Adaptive monitoring to a large-scale restoration action – The Elwha River dam removal

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Disclaimer

Any opinions expressed today are my own & not necessarily shared or represented by NOAA.

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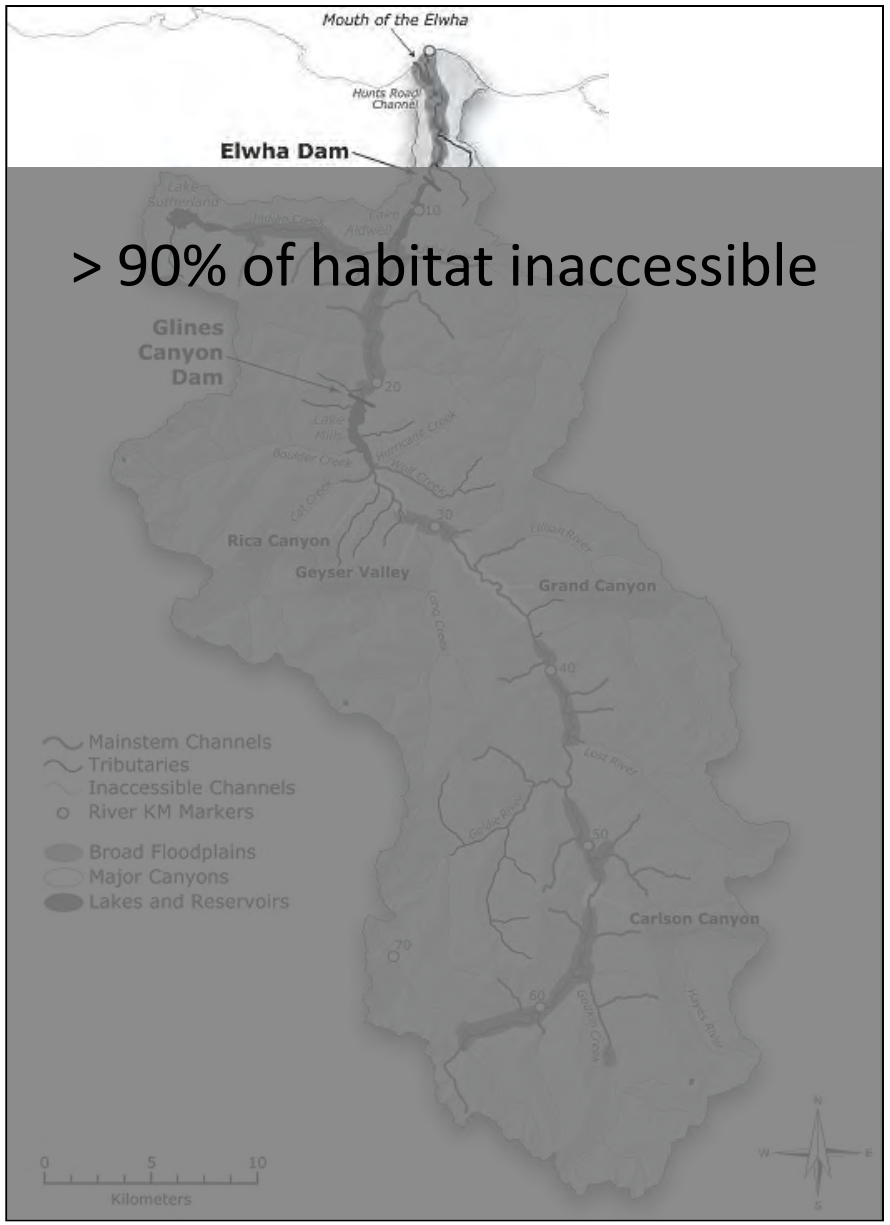
Roadmap for today's talk

- Watershed overview
- Background
- The action
- Questions
- Results
- Summary

Looking upstream at Glines canyon dam

Impacts of the Dam – Fish Passage



Elwha fishes

Coho salmon

Pink salmon

Chinook salmon

Steelhead

Chum salmon

Sockeye salmon

Sculpin spp.

Bull trout

Brook trout

Elwha fishes

Threespine stickleback

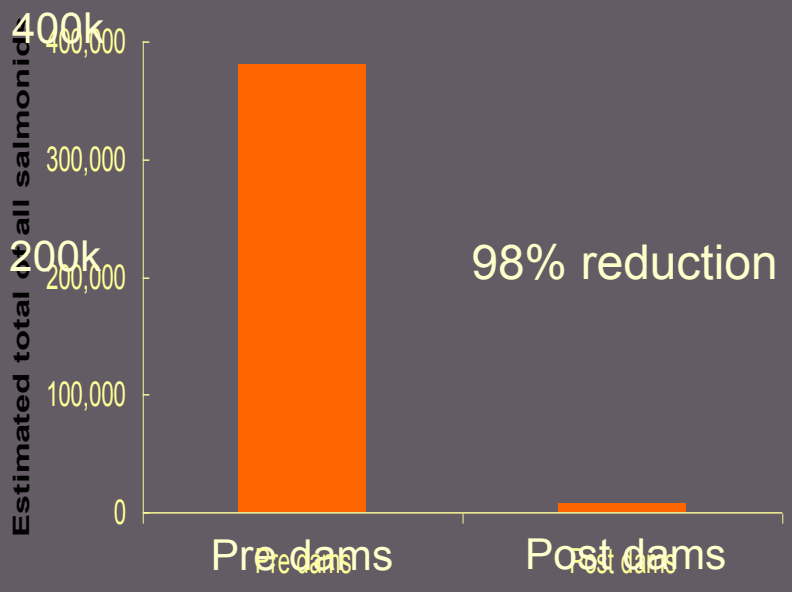
Redside shiner

Eulachon

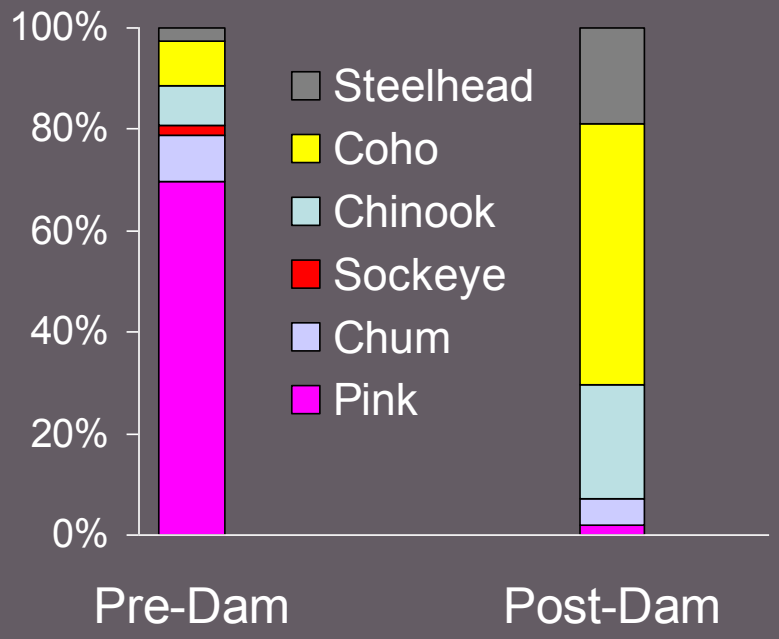
Pacific lamprey

Impacts of the Dam – Salmon Populations

Total population decline



Shift in species composition



All native populations are very low in abundance

Species of interest

Species	Estimated population size below dams	% Hatchery
Spring Chinook	Unknown	Unknown
Summer/Fall Chinook	~2,000	**~75**
Coho	~2,000	**~76**
Chum	~100	0
Pink	~100	0
Sockeye	~25	0
Winter steelhead	~300	**~?**
Summer steelhead	~50	0
Sea-run cutthroat	Unknown	0
Char	~500	0

Elwha River Ecosystem & 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

September 2011

October 2012

What's Going to Happen To All the Sediment?

~ 20 million m^3 of sediment accumulated in reservoirs

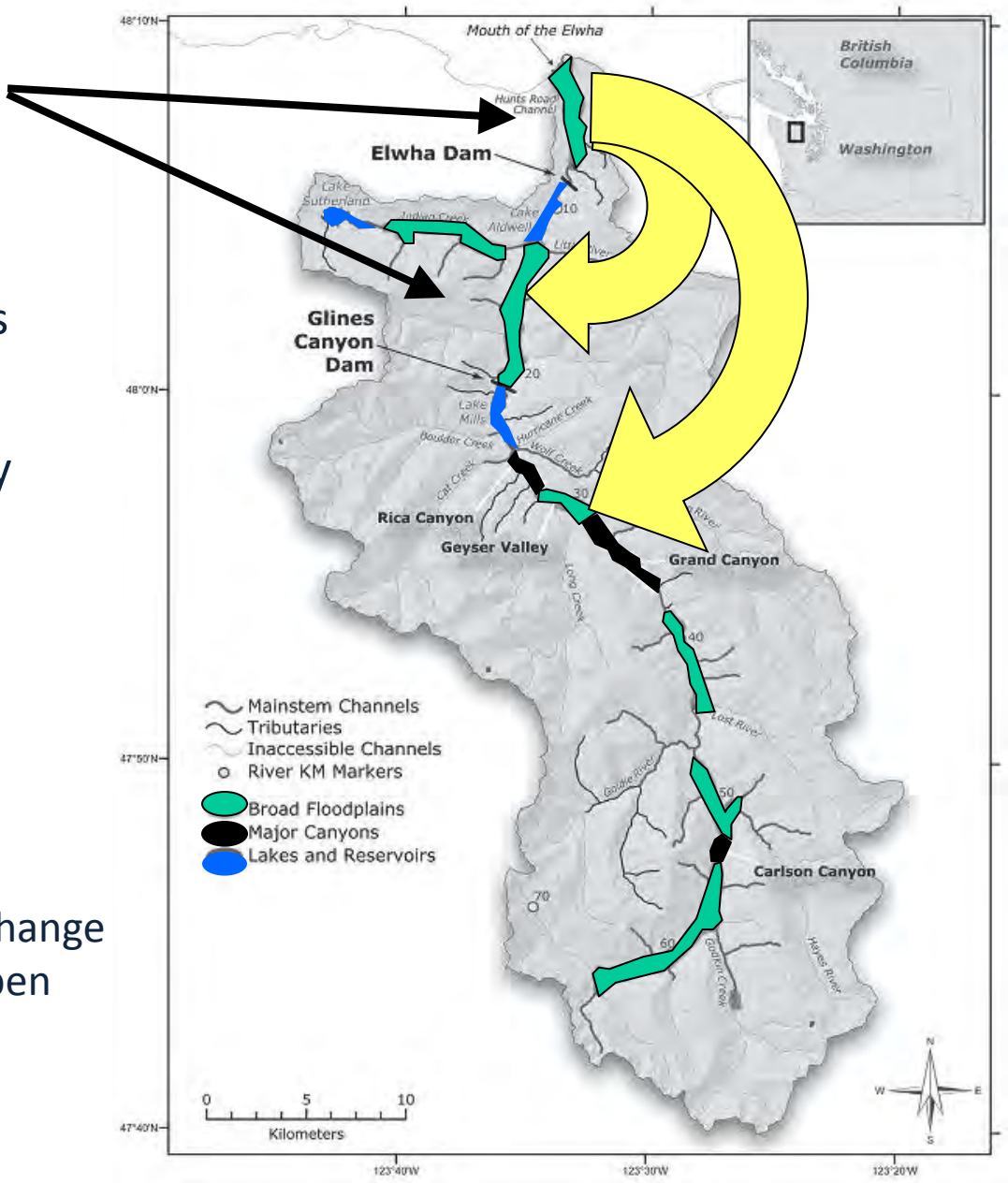
- ~ 54% fine, ~46% coarse
- ~40% predicted to erode downstream

Predictions

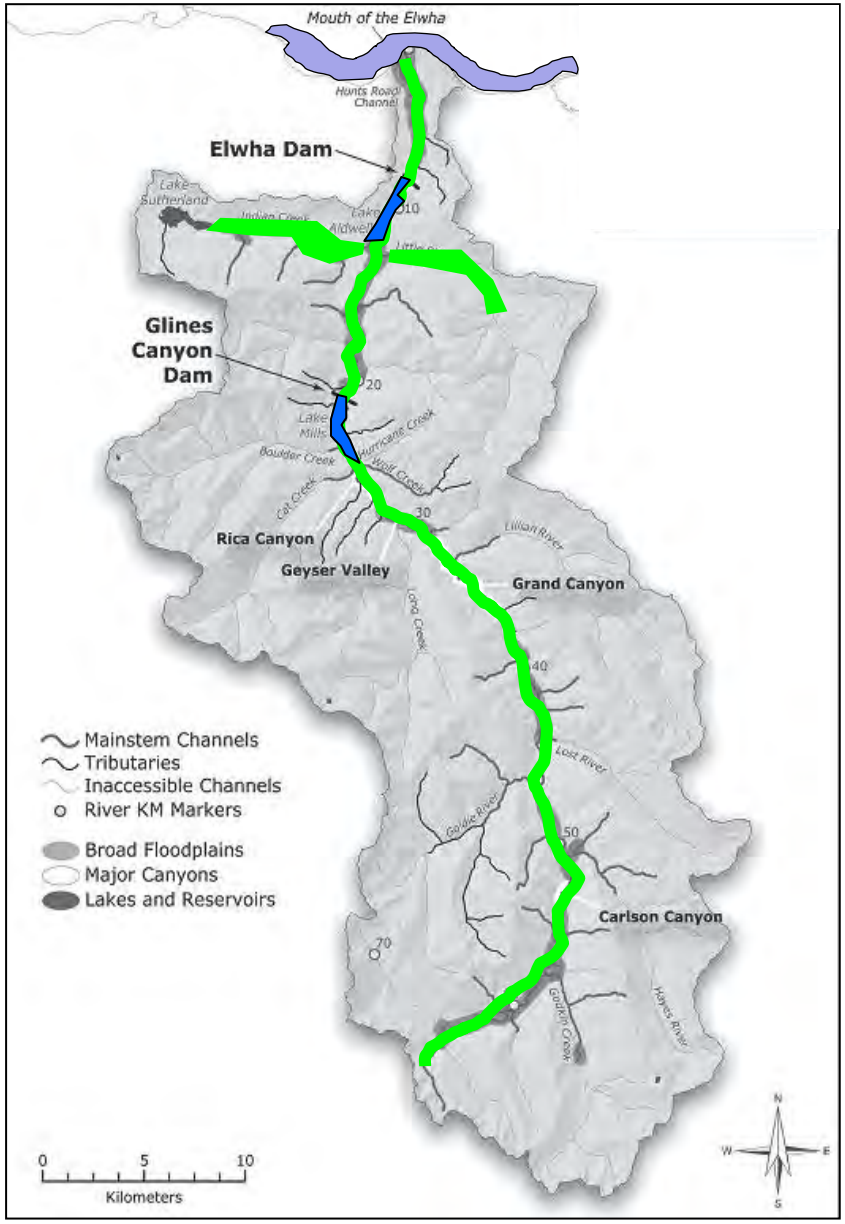
- suspended-sediment > 10,000 ppm
- temporary deposition of fines in pools
- more dynamic floodplain
- bed aggradation in lower river
- beach formation in estuary

How will habitat conditions & salmon populations change?

- Lower and Middle River
  - How will mainstem habitat conditions change?
  - How will floodplain channels respond?
  - How will stream productivity change?
  - How will different habitats respond to turbidity?
- Middle and Upper River
  - How will salmon populations change when they recolonize newly open habitats?



What has occurred with the Elwha Dam removal?



Location

- Dams & former reservoirs
- Nearshore
- River ecosystem

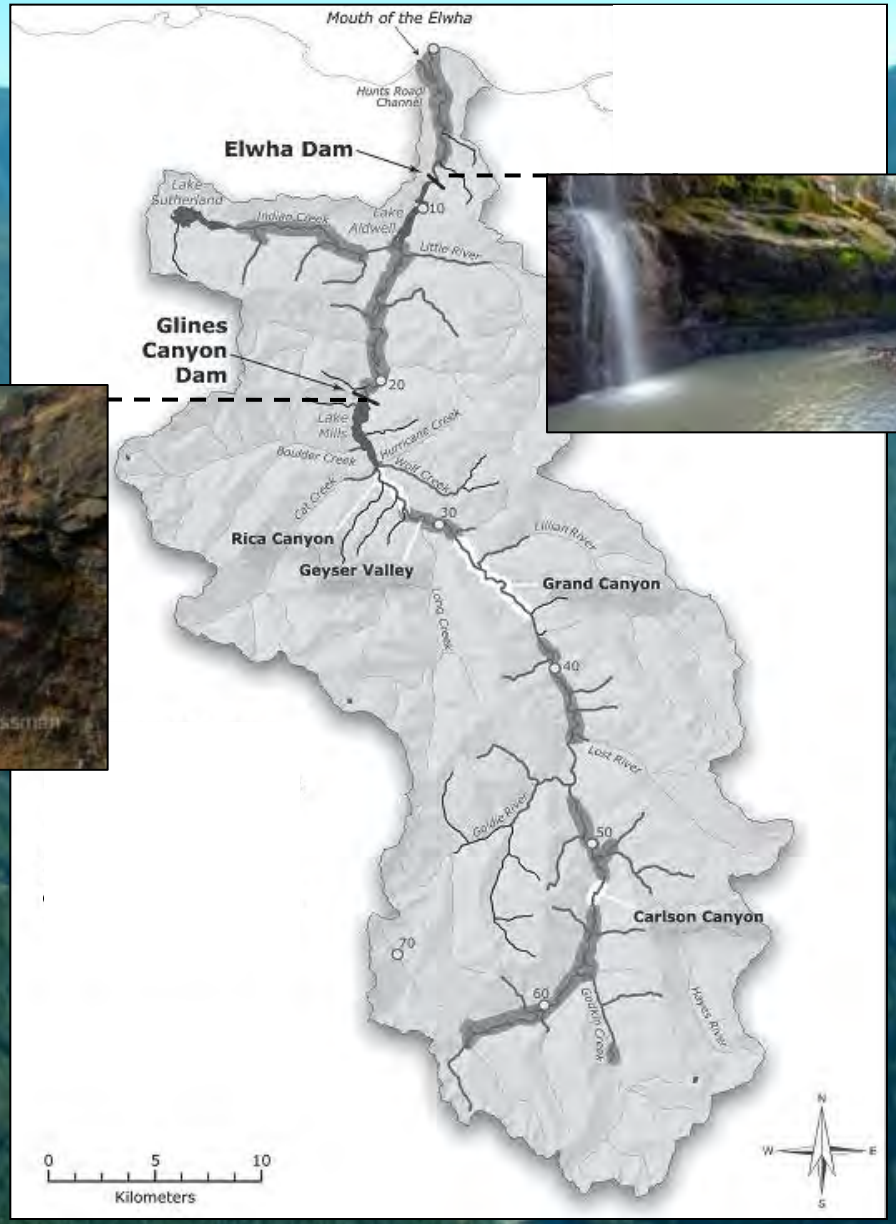
Processes

- Sediment dynamics
- Stream productivity
- Fish recolonization
- Fish impacts

The Elwha River Basin

Photos: John Gussman

The Elwha River Basin



Photos: John Gussman

How Are the Elwha Dams Being Removed?

- Concurrently in controlled increments over 2-3 years
- Fast enough to limit duration of physical impacts
- Slow enough to limit severity of biological impacts
- Deconstruction temporarily halted during fish windows

Glines Canyon Dam – U.S. NPS Webcam

Glines Canyon Dam – Jan 2012

Glines Canyon Dam – Jan 2013

Glines Canyon Dam – Jan 2014

John Gussman

Glines Canyon Dam – Jan 2014

John Gussman

Glines Canyon Dam – Jan 2014

Former Mills Reservoir – January 2014

John Gussman

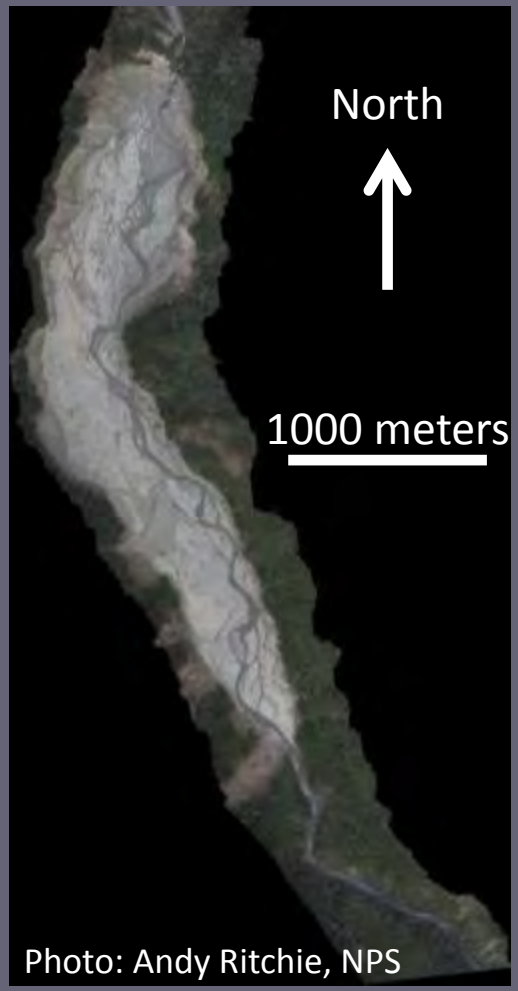
Elwha Dam

Elwha River – Elwha Dam

Elwha River – Elwha Dam

Elwha River – Former Elwha Dam

How has sediment supply changed?



Above Dams

Below Dams

Year 1: ~ 8% of sediment mobilized

FNU/FBU

1000

0

Aug-11 Oct-11 Dec-11 Feb-12 Apr-12 May-12 Jul-12 Sep-12 Nov-12 Jan-13 Mar-13

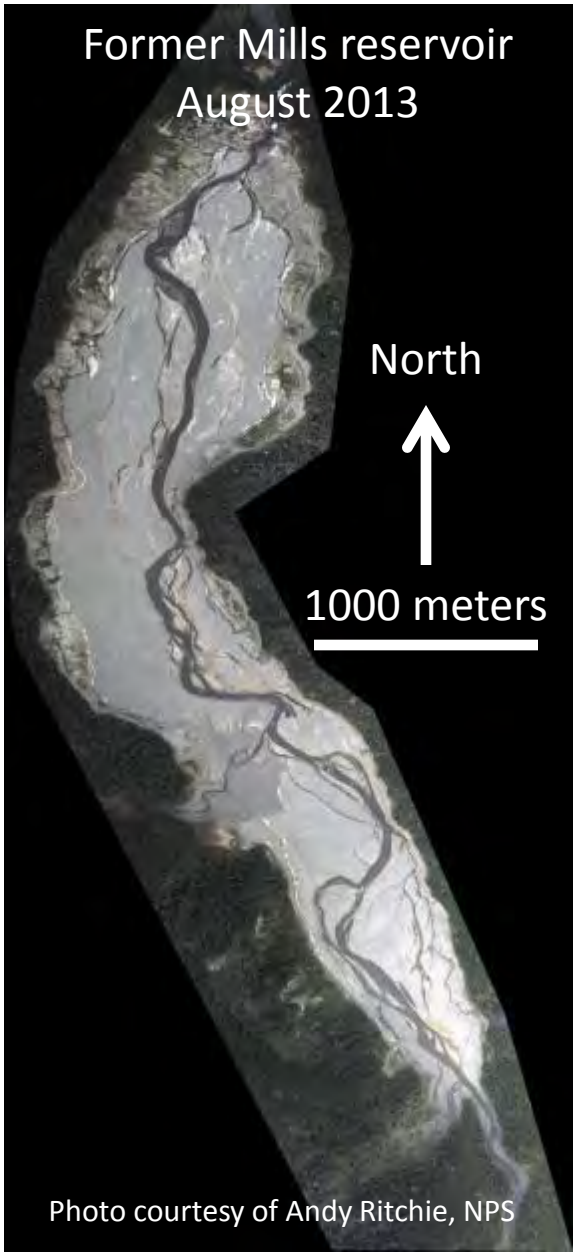
Dam removal begins

Elwha Dam removed

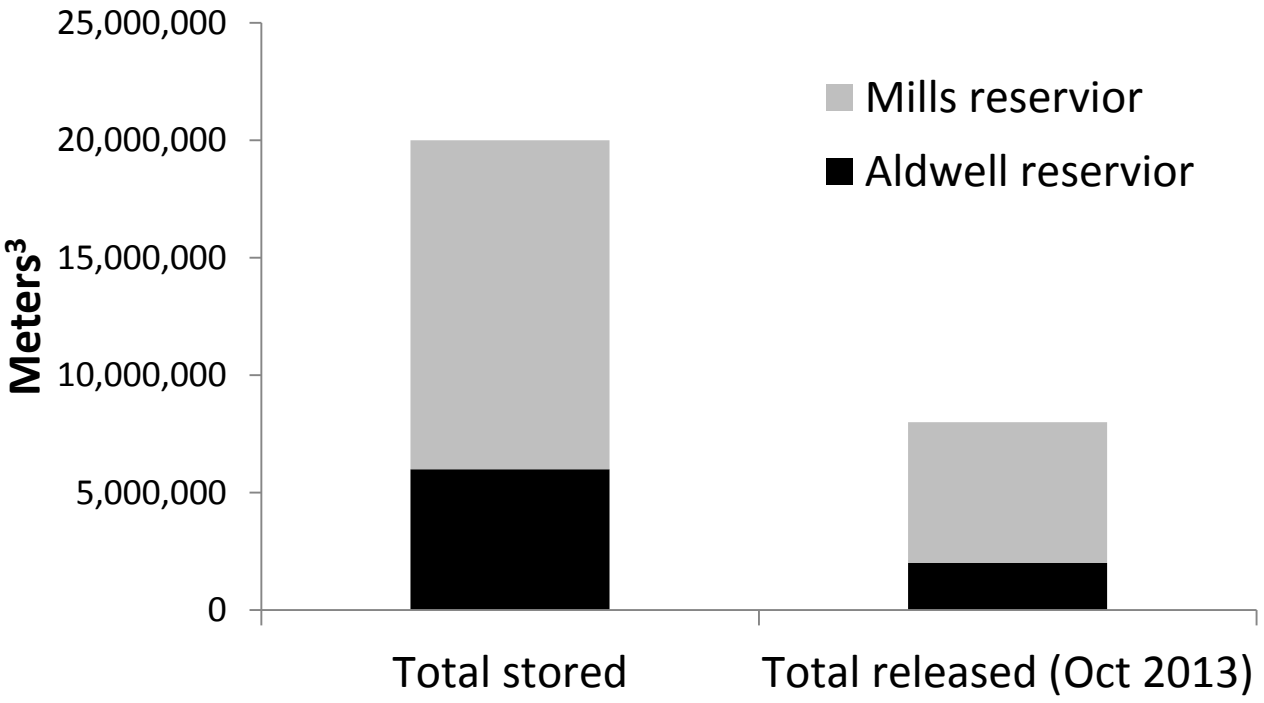
Lake Mills gone

Datasource: USGS

How much sediment to date?



