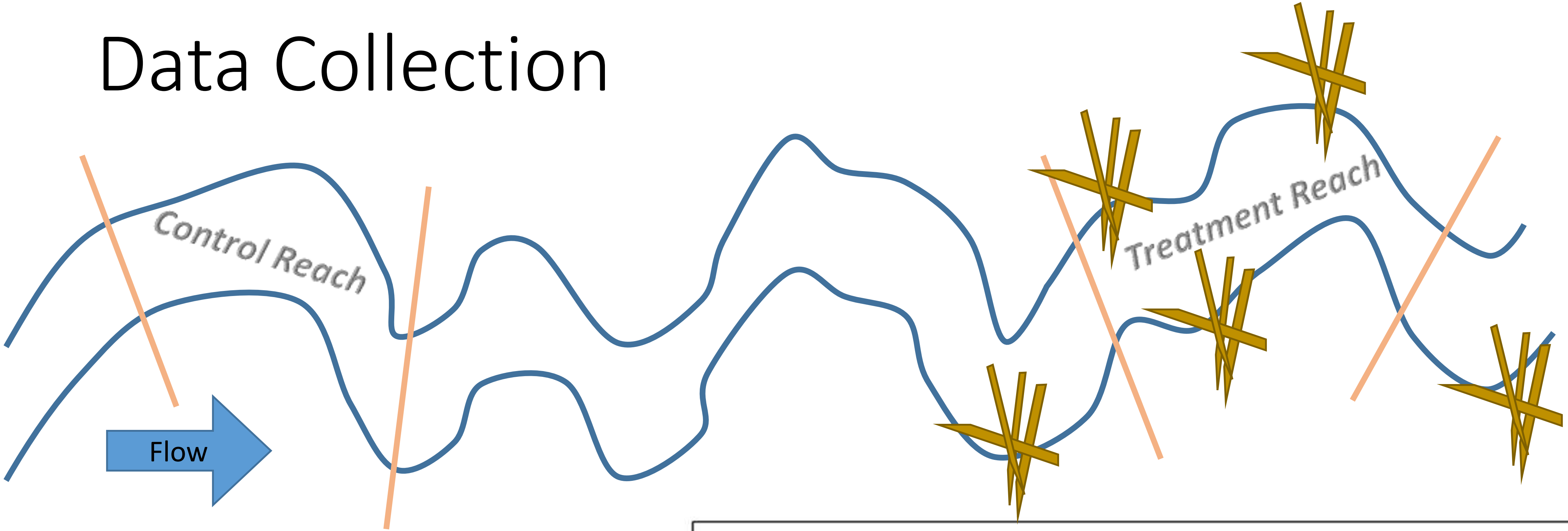
Stats	Low	High
Restoration Year	2004	2014
Km Treated	0.16	12
Structures per km	3	68
Stream Width (m)	1	40

Before-After Control-Impact (BACI) Study Design





Data Collection



Habitat Surveys
- Habitat Unit Delineation
- Channel Topography

also…
- Pebble Counts
- LWD Counts
- Instream / Overhanging Cover
- Riparian Vegetation
- Macroinvertebrate Samples
- Discharge
- Snorkel Surveys

