

Ecosystem response to the removal of the Elwha River Dams



Photo by John McMillan

November 2018



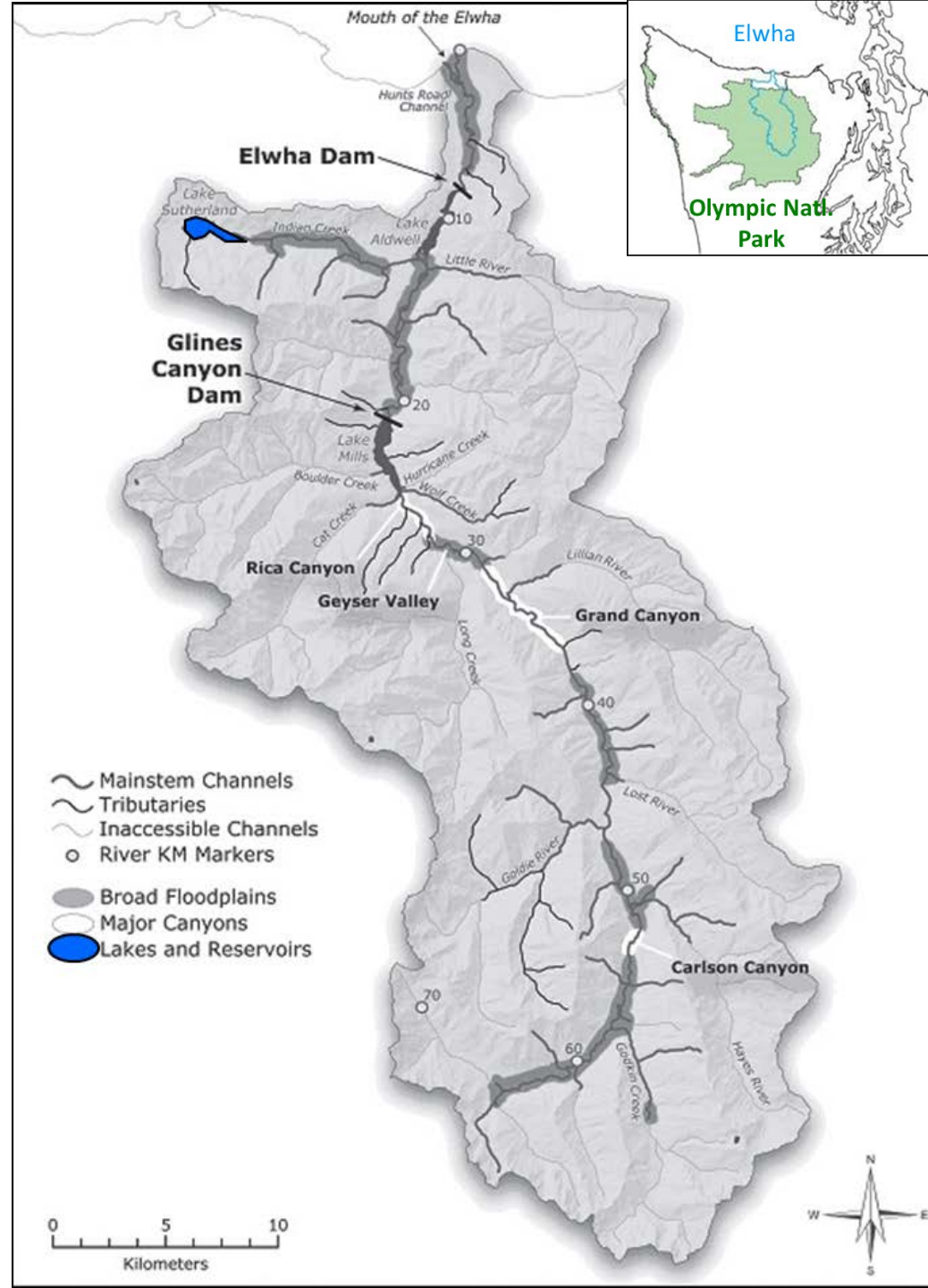


K Denton & associates



Location

- 833 km²
- ~72km of mainstem habitat
- 8 major tributaries
- Sea level to 1,372m
- Dry, warm summers and cool, wet winters
- Marine sedimentary, Crescent basalt, and Unconsolidated glacial till
- Western hemlock, Douglas Fir, Western Red Cedar, Red alder, cottonwood, and big leaf maple



Location

Elwha River Fishes

Coho salmon



Pink salmon



Chinook salmon



Steelhead



Chum salmon



Sockeye salmon



Eulachon



Bull trout



Pacific lamprey



Purpose

Elwha River Ecosystem and Fisheries Restoration Act

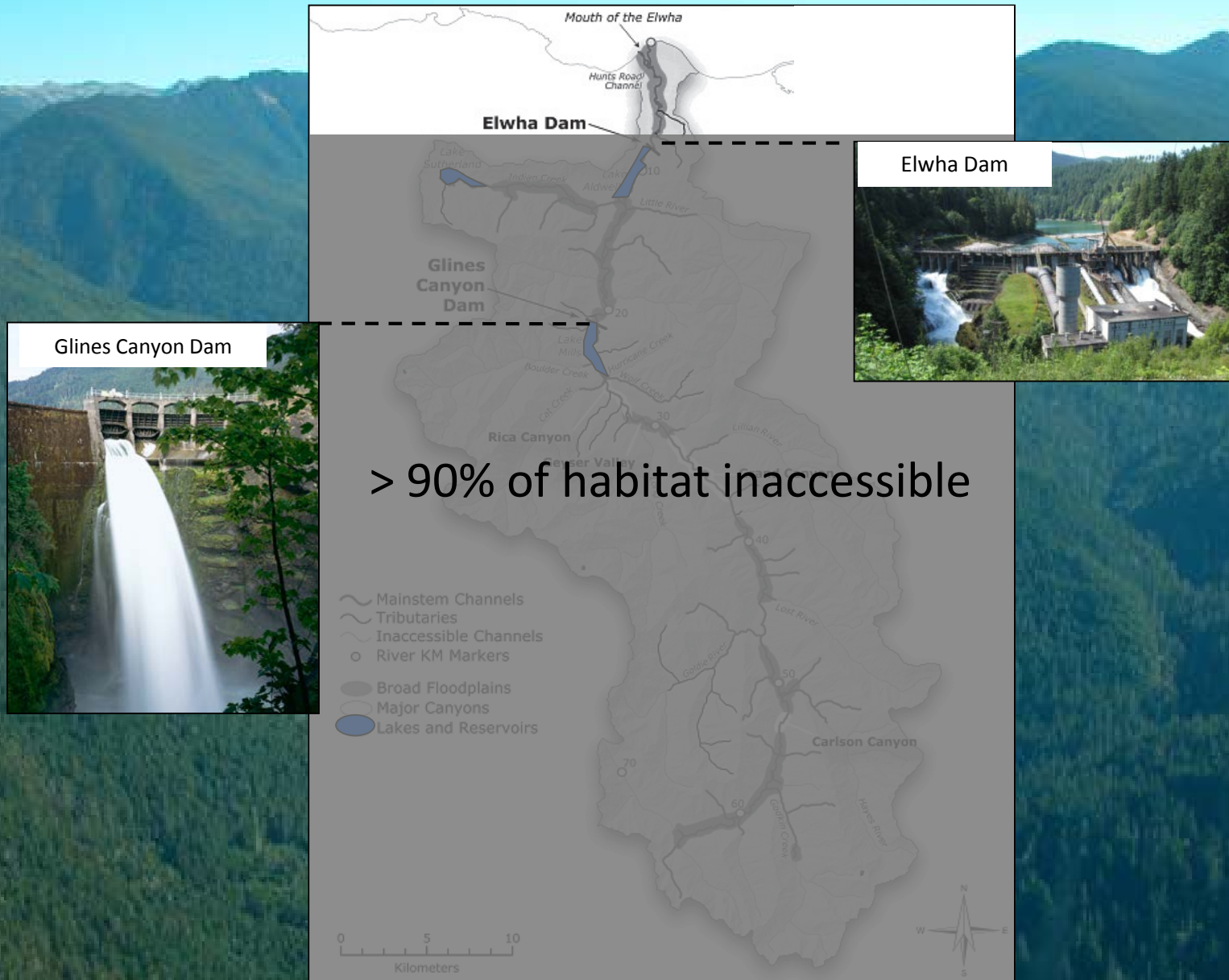
“...for the removal of the dams and full restoration of the Elwha River ecosystem and native anadromous fisheries.”

102nd Congress of the U.S.A.
January 3, 1992



Photo by John McMillan

Dam removal will result in fish passage to the Elwha River

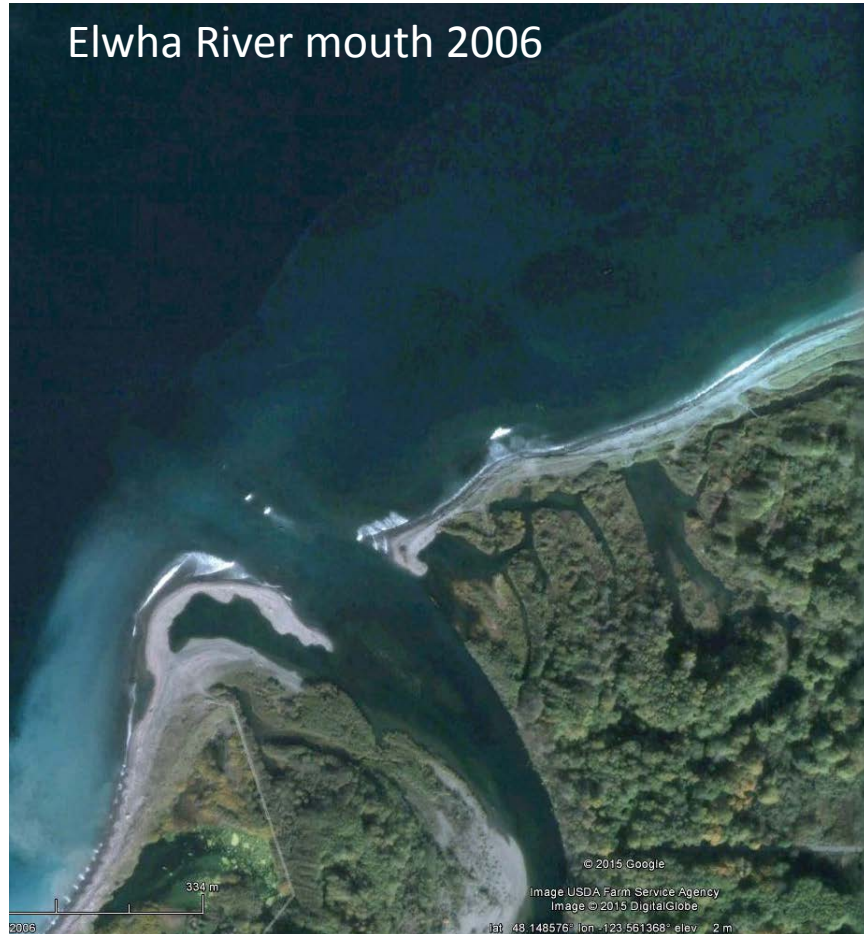


Dam removal will result in fish passage to the Elwha River



Restored sediment dynamics will result in the creation & maintenance of existing and “lost” habitats

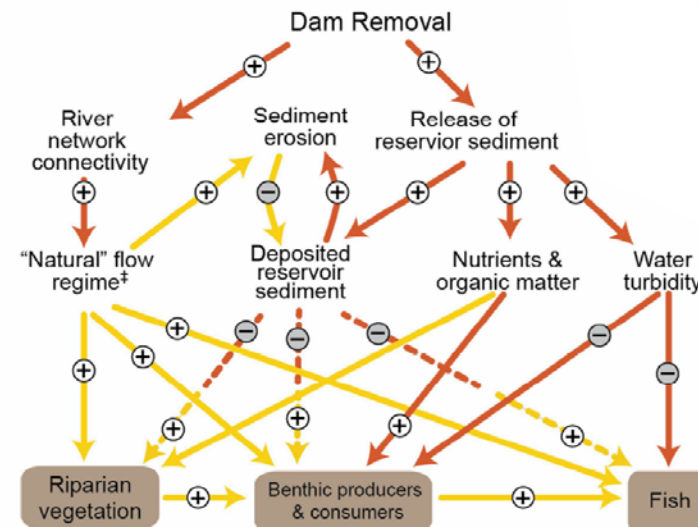
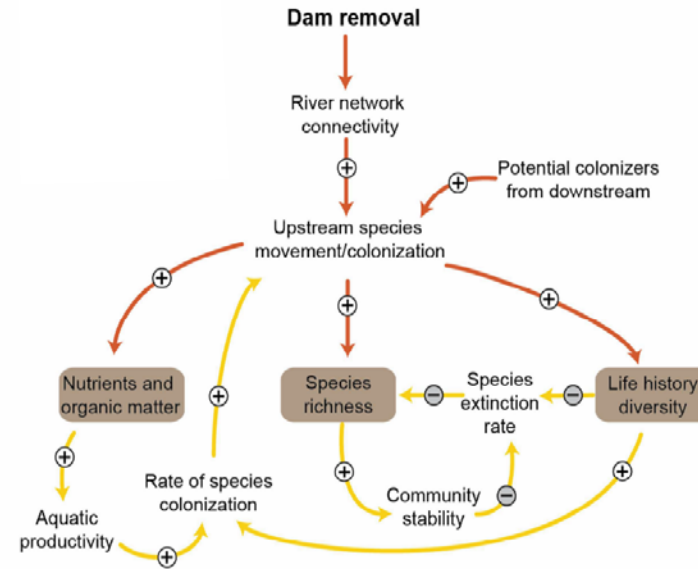
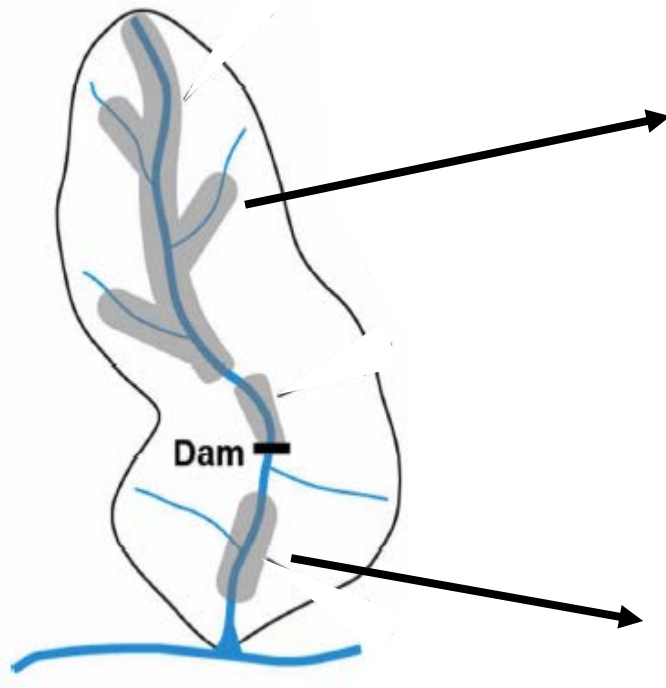
Elwha River mouth 2006



Elwha River mouth 2015



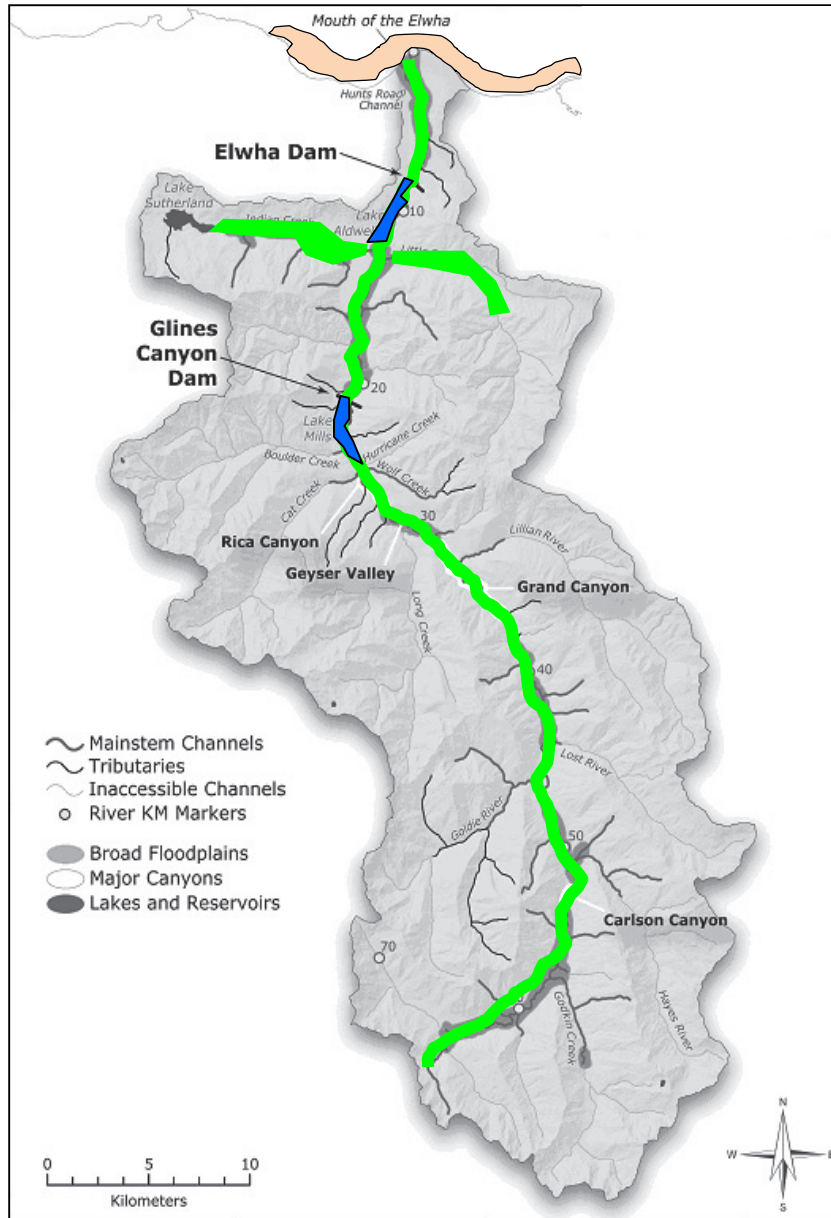
Restored connectivity for fish and sediment dynamics will lead to restored riverine foodwebs, terrestrial linkages, and revegetation



[‡]Includes temperature, sediment, and nutrient regimes

Bellmore et al. in press

Study design



Location

- Dams & former reservoirs
- Nearshore
- River ecosystem

Processes

Sediment dynamics

Fish recolonization



Riverine foodwebs

Terrestrial linkages

Revegetation

Study design

	Experimental design	Spatial design	Temporal design
Adult fish	Multiple before/after/ Control/impact (MBACI)	Stratified systematic survey (SSS) Opportunistic (O)	Daily, weekly, & seasonal
Juvenile fish	BACI	SSS/O	Monthly, seasonal, & annual
Foodwebs	MBACI	SSS/O	Seasonal
Habitats	BA	SSS/Census	Annual
Sediment	BA	SSS	Daily, seasonal
Riparian	BA	SSS/O	Seasonal, annual

- Spatial extent critical
- Need to natural v. treatment variability
- Annual analysis of data

What's going to happen to all the sediment?