Approximately 40% of the total stored sediment has been estimated to be released as of October of 2013



Data courtesy of Jennifer Bountry , U.S. Bureau of Reclamation and Andy Ritchie, NPS and USGS

Photo courtesy of Andy Ritchie

Photo courtesy of Andy Ritchie

Former reservoirs – Lake Mills

Former reservoirs – Lake Mills

Slide courtesy Josh Chenoweth, U.S. NPS

Former Reservoir – Lake Aldwell

Former Reservoir – Lake Aldwell

Former Reservoir – Lake Aldwell

Former Reservoir – Lake Aldwell

Revegetation Plan

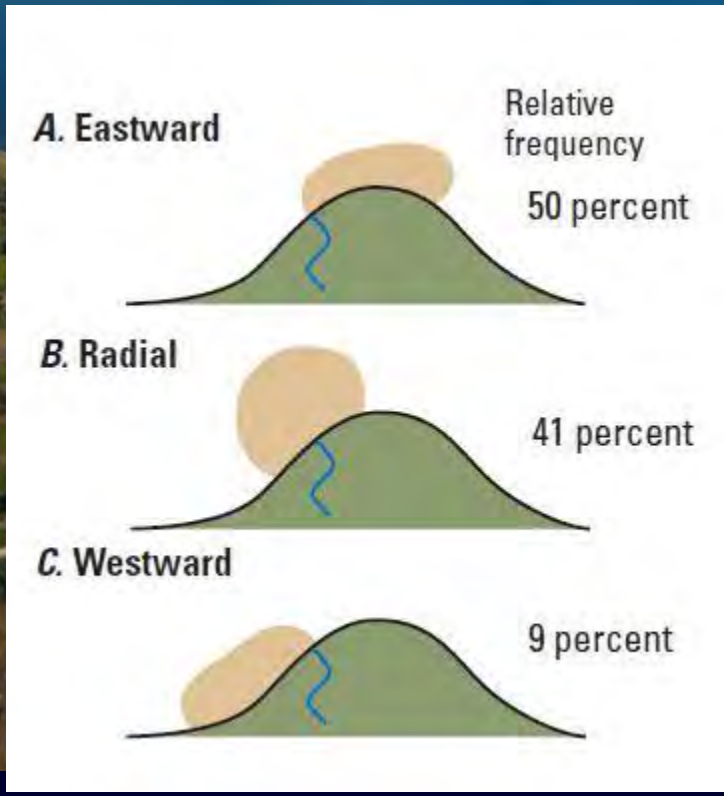
- 7 year plan
- Plant 400,000 native plants
- Sow 5,000 pounds of locally harvested seed

USGS

Slides courtesy Josh Chenoweth

Mouth of Elwha River - nearshore

Photo: Matt Beirne, Lower Elwha Klallam Tribe



Warrick, J.A., and Stevens, A.W., 2011, A buoyant plume adjacent to a headland - observations of the Elwha River plume: Continental Shelf Research, v. 31, p. 85-97.

USGS

Mouth of Elwha River ~ 2006

Mouth of Elwha River April 2012

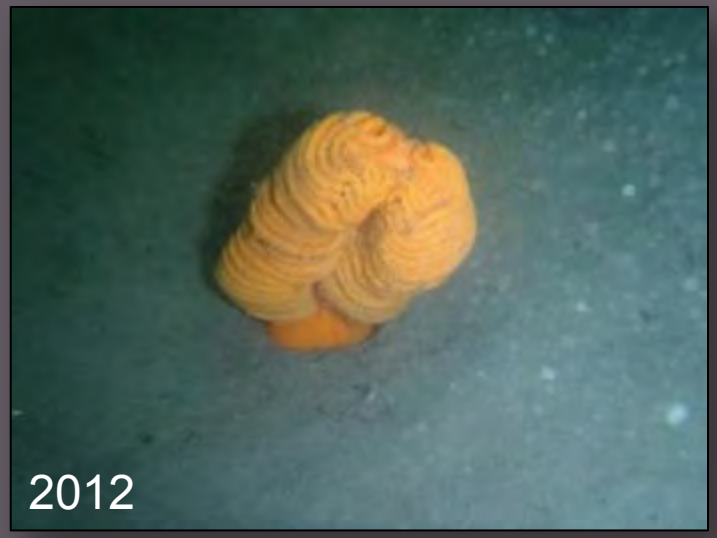
Much suspended sediment transported to the Strait of Juan De Fuca

Mouth of Elwha River Feb 2013

Photo courtesy of
Andy Ritchie, NPS

Mouth of Elwha River Feb 2014

Sediment dynamics – Nearshore biota



Rubin, Elder, et al.

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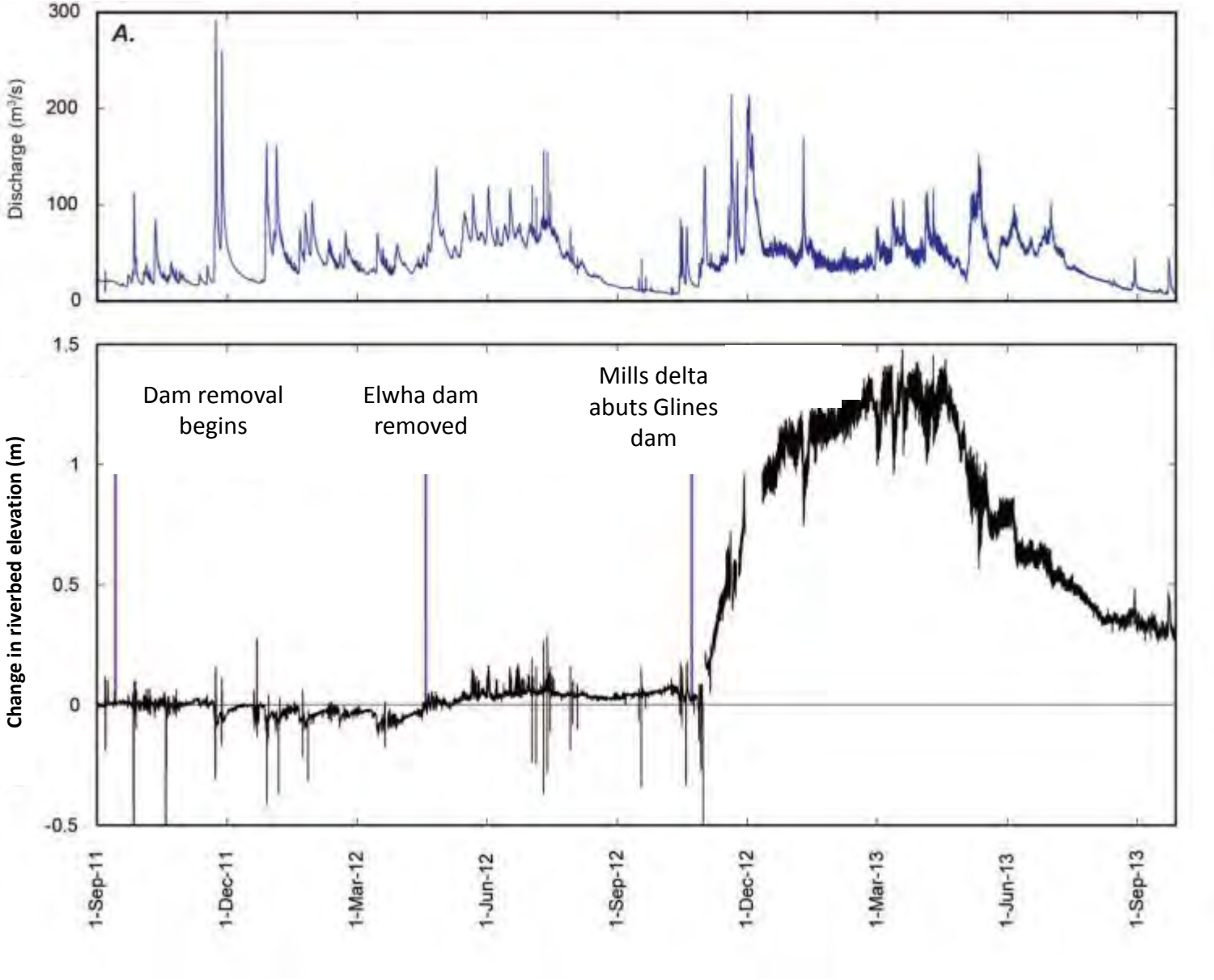
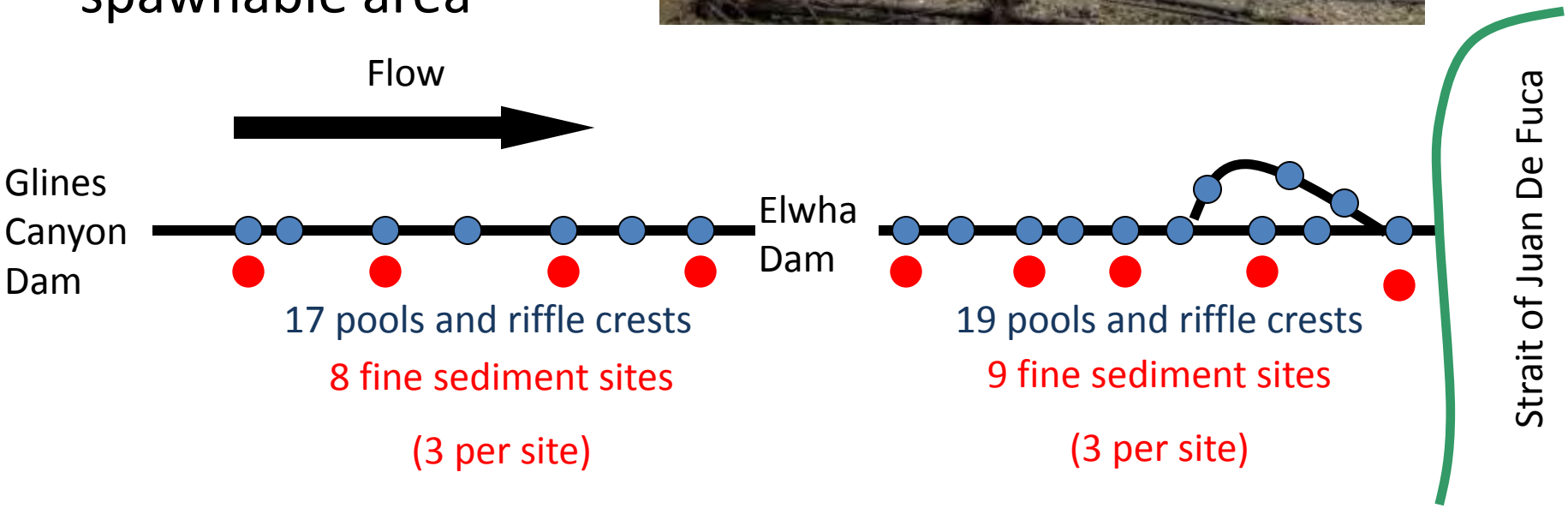
Changing sediment supply in the Elwha River



Slide courtesy of Chris Magirl, USGS

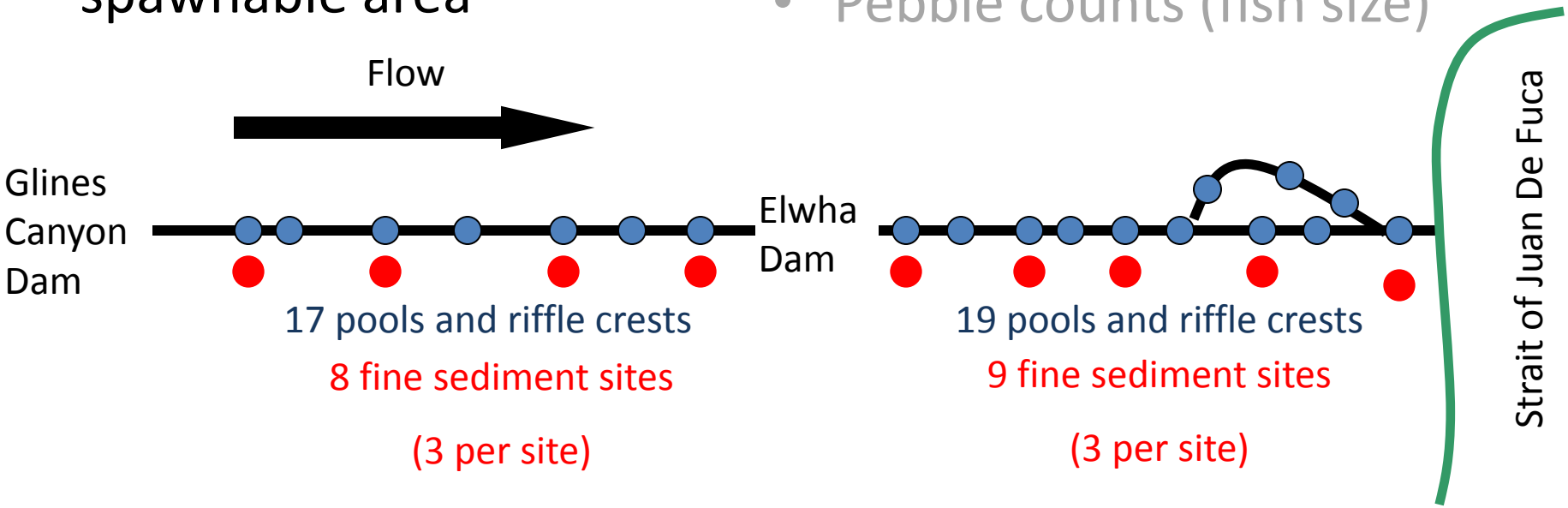
How will mainstem habitat conditions change?

- Pool filling
- Change in substrate size
- Change in spawnable area

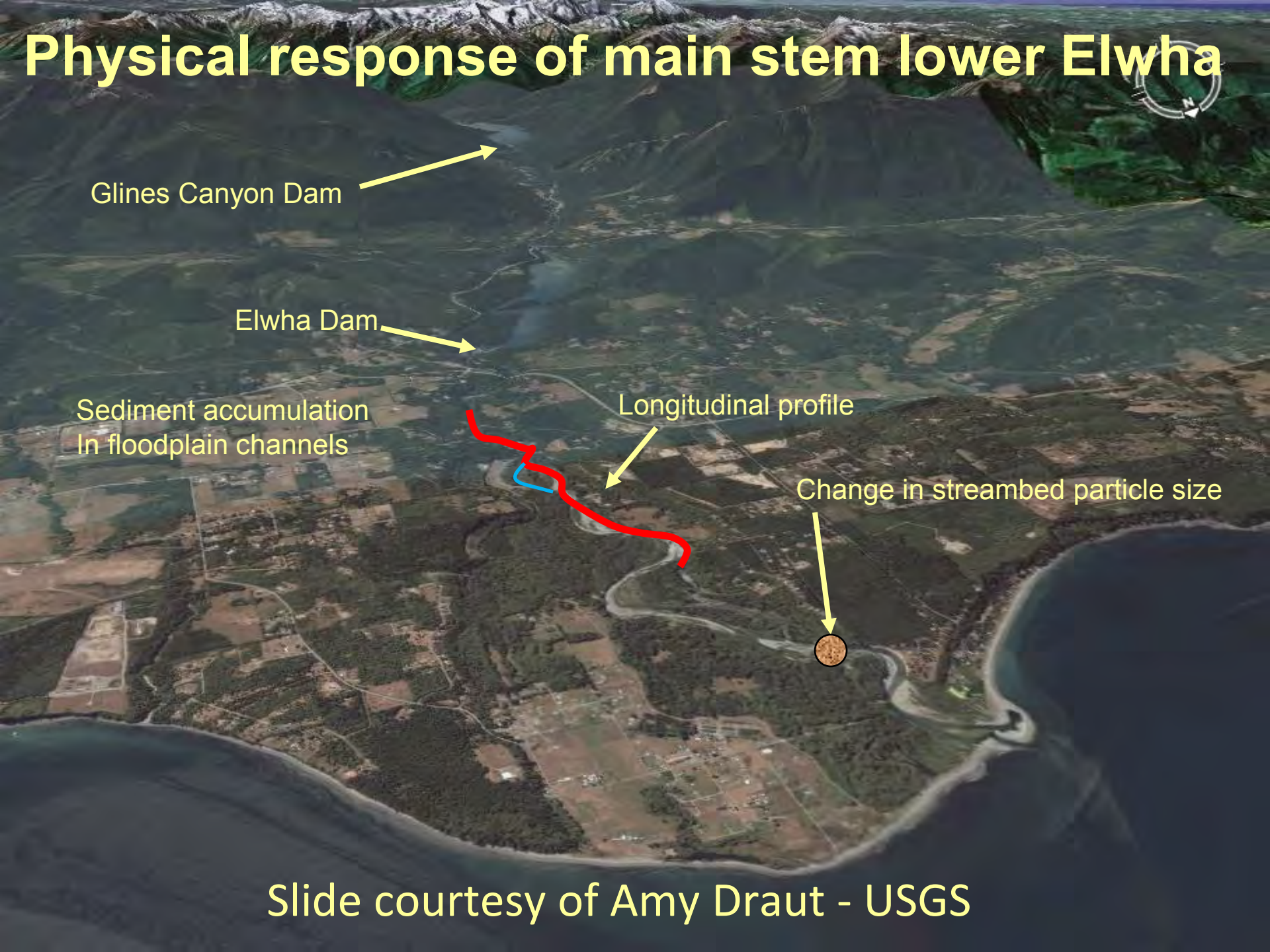


How will mainstem habitat conditions change?

- Pool filling
- Change in substrate size
- Change in spawnable area
- Longitudinal profiles & residual pool depths
- Shovel samples for fine sediment in riffle crests
- Pebble counts (fish size)



Physical response of main stem lower Elwha



Slide courtesy of Amy Draut - USGS

September 2011 – Start of dam removal

Cobbles (~110 mm)

USGS

Slide courtesy of Amy Draut, USGS

April 2012 – Lower dam removed

Cobbles (~110 mm) & mud (~0.04mm)

USGS

Slide courtesy of Amy Draut, USGS

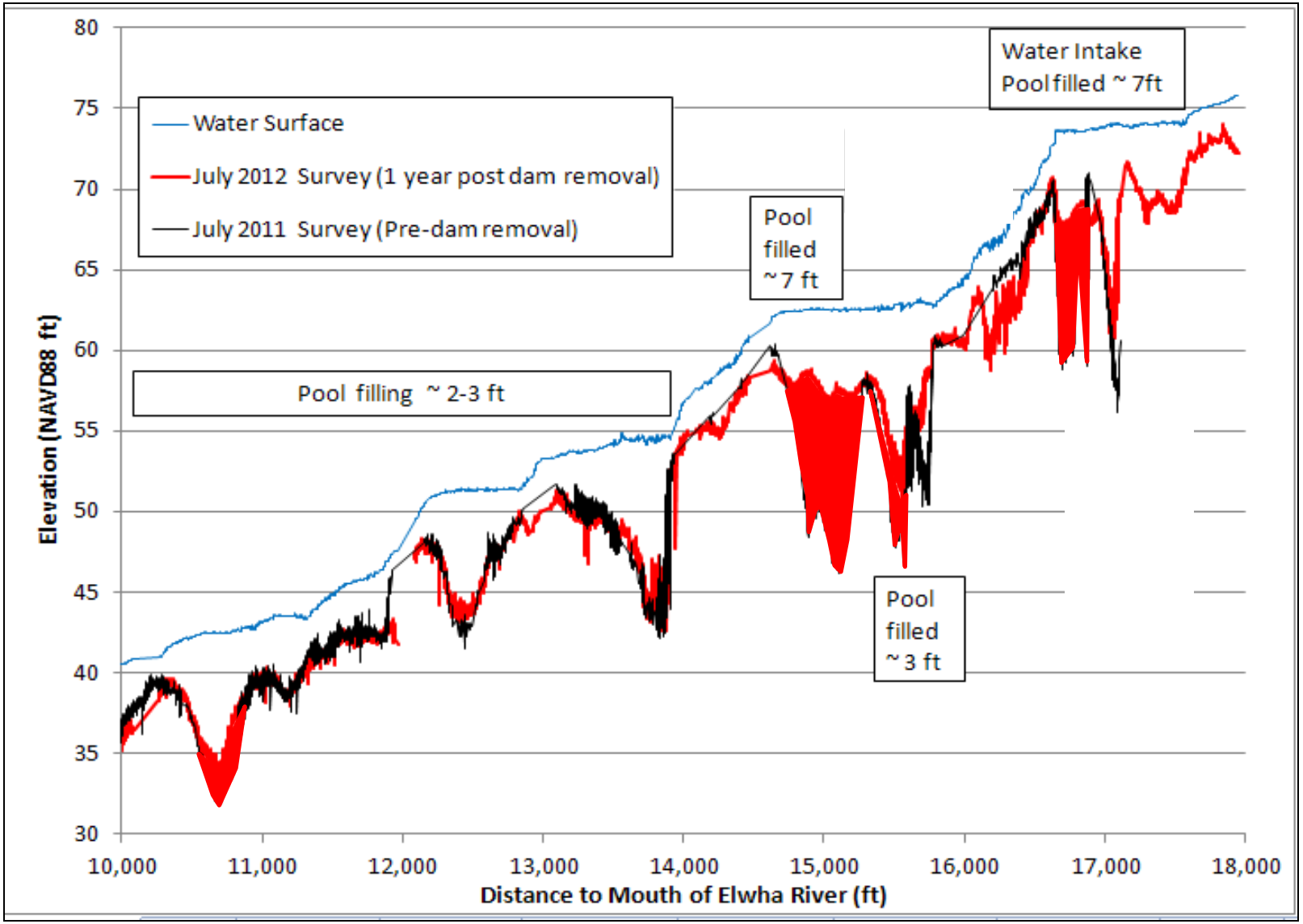
August 2012 – Upper dam removal in progress

Pebble/gravels (~25mm)

USGS

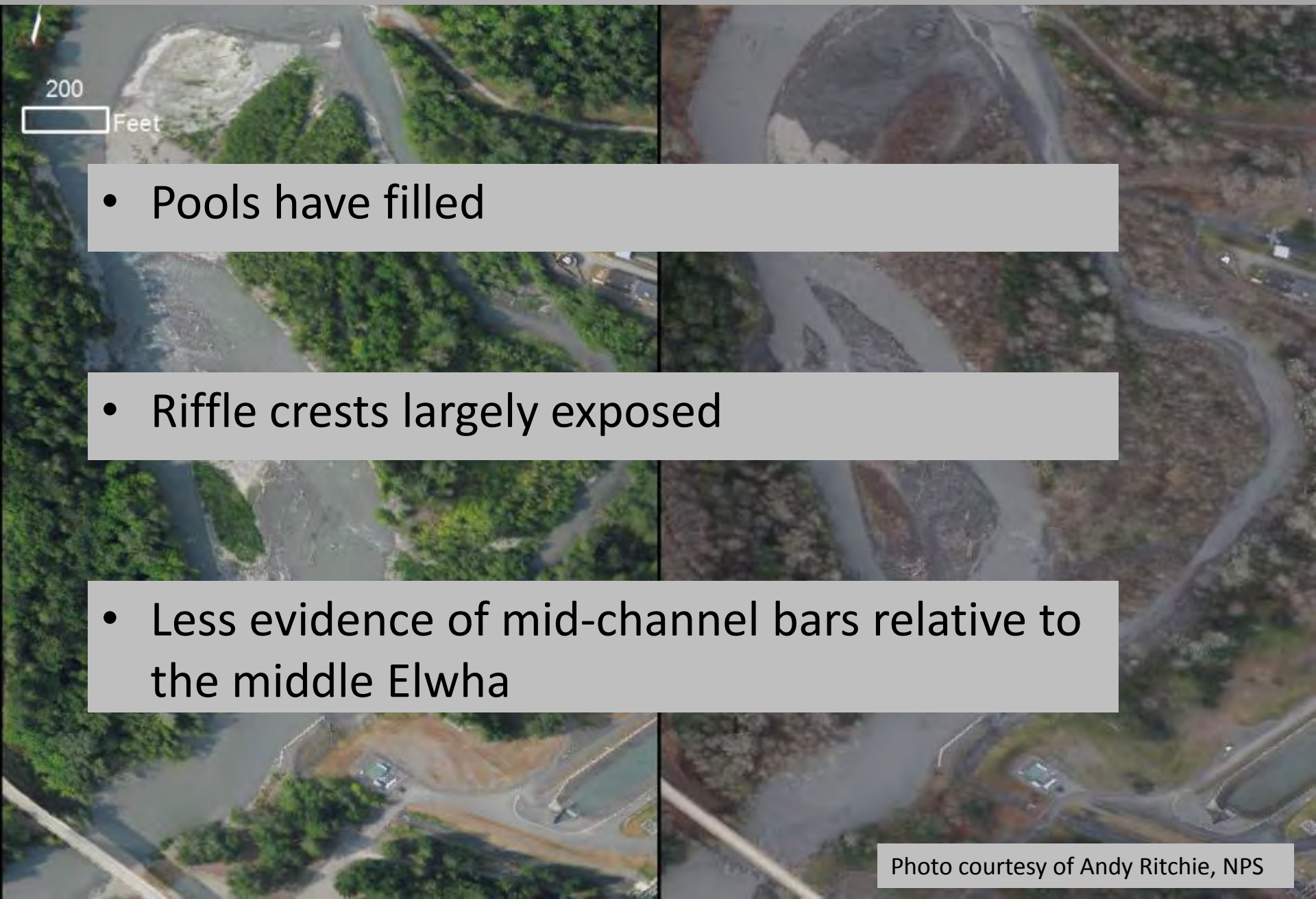
Slide courtesy of Amy Draut, USGS

Physical response of main stem lower Elwha



Slide courtesy of Jennifer Bountry and Tim Randle, Bureau of Reclamation

Physical response of main stem lower Elwha



- Pools have filled
- Riffle crests largely exposed
- Less evidence of mid-channel bars relative to the middle Elwha