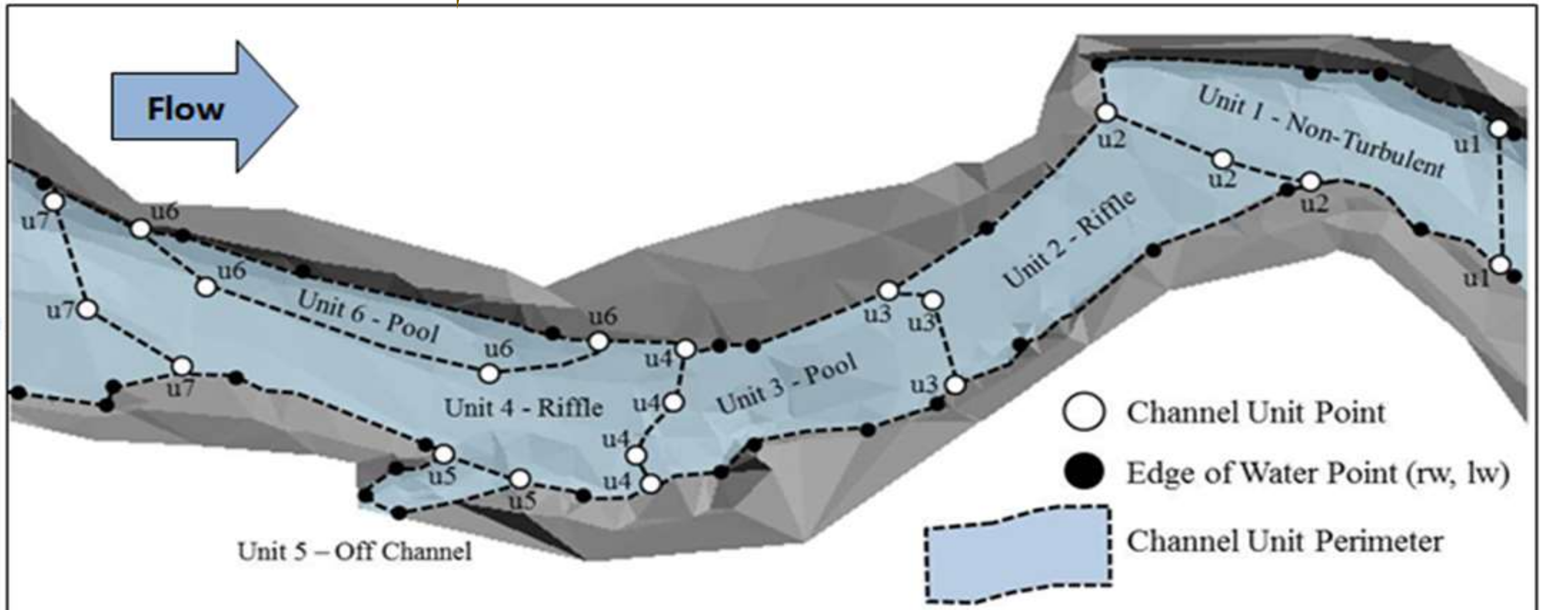
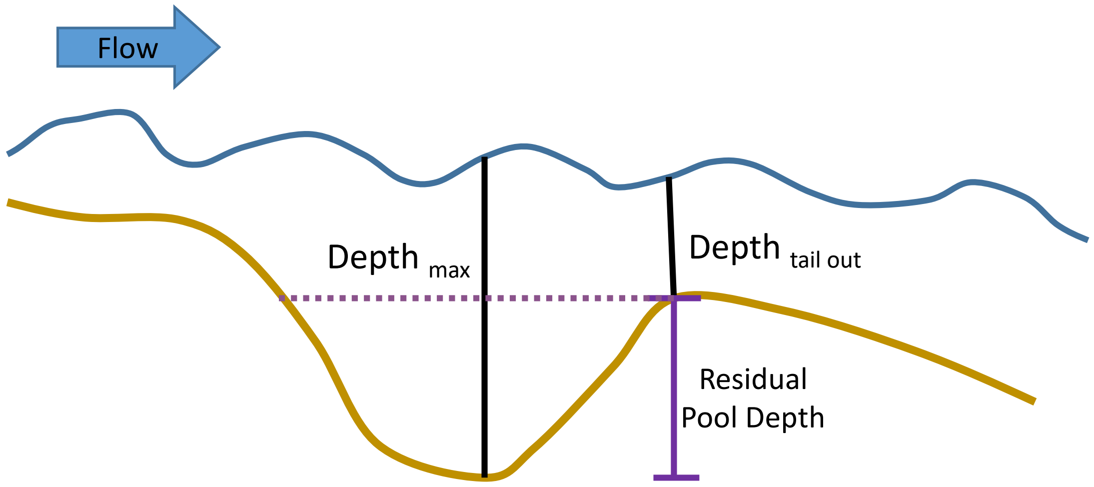


Photo Source: PNWAMP 2015

Response Variables

1. Mean Residual Pool Depth (m)
   - RPD = Depth $_{max}$ – Depth $_{tail\ out\ minimum}$
   - i.e. Remaining water depth if flow stopped