~ 21 million m³ of sediment accumulated in reservoirs

- ~ 54% fine, ~46% coarse
- ~40%-60% predicted to erode downstream

Predictions

- suspended-sediment > 10,000 ppm
- temporary deposition of fines in pools
- more dynamic floodplain
- bed aggradation in lower river
- beach formation in estuary



N. Chism/Lighthawk

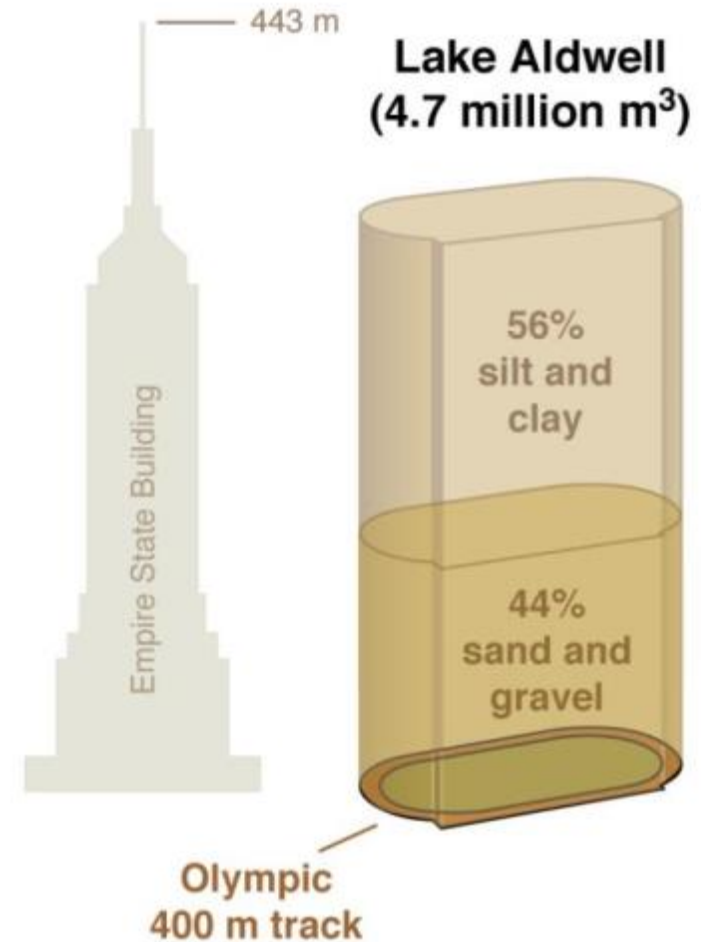
Elwha Dam removal

Before Dam Removal: September, 2011



Elwha Webcams courtesy NPS

- Completed in 1912
- 33m concrete gravity dam





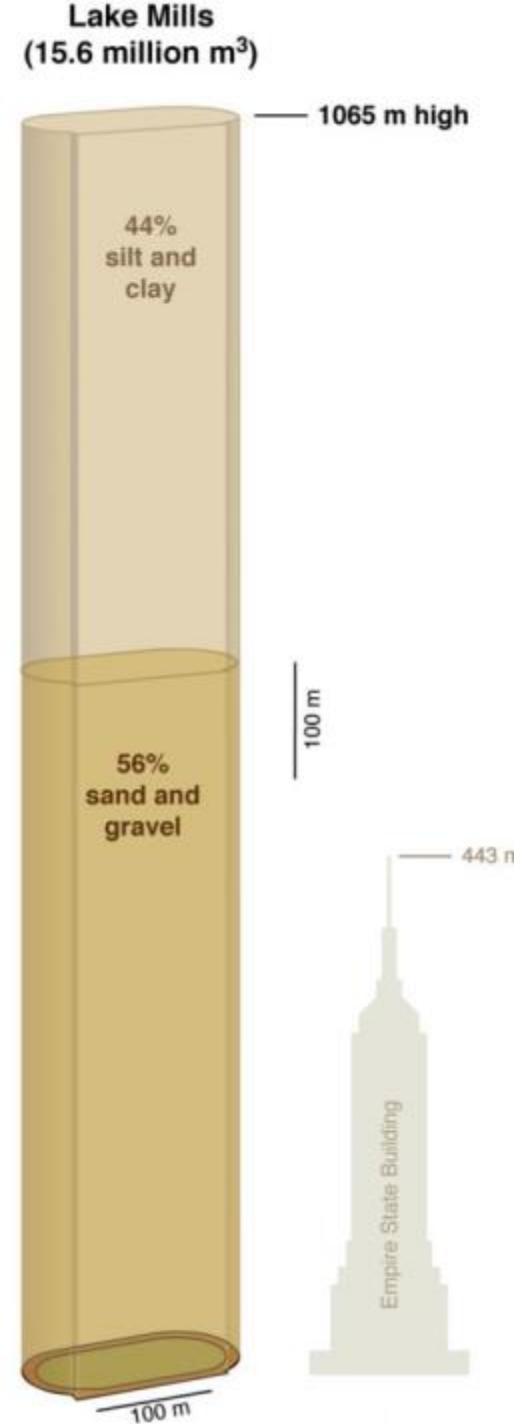
Glines Canyon Dam removal

Before Dam Removal: September, 2011



Elwha Webcams courtesy NPS

- Completed in 1927
- 64m concrete arch dam





Blasting at Glines Canyon Dam



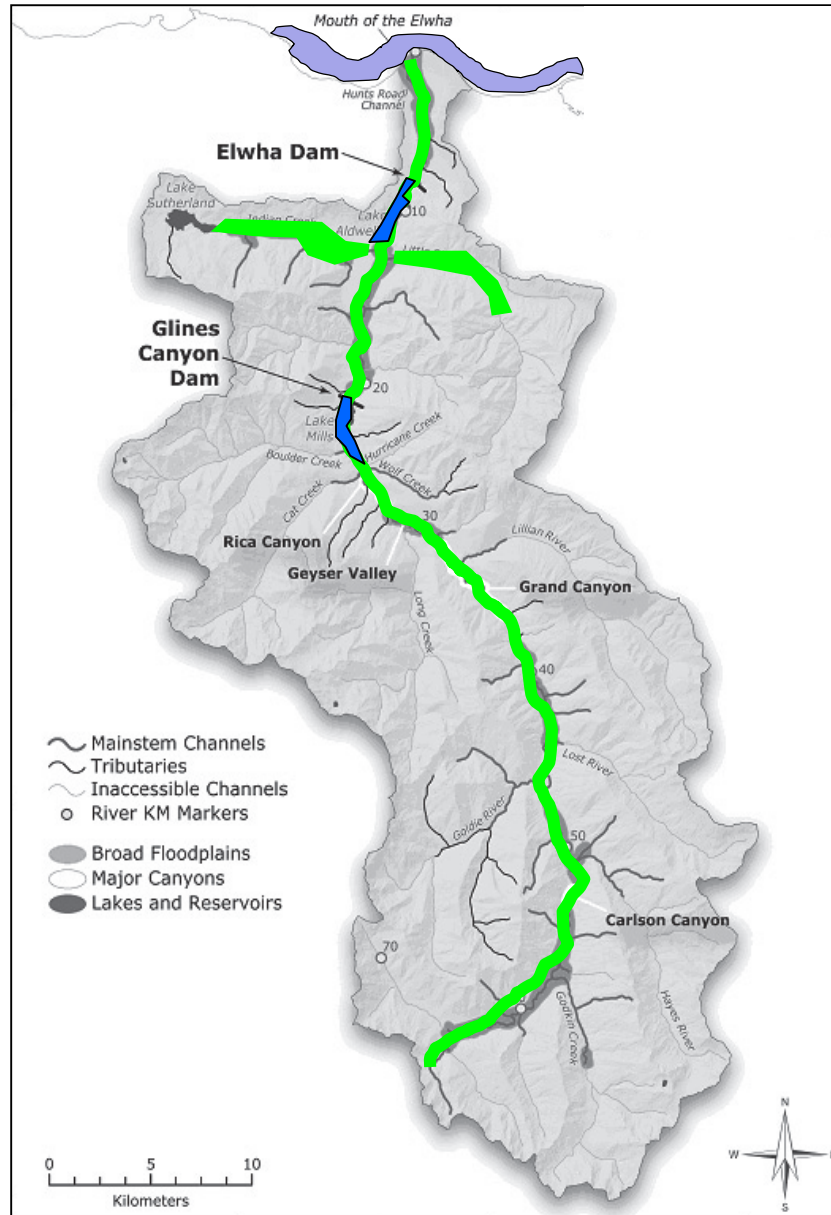
© John Gussman

John Gussman

Glines Canyon Dam removal



What has occurred with the removal of the Elwha River dams?



Location

- Dams & former reservoirs
- Nearshore
- River ecosystem

Processes

Sediment dynamics

Fish recolonization



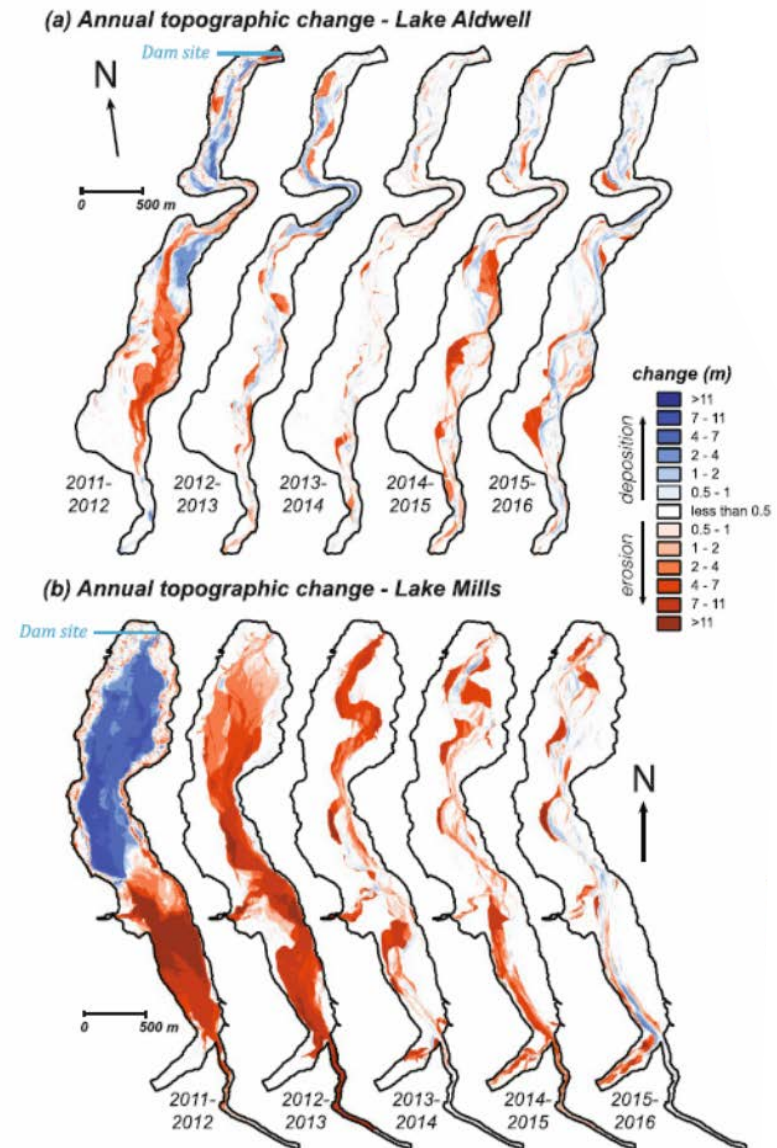
Riverine foodwebs

Terrestrial linkages

Revegetation

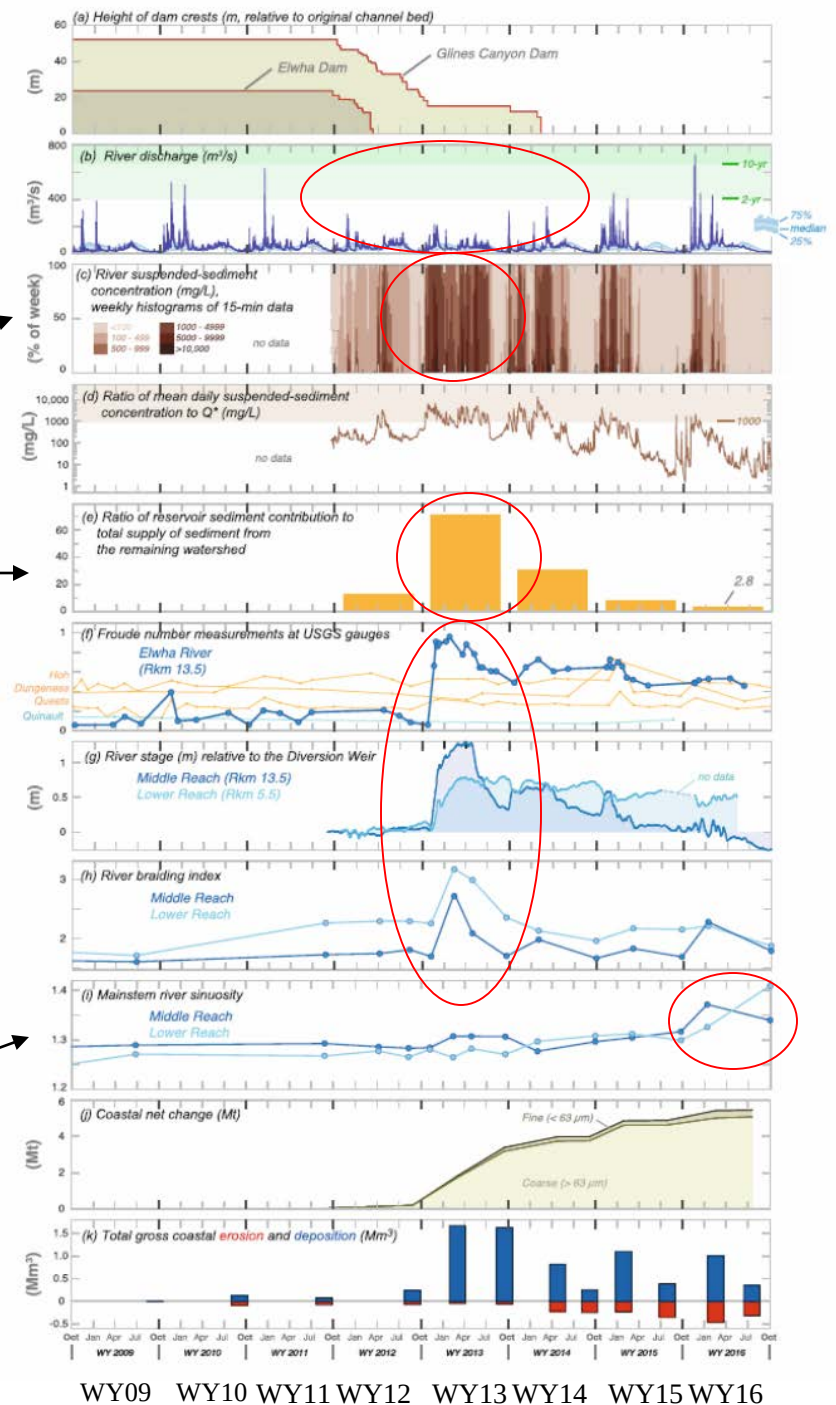
Elwha River dam removal sediment supply

- Water years (WY) 2011-2013 were most active years
- WY 2011/2012 – Sediment redeposits in former reservoirs
- WY 2012/2013 – Former Mills reservoir exports 8.8 ± 1.8 Mt
- WY 2011 through 2016 ~65% of the initial sediment stored exported