Photo courtesy of Andy Ritchie, NPS

Physical response of floodplain channels - Lower Elwha

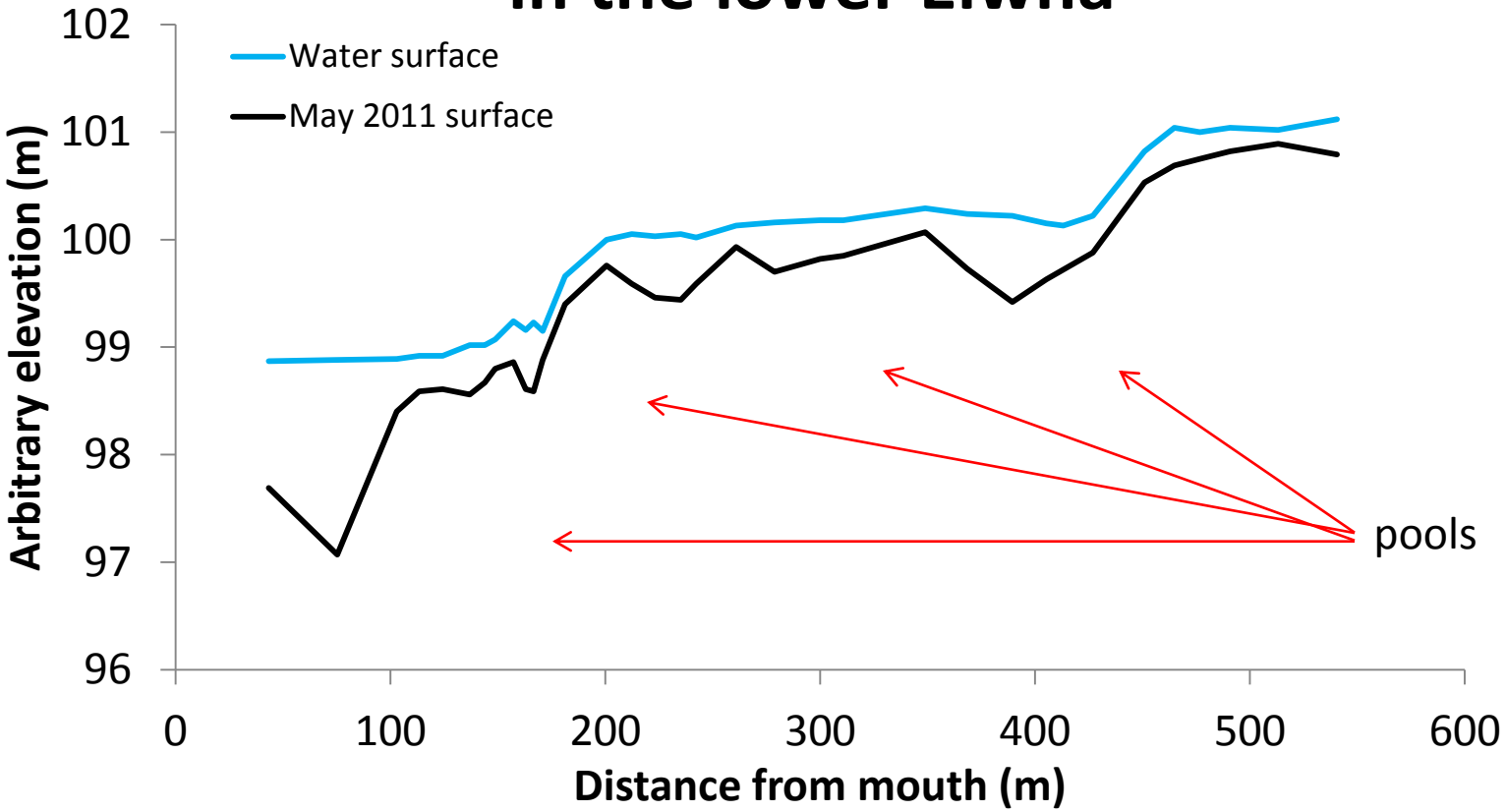
Boston Charley 1997

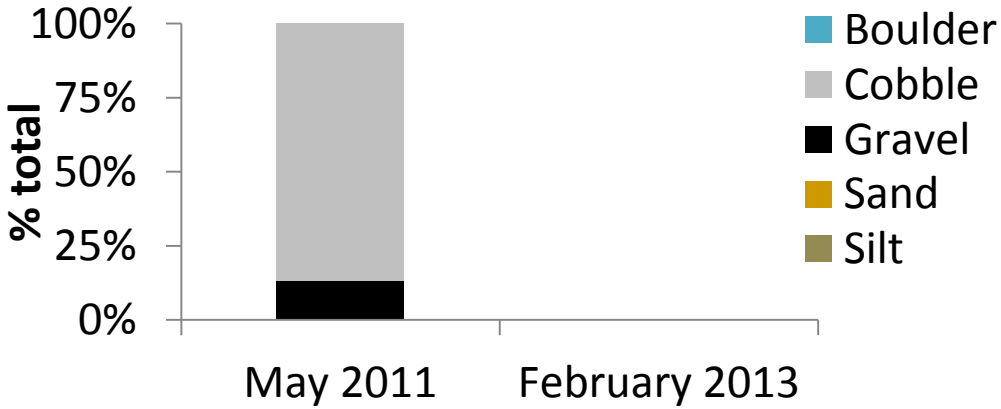
Boston Charley 2013

Photos: Mike McHenry LEKT

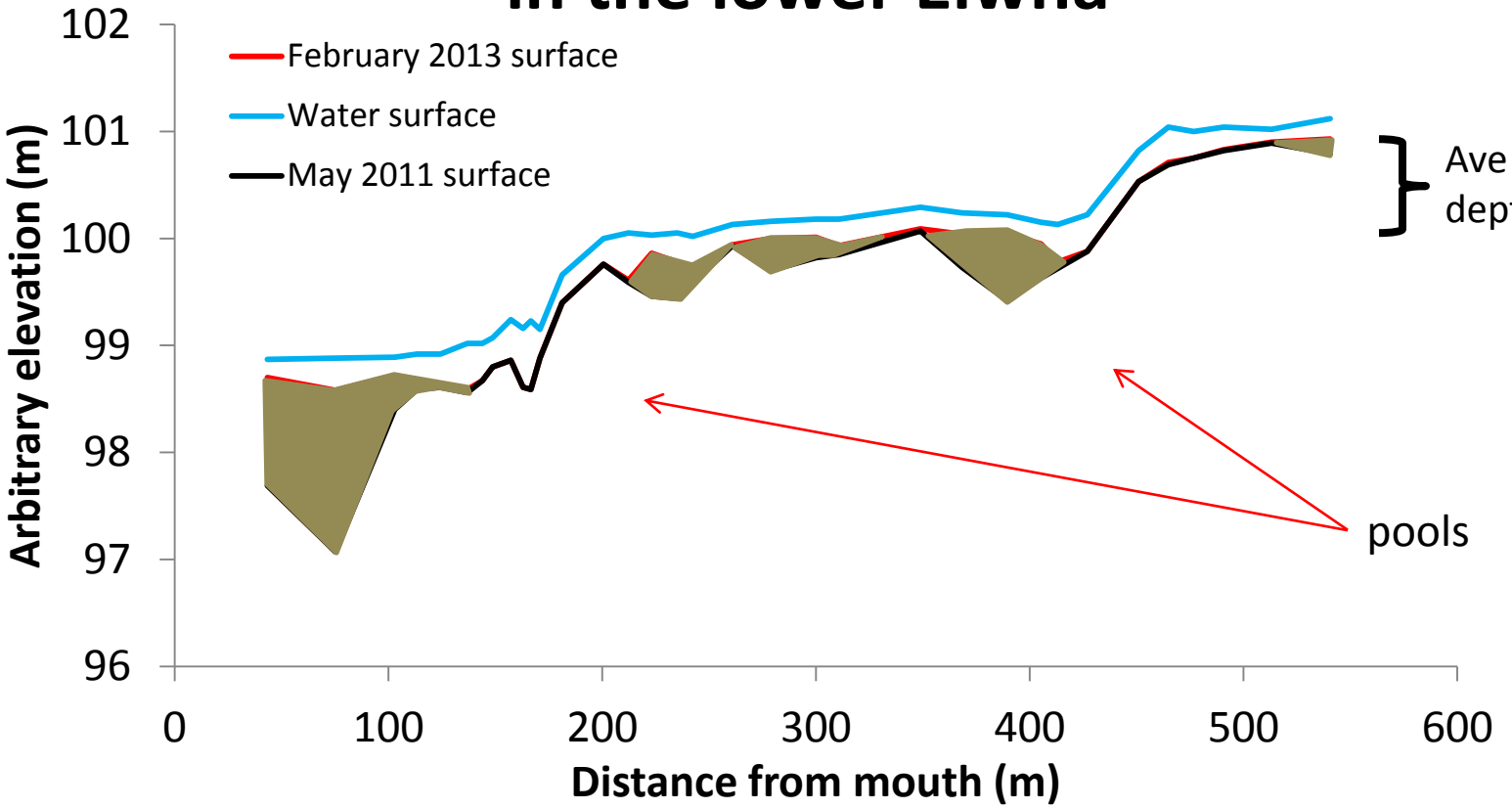
Physical response of floodplain channels in the lower Elwha

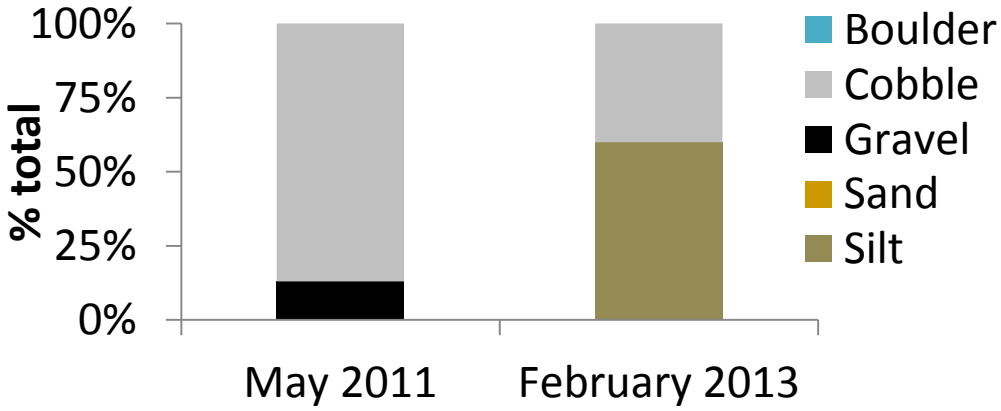
Physical response of floodplain channels in the lower Elwha



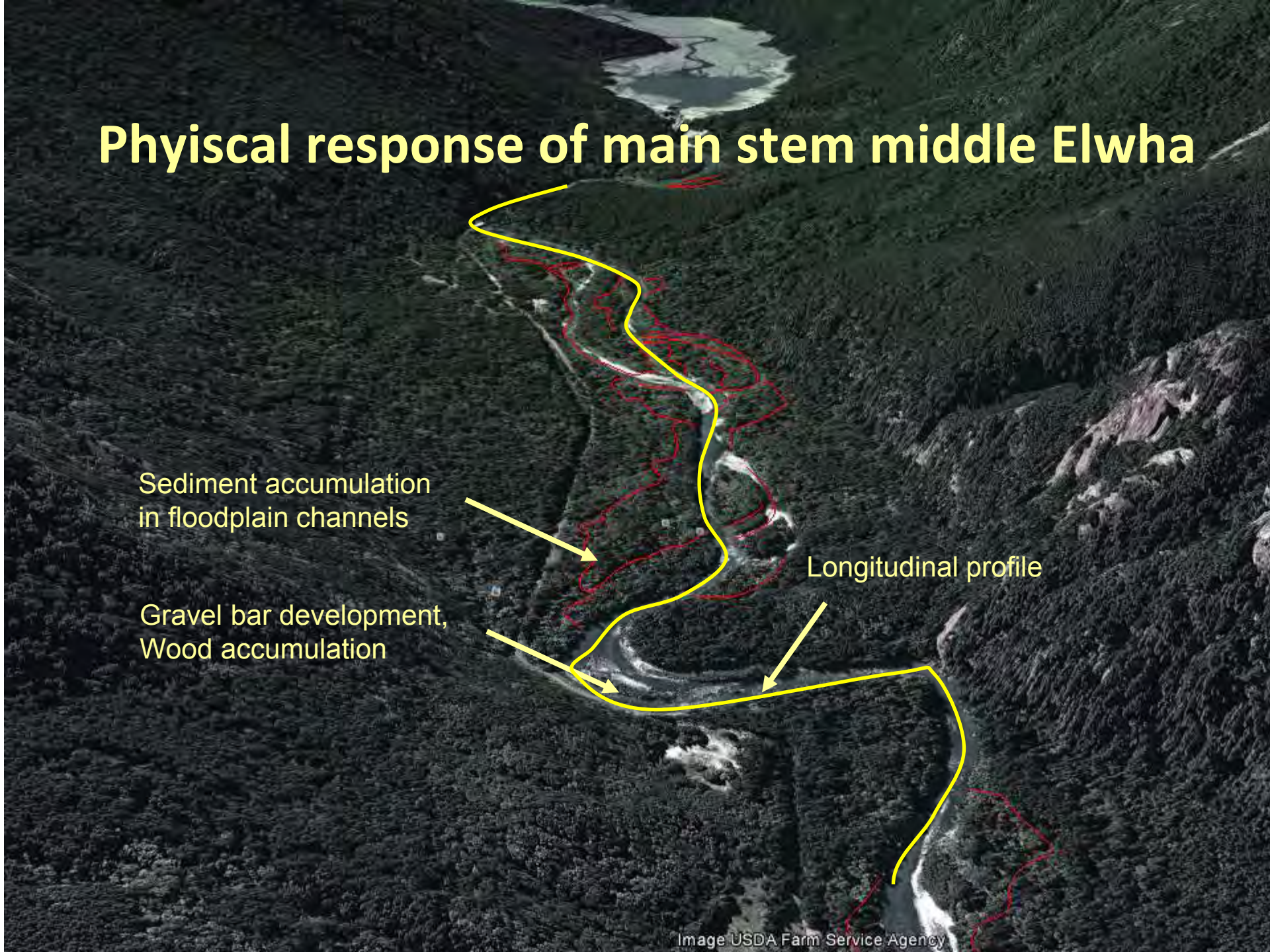


Physical response of floodplain channels in the lower Elwha





Phyiscal response of main stem middle Elwha



Physical response of main stem middle Elwha

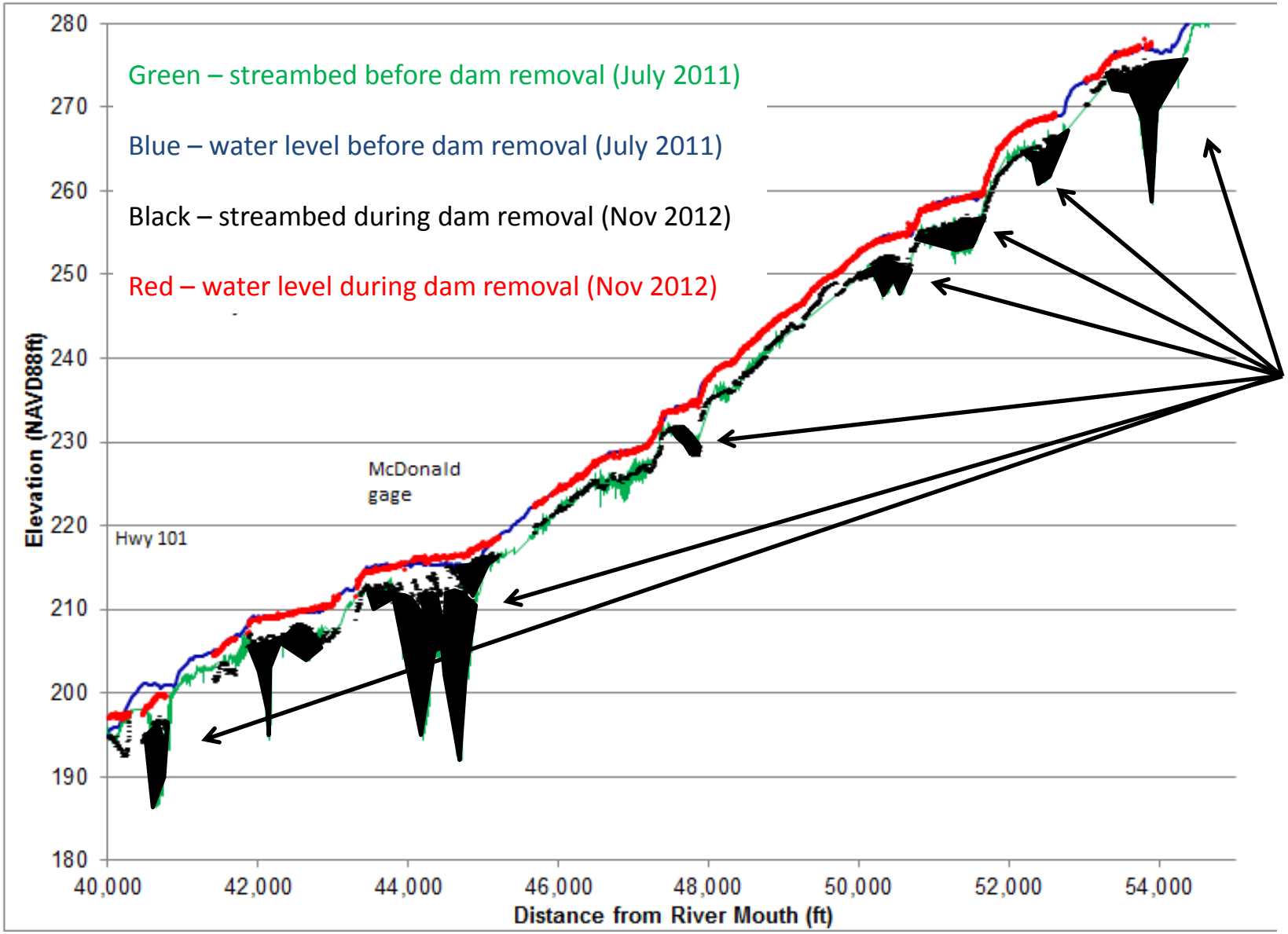
Physical response of main stem middle Elwha

Mainstem middle Elwha – Fisherman's Bend

October 2012

March 2013

Physical response of main stem middle Elwha



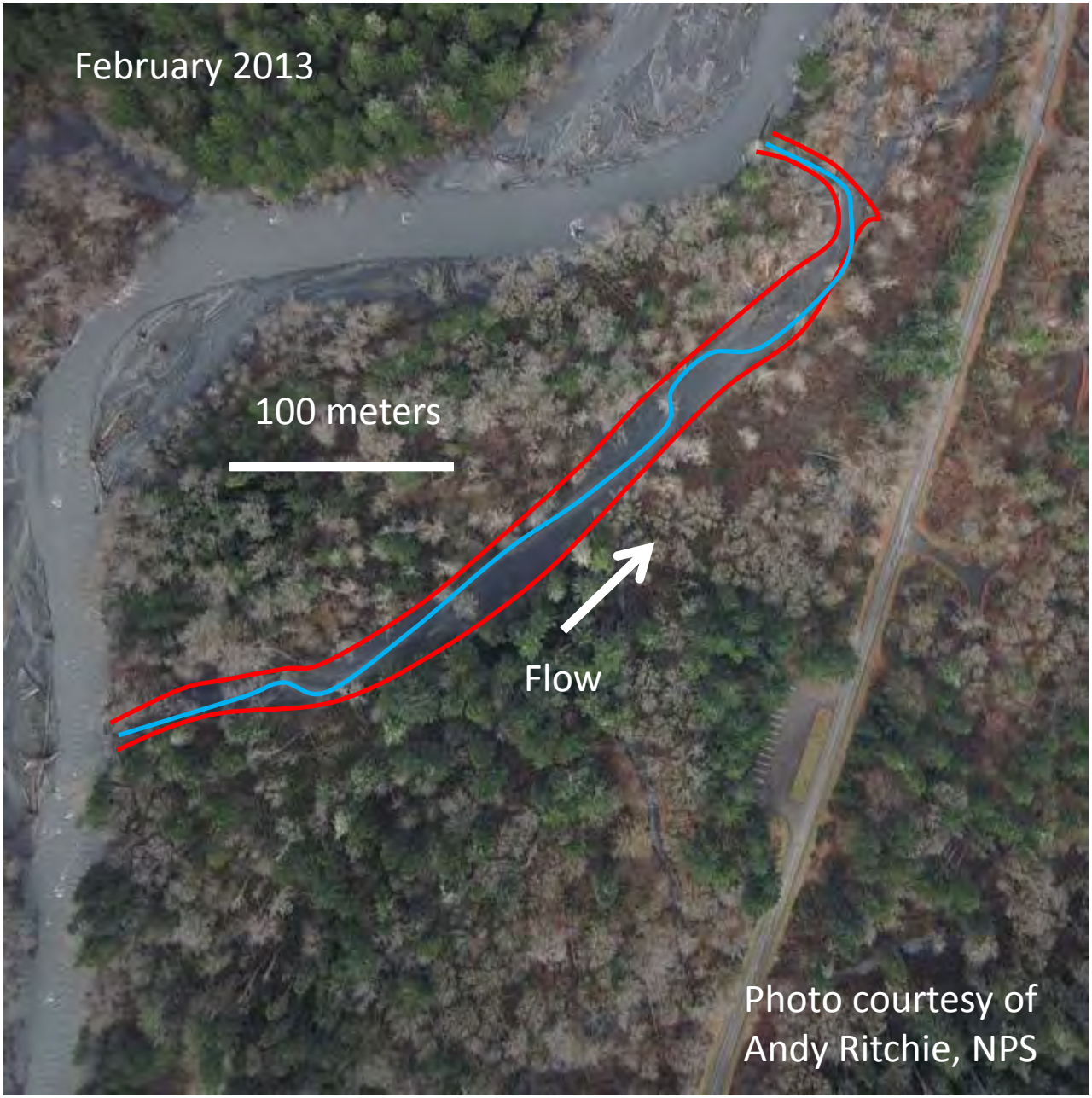
Slide courtesy of Jennifer Bountry and Tim Randle, Bureau of Reclamation

Physical response of main stem middle Elwha

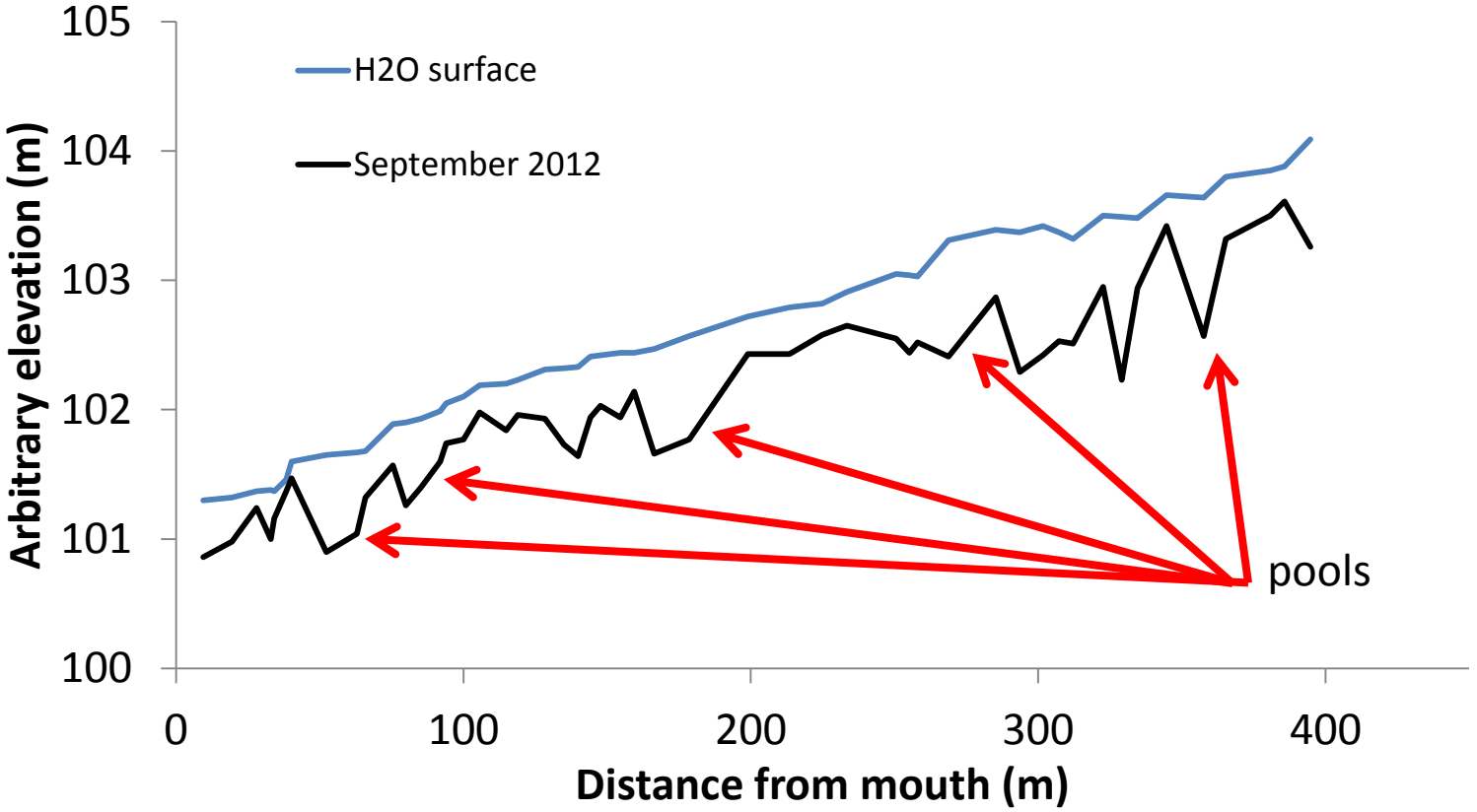
- All pools have filled
- Aggradation of riffle crests up to McDonald Gage
- Coarse sediment wave propagating downstream