2. Habitat Diversity Index (*H*)
   - Shannon's Diversity Index
   - Habitat Units (riffle, run, pool)

$$H = -\sum_{i=1}^{S} p_i Ln(p_i)$$

S total # of Habitat Units at the site (richness)

p_i proportion of ***S*** made up of the *i* *th* Habitat Unit

3. Ratio of Pool Area (m^2) to Study Reach Area (m^2)
   - Based on Identified Habitat Units

$$Pool : Reach = \frac{\sum Pool\ Area\ (m2)}{Total\ Study\ Reach\ Area\ (m2)}$$

Model Design: Mixed Effects Modelling

RV ~	β_0 +	Time x β_1 +	Treatment Status x β_2 +	Post-Treatment Time x β_3 +	$\mu_{intercept\text{-}Watershed}$ +	$\epsilon_{residuals}$
Response Variable	Intercept (mean)	The year of restoration is 0. All years before are negative, after are positive.	Have restoration occurred at this site? No = 0 Yes = 1	Has restoration occurred at this site? No = 0 Yes = 1, 2, 3… Values rise with passage of Time.	Random Effects intercept by watershed.	Residuals
		• Accounts for passage of time (years), regardless of restoration status. • Normalized to the year of restoration for each watershed	• Accounts for immediate changes in RV due to restoration. • Immediate changes are those observed at first monitoring event after restoration.	• Accounts for changes in RV *over time* due to restoration. • Allows slope of treatment sites to change after restoration.	• Pairs the Control and Treatment sites within a watershed. • Allows each watershed to have its own baseline value for RV (i.e. intercept)	

- Continuous Autoregressive Covariance Structure (Subject = Study Reach)
- Repeats Over Calendar Year

- 1 – 4 years of Pre-Restoration Monitoring
- 3 – 10 years of Post-Restoration Monitoring

Results: Residual Pool Depth

RPD ~ β_0 + Time x β_1 + Treatment Status x β_2 + Post-Trt Time x β_3 + Reach Width (m) x β_4 + μ intercept-Watershed + ϵ residuals

~~Immediate Change~~ (Treatment Status)

Change Over Time (Post-Trt Time) ✓

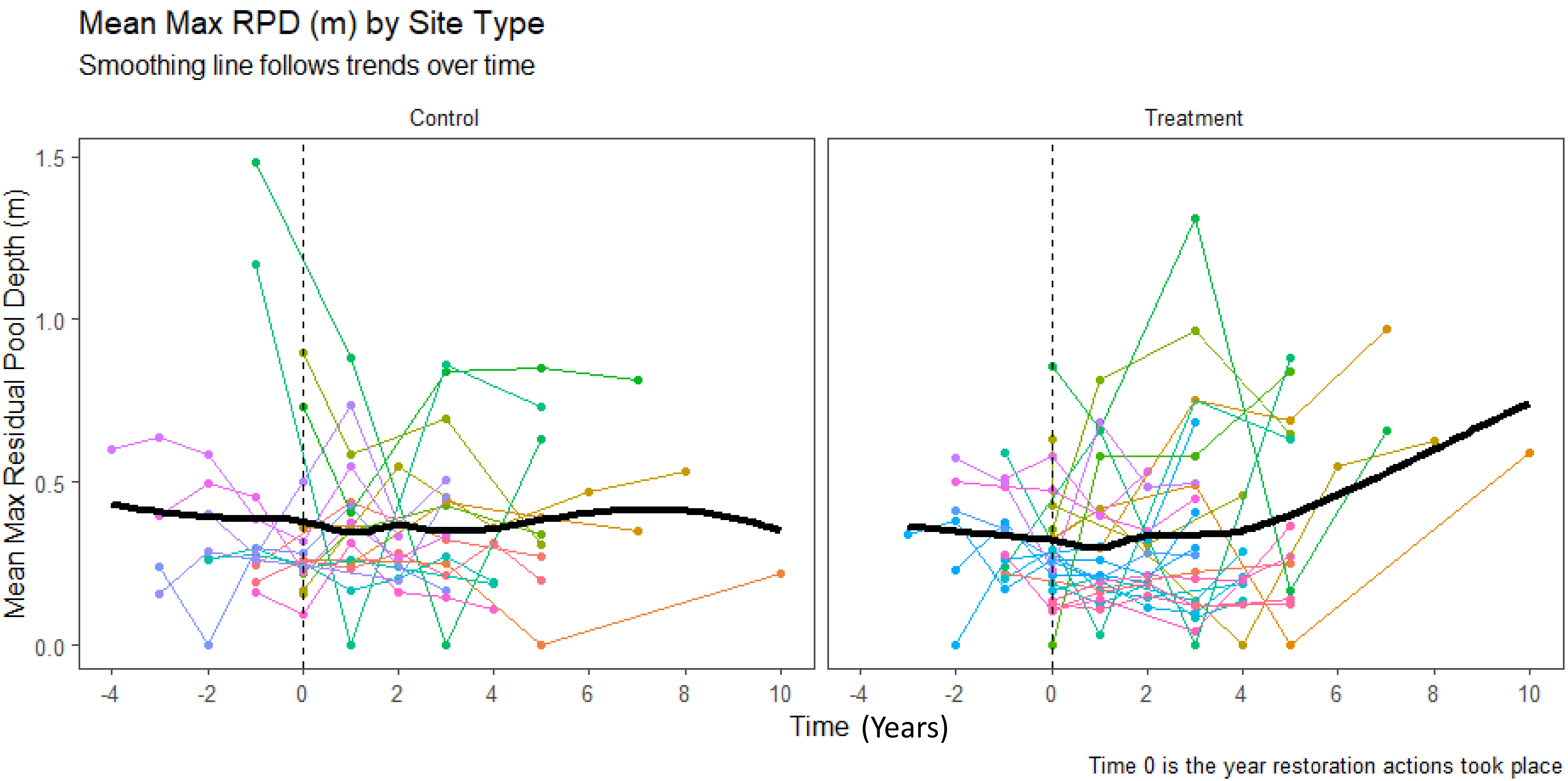
Fixed effects: RPD ~ 1 + time + treatment + time.rest + reach.width