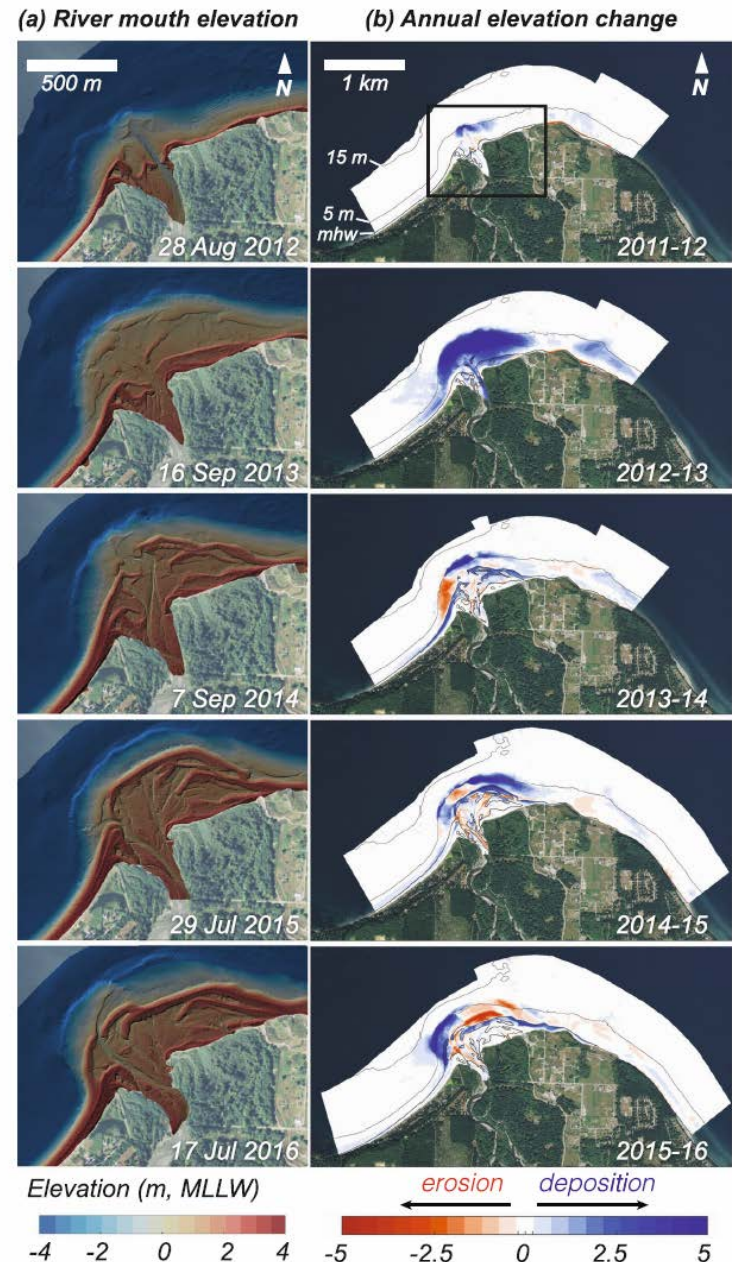
Elwha River - downstream effects of renewed sediment supply

- Suspended sediment concentrations
 - 1000s mg/L
 - Peaked during WY2013 when former Mills became river and bed material was mobilized.
 - Largest contribution relative to natural sediment supply during this time
- River characteristics
 - Longitudinal profile smoothed with pool filling
 - Streambed aggradation (1-1.5m)
 - Braiding increased
- Flow
 - No flows > 2yr R.I. WY 2012-2014
 - Sinuosity changed last 3 years when larger flows occurred



Expansion of the Elwha River delta due to dam removal

- Elwha River mouth became a depositional area
- Majority of sediment deposited consisted of sand and gravel
- Deposition occurred up to 12 meters deep and ~2km east of the river mouth



Mouth of the Elwha River - April 2014

Elwha River mouth 6 April 2014 Tom Roorda and CWL
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Pre

2012

2013

2014

Where has the sediment gone since dam removal?

~64% (13.0 ± 3.2 Mt) was transported beyond the coastal delta to the Strait of Juan de Fuca



~26% (5.4 ± 1.6 Mt) was deposited in and around the coastal delta



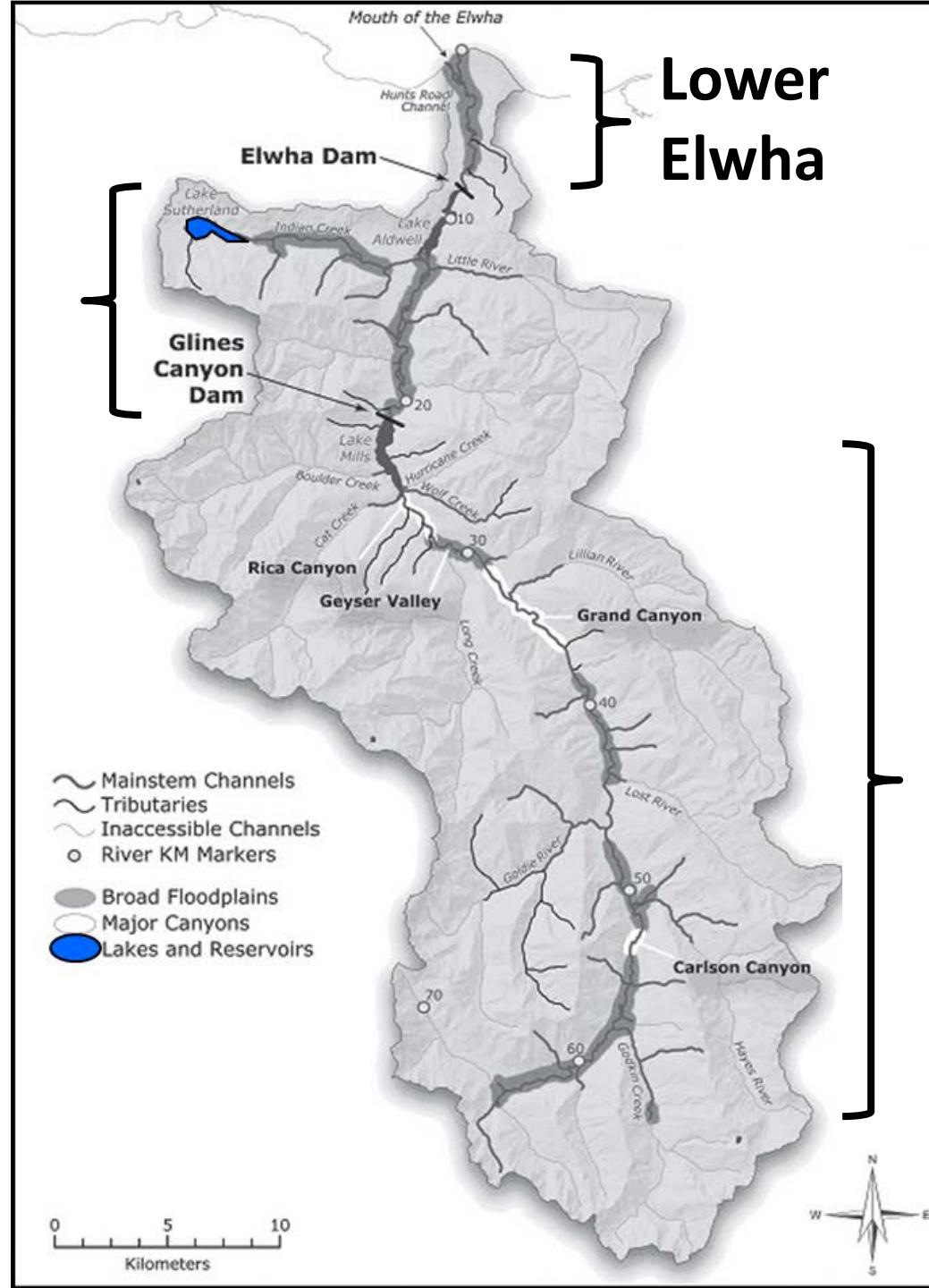
~10% (2.1 ± 0.4 Mt) was deposited in the river channel & floodplain



~20.5Mt (± 3.2 Mt) released



Middle Elwha



Lower Elwha

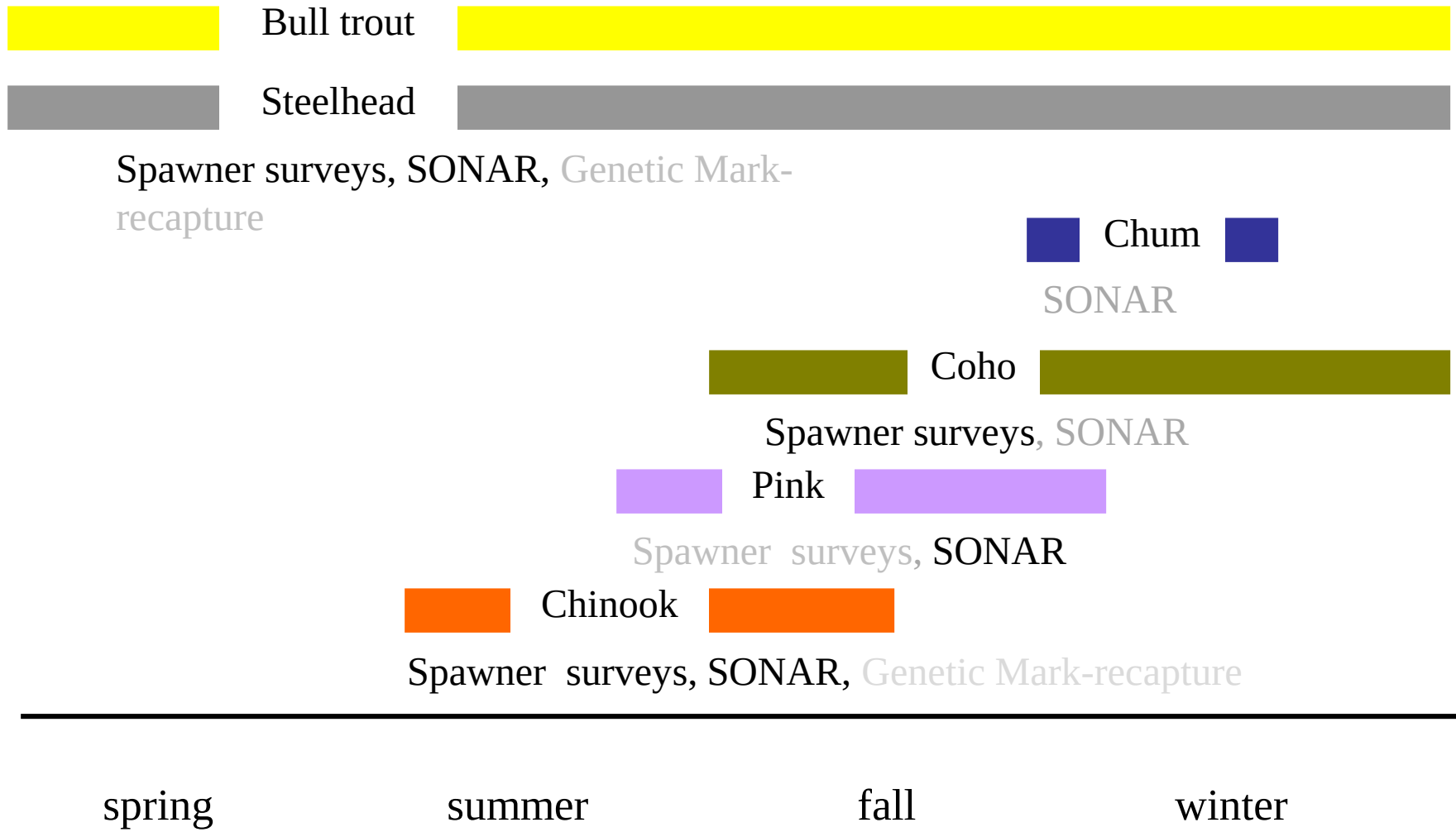
Upper Elwha

How have salmon responded to the removal of the Elwha River dams?

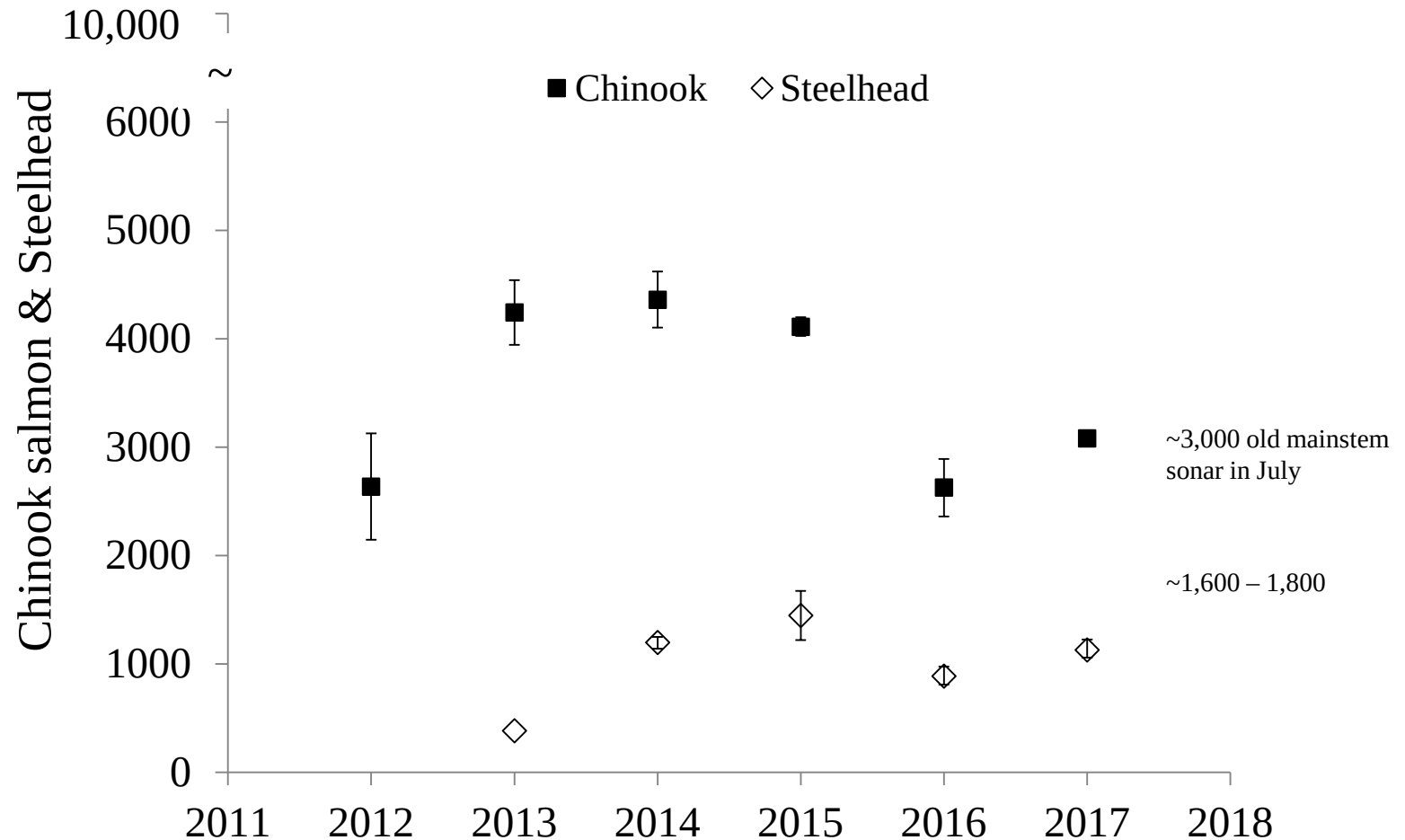
- Adult returns
- Smolt outmigration
- Sediment impacts
- Natural recolonization & assisted relocation
- Life history diversity
- Non salmonid species