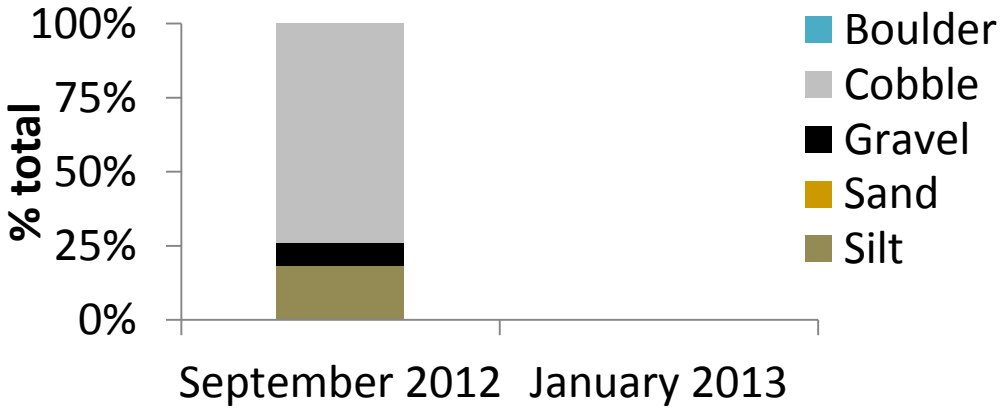
Photo courtesy of Andy Ritchie, NPS

Physical response of floodplain channels – middle Elwha

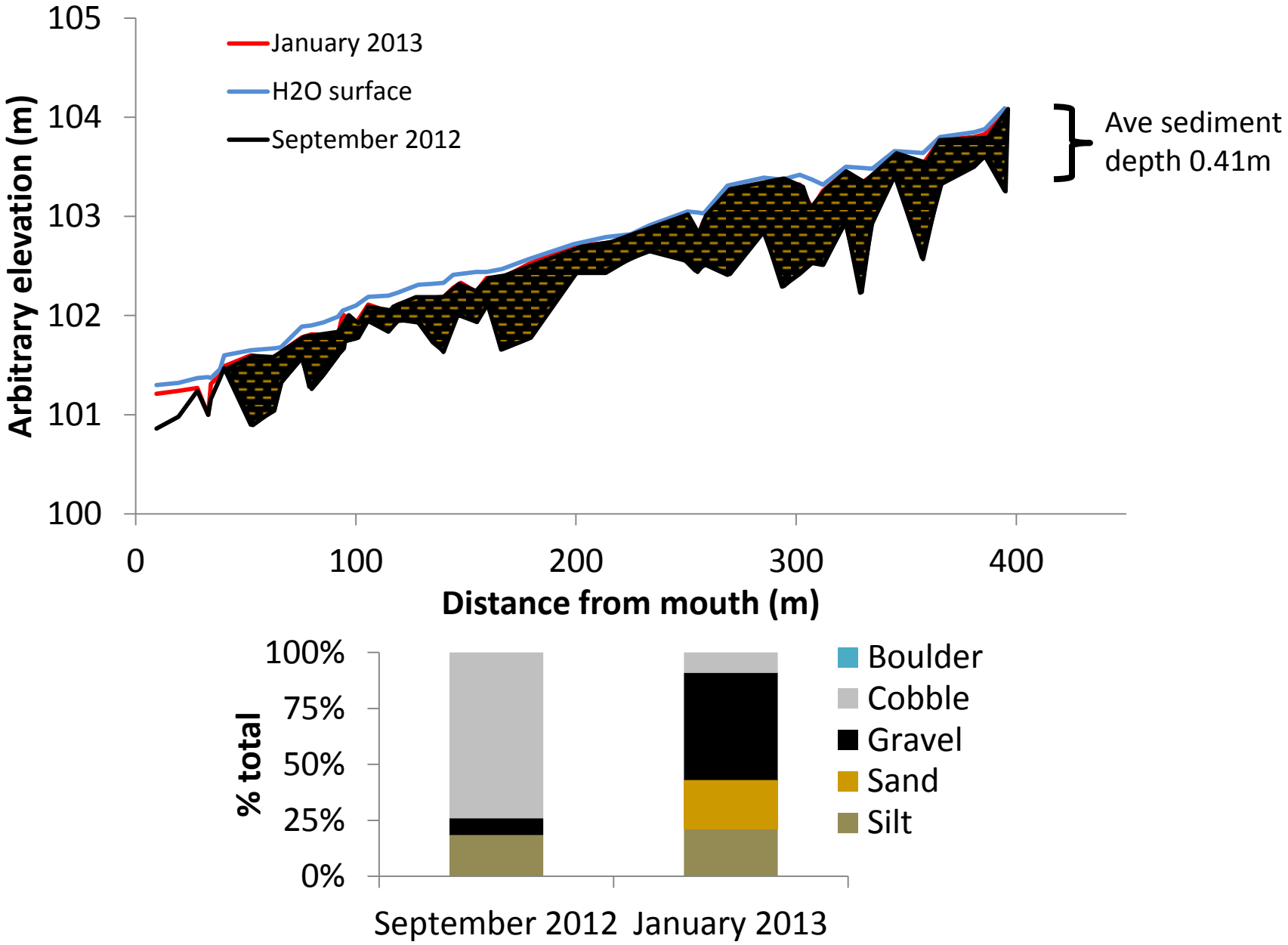


Physical response of floodplain channels – middle Elwha



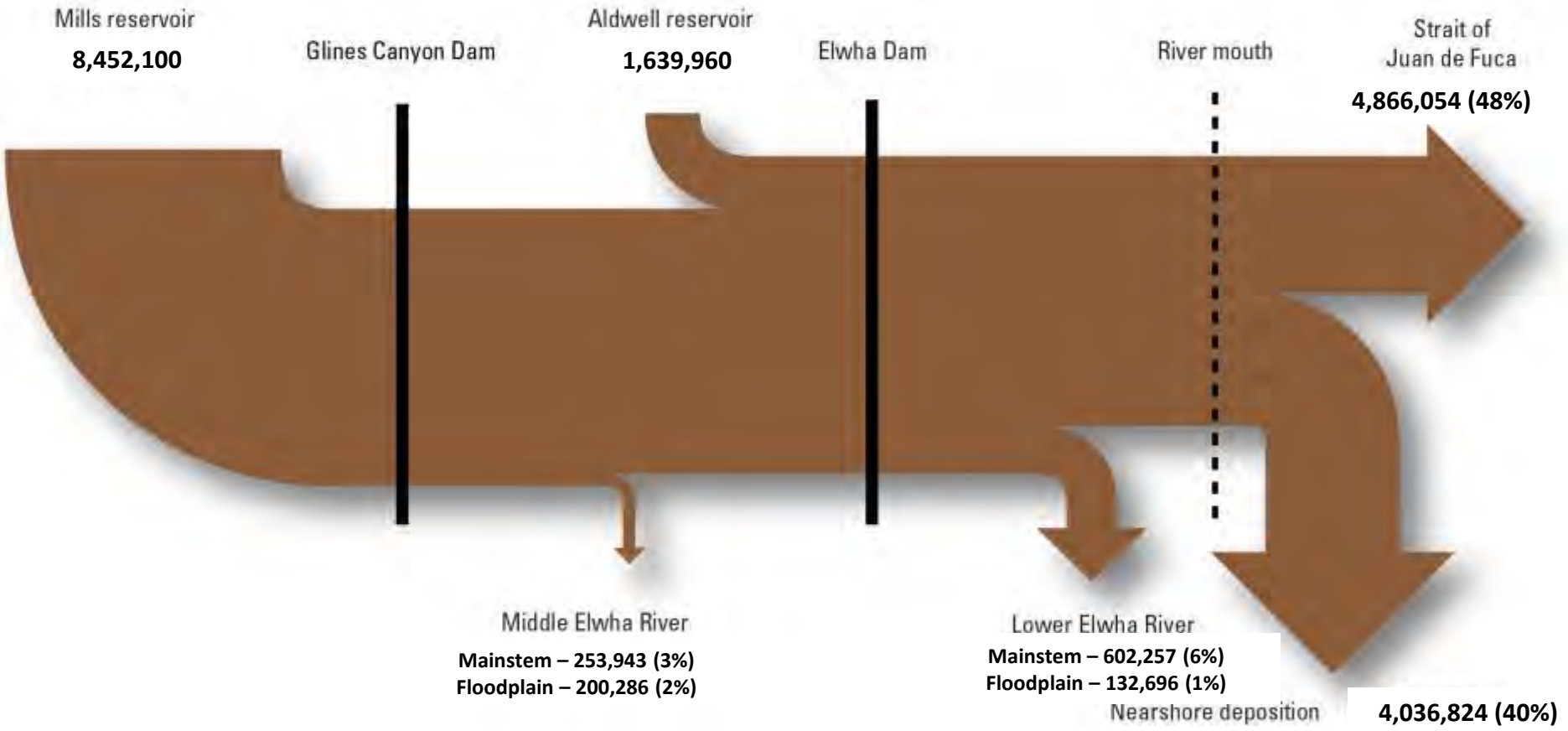


Physical response of floodplain channels – middle Elwha



Highway of Sediment

Sediment as of September 2013 in metric tonnes



Data is provisional, subject to change

How will stream productivity change?

Consumers
Resident Fish

Secondary Producers
Invertebrates

Direct
(tissue & eggs)

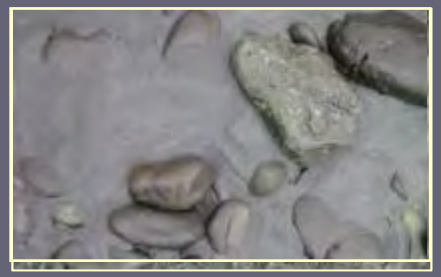
Spawners
Anadromous

Primary Producers
Periphyton

Indirect
(nutrients)

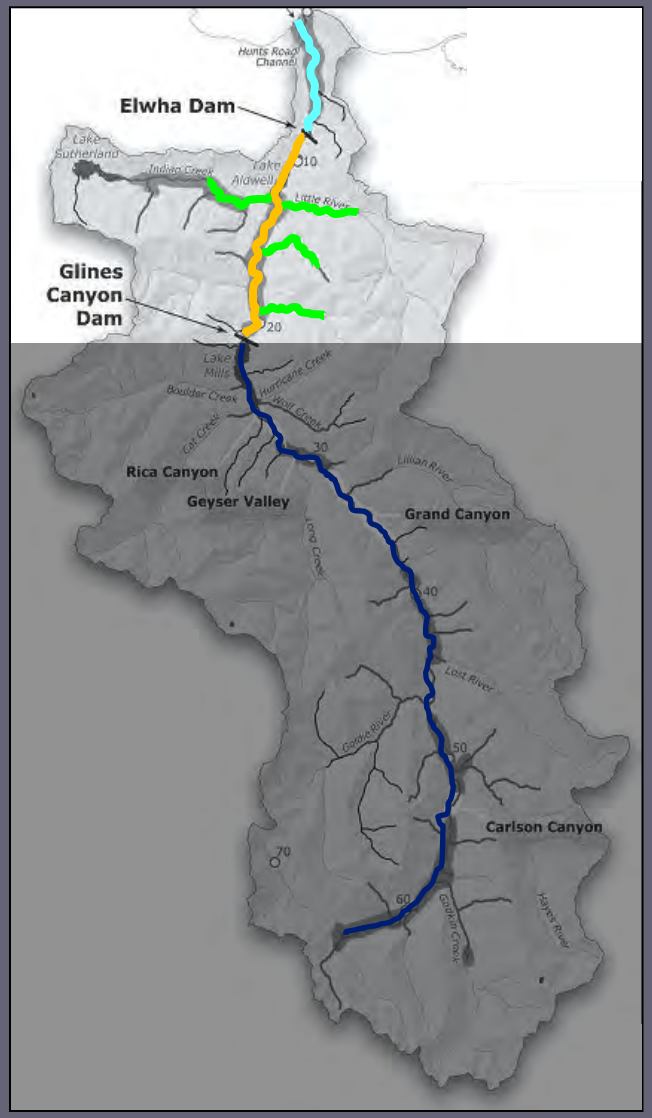
Physical Habitat

Water Chemistry



Photos: John McMillan, Amy Draut

Study design to determine how stream productivity will change with increased sediment



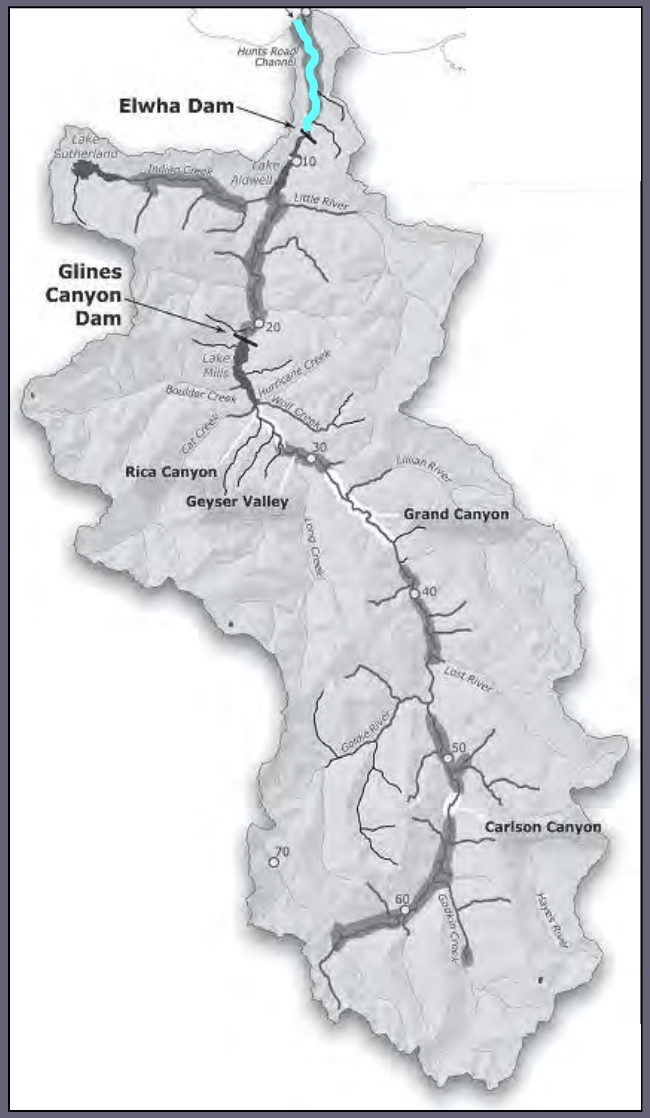
River sections: Below
Between
Above

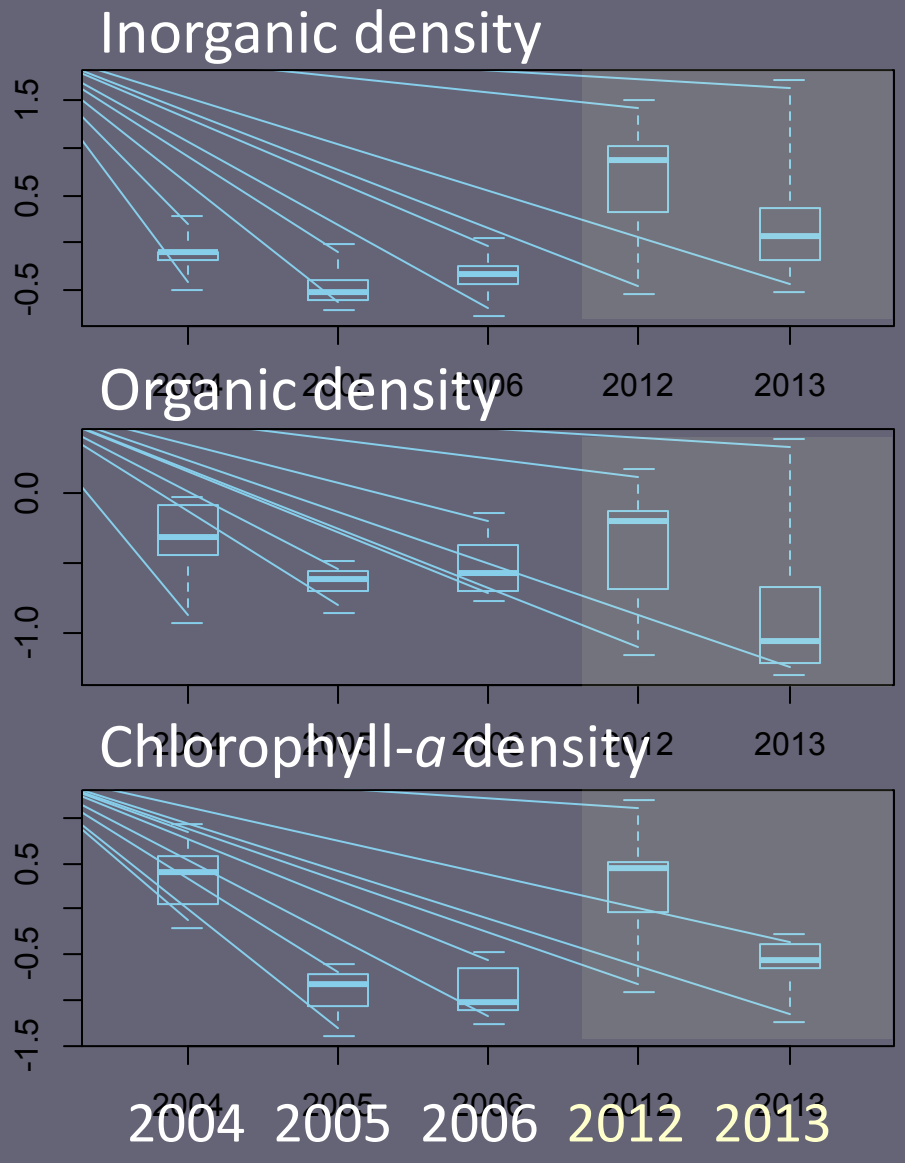
Habitat types: Mainstem
Side channels
Tributaries

Pre-removal: 2004-2011

Post-removal: 2012

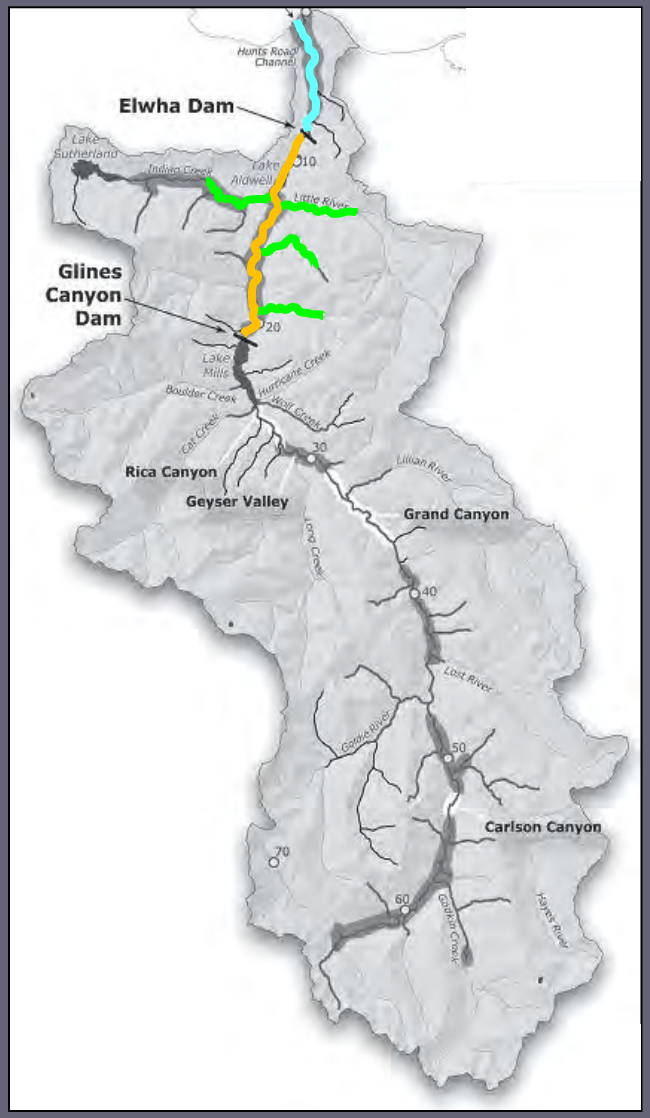
Periphyton Standing Crop

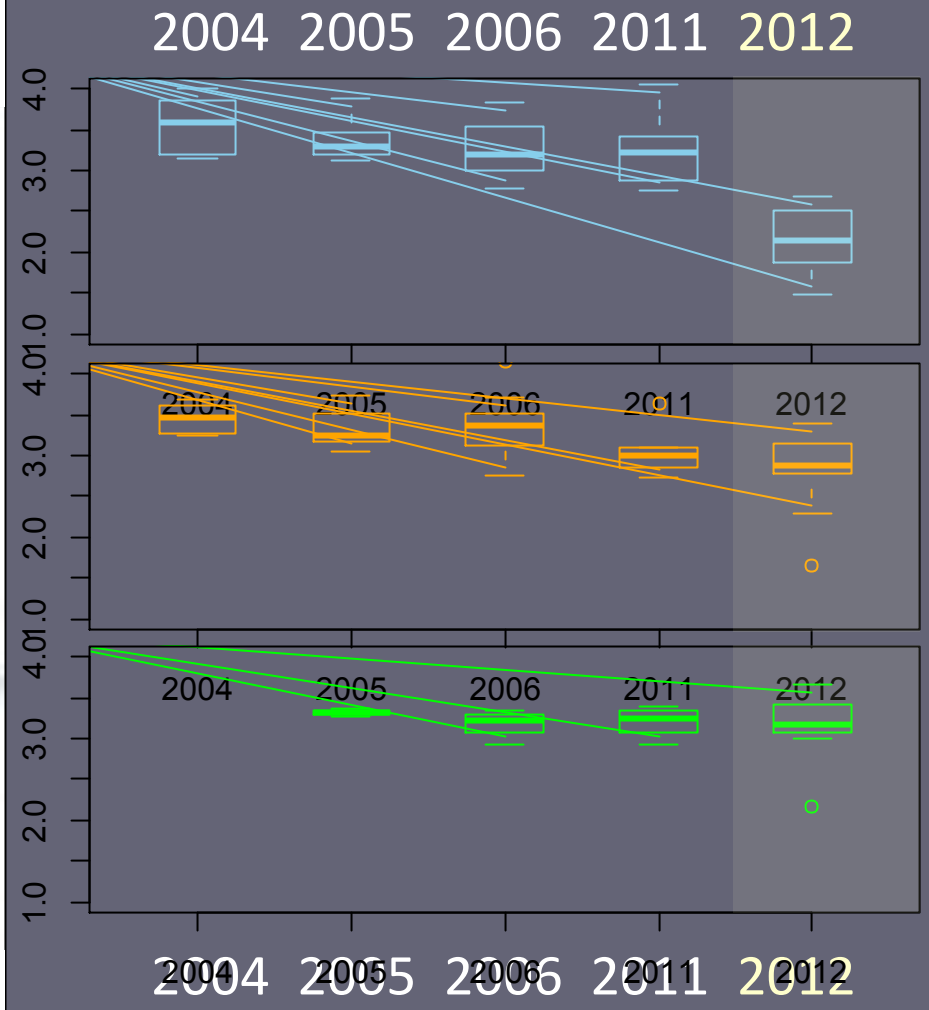




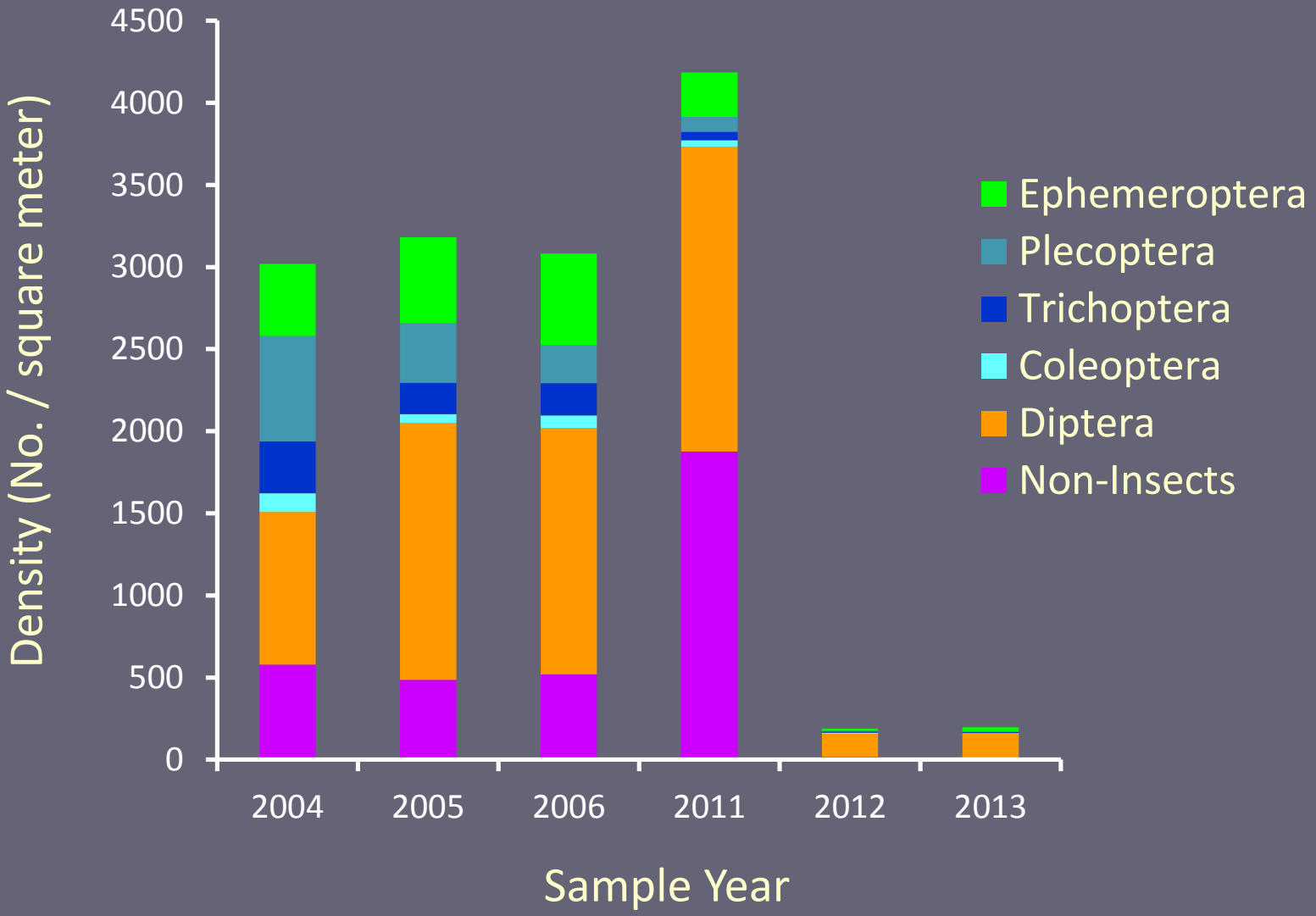
10-30 x higher

Benthic Invertebrate Densities – Results from Year 1

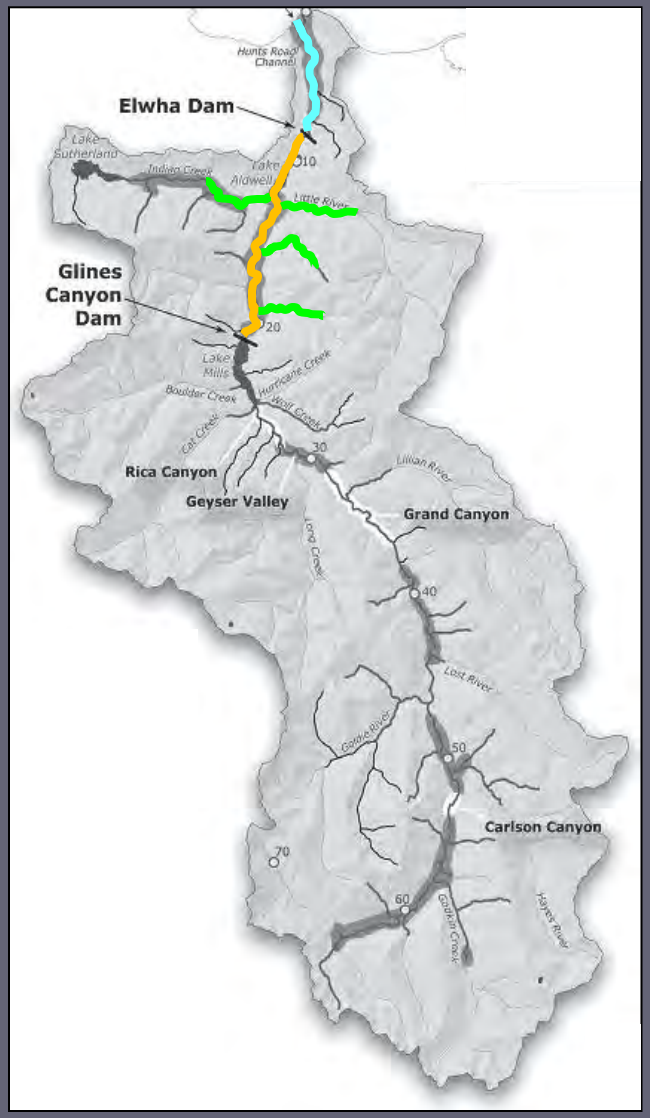




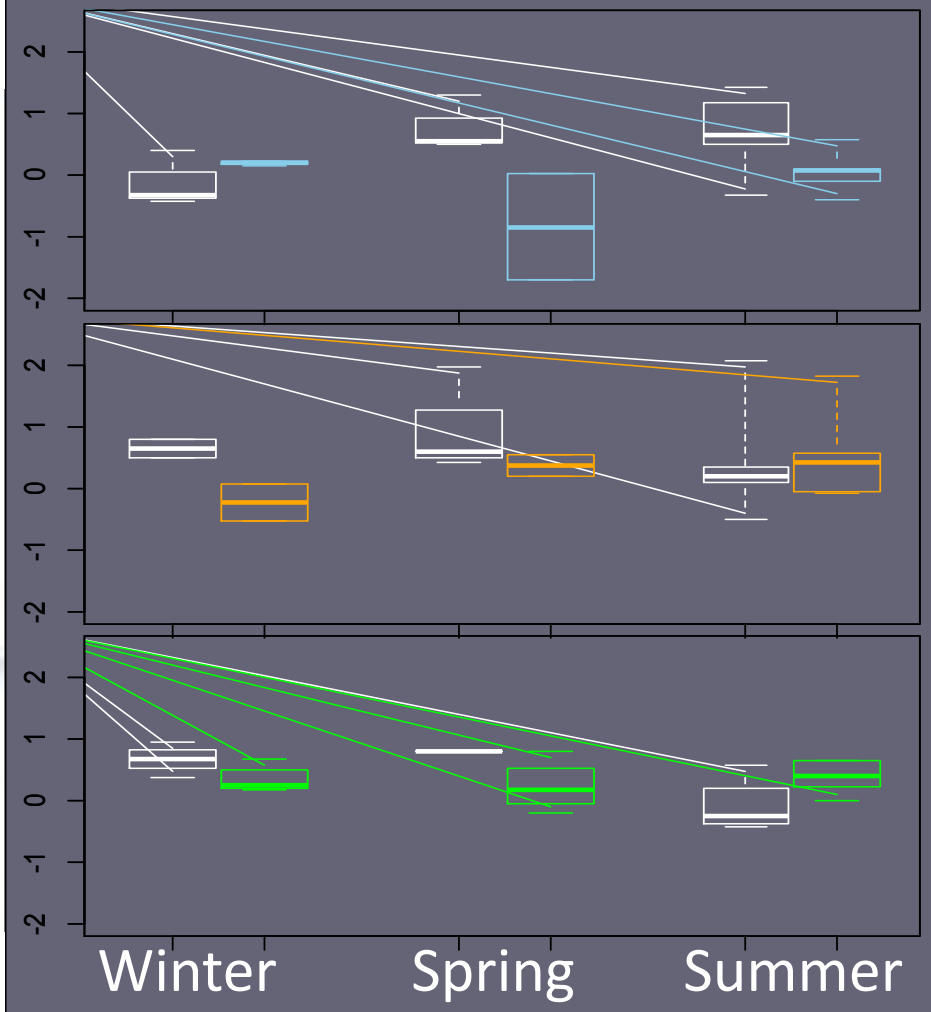
Benthic Invertebrate Taxonomic Composition