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.19608528	0.04027032	206	4.869225	0.0000*
time	-0.02691093	0.00995706	206	-2.702699	0.0075*
Trt_Status	0.00457319	0.01829789	206	0.249930	0.8029
Post.Trt_Time	0.03915976	0.01146434	206	3.415789	0.0008*
reach.width	0.01854276	0.00269212	206	6.887787	0.0000*

* *Statistically significant at $p < 0.05$ level, method = ML*

<u>Takeaway</u>: Engineered logjams have no immediate effect on Residual Pool Depth, but they do have a significant positive effect over time.

Residual Pool Depth (m)



Results: Habitat Diversity Index

$$\textit{Habitat Diversity} \sim \beta_0 + \text{Time} \times \beta_1 + \text{Treatment Status} \times \beta_2 + \text{Post-Trt Time} \times \beta_3 + \text{Survey Method} \times \beta_4 + \mu_{\text{intercept-Watershed}} + \epsilon_{\text{residuals}}$$

✓ [Immediate Change]

[~~Change Over Time~~]

Fixed effects: diversity ~ 1 + time + treatment + time.rest + survey.method

	Value	Std.Error	DF	t-value	p-value
(Intercept)	1.0022767	0.05707944	213	17.559330	0.0000*
time	0.0101352	0.02922354	213	0.346816	0.7291
Trt_Status	0.0875745	0.03872714	213	2.261321	0.0247*
Post.Trt_Time	-0.0128041	0.03253135	213	-0.393591	0.6943
survey.method(SRFB)	0.2031784	0.06794563	14	2.990309	0.0097*

** Statistically significant at $p < 0.05$ level, method = ML*

Takeaway: Engineered logjams have an immediate, positive effect on habitat diversity. But habitat diversity does not continue to improve over time.

Results: Pool Area (m^2) : Study Reach Area (m^2)

Pool Area : Reach Area ~ β_0 + Time x β_1 + Treatment Status x β_2 + Post-Trt Time x β_3 + Survey Method x β_4 + Date x β_5 + $\mu_{intercept\text{-}Watershed}$ + $\epsilon_{residuals}$

[Immediate Change] ✓ [Change Over Time] ✓

Fixed effects: pool.reach.ratio ~ 1 + time + treatment + time.rest + survey.method + date

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.05578790	0.04542752	212	1.228064	0.2208
time	-0.01296033	0.00862520	212	-1.502612	0.1344
Trt_status	0.06171710	0.01580684	212	3.904456	0.0001*
Post.Trt_Time	0.02090664	0.01040583	212	2.009128	0.0458*
survey.method(SRFB)	0.15671482	0.02500507	14	6.267322	0.0000*
date	0.00036254	0.00017565	212	2.063971	0.0402*

* *Statistically significant at $p < 0.05$ level, method = ML*

Takeaway: Engineered logjams have an immediate, positive effect on pool area and continue to increase pool area over time.

In Summary

Engineered logjam restoration projects result in an immediate increase in habitat diversity as small pools develop. Over time, these pools continue to grow in area and depth, resulting in more deep pool habitat.

Next Phase: Are Salmon Responding?

Special Thanks

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