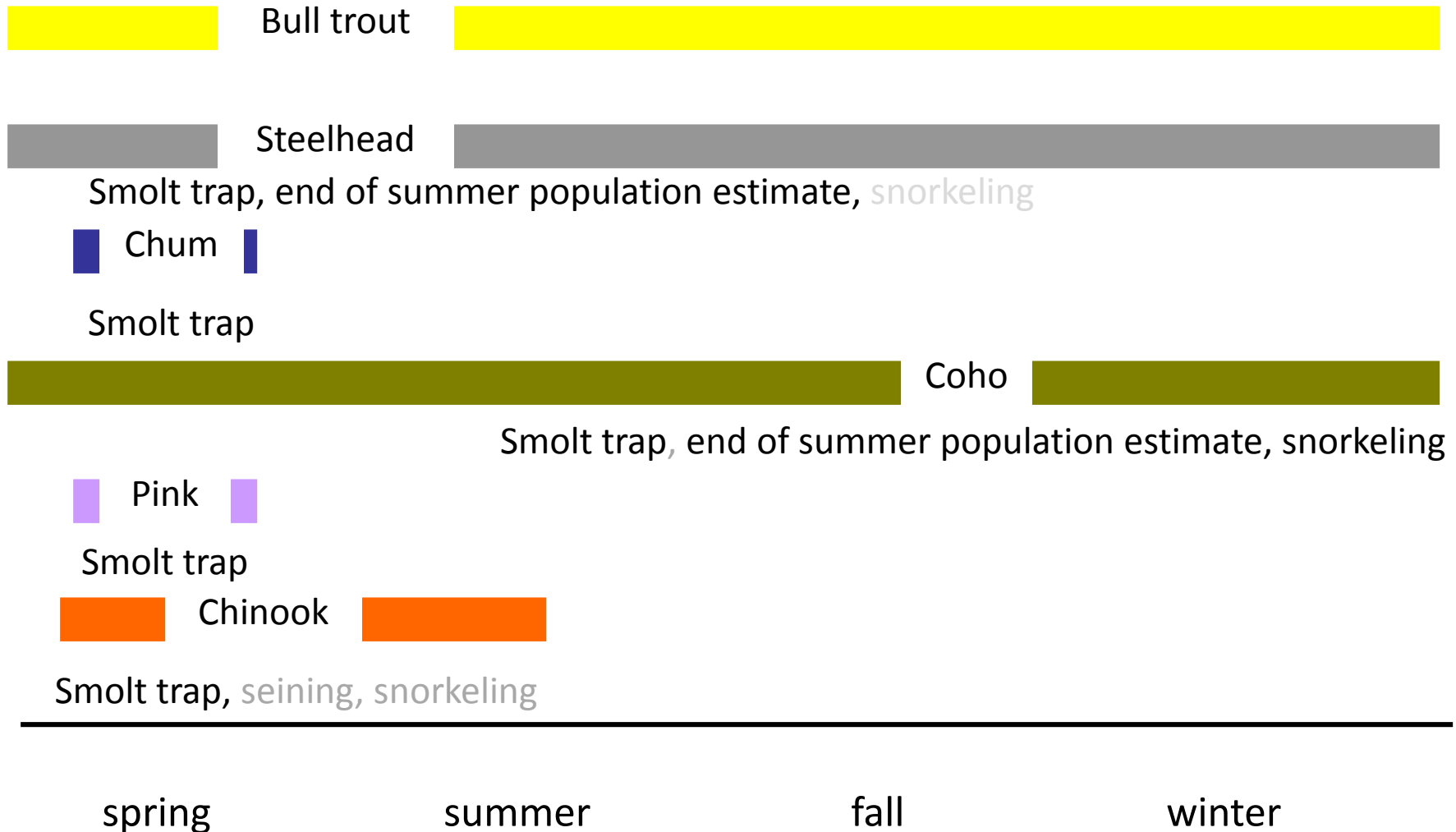
How is change measured for Elwha River adult salmon?



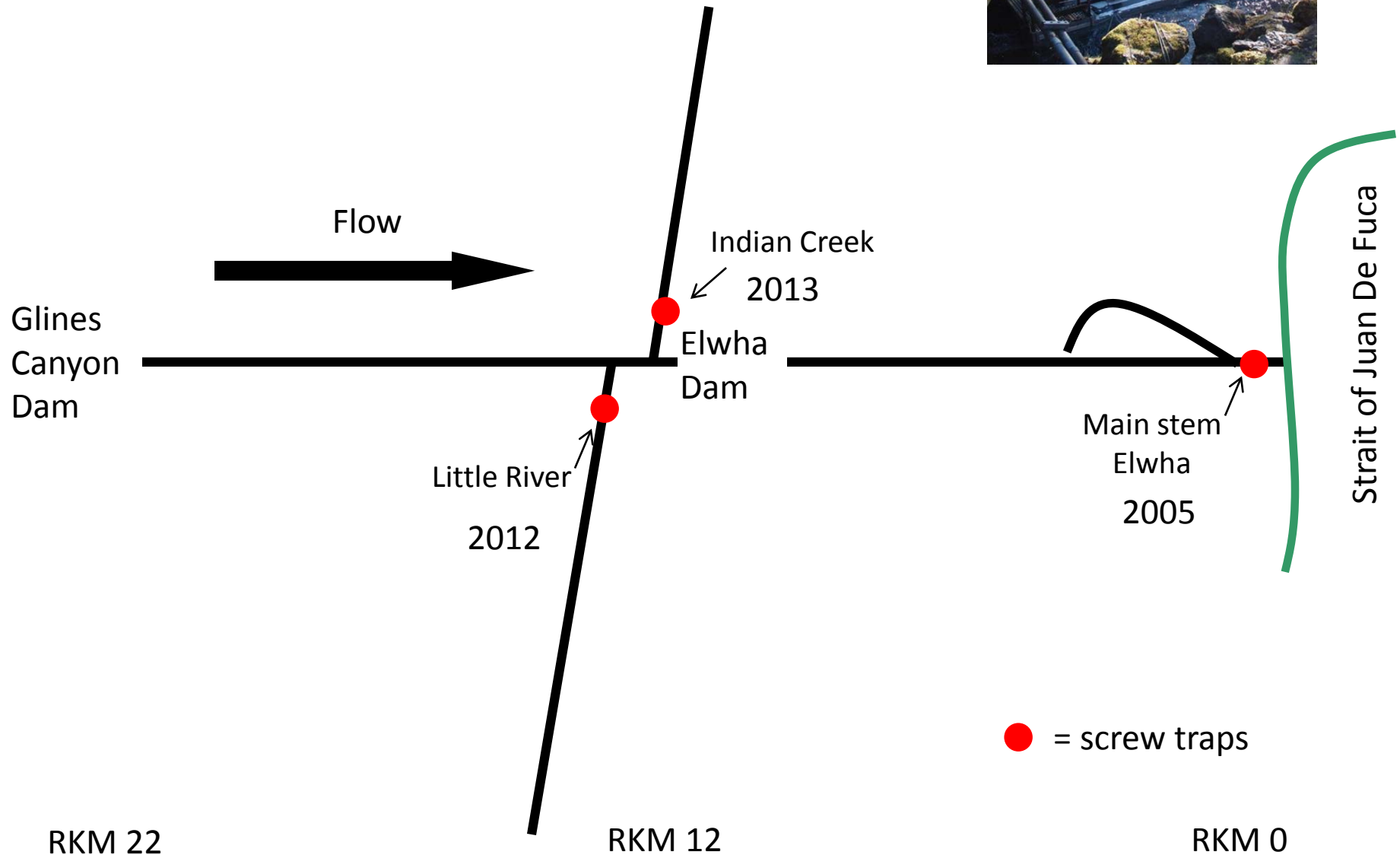
Chinook salmon & steelhead SONAR abundance estimate



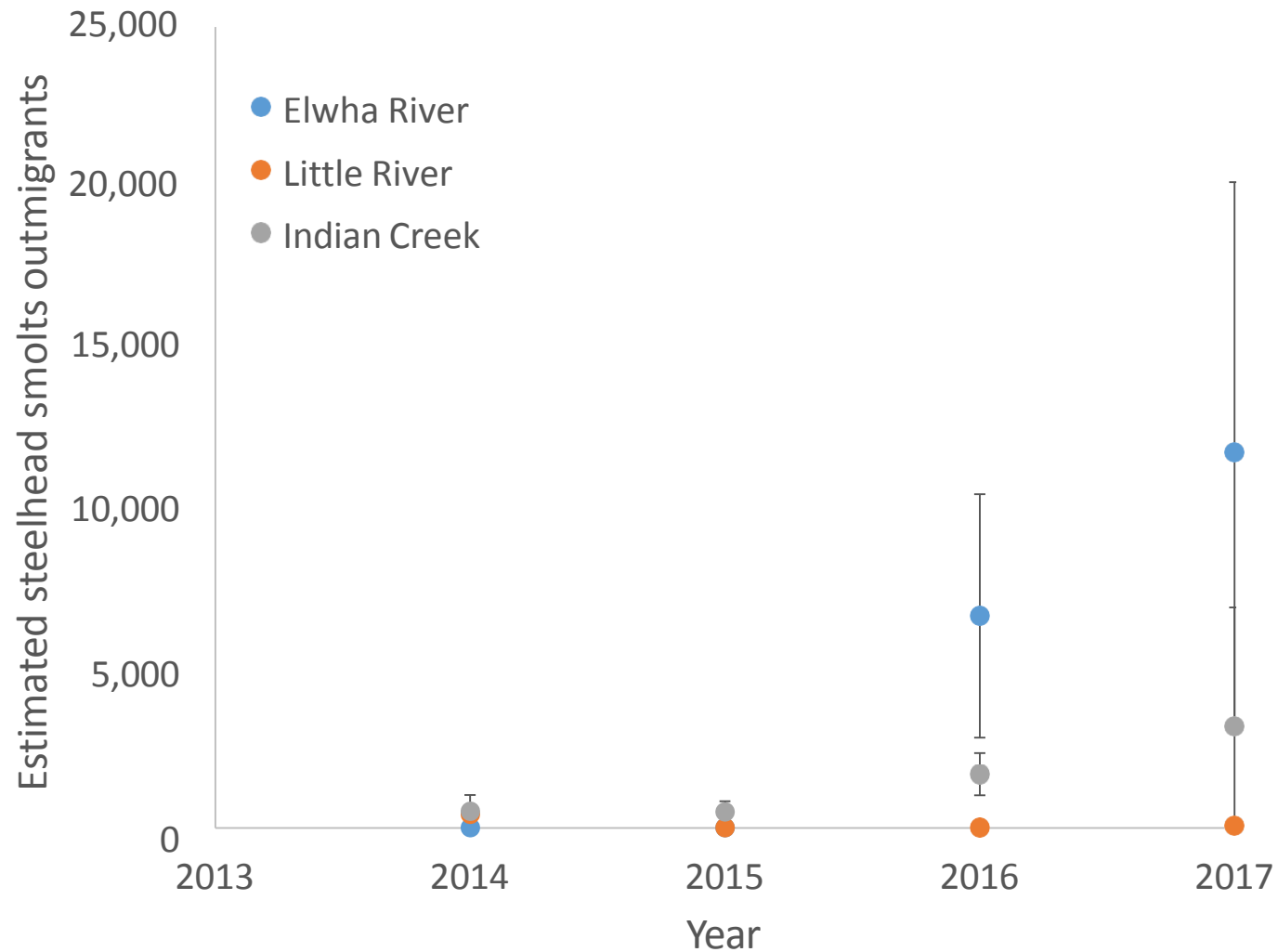
How is change measured for Elwha River juvenile salmon?



Elwha River screw trap locations

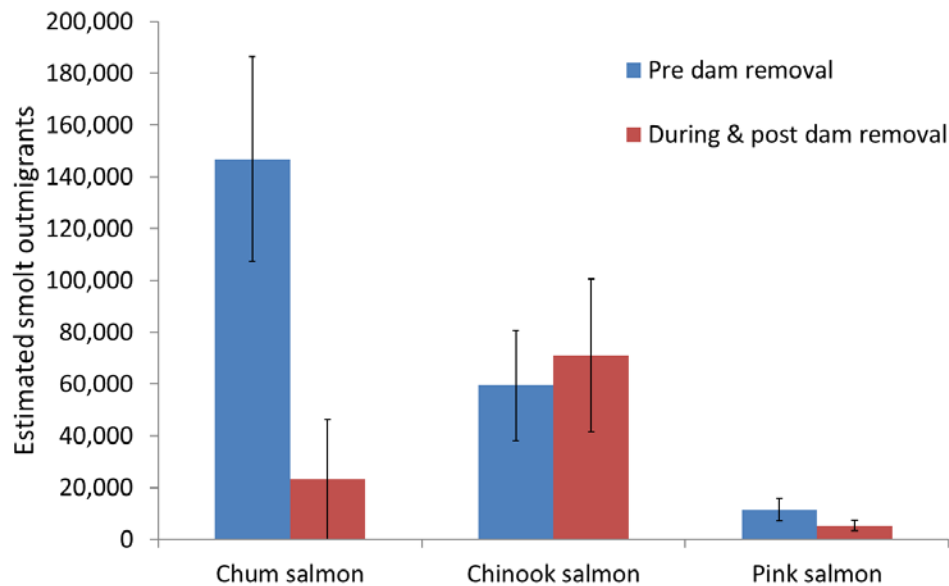
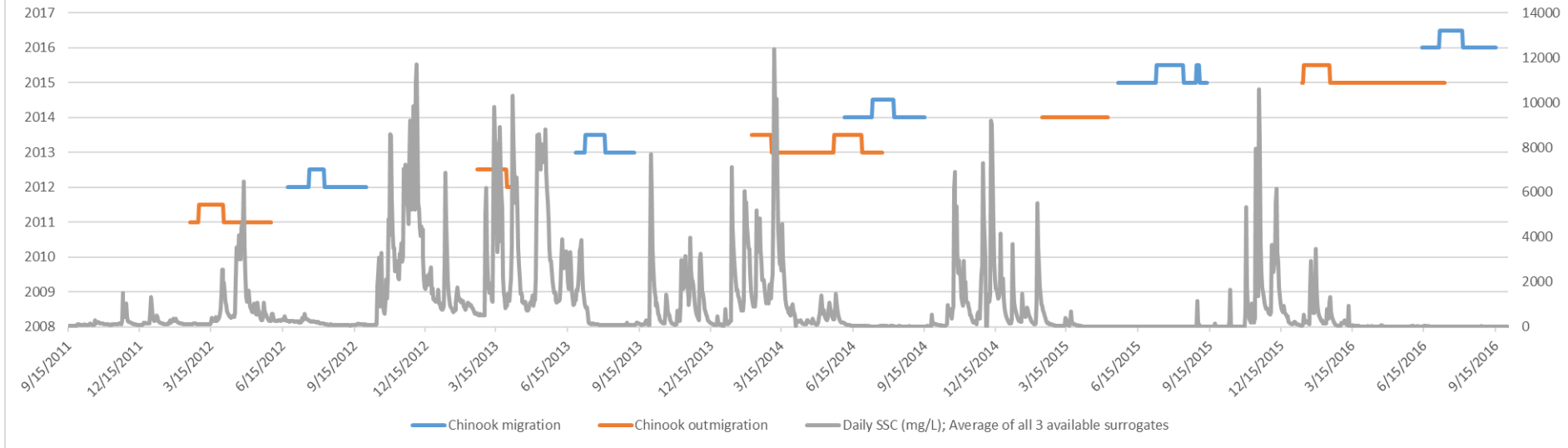


Elwha River, Indian Creek, & Little River Steelhead smolts



Sediment impacts during dam removal

Suspended sediment concentrations, Adult Chinook salmon returns, and juvenile Chinook salmon smolt outmigration



Relocation & natural recolonization of salmon recolonization between the dams

- Assisted Relocation

- Hatchery & wild adult coho salmon
- Wild steelhead

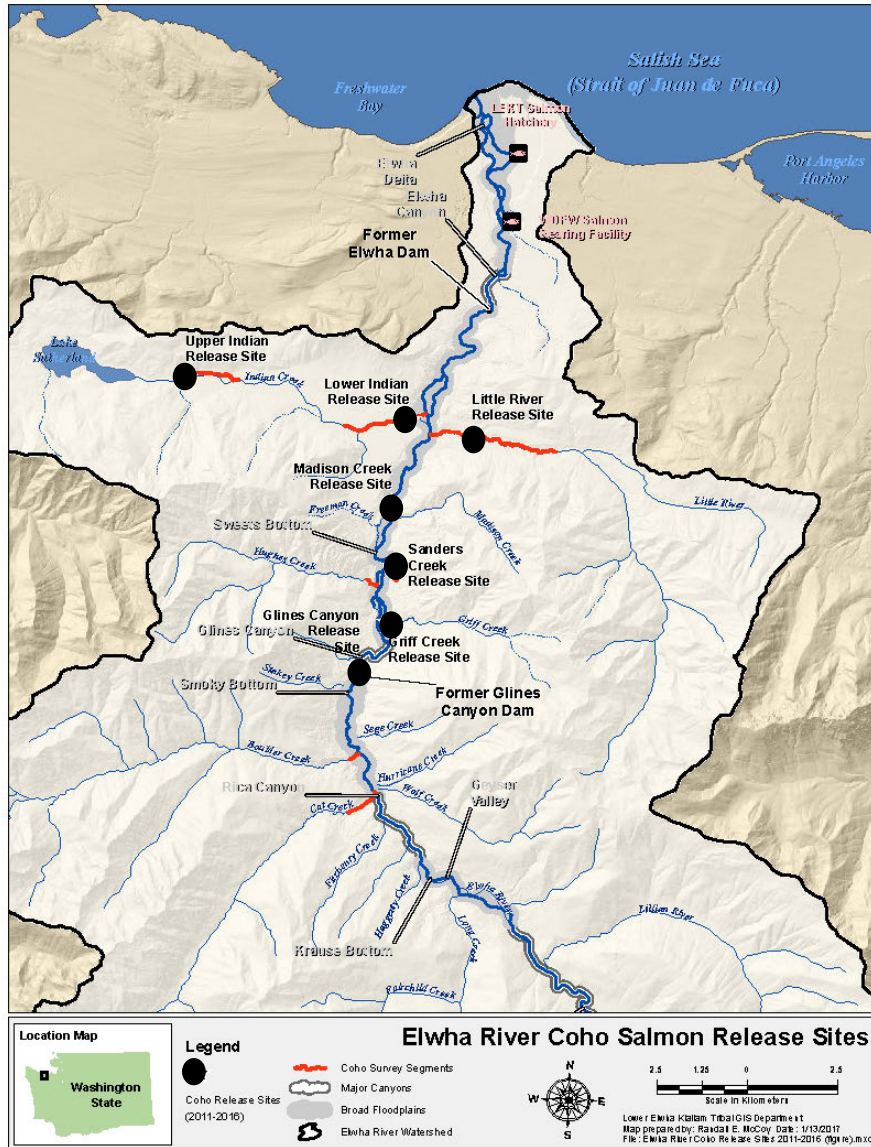


- Natural colonization

- Steelhead, Chinook salmon, Coho salmon, Pink salmon, Sockeye salmon, & Pacific Lamprey