Drift Invertebrate Densities – Results from Year 1



Before = 2011

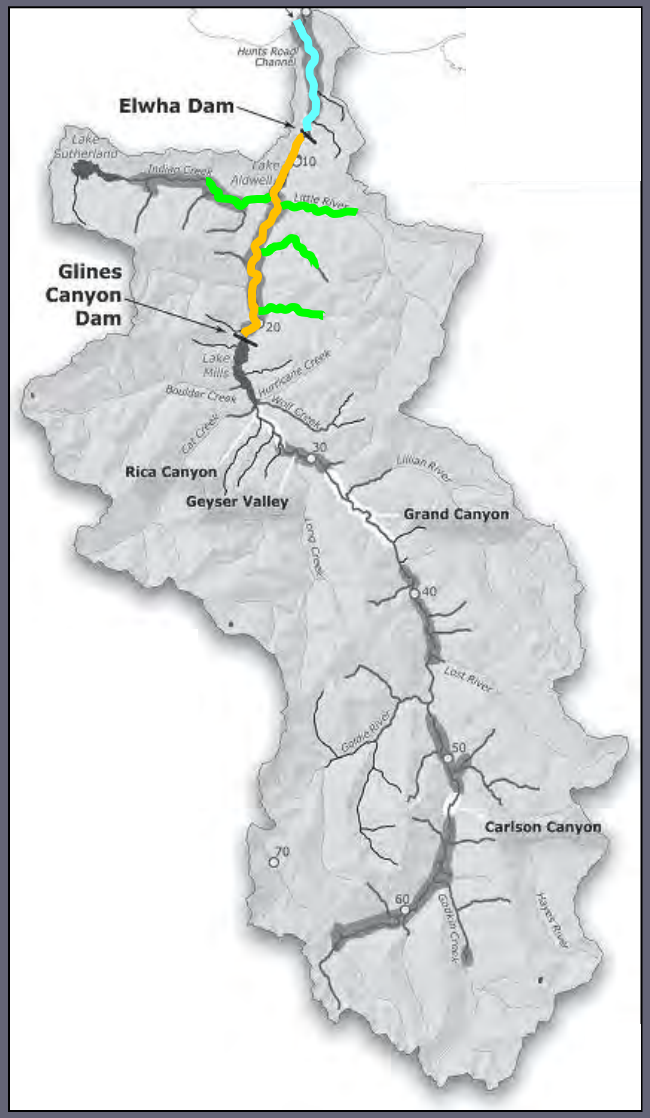


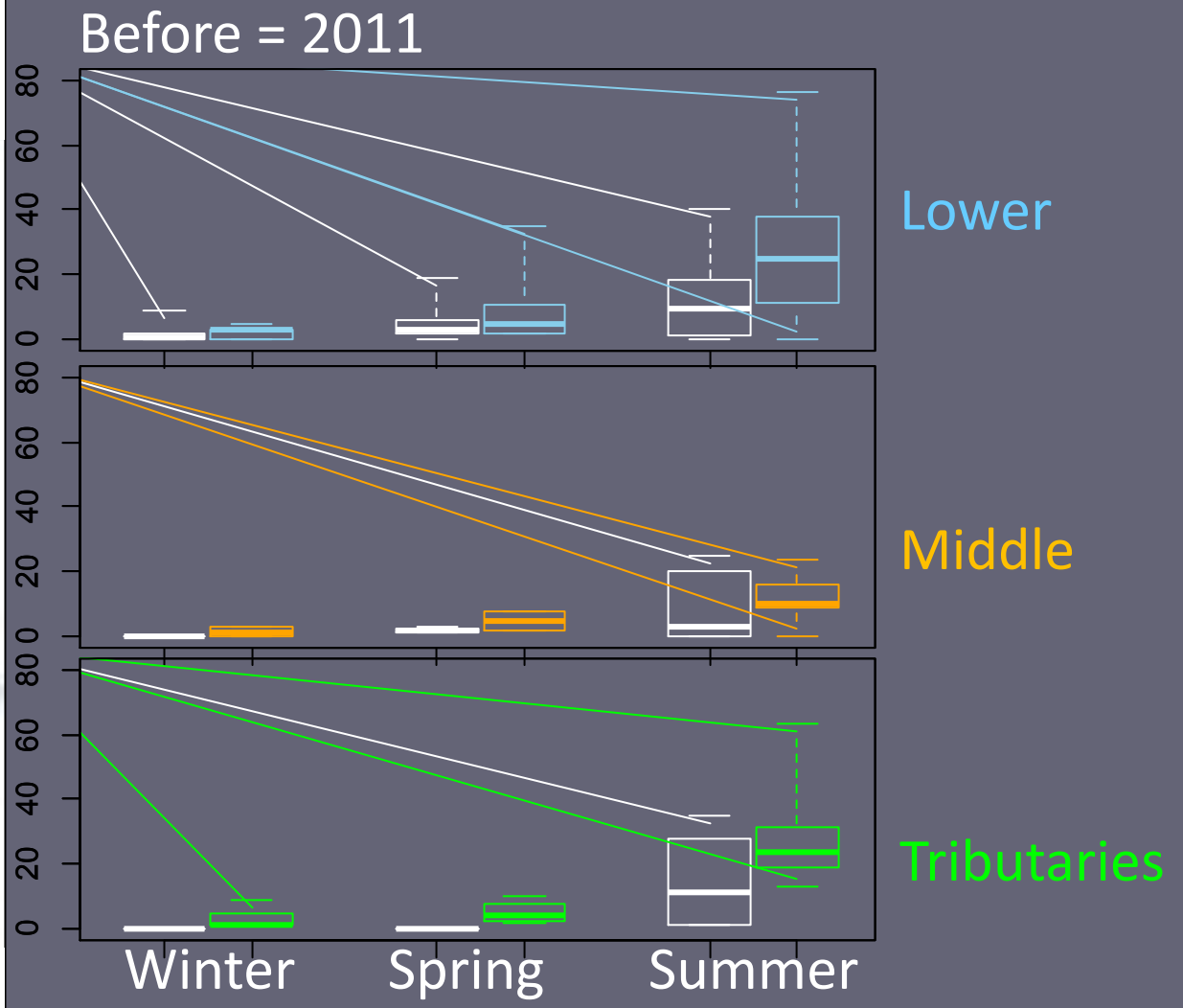
Lower

Middle

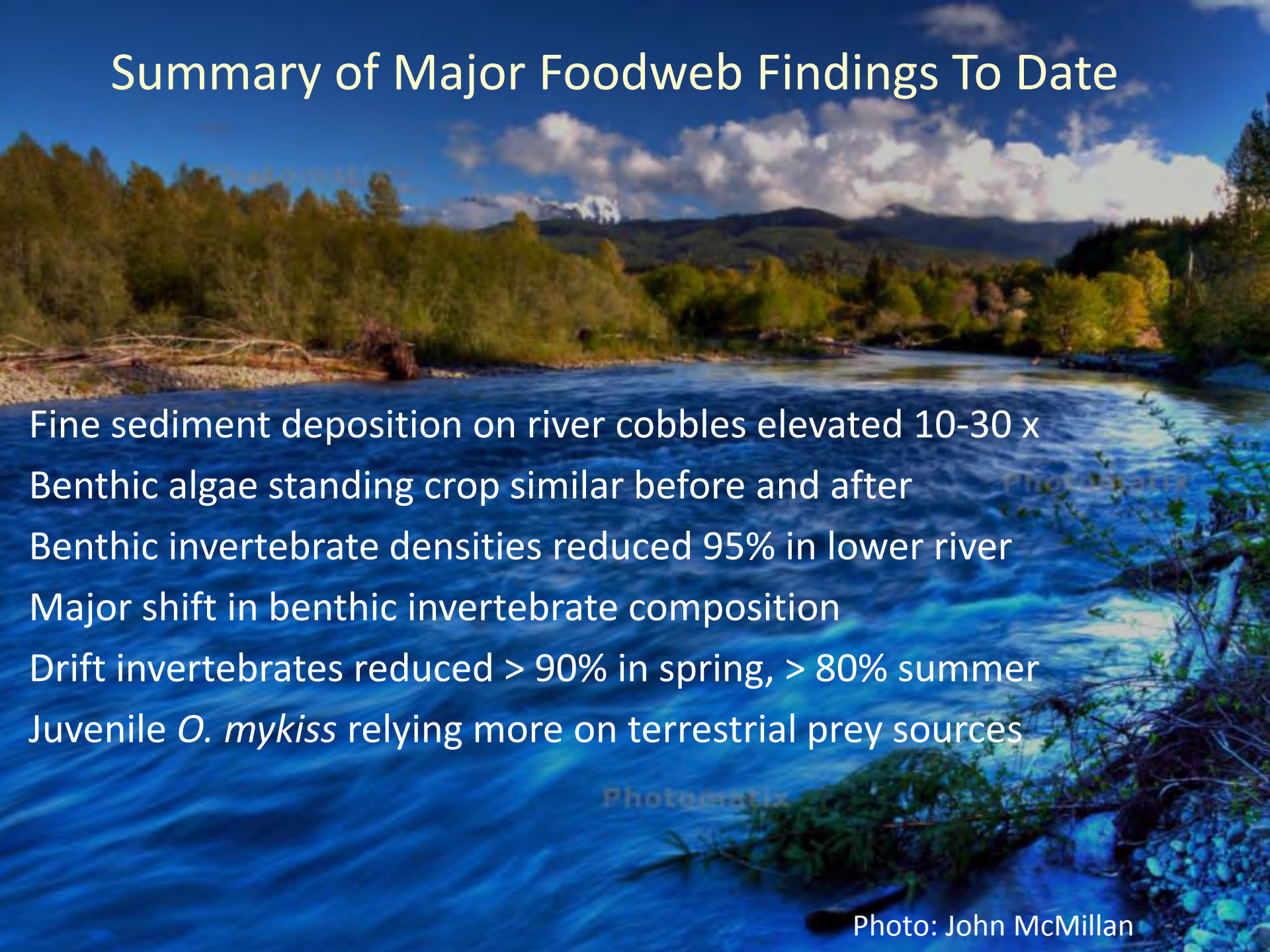
Tributaries

Juvenile Salmonid (*O. mykiss*) Diet – % Terrestrial





Summary of Major Foodweb Findings To Date



Fine sediment deposition on river cobbles elevated 10-30 x

Benthic algae standing crop similar before and after

Benthic invertebrate densities reduced 95% in lower river

Major shift in benthic invertebrate composition

Drift invertebrates reduced > 90% in spring, > 80% summer

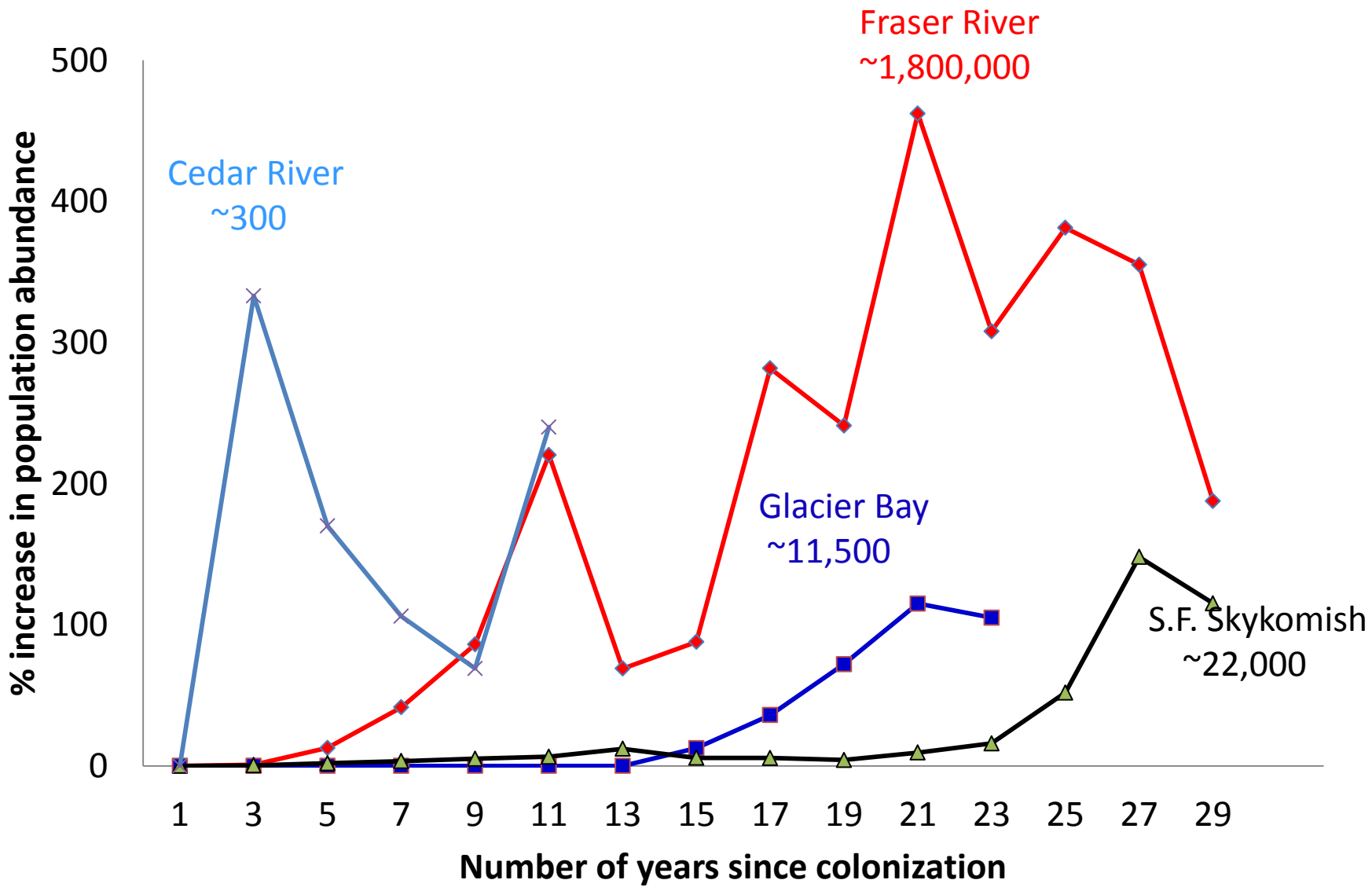
Juvenile *O. mykiss* relying more on terrestrial prey sources

Photo: John McMillan

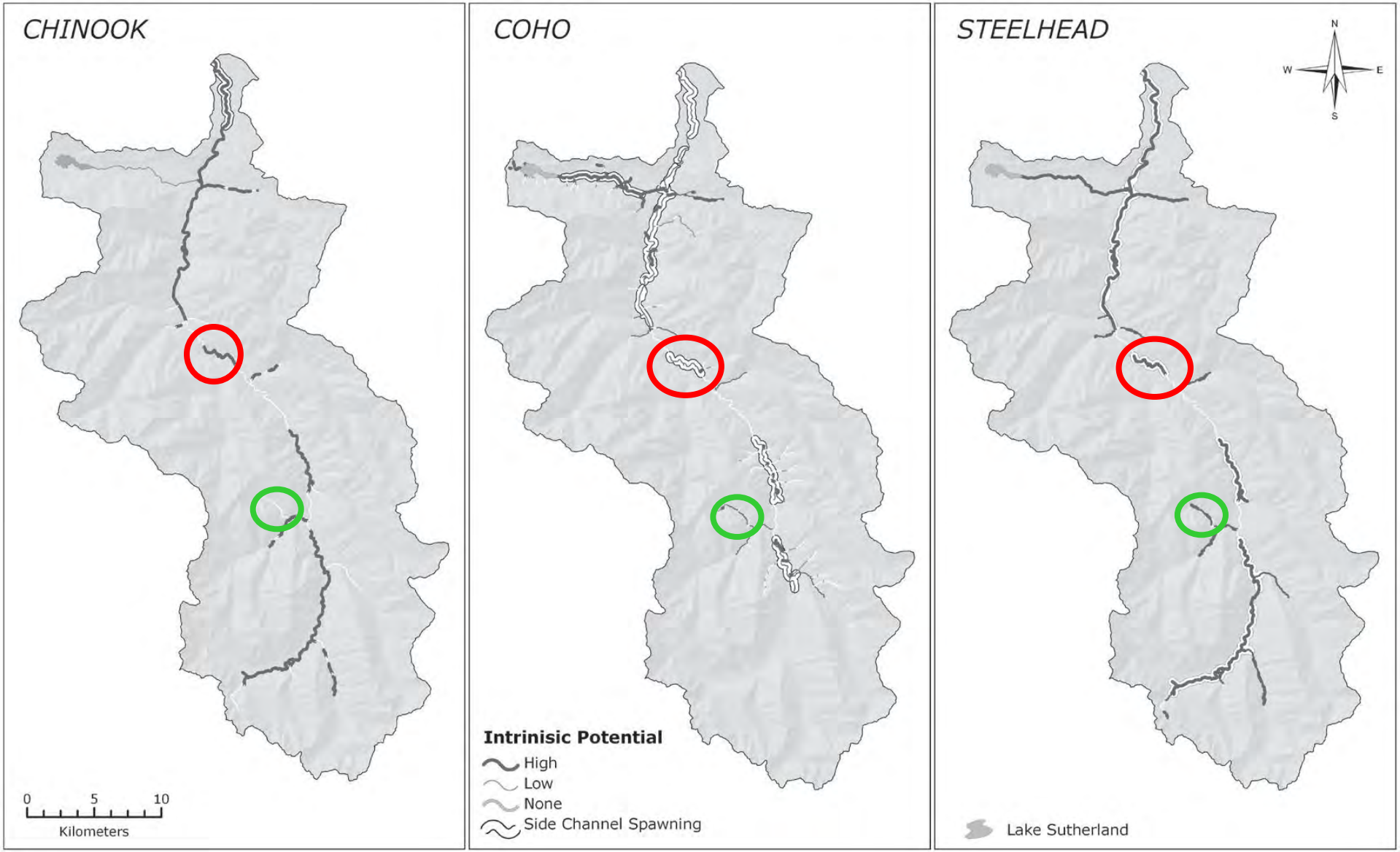
How will salmon populations change with the removal of the Elwha River dams?

- How long will it take salmon to colonize & establish spawning populations?
- What habitats & locations will different salmon species colonize?
- How many more salmon will there be?
- How will we measure change?
- What are some of the results to date?

Salmon can successfully colonize newly available habitats



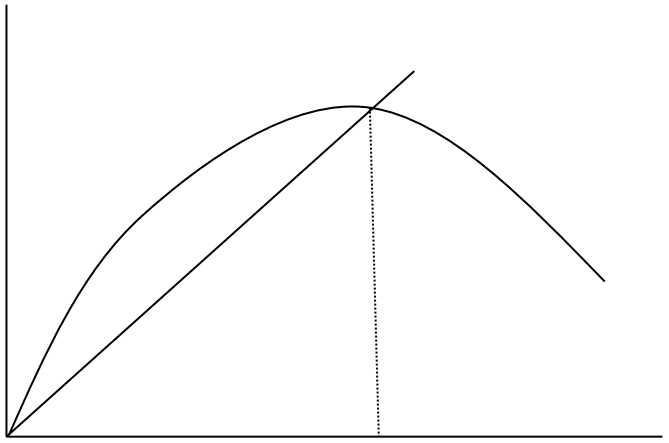
What habitats and locations will different salmon species colonize?



How many more salmon will there be?

$$S_{rep} = \chi \hat{b} * e^{\ln \hat{a} + (\frac{\hat{\sigma}^2}{2})}$$

χ = drainage area (km^2)



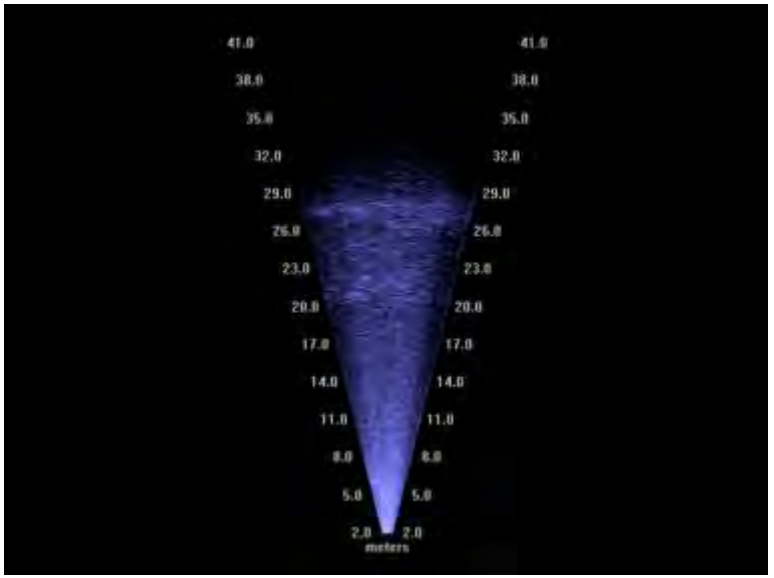
S_{rep} = *Equilibrium Population Size*

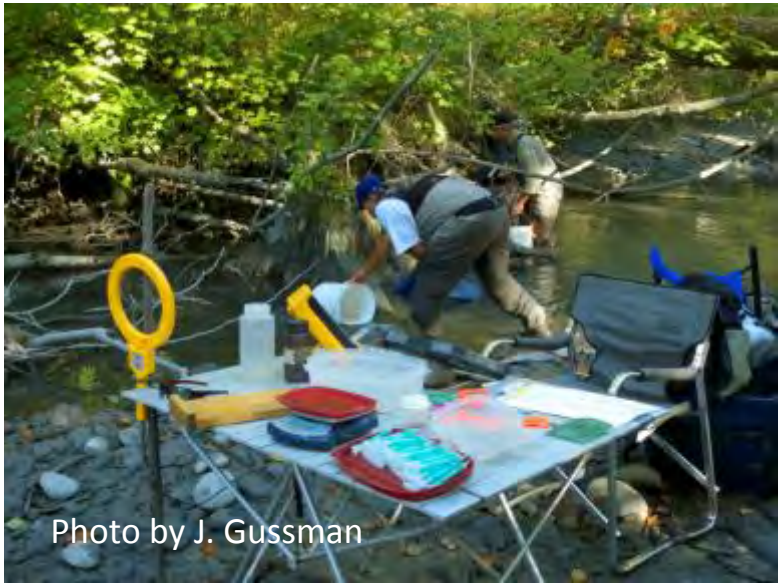
Elwha Chinook Estimate	Equilibruim Population Size
Stream type	**4,589**
Ocean type	**10,099**

Parken C.K., McNicol R.E. & Irvine J.R. (2006) Habitat Based Methods to Estimate Escapement Goals for Chinook Salmon Stocks in British Columbia, 2004. Research Document 2006/083. Ottawa, ON: Canadian Science Advisory Secretariat, 74 pp.