Relocation of adult coho salmon in the middle Elwha 2011 to 2016

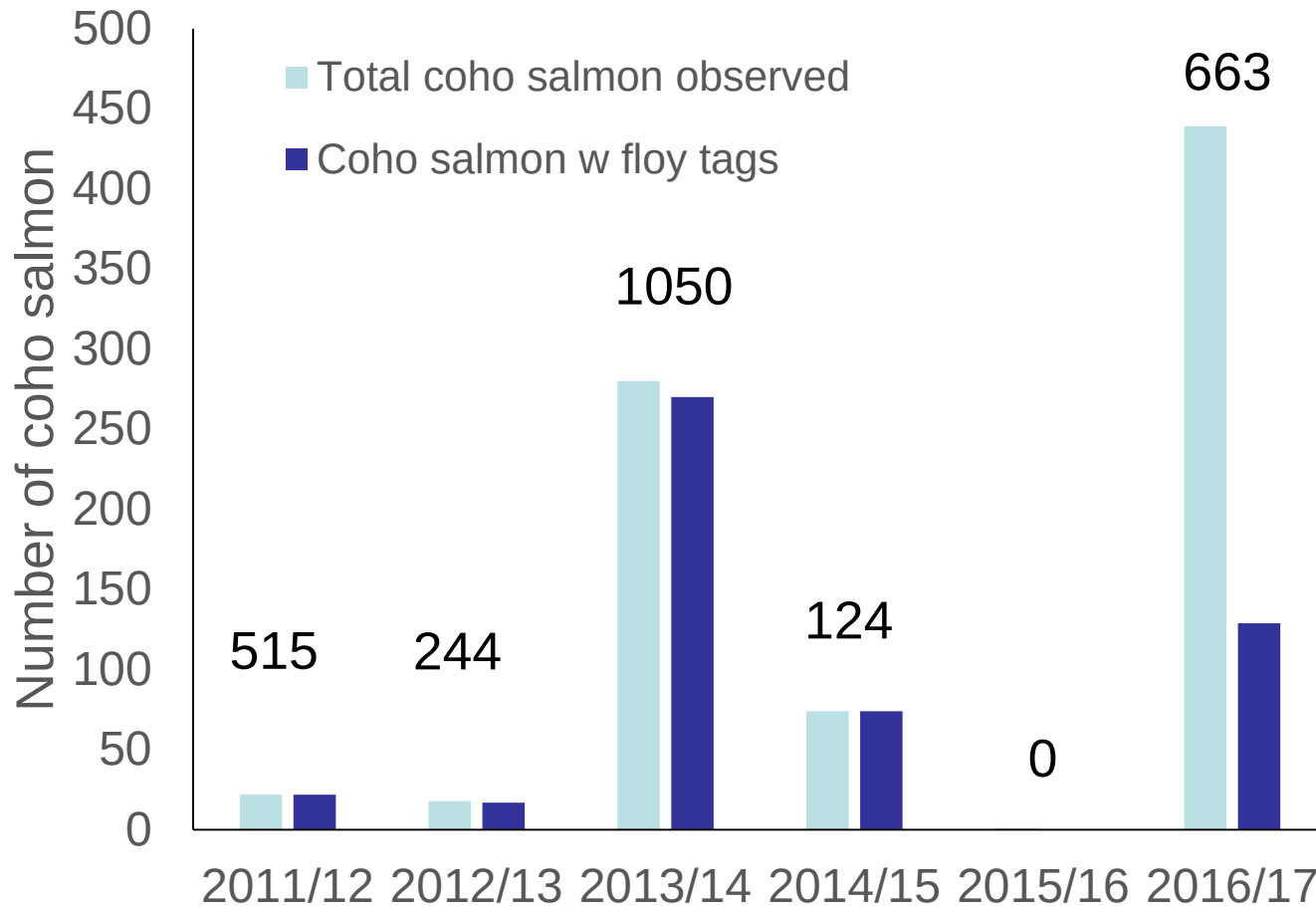


Release Location	Male Coho	Female Coho
Mainstem	150	153
Lower Indian Creek	334	305
Upper Indian Creek	260	296
Little River	265	179
Madison Creek	10	15
Sanders Creek	34	33
Griff Creek	15	13
Glines Canyon	93	119



Photo by John McMillan

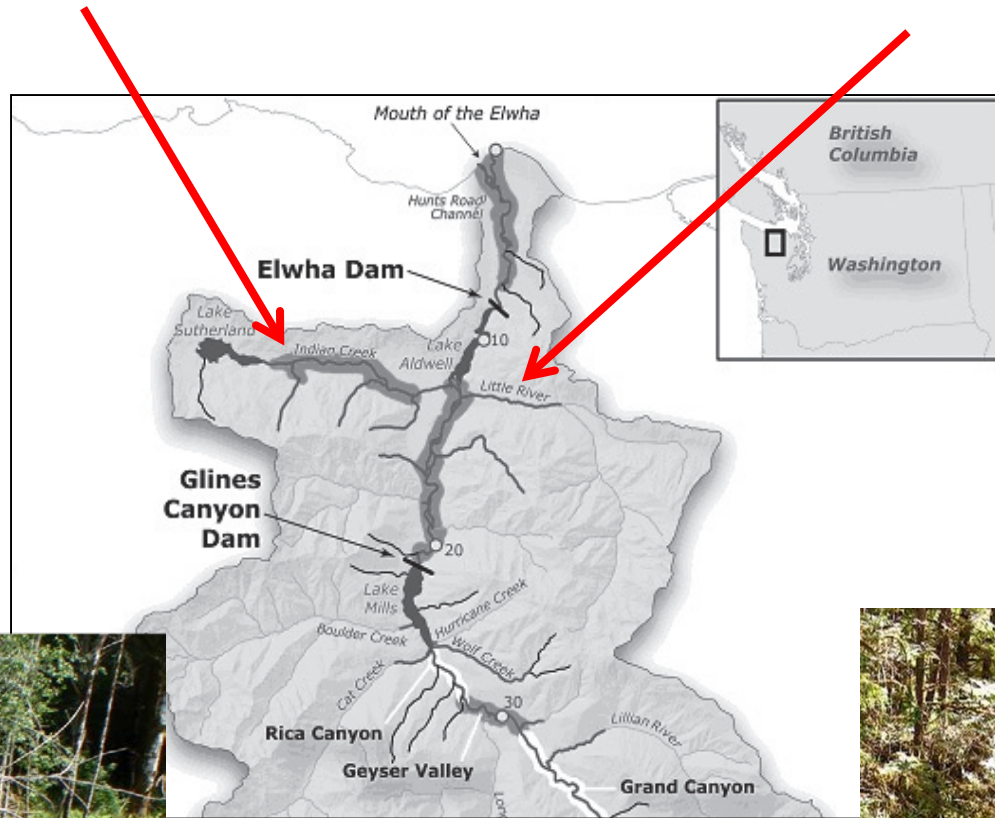
Coho salmon on spawning grounds



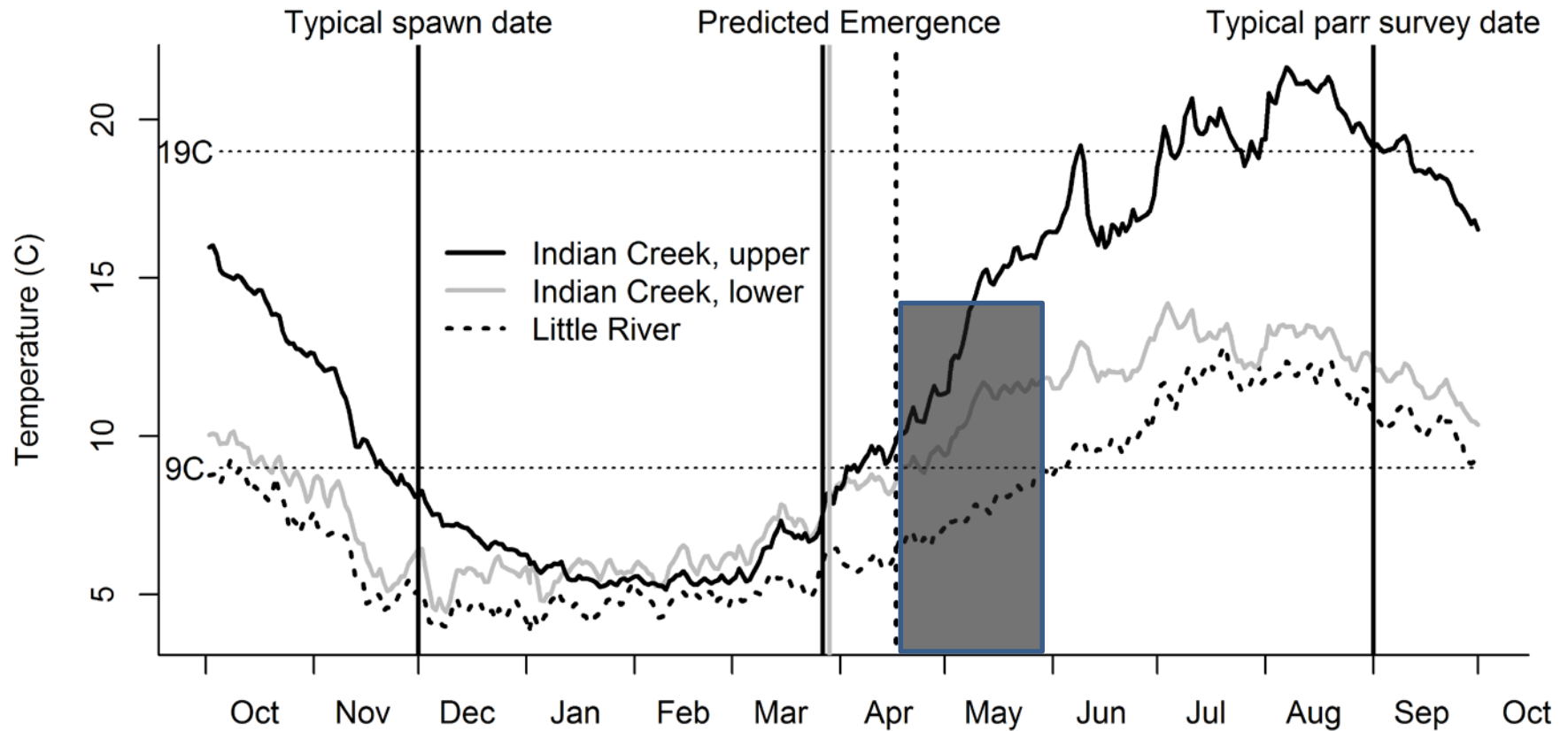
Almost 50% of the adult coho salmon seen on spawning grounds in the Middle Elwha in 2016-2017 did not have a floy tag

**Indian Creek is a low gradient,
wetland dominated system the
flows from Lake Sutherland**

**Little River is a steep gradient
channel, snowmelt dominated
stream**

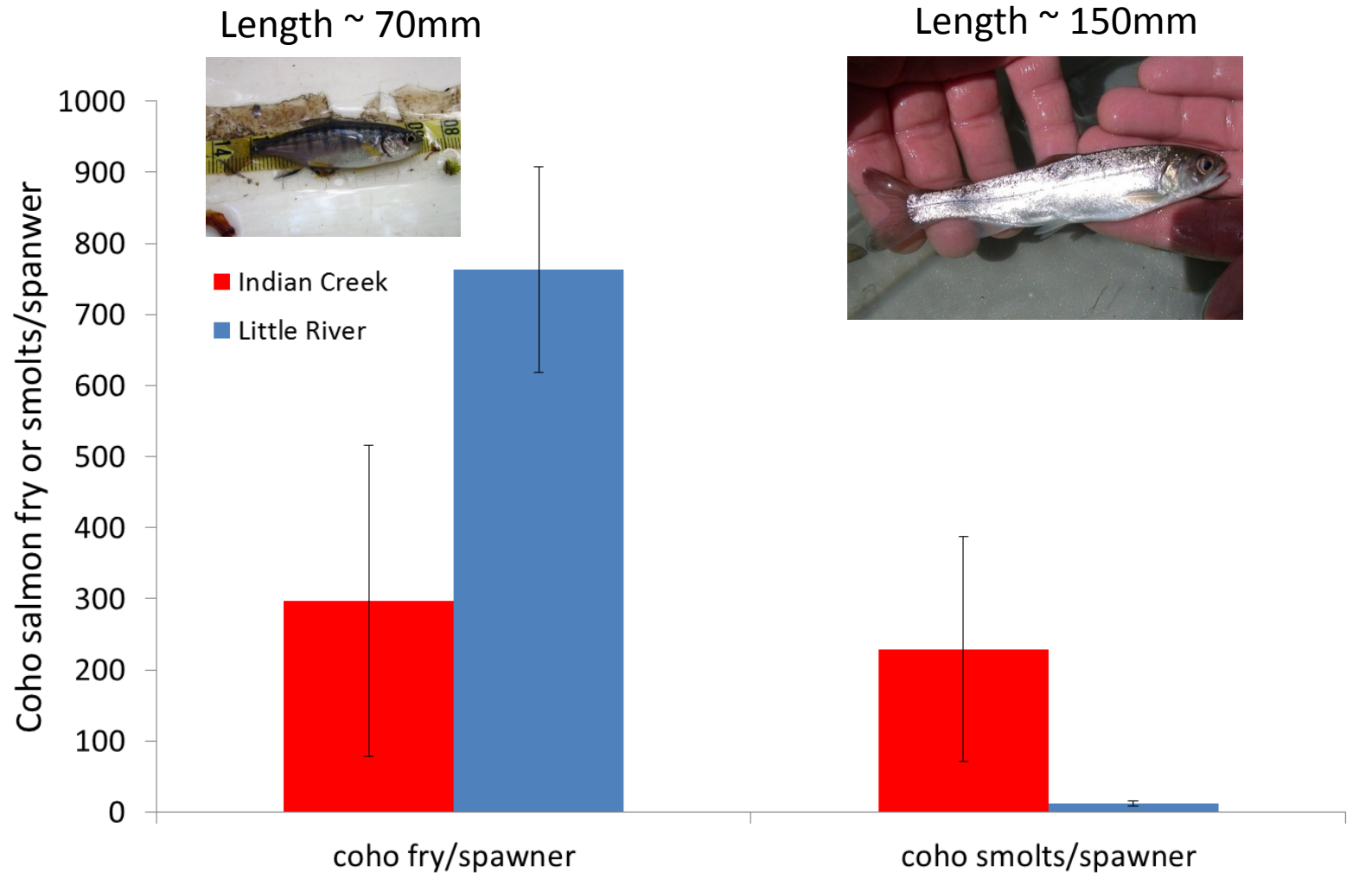


Indian Creek v. Little River stream temperature



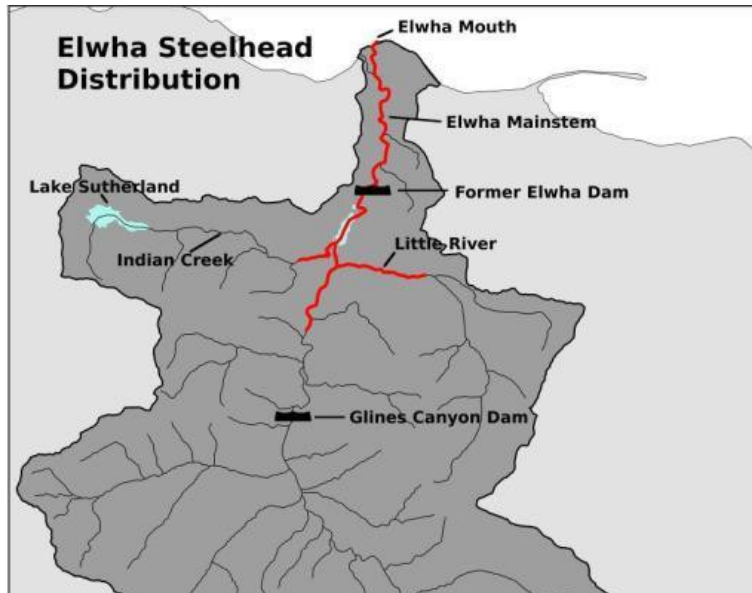
2 month growth advantage - April v. June

Indian Creek & Little River juvenile coho salmon outmigration



The progeny of the first generation of anadromous salmonids has resulted in different life history types of individuals with the same genetic composition in Indian & Little