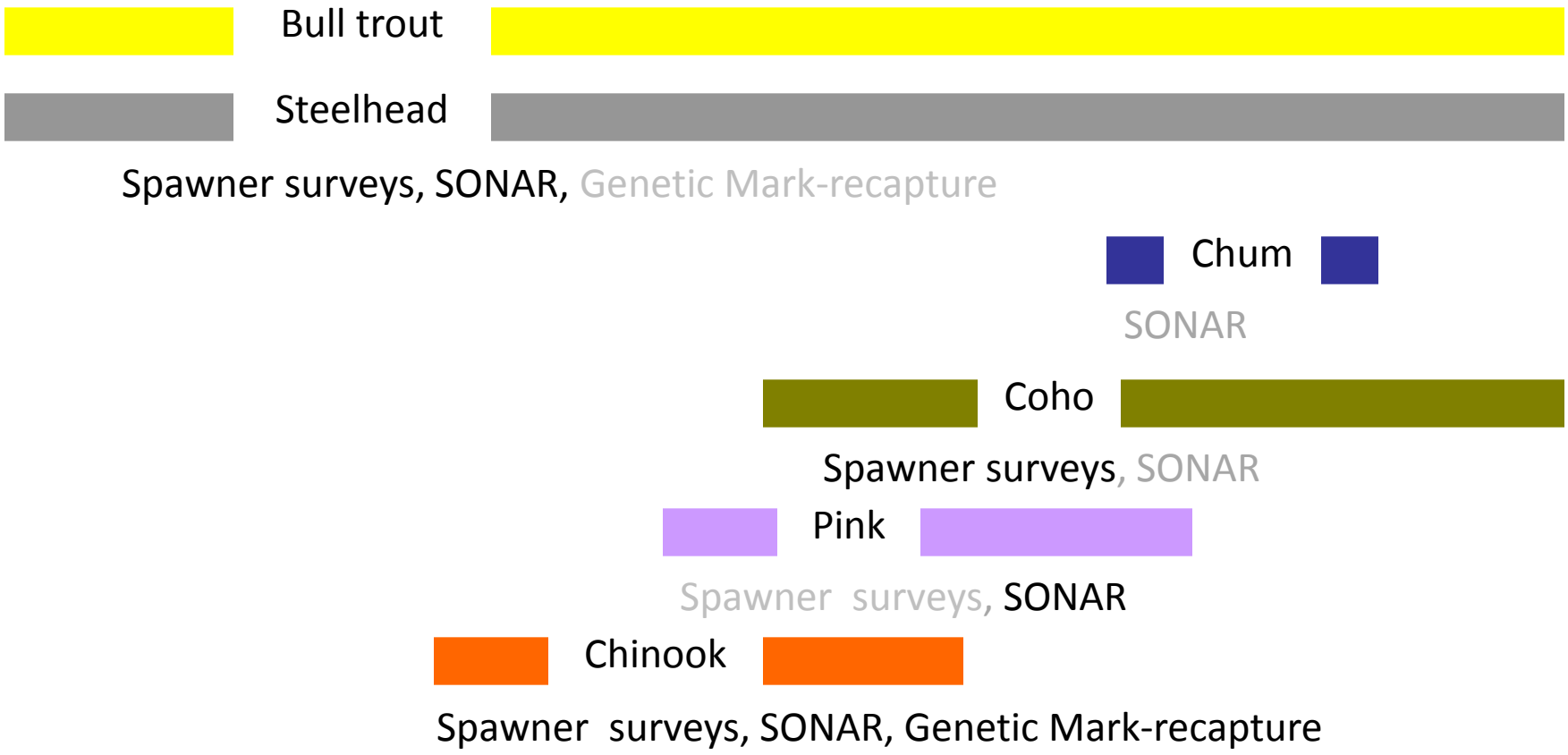
How will we measure change?

- Adults
  - SONAR
  - Redd surveys
  - Snorkel surveys
  - Genetics
- Juveniles
  - Snorkel surveys
  - Seining
  - Electrofishing
- Smolts
  - Smolt traps



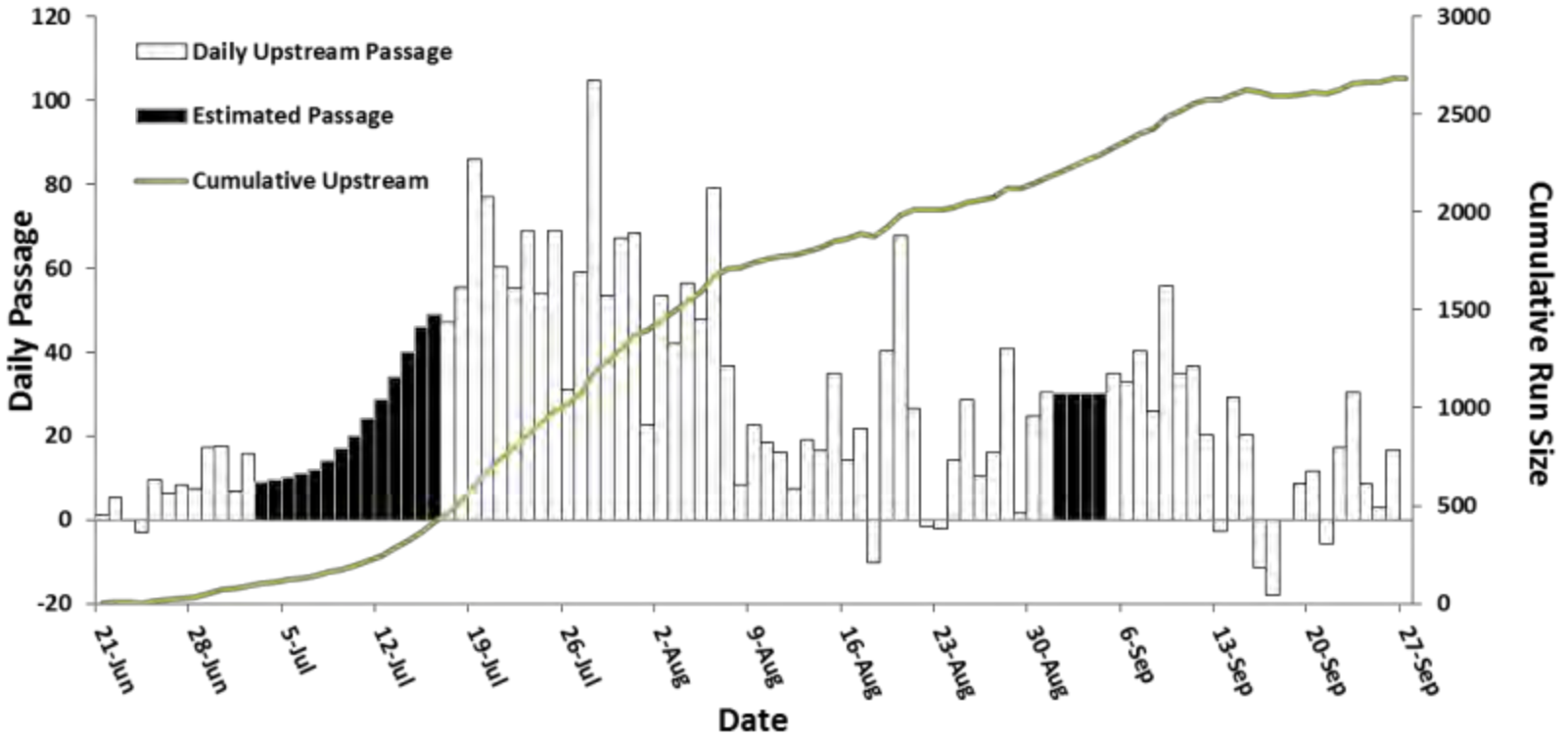


Elwha Adult Residence

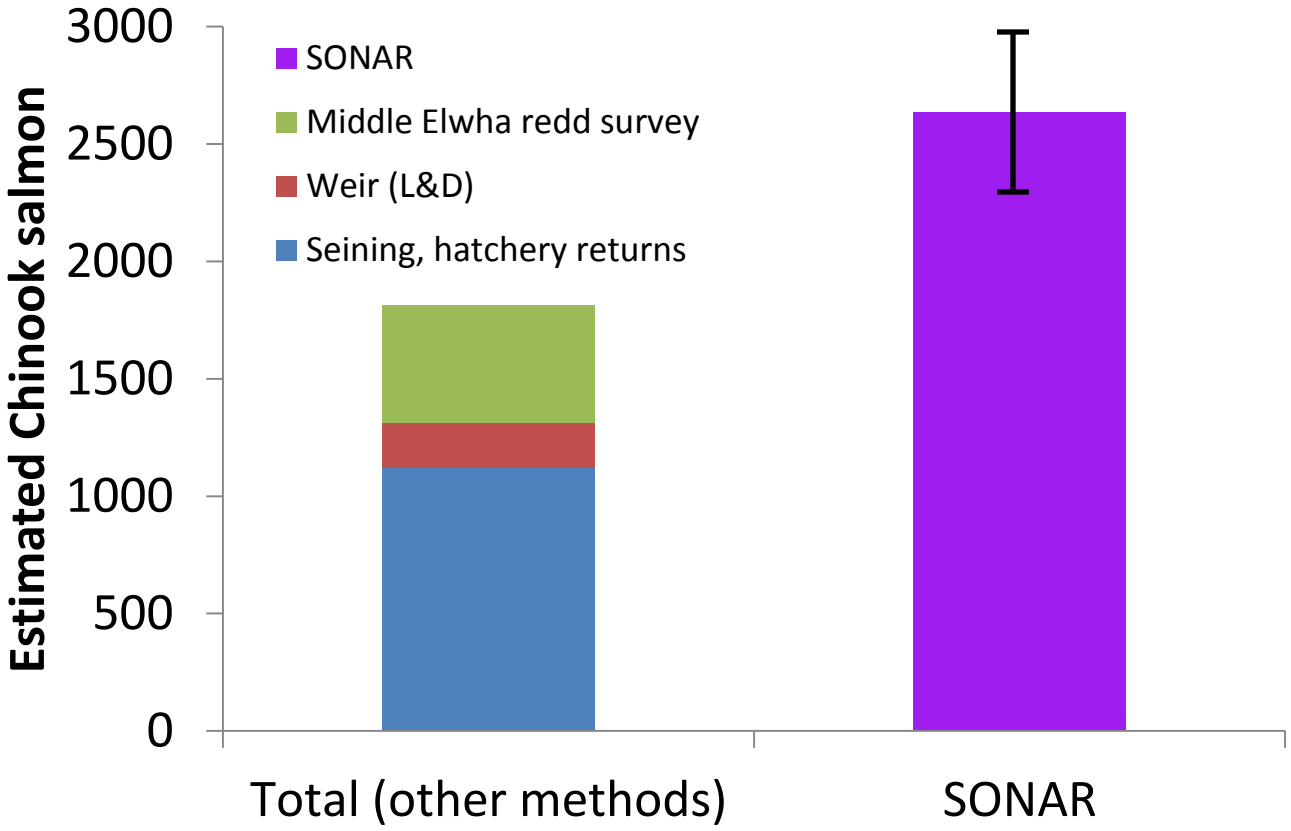


Elwha SONAR location

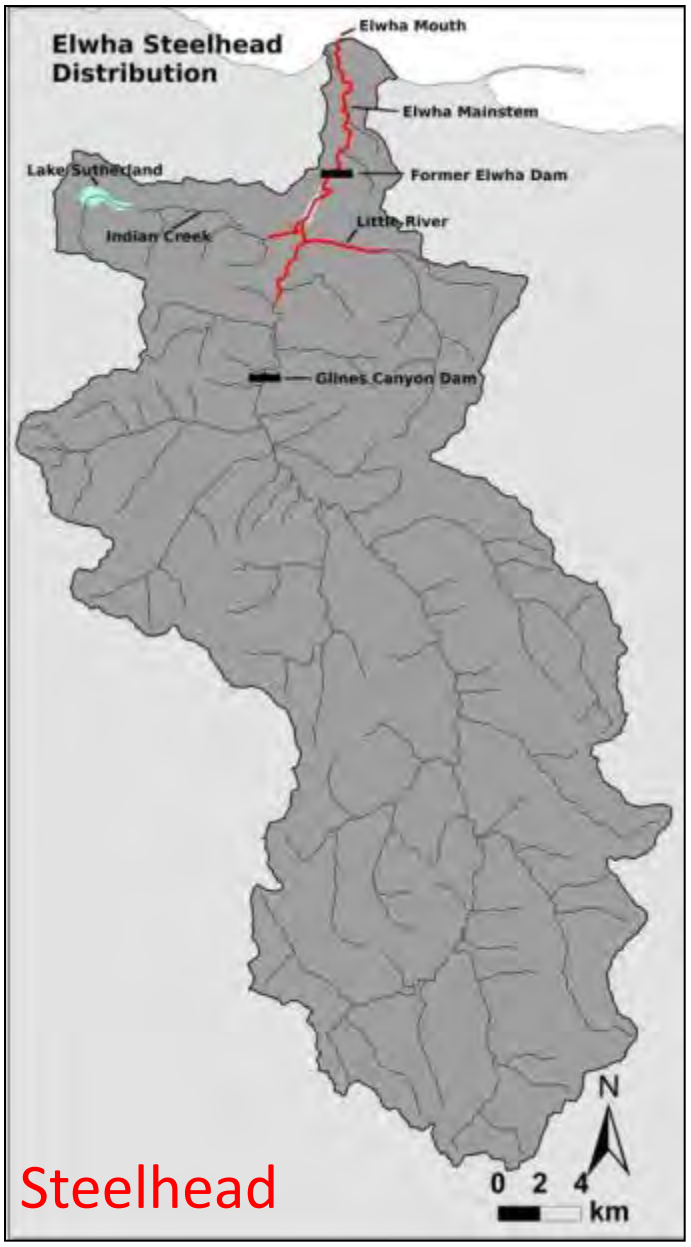
Elwha SONAR Results – Chinook 2012

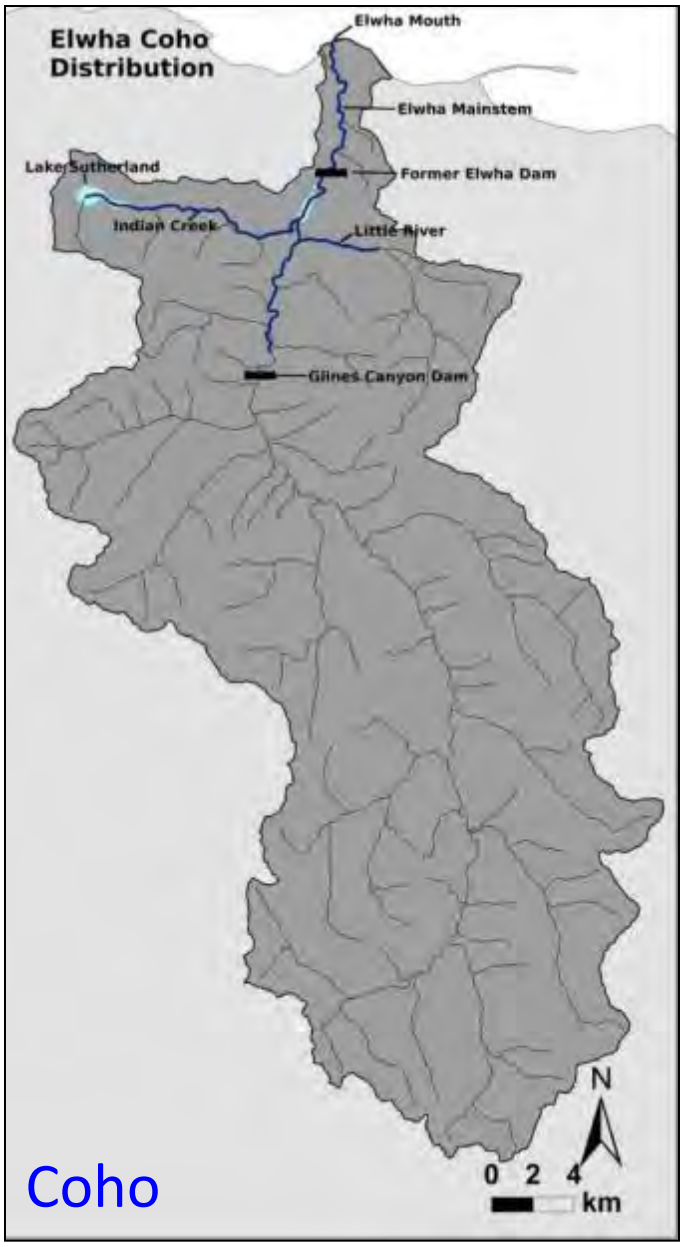


Elwha SONAR Results – Chinook 2012



Adult Recolonization – Results from Year 1 (2011)



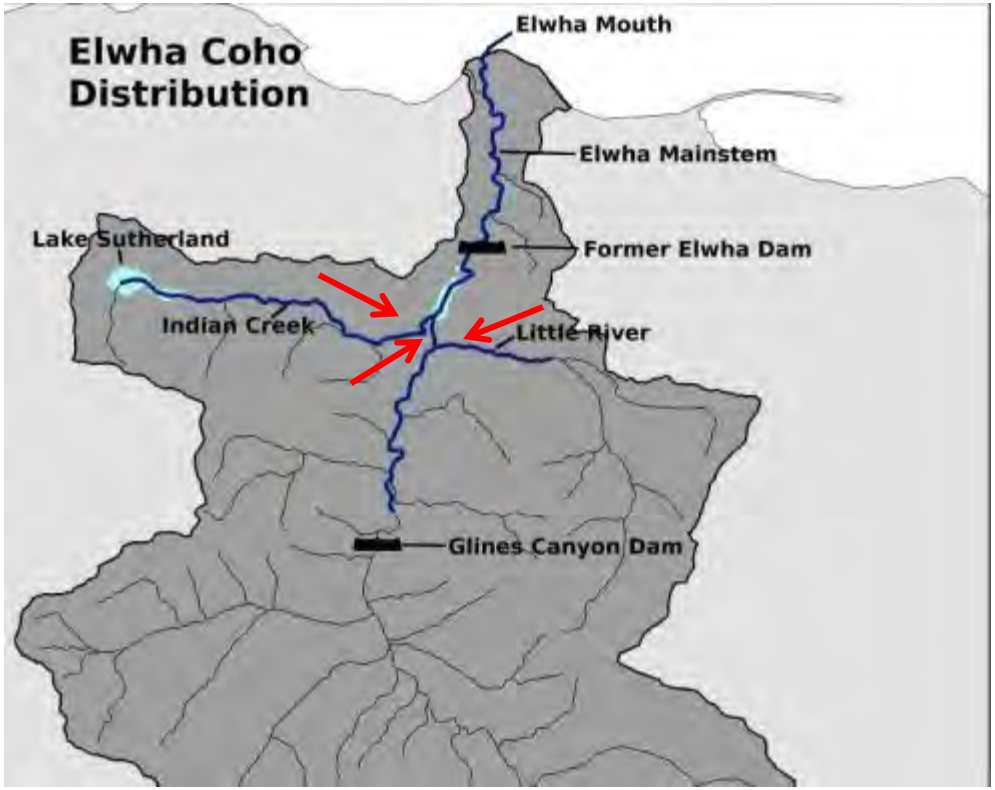


Fish recolonization in the middle Elwha

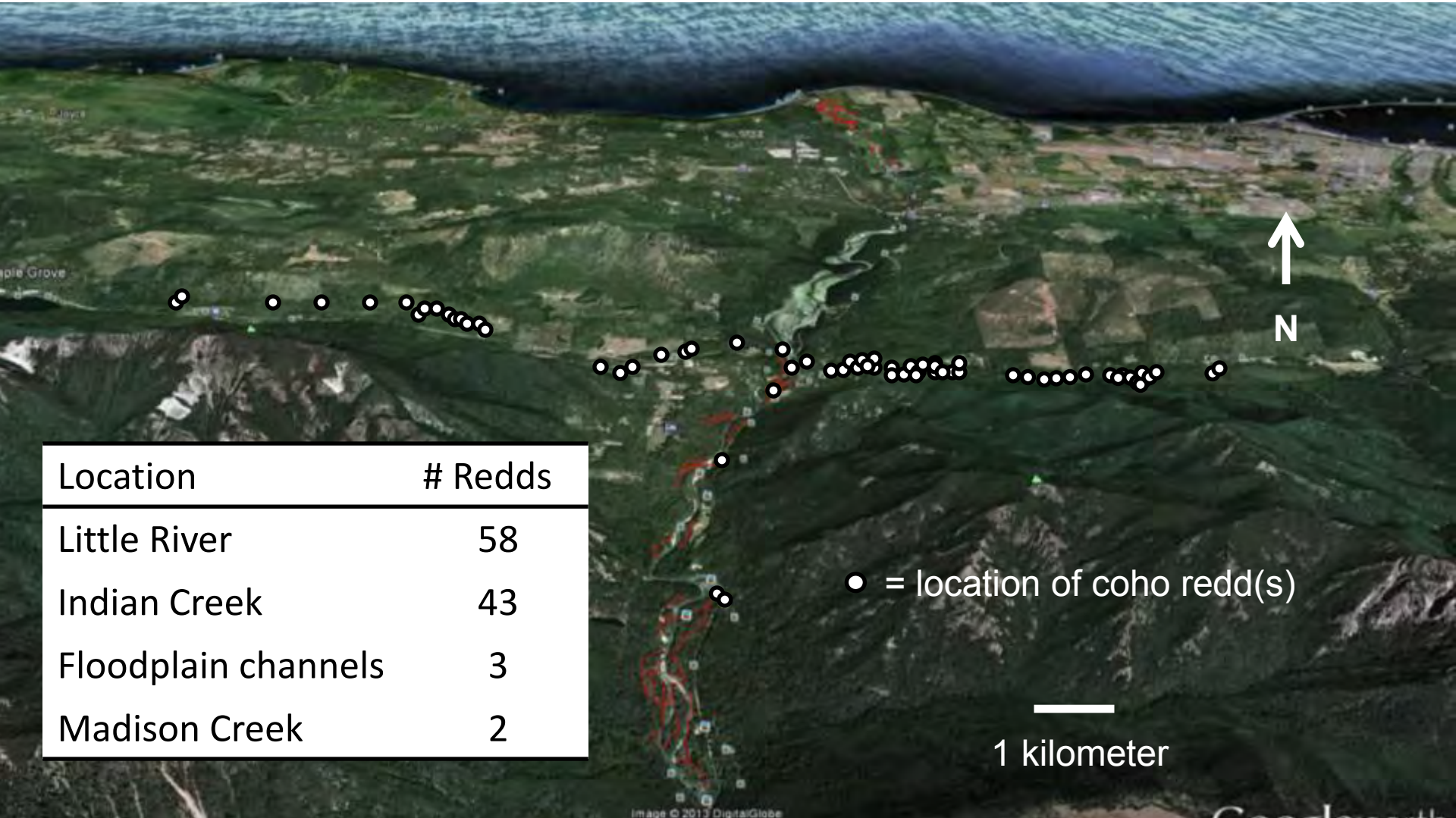
- 2011-2014 Relocation
  - Hatchery & wild adult coho salmon
  - Wild steelhead
- 2011-2014 Natural colonization
  - Steelhead
  - Pink salmon
  - Chinook salmon
  - Coho salmon
- Life stage specific distribution & abundance
  - Redd counts
  - Snorkel surveys
  - Summer parr estimates
  - Smolt estimates

Relocation of adult coho salmon in the middle Elwha Fall of 2011

Release Location	Male Coho	Female Coho
Mainstem Elwha	260	223
Little River	102	70
Indian Creek	28	43



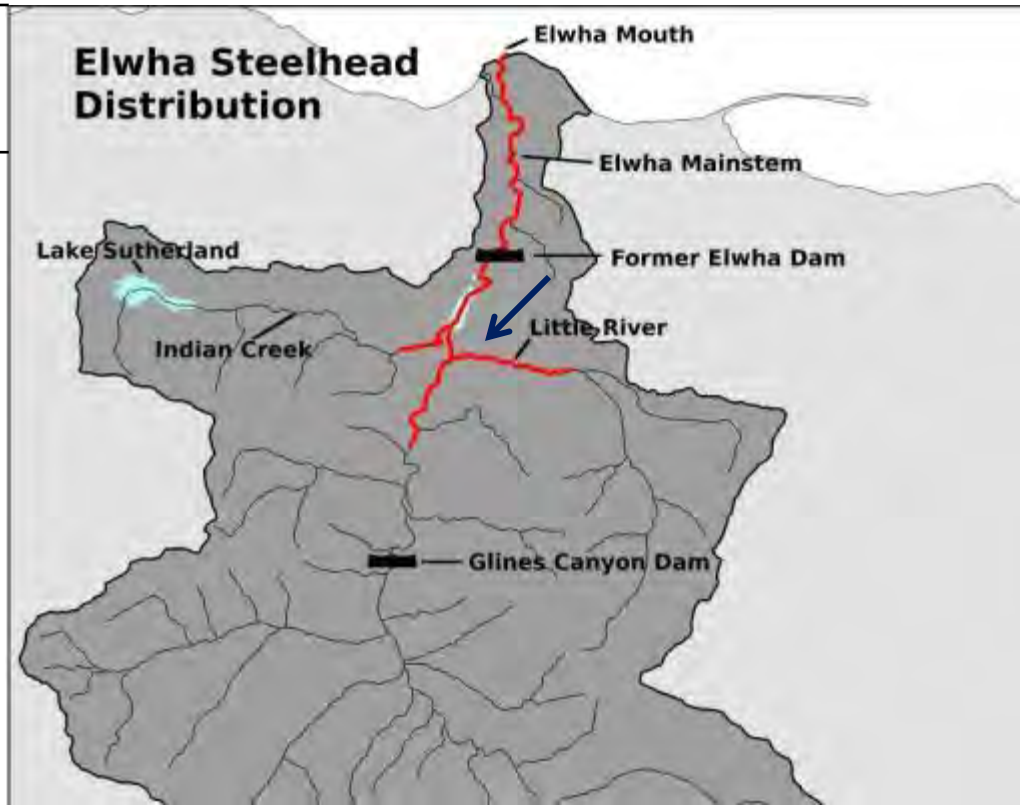
Coho salmon redds in the middle Elwha
Fall of 2011



Location	# Redds
Little River	58
Indian Creek	43
Floodplain channels	3
Madison Creek	2

Relocation of adult steelhead in the middle Elwha Spring of 2012

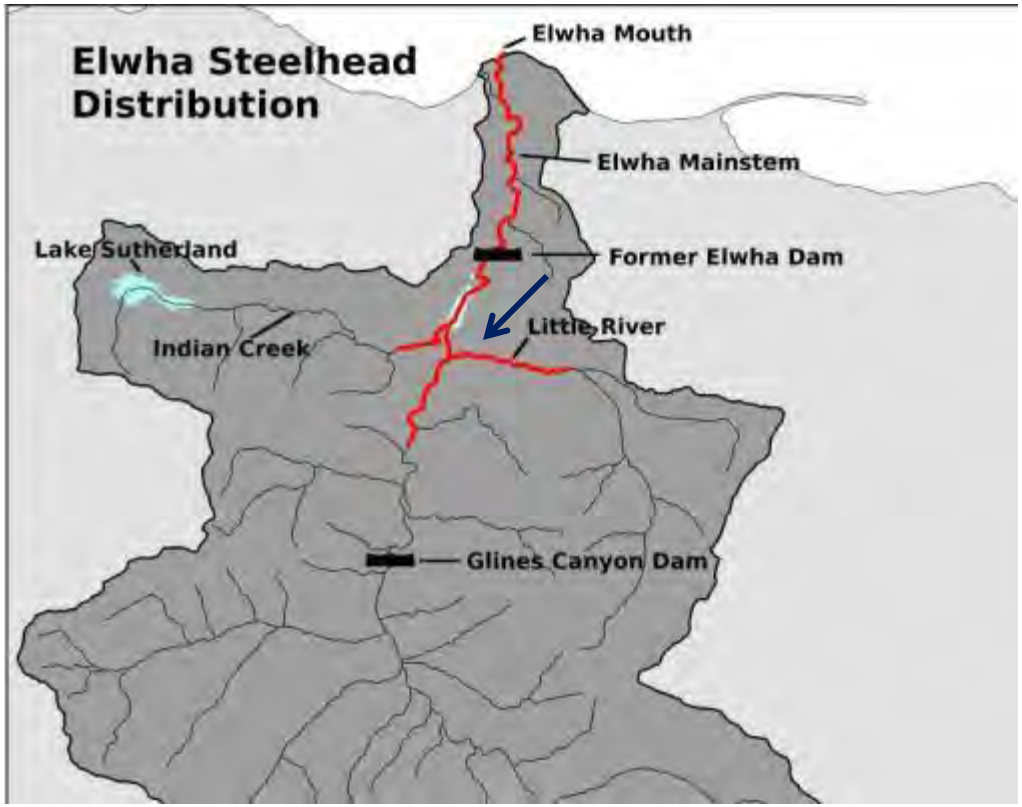
Release Location	Male Stlhd	Female Stlhd	Rainbow trout
Little River	11	39	15