Steelhead Natural & Assisted Recolonization



Year	Indian Creek		Little River	
	Fish relocated	Redds	Fish relocated	Redds
2012	11	9	35	43
2013	0	24	88	47
2014	0	36	59	73
2015	0	6	0	36
2016	34	7	0	28
2017	0	16	0	37

Data source: McMillan et al. 2018

Summary of 2017 winter steelhead surveys in the Elwha River

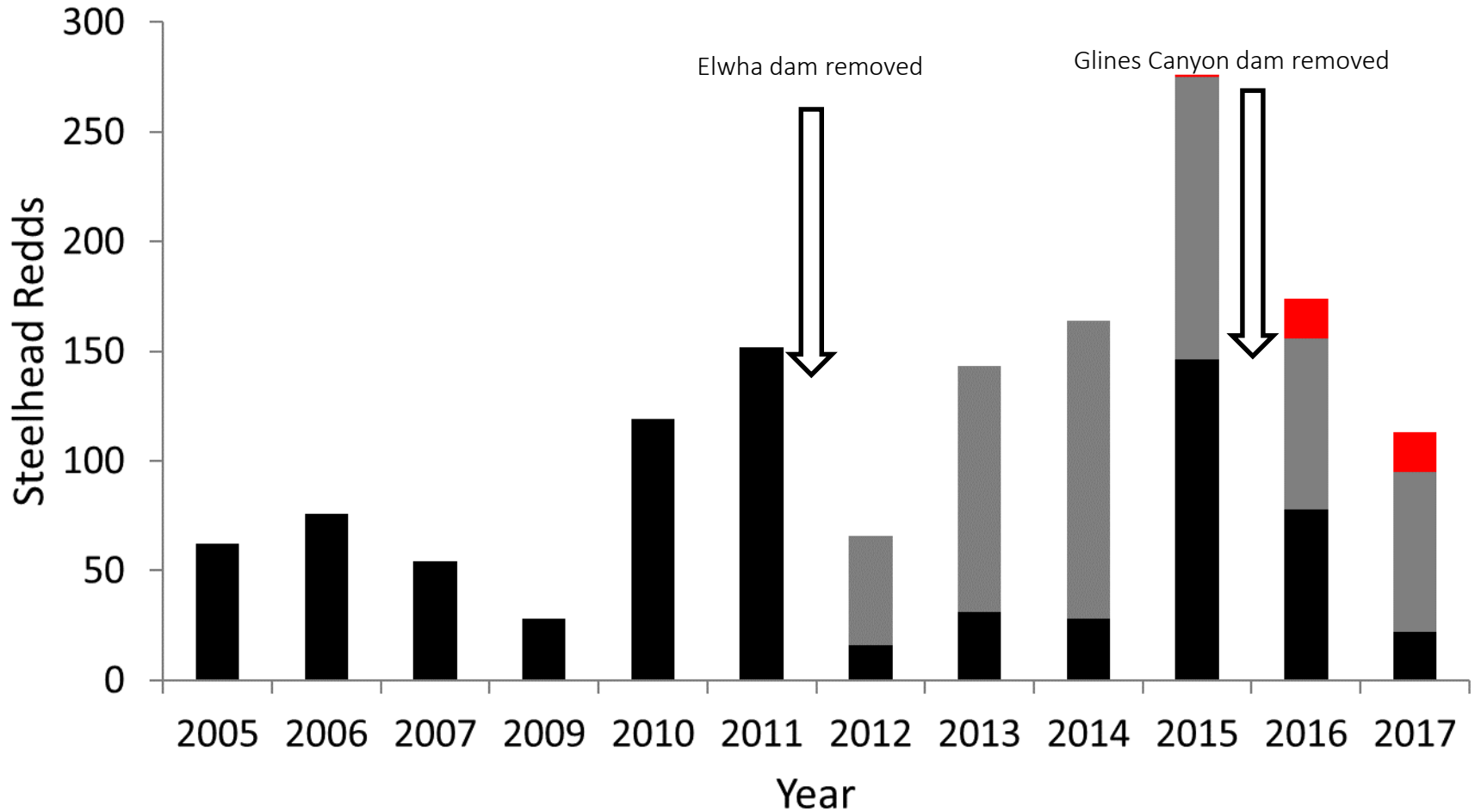
Note – 25% of Indian Creek and 90% of Little River is surveyed for spawners. Number of redds is not representative of the total number of spawners in each creek

Steelhead redds spatial distribution

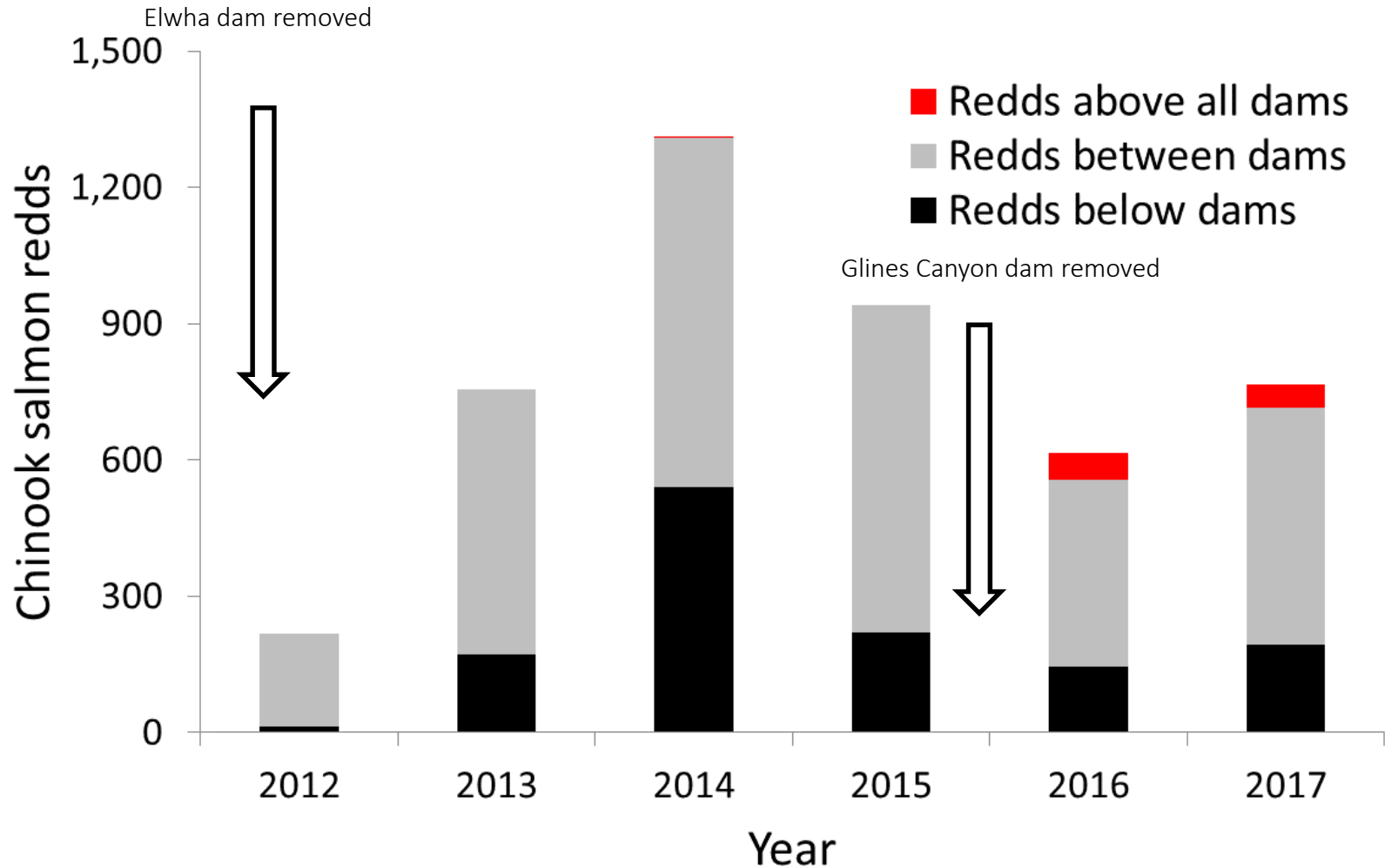
Downstream of Elwha Dam = black

Between the dams = grey

Above both dams = red

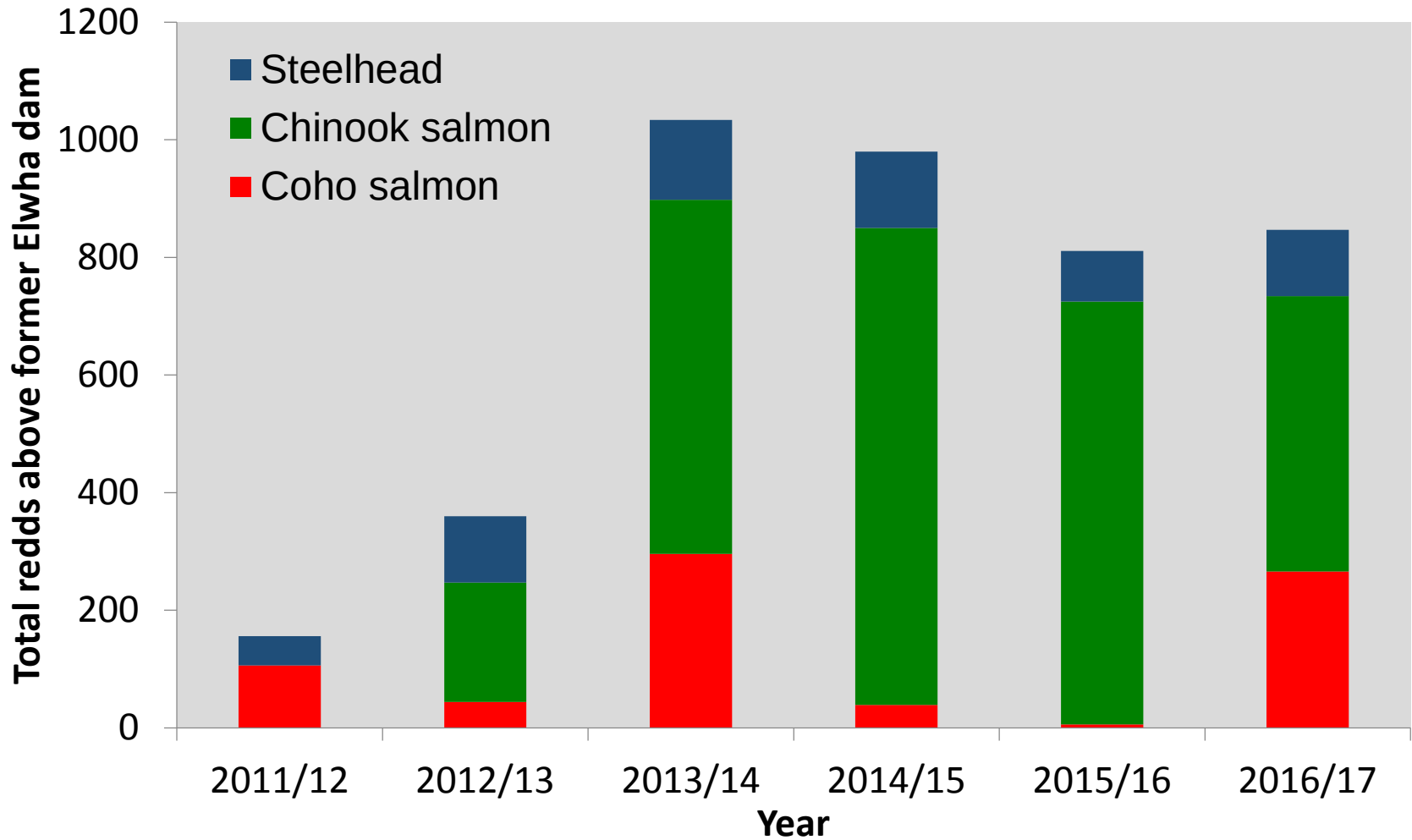


Natural recolonization by Chinook salmon

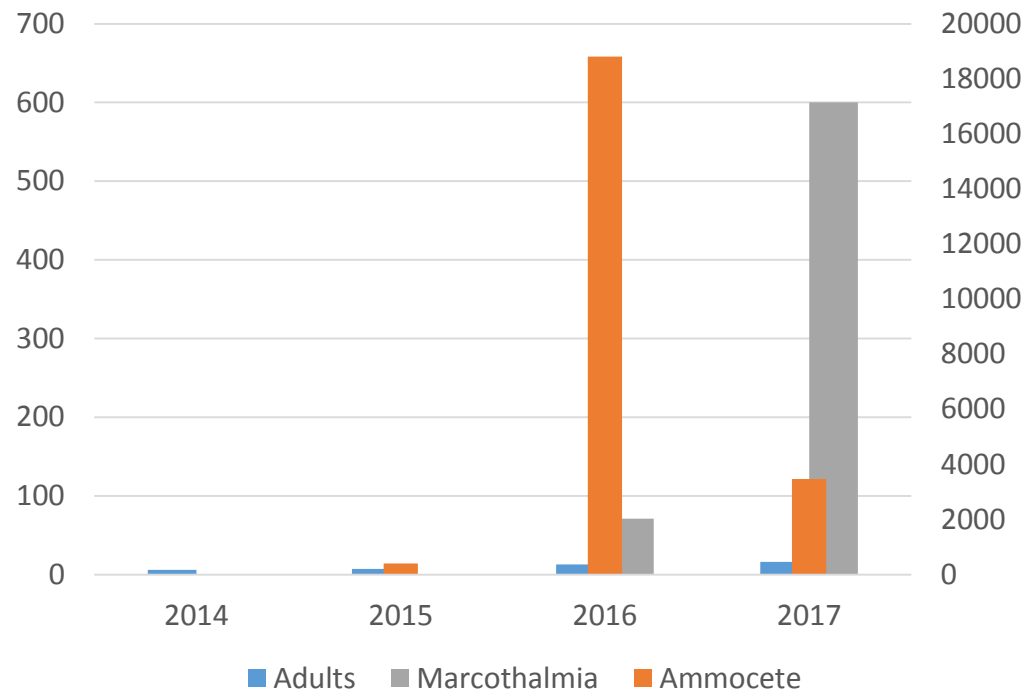


We had 59 and 52 redds above former Glines Canyon Dam in 2016 & 2017

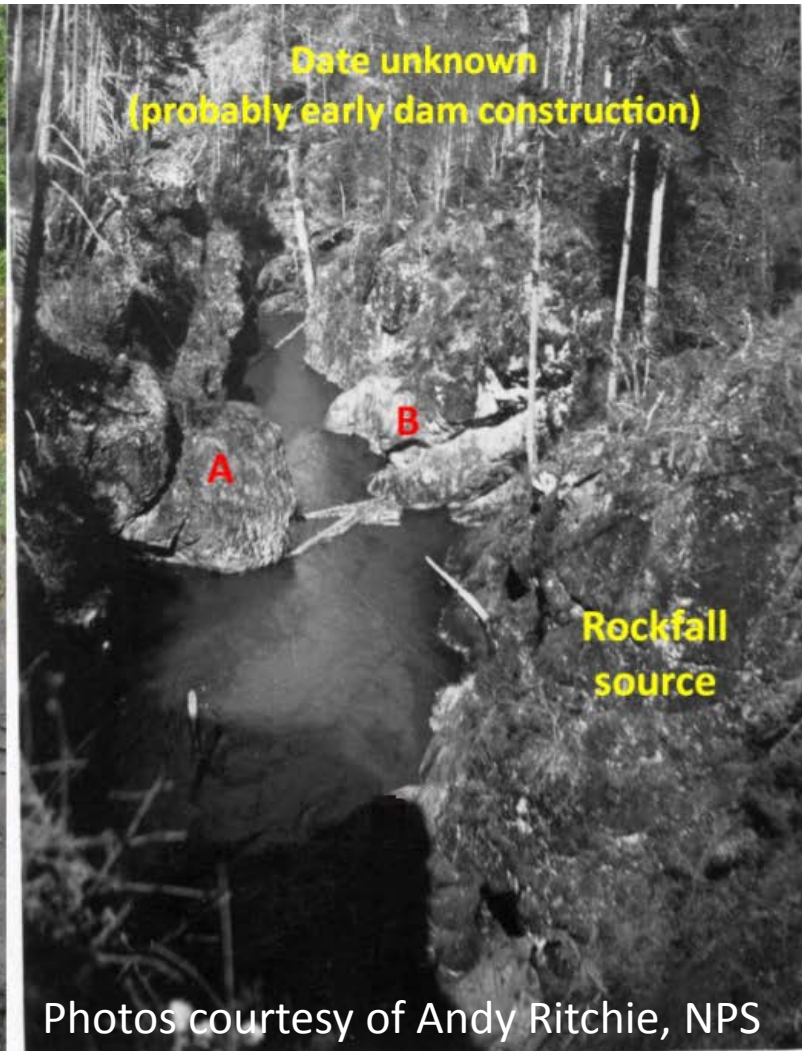
Salmon recolonization between and above the dams



Pacific lamprey increasing in Indian Creek



Adult salmon had issues at former Glines Canyon dam



Former Glines Canyon Dam rockfall blast September/October 2015



Photos courtesy of Andy Ritchie , NPS

Former Glines Canyon Dam Pre, during, and post rockfall

Pre rock fall



Rock fall

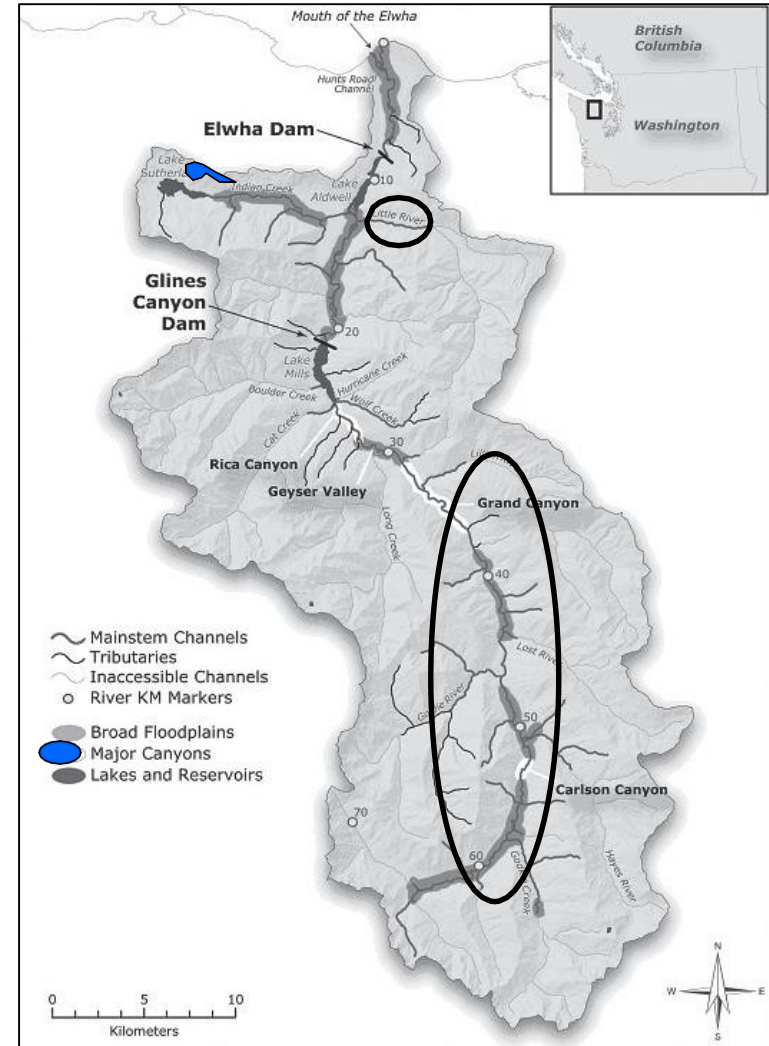
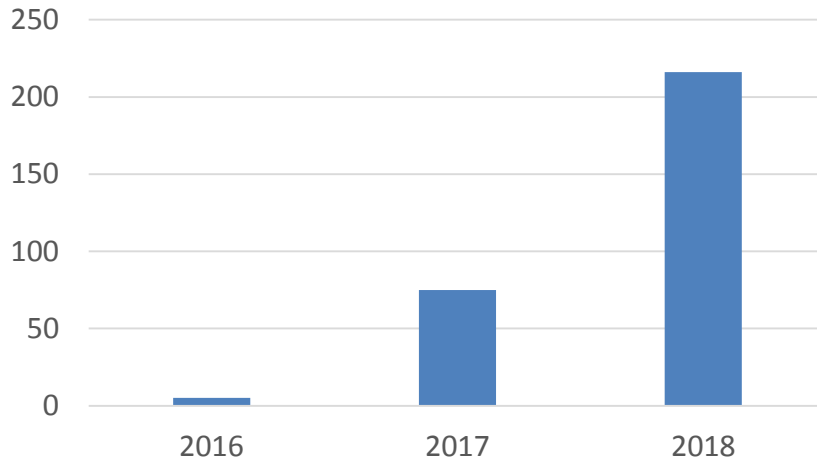


Post rock fall

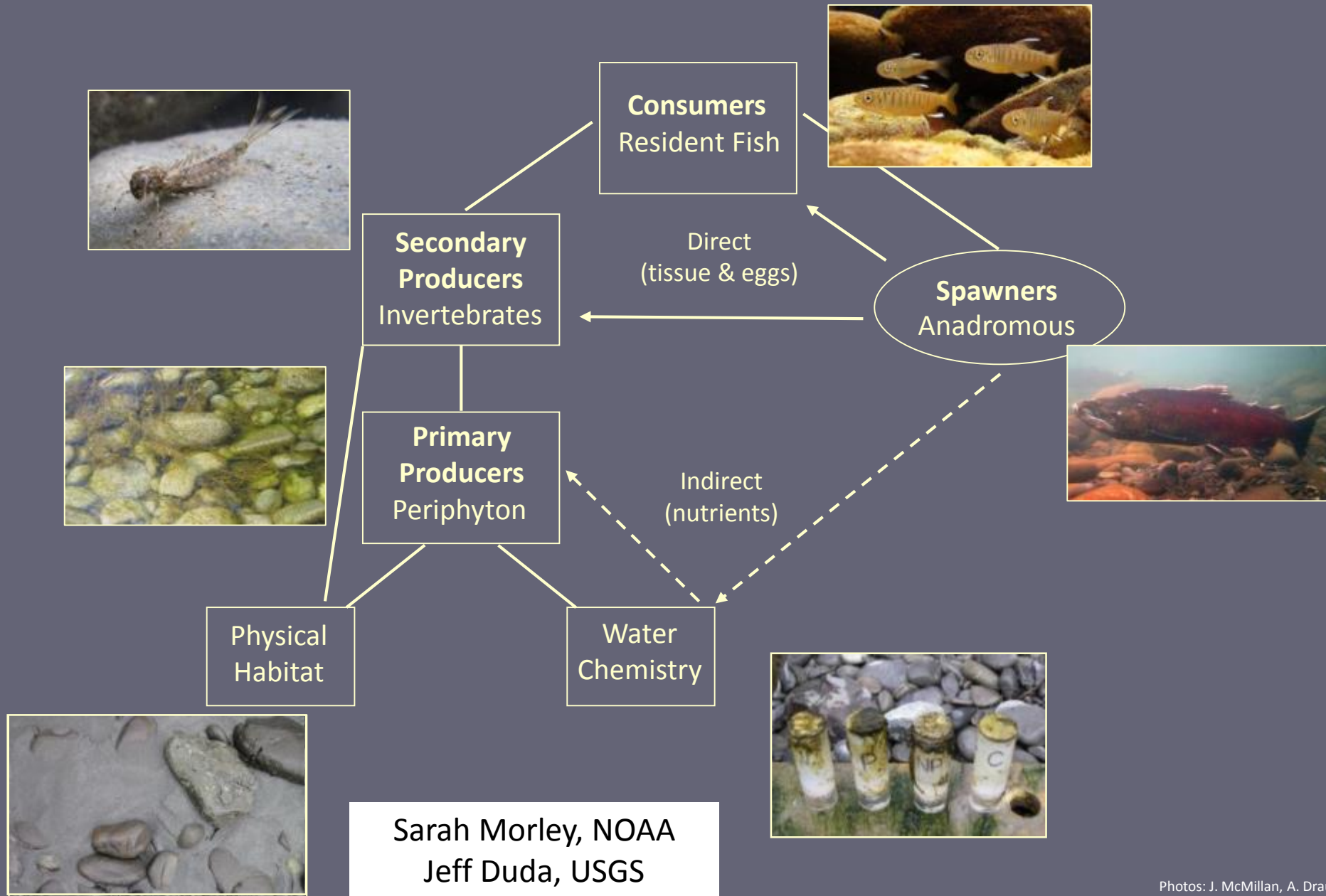


Upper Elwha summer steelhead observations

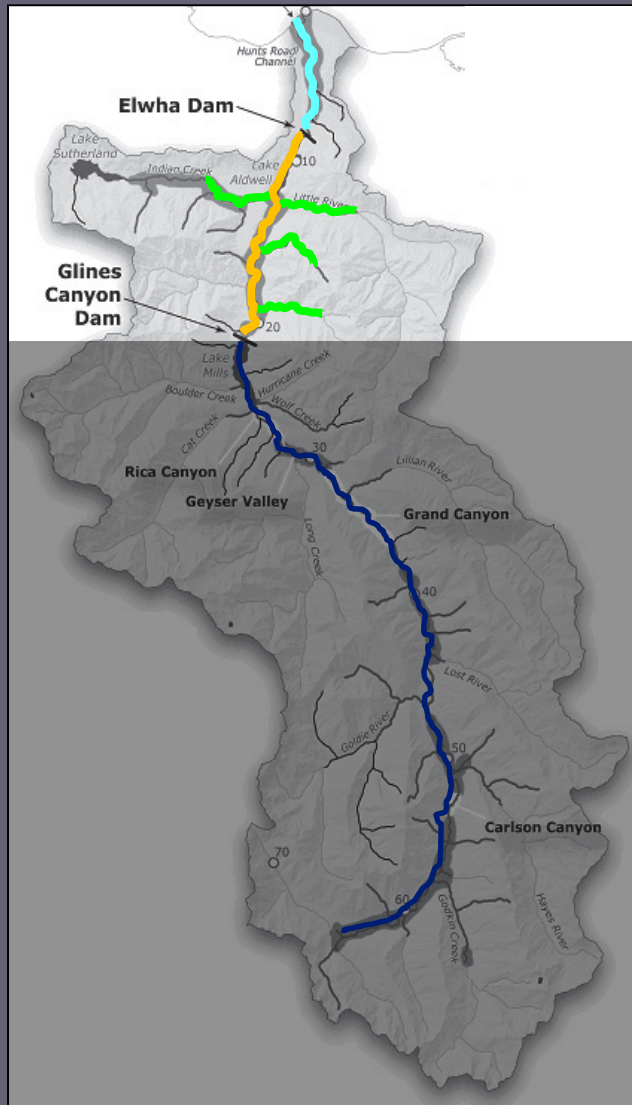
Summer steelhead observed



Benthic foodweb



Elwha River dam removal benthic foodweb study design



River sections: Below
Between
Above

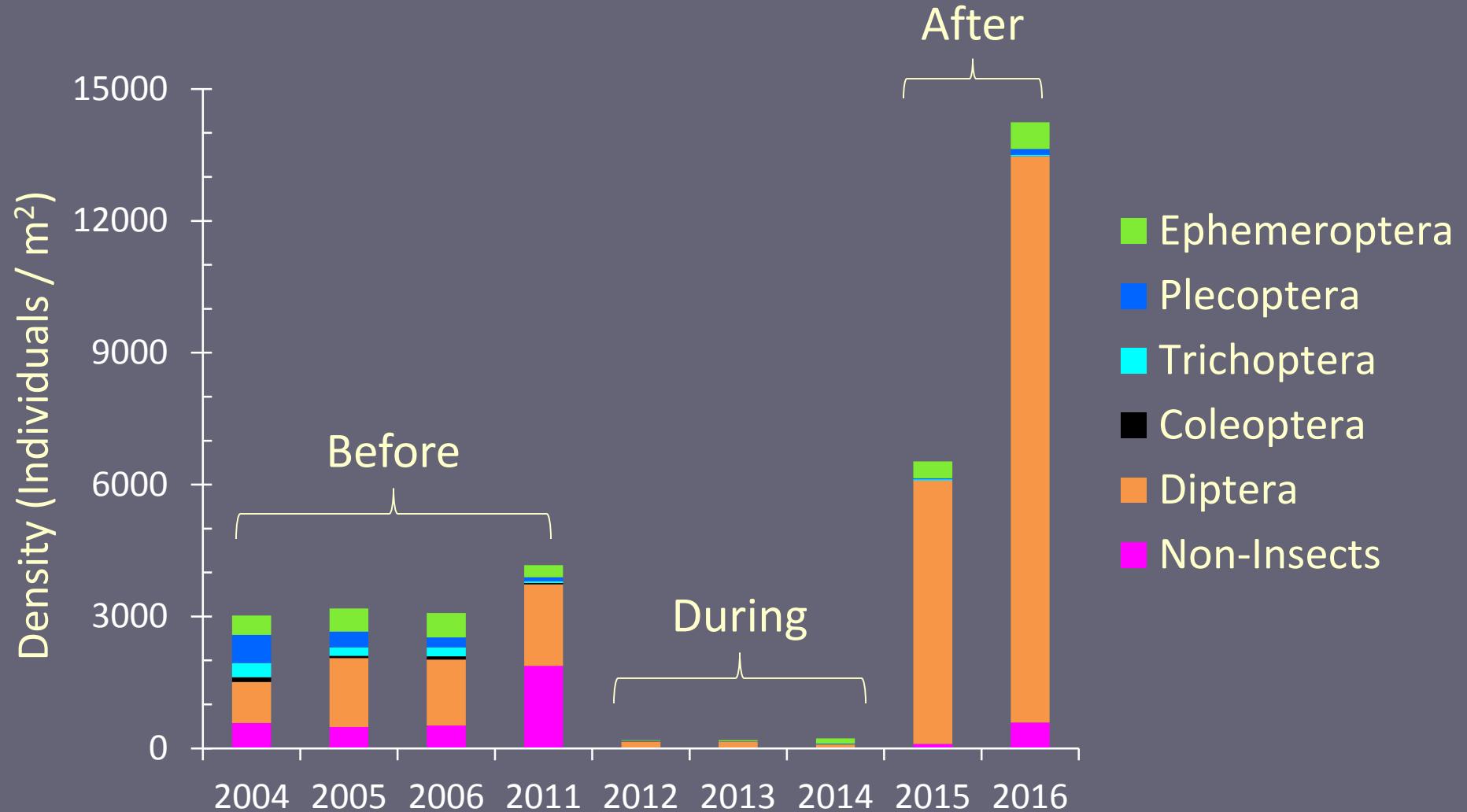
Habitat types: Mainstem
Side channels
Tributaries

Pre-removal: 2004-2011

During-removal: 2012-2014

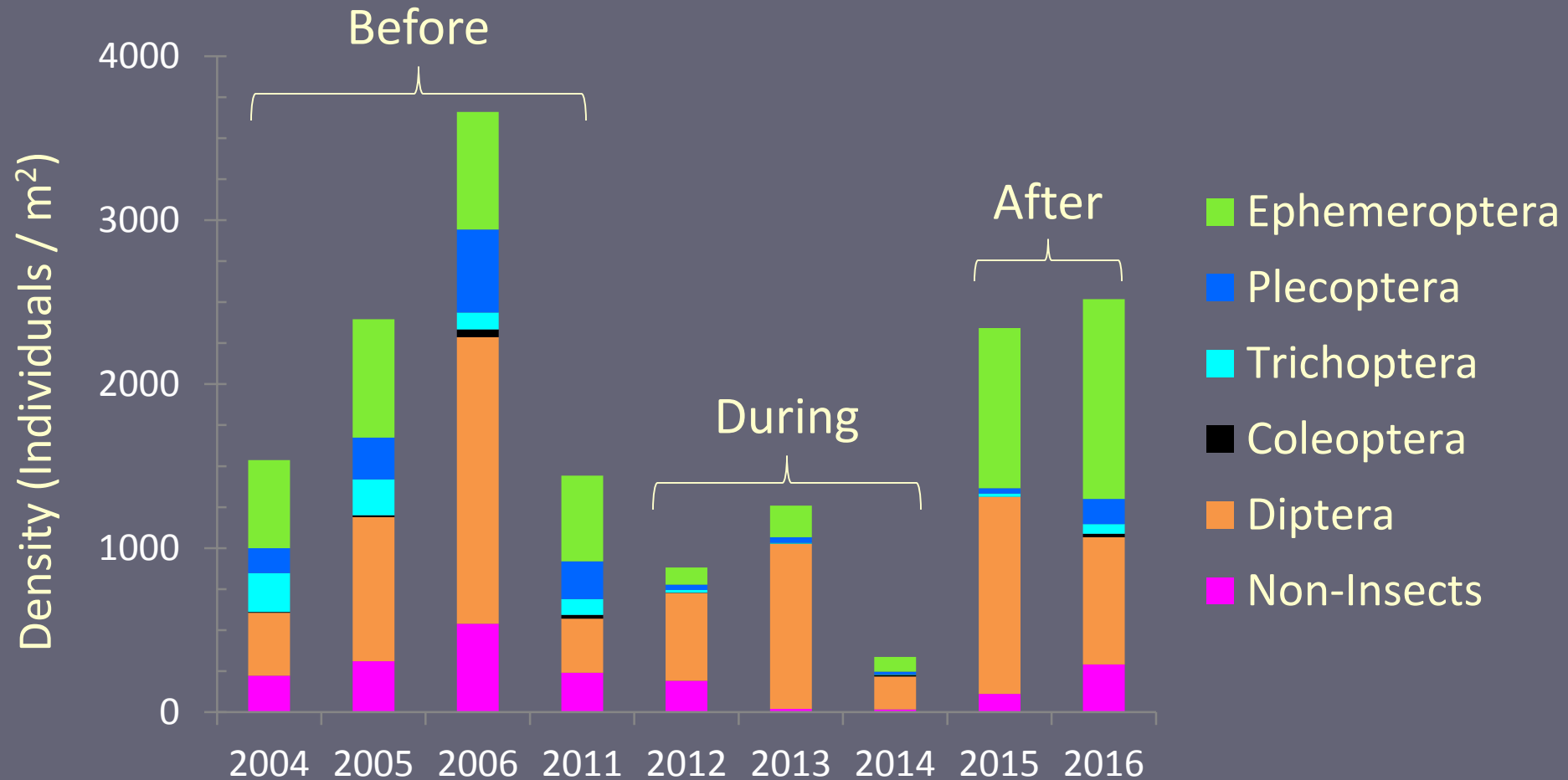
Benthic Invertebrate Taxonomic Composition