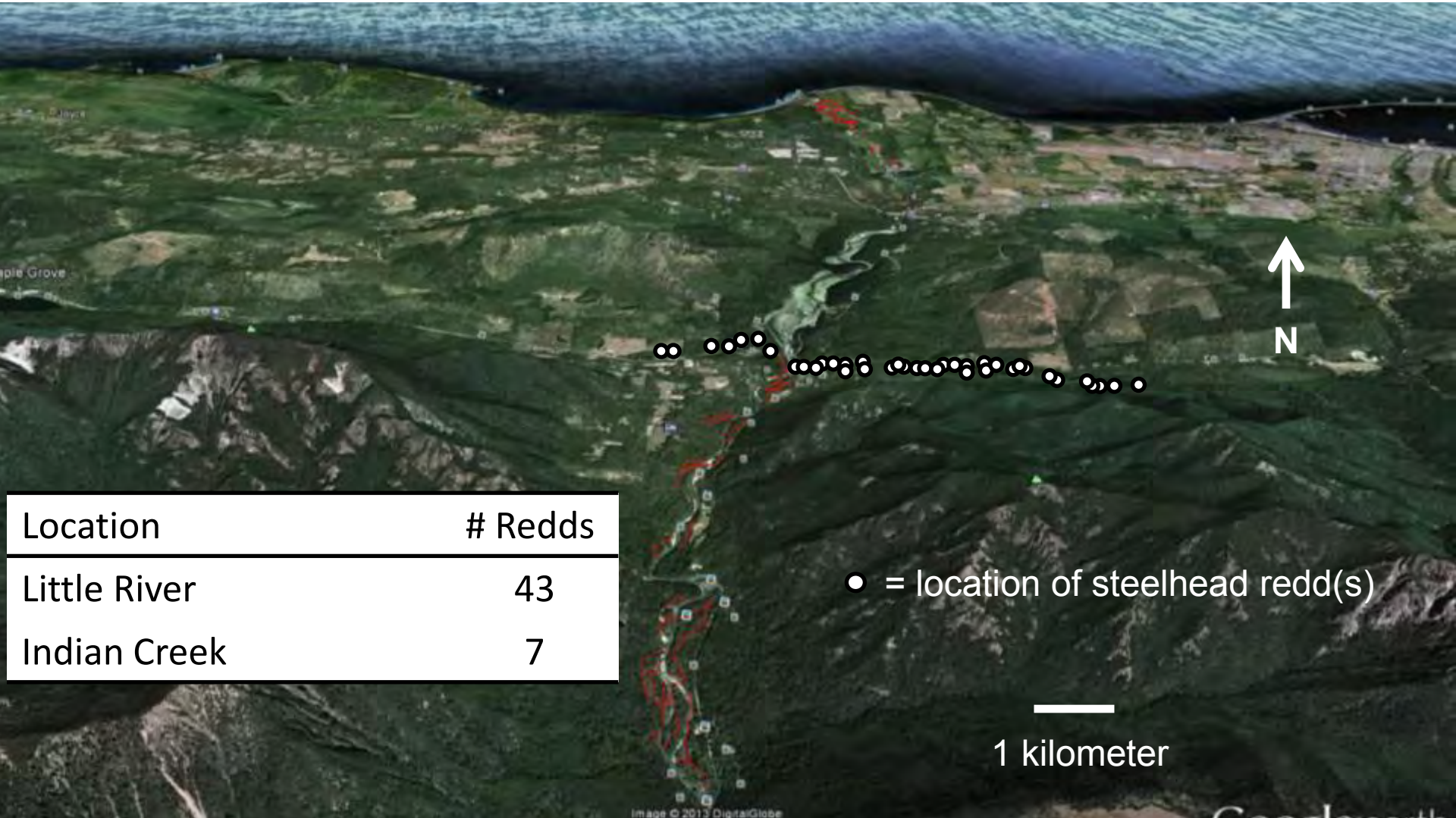
Natural colonization of adult steelhead in the middle Elwha for 2011-2013

Natural colonizers	Male Stlhd	Female Stlhd
Little River	5	3
Indian Creek	6	4

Photo by John McMillan



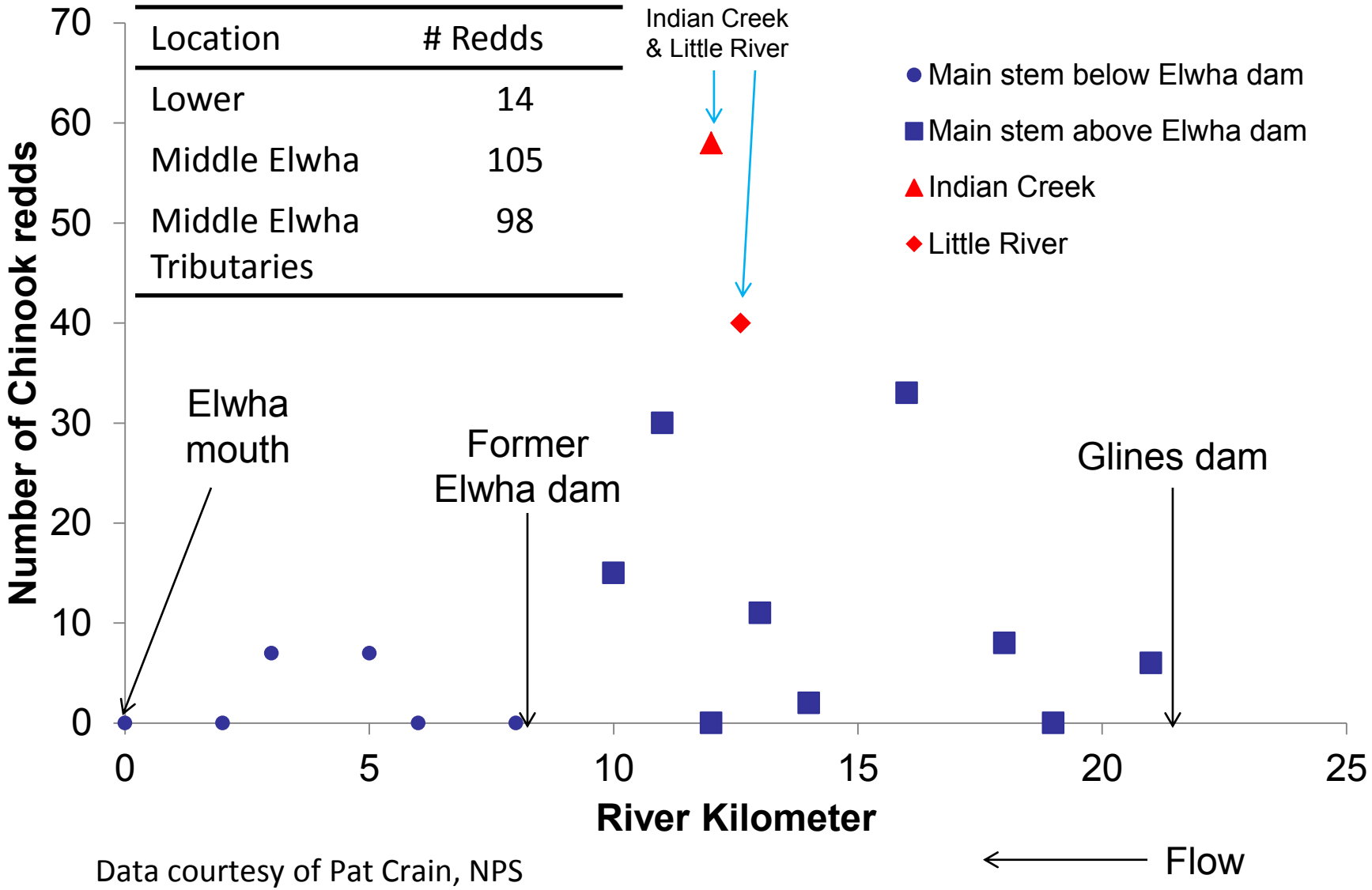
Steelhead redds in the middle Elwha
Spring & summer of 2012



Location	# Redds
Little River	43
Indian Creek	7

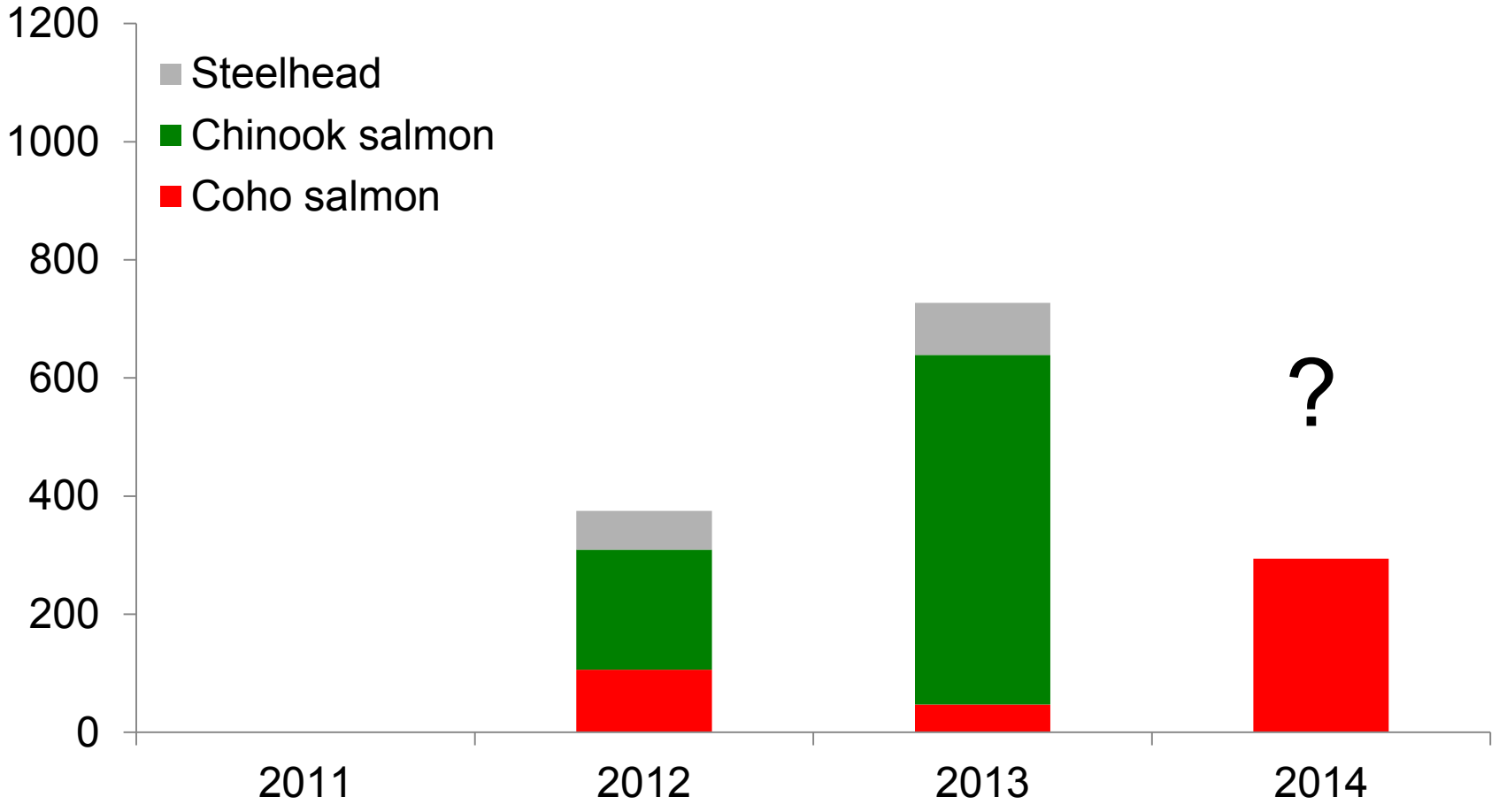
Natural recolonization of Chinook salmon in the middle Elwha River – Summer 2012

Location	# Redds
Lower	14
Middle Elwha	105
Middle Elwha Tributaries	98

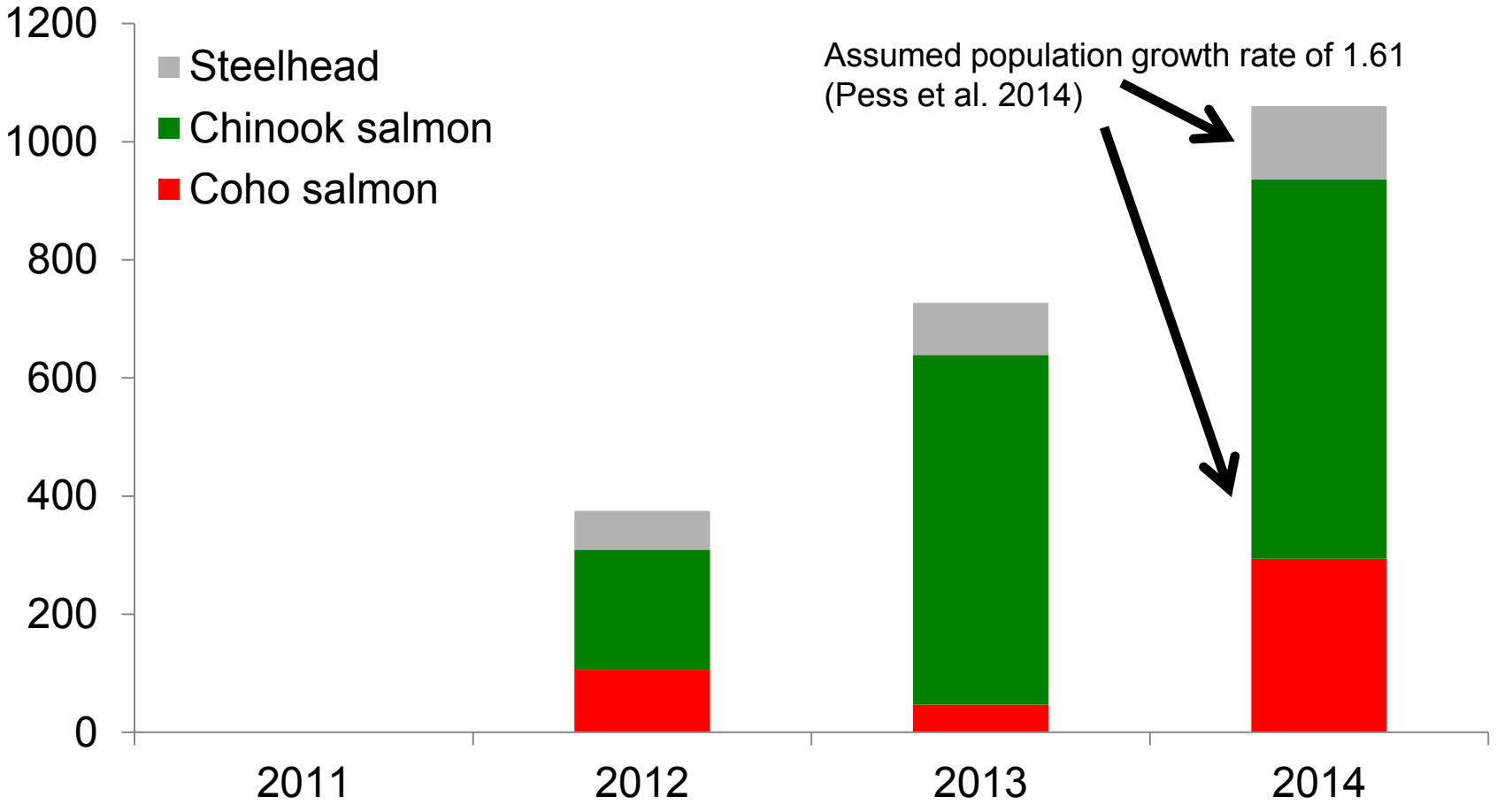


Data courtesy of Pat Crain, NPS

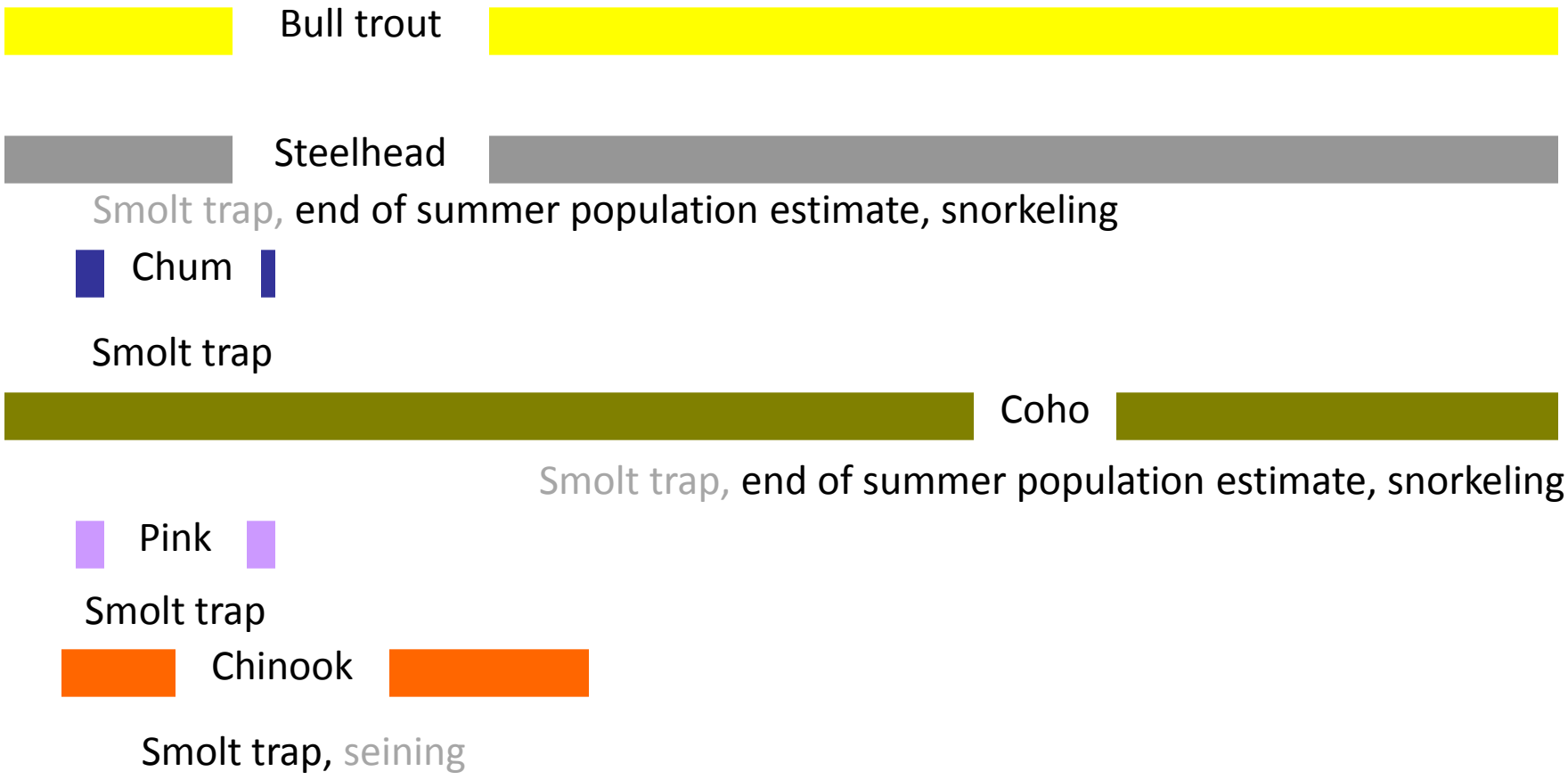
Number of redds above former Elwha dam 2012 to 2014



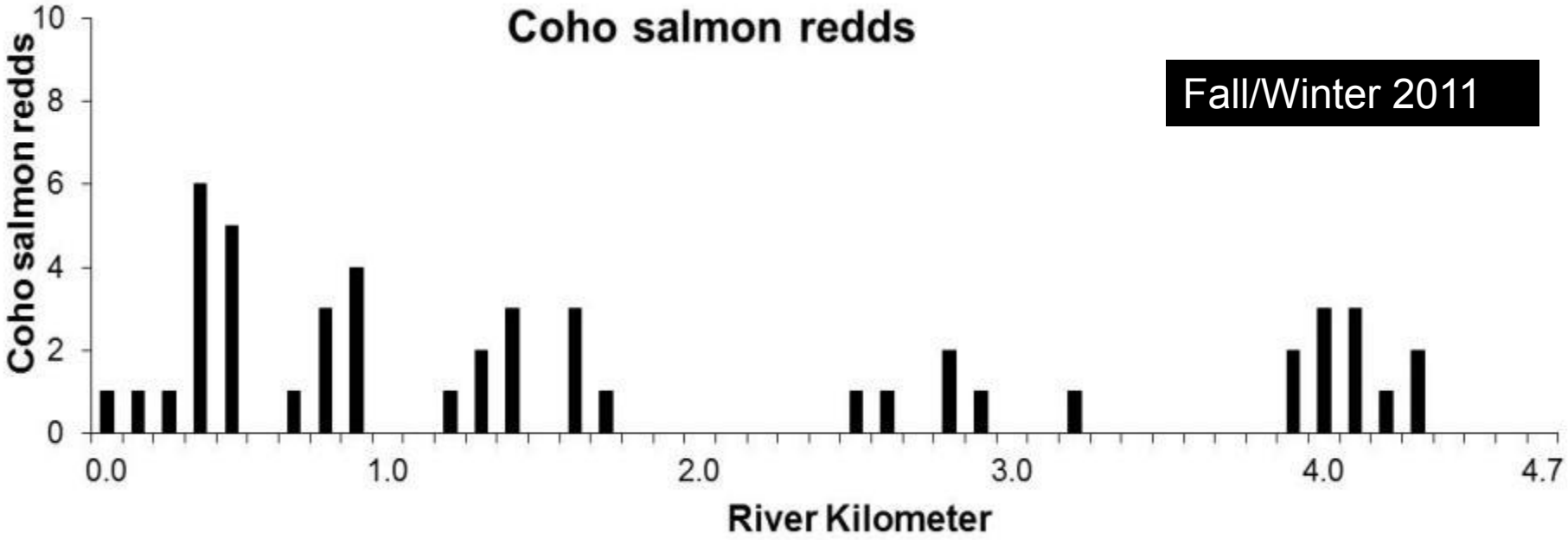
Number of actual & estimated redds above former Elwha dam 2012 to 2014

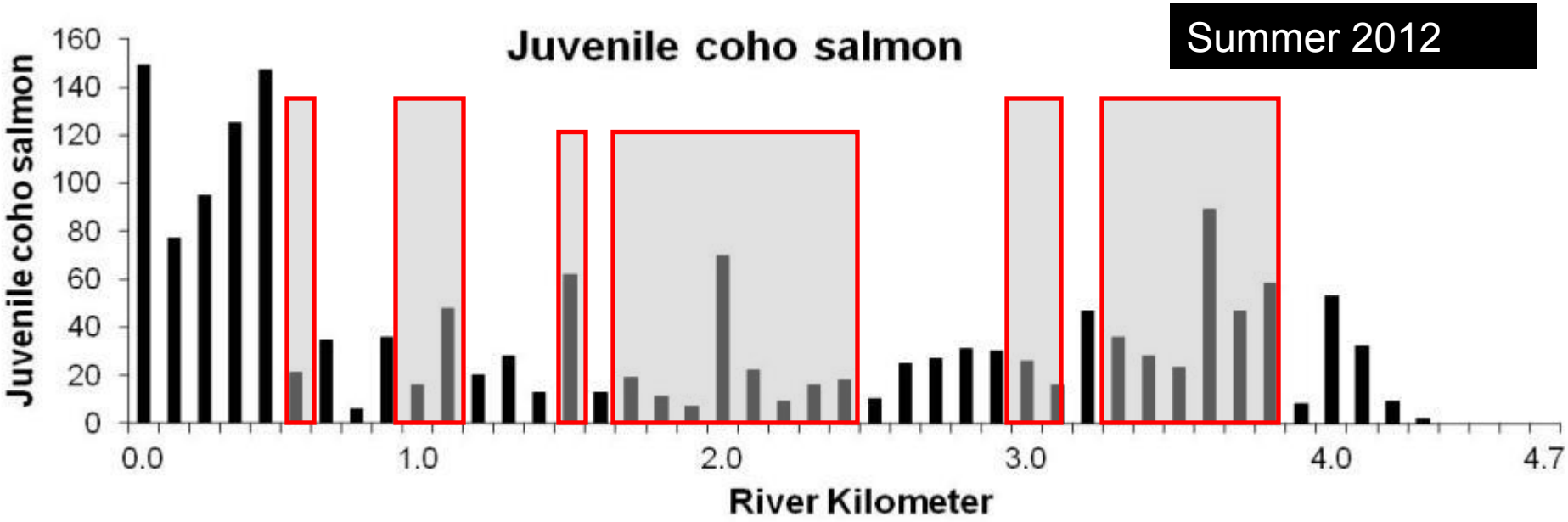


Elwha Juvenile Residence



Little River coho salmon redd & juvenile snorkel surveys





Juvenile sampling population estimates

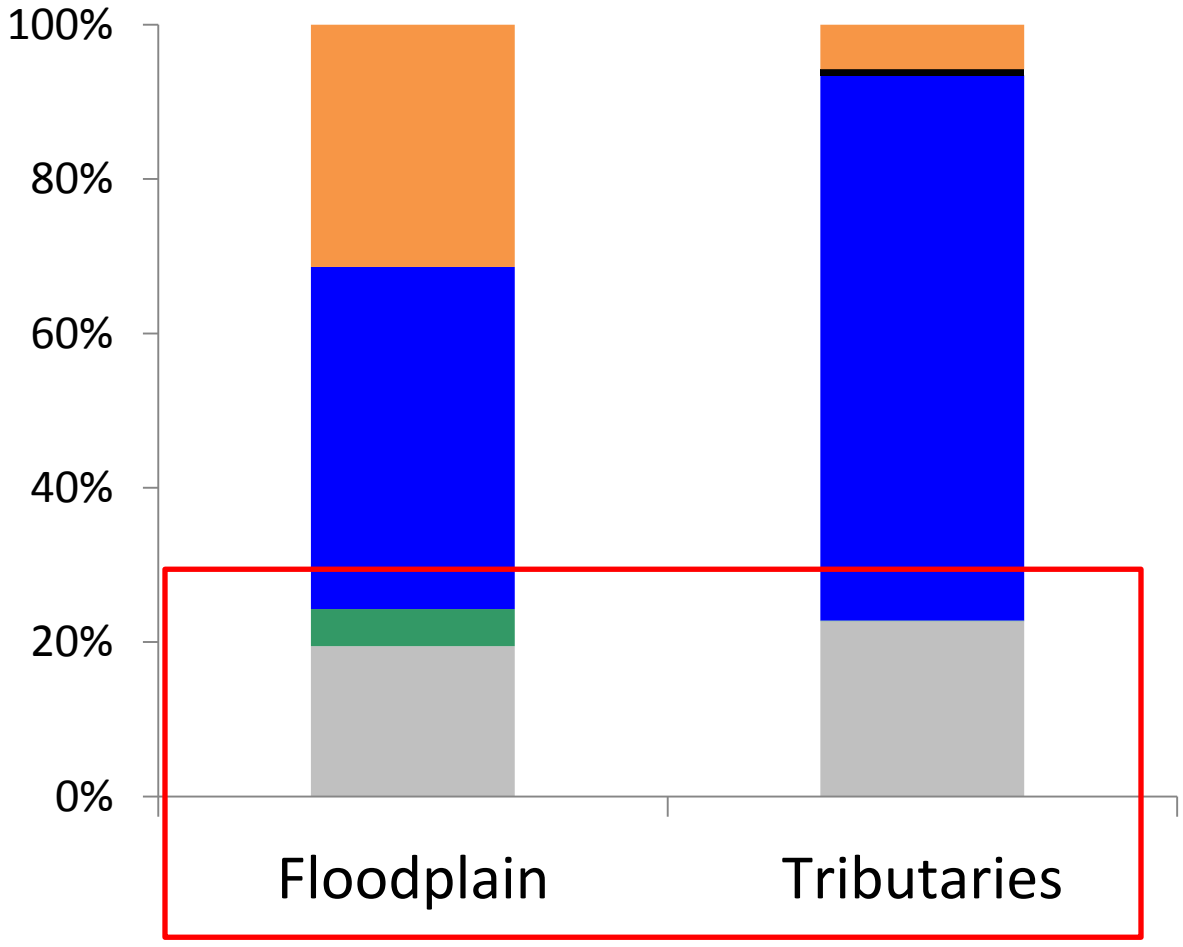
- 15 sites
  - 8 tributary
  - 7 floodplain
  - Sampling ~5% of anadromous zone in Middle Elwha
- 3 pass electroshock
  - 100 meter reaches