Below Elwha Dam



Benthic Invertebrate Taxonomic Composition

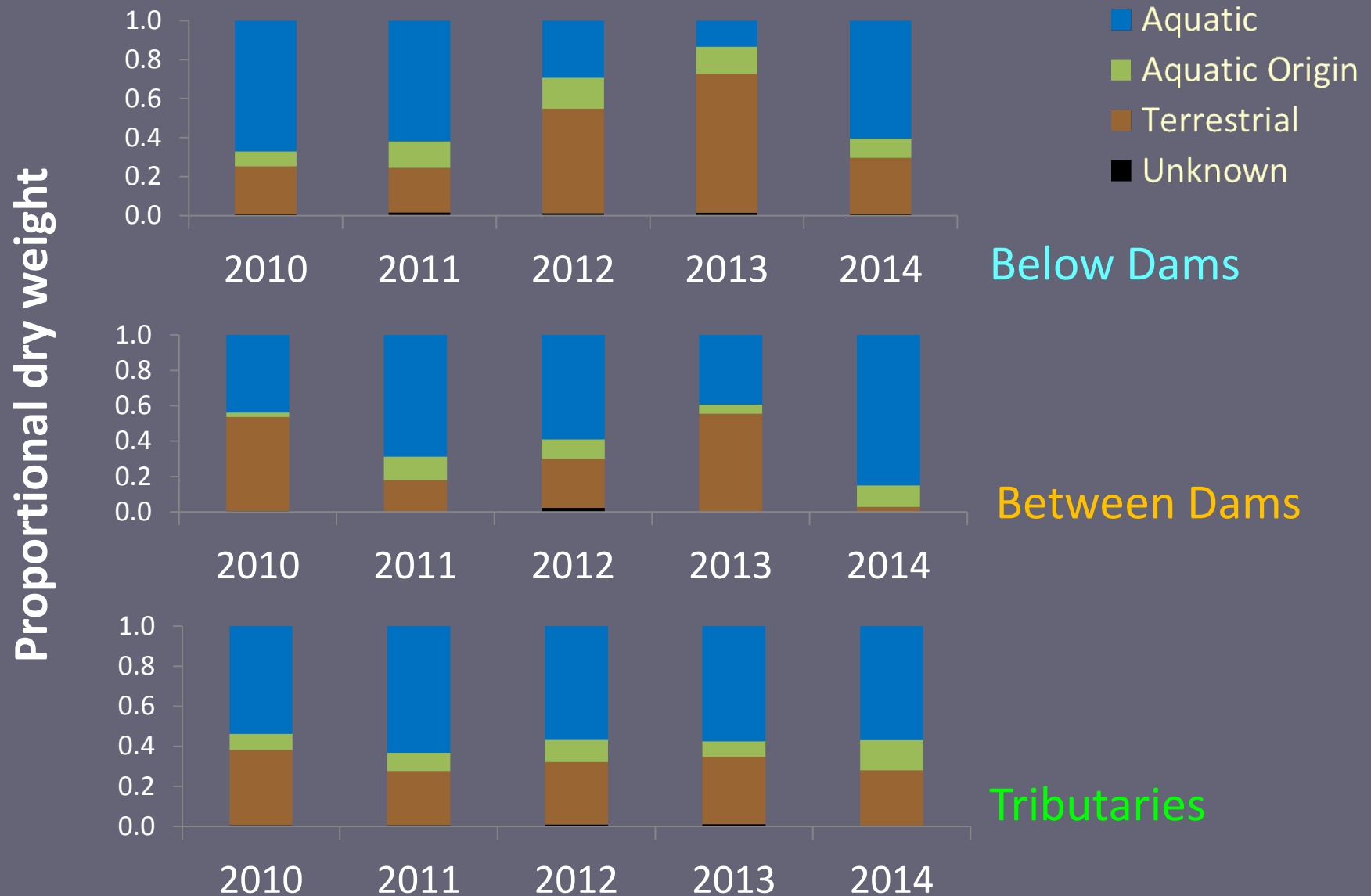
Between Dams



Diet Results



Juvenile *O. mykiss* Summer Diet Origin



Terrestrial linkages

Examining body condition and demographics in relation to marine-derived nutrients

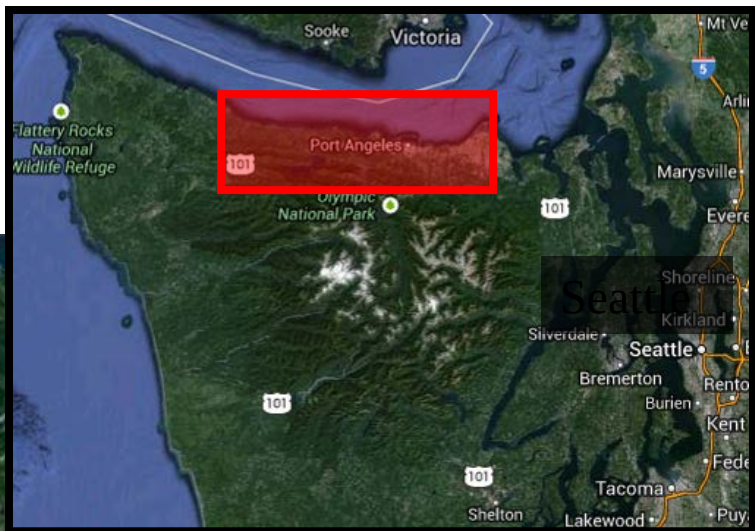
The case of the American dipper (*Cinclus mexicanus*)



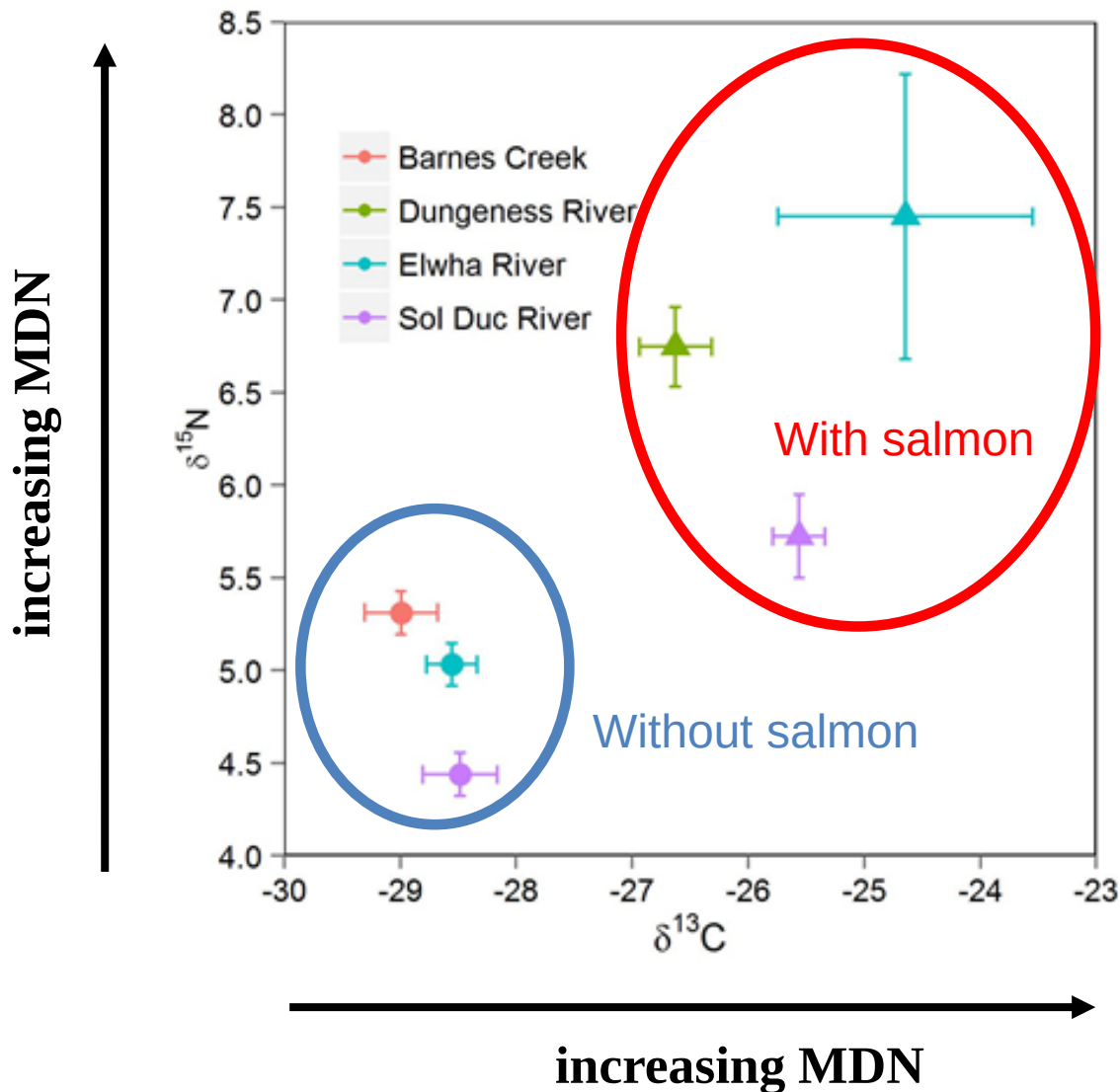
Photo by Chris Tonra



Photo by John McMillan



Increased MDN in areas with salmon



(Tonra et al. 2016)

Salmon nutrients affect life history variation & survival

- Higher female body condition with salmon
- Higher survival below obstructions
- Adult dippers **13 times** more likely to be year-round residents below obstructions
- Dippers below obstructions **20 times** more likely to attempt multiple broods

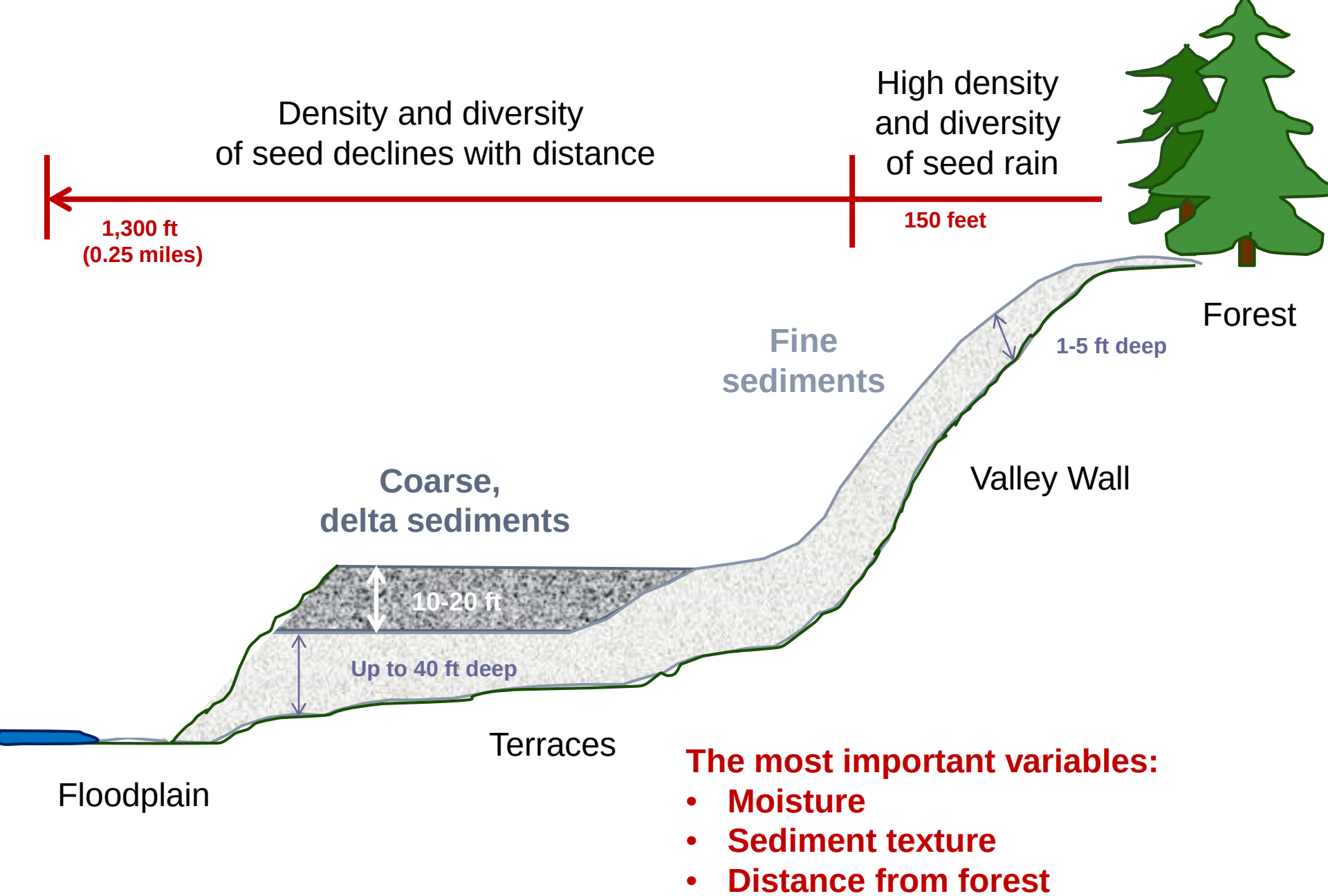


Revegetation - Reservoir revegetation plan



- 7 year plan
- Plant 400,000 native plants
- Sow 5,000 pounds of locally harvested seed





Revegetation – Josh Chenoweth, NPS

2012

2014

Fine
sediments



Coarse
sediments



Aug 2012



July 2013



July 2016



Changes to former Aldwell Reservoir – 2012 to 2016

Elwha River dams and former reservoirs

- Elwha and Glines canyon dam removal complete.
- ~65% of total stored sediment has been released.
- Reservoirs being re-vegetated both naturally and with restoration efforts.
- Vegetation thrive in fine sediments and coarse substrate has proven more difficult.



Elwha River nearshore, main stem, & floodplains

- Majority of sediment transported to Strait of Juan de Fuca
- Delta at river mouth has prograded into the Strait of Juan De Fuca.
- ~10% of sediment stored in-river.
- Main stem & floodplain channels downstream of dams aggraded (~1-2m)
- Gravels bars developed, large increase in wood accumulation



Fish Recolonization

- Adult salmonids making it above former Elwha Dam and Glines Canyon Dam
- Coho, steelhead & Chinook salmon redds have reached over 1,000 in the middle Elwha River.
- Salmonids are adapting to the local environmental conditions resulting in differences in life history types
- Non-salmon species are being seen and increasing in numbers



J. McMillan

Riverine Foodwebs

- Benthic invertebrates reduced over 95% in lower Elwha, now making a comeback
- Juvenile salmon adapted to change in foodweb
- American dippers benefiting from return of salmon & altering their migratory behavior



Thank you



Photo by John McMillan

Recent publications

Ritchie, A.C., Warrick, J.A., East, A.E., Magirl, C.S., Stevens, A.W., Bountry, J.A., Randle, T.J., Curran, C.A., Hildale, R.C., Duda, J.J. and Gelfenbaum, G.R., 2018. Morphodynamic evolution following sediment release from the world's largest dam removal. *Scientific reports*, 8.

Duda, J.J., Beirne, M.M., Warrick, J.A. and Magirl, C.S., 2018. Science partnership between US Geological Survey and the Lower Elwha Klallam Tribe—Understanding the Elwha River Dam Removal Project (No. 2018-3025). US Geological Survey.

Lincoln, A.E., Shaffer, J.A. and Quinn, T.P., 2018. Opportunistic use of estuarine habitat by juvenile bull trout, *Salvelinus confluentus*, from the Elwha River before, during, and after dam removal. *Environmental Biology of Fishes*, pp.1-11.

Foley, M.M., Warrick, J.A., Ritchie, A., Stevens, A.W., Shafroth, P.B., Duda, J.J., Beirne, M.M., Paradis, R., Gelfenbaum, G., McCoy, R. and Cubley, E.S., 2017. Coastal habitat and biological community response to dam removal on the Elwha River. *Ecological Monographs*, 87(4), pp.552-577.

Peters, R.J., Liermann, M., McHenry, M.L., Bakke, P. and Pess, G.R., 2017. Changes in streambed composition in salmonid spawning habitat of the Elwha River during dam removal. *JAWRA Journal of the American Water Resources Association*, 53(4), pp.871-885.

Liermann, M., Pess, G., McHenry, M., McMillan, J., Elofson, M., Bennett, T. and Moses, R., 2017. Relocation and recolonization of Coho Salmon in two tributaries to the Elwha River: implications for management and monitoring. *Transactions of the American Fisheries Society*, 146(5), pp.955-966.