Photos by John McMillan

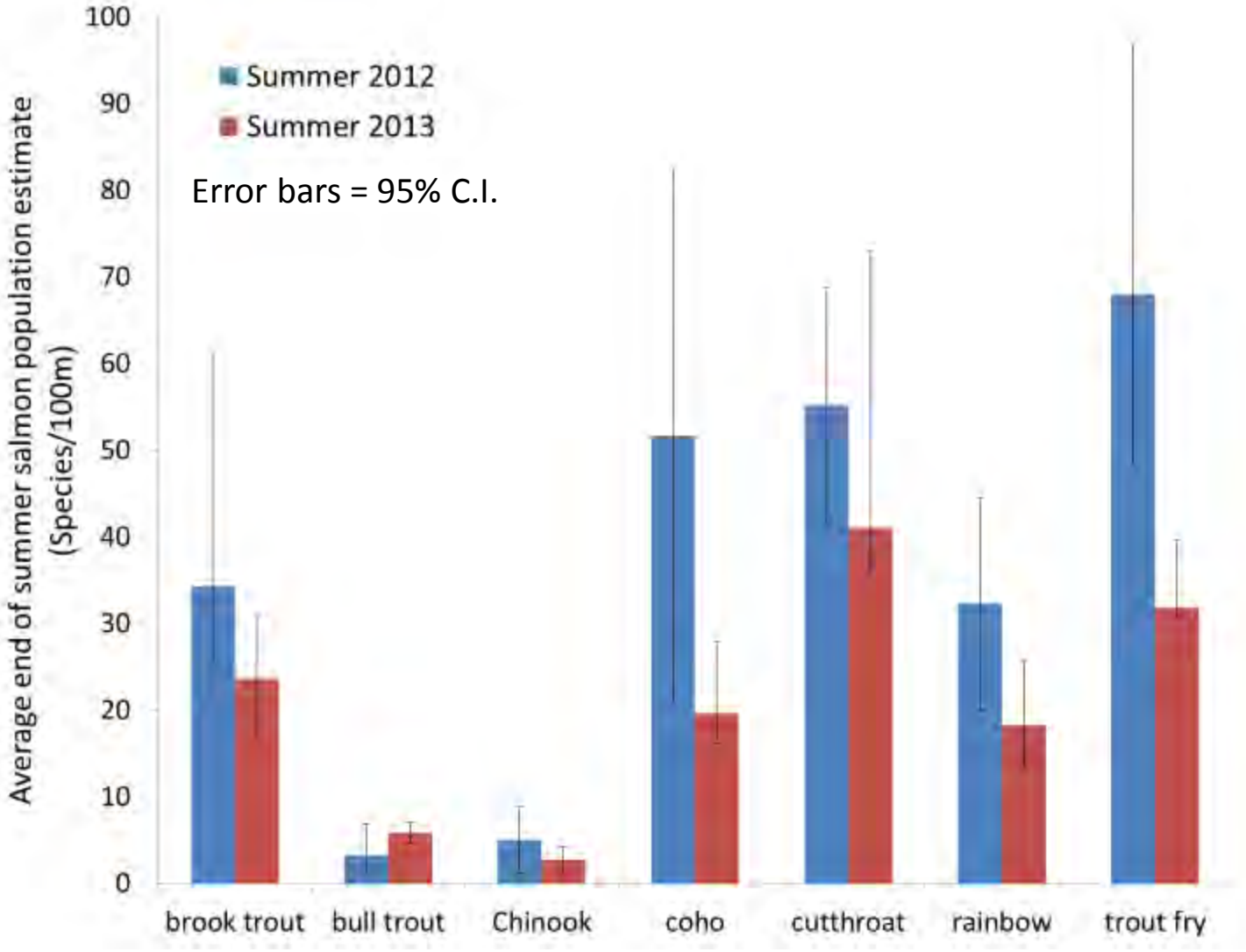
Mike McHenry, George Pess, Raymond Moses, John McMillan, Roger Peters, Mel Elofson, Sonny Sampson, Jeff Duda, Tim Beechie, Wilson, Alan Bennett, Heidi Hugunin, Anna Torrance, Sam Brenkman, Martin Liermann, Todd Bennett, WCC crew, Emily Thornton, Neala Kendall, KathiJo Jankowski

2012 Middle Elwha summer juvenile salmon population estimates

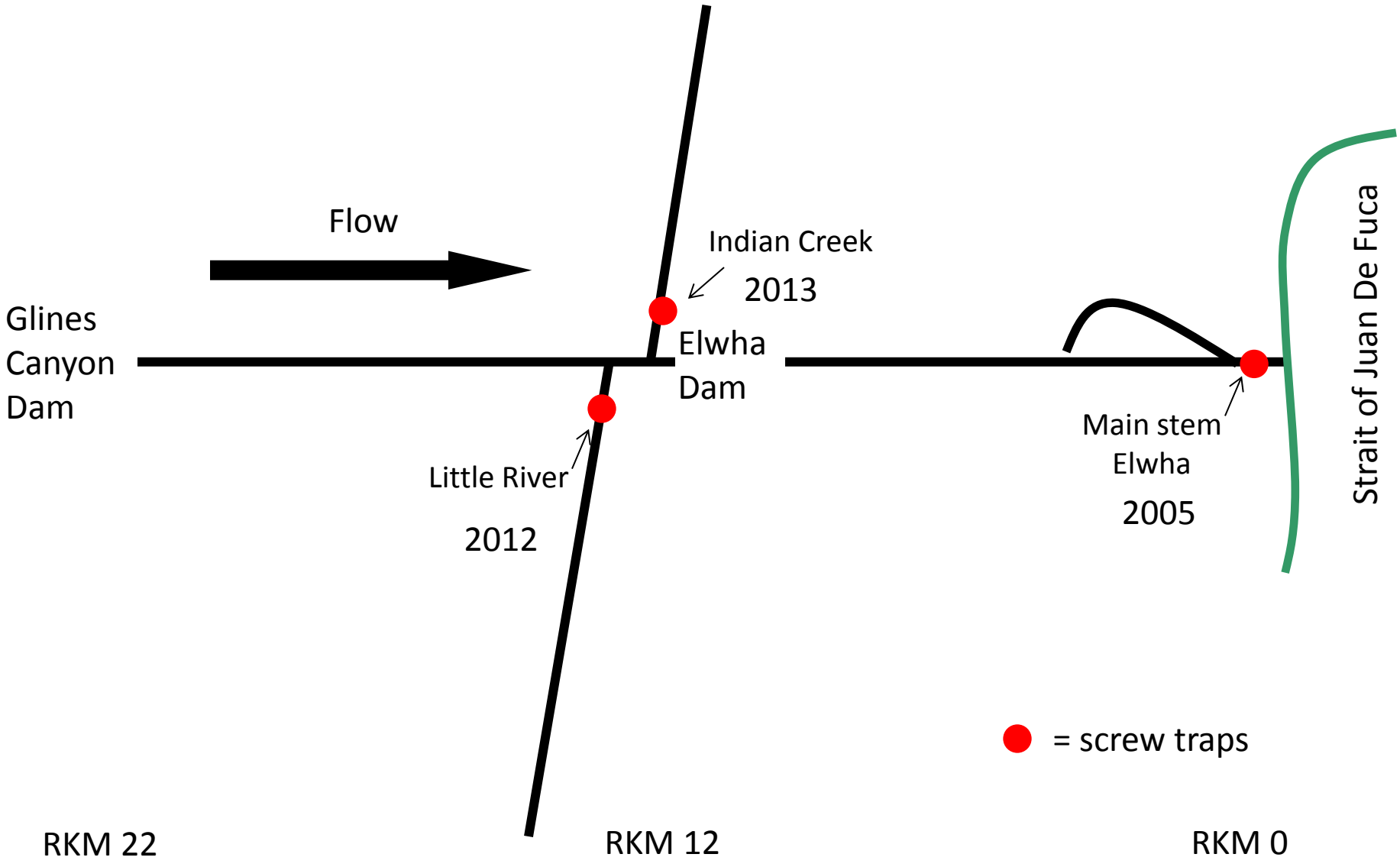
2012 Juvenile salmon composition between the dams



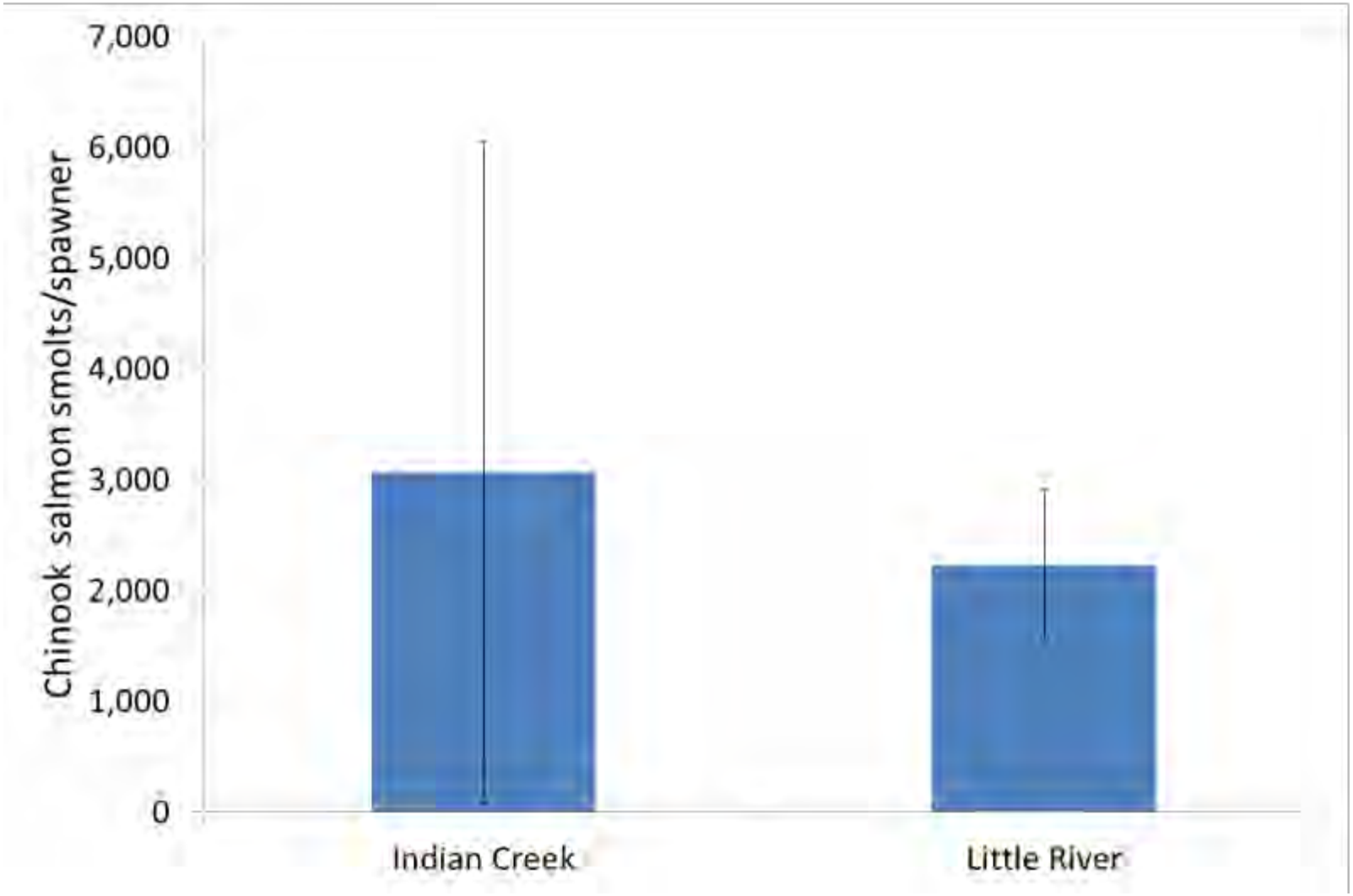
Middle Elwha River
Ave end of summer salmon population estimate (all locations)



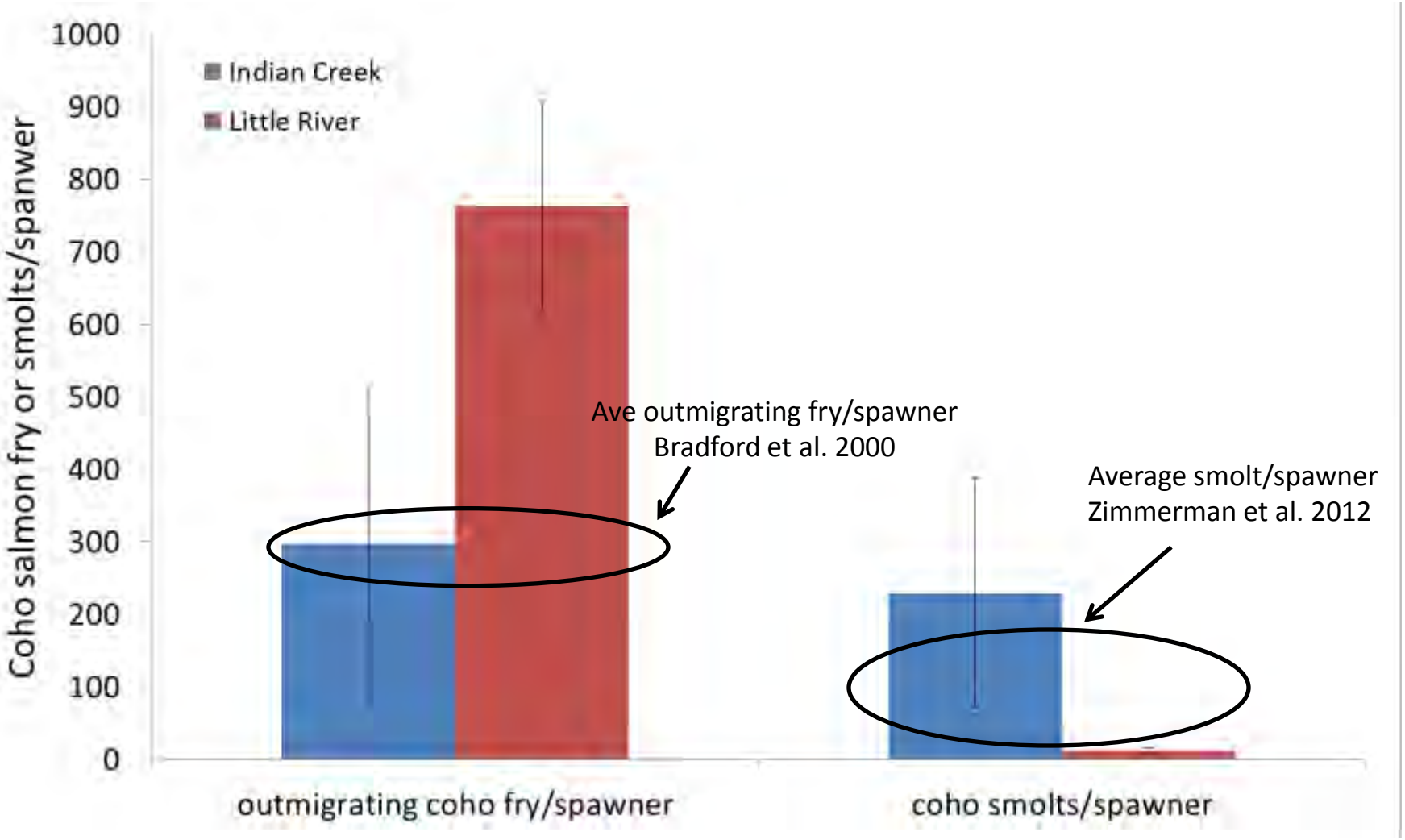
Elwha River smolt trap locations



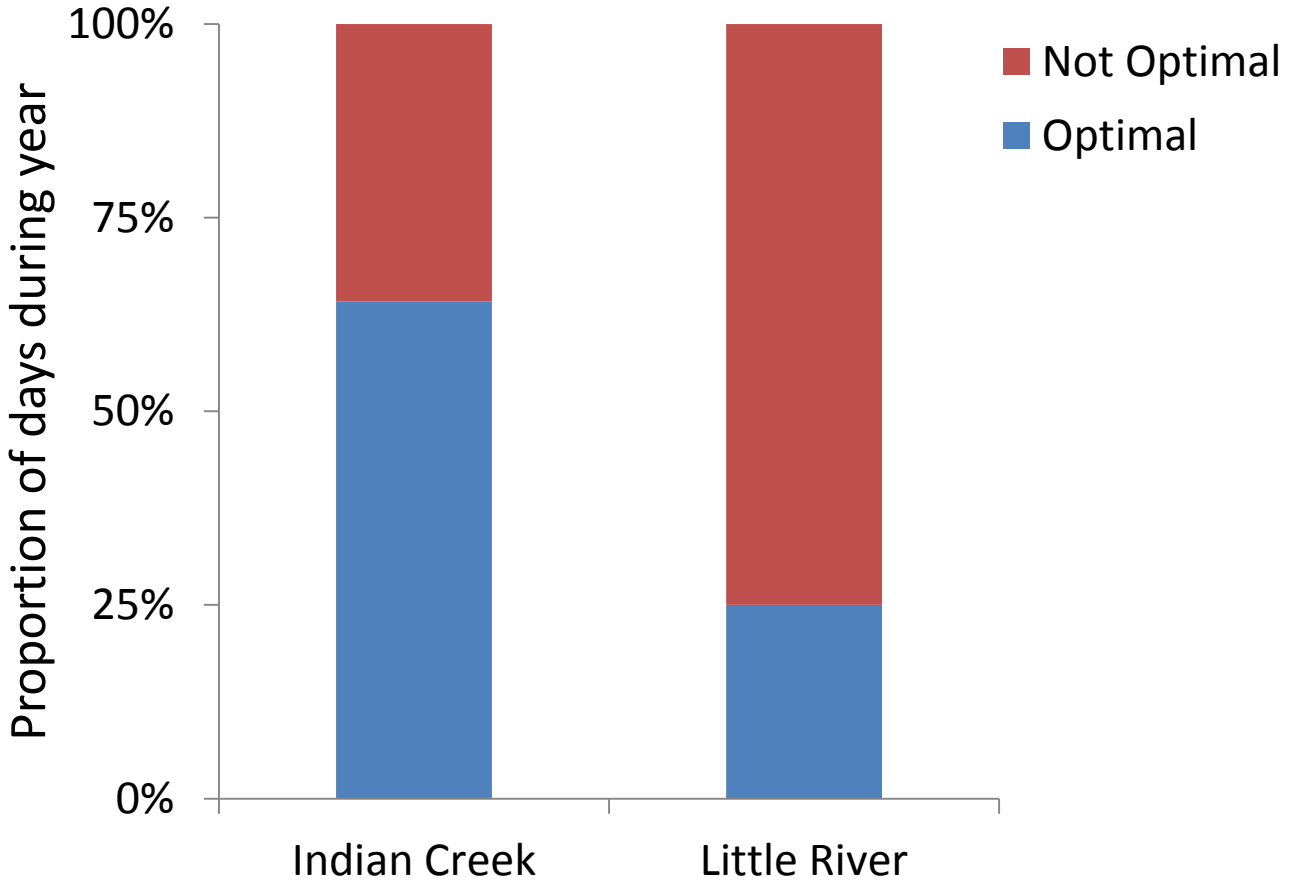
Chinook salmon productivity
Little River v. Indian Creek



Coho productivity
Little River v. Indian Creek



Optimal growing temperatures (9 to 13 C) Little River v. Indian Creek



Growth period for Indian Creek – April through September (6 months)
Growth period for Little River – July through September (3 months)

2013 Fish recolonization highlights

- First documented lamprey above Elwha dam

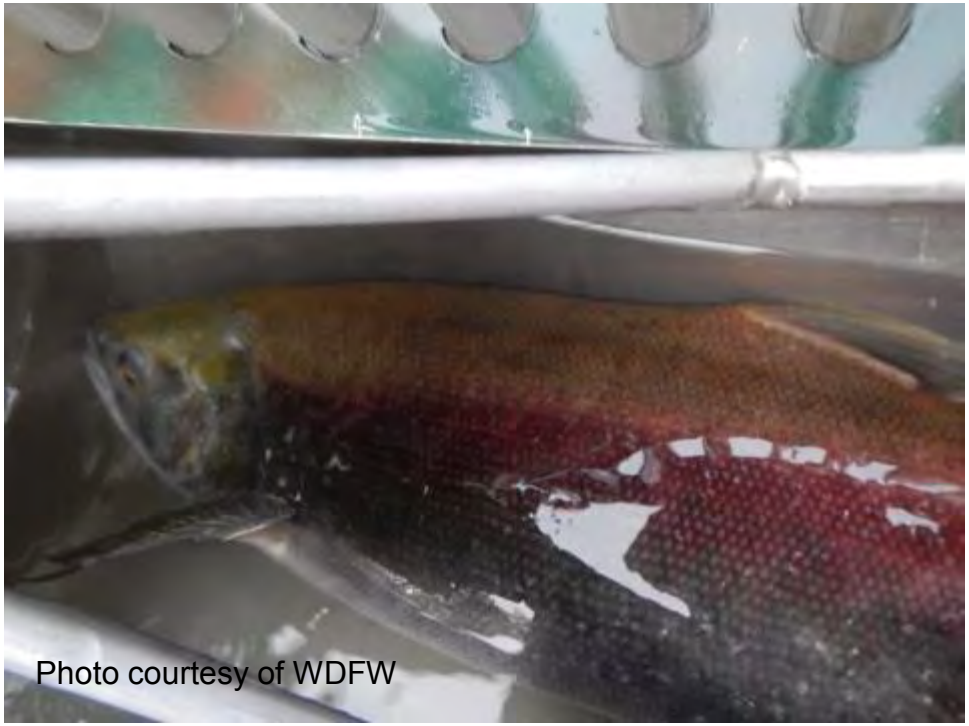
- First documented sockeye salmon in Indian Creek

- First documented summer steelhead in Little River

2013 Fish recolonization highlights

- First documented lamprey above Elwha dam.

- First documented sockeye salmon in Indian Creek



- First documented summer steelhead in Little River

2013 Fish recolonization highlights

- First documented lamprey above Elwha dam.

- First documented sockeye salmon in Indian Creek

- First documented summer steelhead in Little River

Sediment Impacts to Fish

- Peak turbidity event April 6-8th 2013 (~ 4,000 NTU)
- Coincided with WDFW hatchery release of yearly Chinook salmon
- Dead smolts observed from hatchery to estuary
- Hypothesized mortality from stranding, disorientation, and choking

Dam removal and reservoirs summary

- Elwha dam removal complete, Glines canyon dam almost complete.
- 40% of total stored sediment has been released as of October of 2013.
- Reservoirs being re-vegetated both naturally and with restoration efforts.

Nearshore, Main stem, & floodplain summary

- Delta at river mouth is prograding into the Strait of Juan De Fuca.
- ~12% of sediment stored in-river.
- Main stem pools filled/evacuated/filling again with sediment.
- Floodplain channels filling with sediment.
- Different composition of sediment between middle and lower Elwha floodplain channels.

Stream productivity summary

- High level of fine sediment deposition on river cobbles.
- Benthic and drift invertebrate densities reduced.
- Juvenile O. mykiss relying more on terrestrial prey sources.

Fish recolonization & sediment impacts summary

- Adults are making it past old Elwha Dam site.
- Coho, steelhead & Chinook salmon redds are in the middle Elwha and tributaries.
- Juveniles are dispersing to colonize new areas.
- Salmon productivity varies as a function of local environmental conditions.
- New species and life histories are being documented.
- High turbidity levels can and has resulted in a fish kill in the Lower Elwha.

Photo by John McMillan

Where to Find Additional Information

USGS Scientific Investigations Report, 2011. Coastal Habitats of the Elwha River, Washington: Biological and Physical Patterns and Processes Prior to Dam Removal.

http://pubs.usgs.gov/sir/2011/5120/pdf/sir20115120.pdf

Northwest Science Special Issue, 2008, Vol. 82: Dam Removal and Ecosystem Restoration in the Elwha River Watershed, Washington State.

http://www.bioone.org/toc/nwsc/82/sp1

www.elwhainfo.org

www.nps.gov/olym/naturescience/elwha-ecosystem-restoration

http://wabc-afs.org/w/wp-content/uploads/downloads/2012/11/WA-BC_Fall-Newsletter_Nov-5th-2012.pdf

Thanks!