The Elwha River – ~ 2 years after the start of dam removal


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Photo by John McMillan
Disclaimer

- Any opinions expressed today are my own and not necessarily shared by or representative of NOAA.

Photo by John McMillan
Roadmap for today’s talk

• Watershed overview
• Background
• The action
• Questions
• Results
• Summary
Impacts of the Dam – Fish Passage

> 90% of habitat inaccessible
Elwha fishes

- Coho salmon
- Pink salmon
- Chinook salmon
- Steelhead
- Chum salmon
- Sockeye salmon
- Bull trout
- Sculpin spp.
- Brook trout
Elwha fishes

Threespine stickleback

Redside shiner

Eulachon

Pacific lamprey
Impacts of the Dam – Salmon Populations

- Total population decline: 98% reduction
- Shift in species composition:
  - Steelhead
  - Coho
  - Chinook
  - Sockeye
  - Chum
  - Pink

All native populations are very low in abundance
<table>
<thead>
<tr>
<th>Species</th>
<th>Estimated population size below dams</th>
<th>% Hatchery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Chinook</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Summer/Fall Chinook</td>
<td>~2,000</td>
<td>~75</td>
</tr>
<tr>
<td>Coho</td>
<td>~2,000</td>
<td>~76</td>
</tr>
<tr>
<td>Chum</td>
<td>~100</td>
<td>0</td>
</tr>
<tr>
<td>Pink</td>
<td>~100</td>
<td>0</td>
</tr>
<tr>
<td>Sockeye</td>
<td>~25</td>
<td>0</td>
</tr>
<tr>
<td>Winter steelhead</td>
<td>~300</td>
<td>~?</td>
</tr>
<tr>
<td>Summer steelhead</td>
<td>~50</td>
<td>0</td>
</tr>
<tr>
<td>Sea-run cutthroat</td>
<td>Unknown</td>
<td>0</td>
</tr>
<tr>
<td>Char</td>
<td>~500</td>
<td>0</td>
</tr>
</tbody>
</table>
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 m³ 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

Processes
- Sediment dynamics
- Stream productivity
- Fish recolonization
- Fish impacts
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
Former Mills Reservoir – January 2014

John Gussman
Elwha River – Elwha Dam
Elwha River – Former Elwha Dam
Elwha River – Former Elwha Dam
How has sediment supply changed?

Above Dams
Below Dams

Year 1: ~ 8% of sediment mobilized

Dam removal begins
Elwha Dam removed
Lake Mills gone

Datasource: USGS

Photo: Andy Ritchie, NPS
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, NPS

Data courtesy of Jennifer Bountry, U.S. Bureau of Reclamation and Andy Ritchie, NPS and USGS
Former reservoirs – Lake Mills

1km
Former reservoirs – Lake Mills

Photo courtesy of Andy Ritchie, NPS
Former reservoirs – Lake Mills

Boulder Creek

Photo by John Gussman
Former reservoirs – Lake Mills

Boulder Creek

Slide courtesy Josh Chenoweth, U.S. NPS
Former reservoirs – Lake Mills

Original forest soils

Slides courtesy of Josh Chenoweth, U.S. NPS
Former Reservoir – Lake Aldwell

September 2011
Former Reservoir – Lake Aldwell

September 2013
Former Reservoir – Lake Aldwell

January 2014
Former Reservoir – Lake Aldwell

December 2012

Photo by John McMillan
Former Reservoir – Lake Aldwell
Revegetation Plan

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

Slides courtesy Josh Chenoweth
Much suspended sediment transported to the Strait of Juan De Fuca
Sediment dynamics – Nearshore biota

Rubin, Elder, et al.
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

Flow

Glines Canyon Dam 17 pools and riffle crests 8 fine sediment sites (3 per site) Elwha Dam 19 pools and riffle crests 9 fine sediment sites (3 per site) Strait of Juan De Fuca

Photo by John McMillan
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

- Glines Canyon Dam
- Elwha Dam
- Sediment accumulation in floodplain channels
- Longitudinal profile
- Change in streambed particle size

Slide courtesy of Amy Draut - USGS
September 2011 – Start of dam removal
Cobbles (~110 mm)

Slide courtesy of Amy Draut, USGS
April 2012 – Lower dam removed
Cobbles (~110 mm) & mud (~0.04mm)

Slide courtesy of Amy Draut, USGS
August 2012 – Upper dam removal in progress
Pebble/gravels (~25mm)

Slide courtesy of Amy Draut, USGS
August 2012: Bed elevation building up

Slide courtesy of Amy Draut, USGS

Reach 1, Transect 1
(~1.2 km below Elwha Dam site)

- August 2012 water surface at 575 cfs
- August 2012 bed
- September 2011 bed

Mud/sand
Gravel, pebbles
Cobbles
Gravel, pebbles
Mud/sand
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

March 2013

Flow

100 meters

Photo courtesy of Andy Ritchie, NPS
Physical response of floodplain channels in the lower Elwha

Water surface

Arbitrary elevation (m)

Distance from mouth (m)

% total

May 2011 February 2013

Boulder Cobble Gravel Sand Silt pools
Physical response of floodplain channels in the lower Elwha

- February 2013 surface
- Water surface
- May 2011 surface

Arbitrary elevation (m)

Distance from mouth (m)

- Pools

% total

- Boulder
- Cobble
- Gravel
- Sand
- Silt

May 2011 | February 2013
Physical response of floodplain channels in the lower Elwha

- February 2013 surface
- Water surface
- May 2011 surface

Ave sediment depth 0.20m

- Boulder
- Cobble
- Gravel
- Sand
- Silt

% total

- 100%
- 75%
- 50%
- 25%
- 0%

Distance from mouth (m)

Arbitrary elevation (m)

- 0%
- 25%
- 50%
- 75%
- 100%

May 2011
February 2013
Physical response of main stem middle Elwha

Sediment accumulation in floodplain channels

Gravel bar development, Wood accumulation

Longitudinal profile
Physical response of main stem middle Elwha

March 2012

Photo courtesy of Lighthawk

Fisherman’s bend, “Boulder garden”

100 meters

Flow
Physical response of main stem middle Elwha

February 2013

Photo courtesy of Andy Ritchie, NPS

Fisherman’s bend, “Boulder garden”

100 meters

Flow
Mainstem middle Elwha – Fisherman’s Bend

Photos courtesy of Mike McHenry

October 2012

March 2013
Physical response of main stem middle Elwha

Green – streambed before dam removal (July 2011)
Blue – water level before dam removal (July 2011)
Black – streambed during dam removal (Nov 2012)
Red – water level during dam removal (Nov 2012)

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

February 2013

100 meters

Flow

Photo courtesy of Andy Ritchie, NPS
Physical response of floodplain channels – middle Elwha

- September 2012
- January 2013

Bar chart showing:
- Boulder: 100%
- Cobble: 25%
- Gravel: 50%
- Sand: 75%
- Silt: 100%

Graph showing:
- Distance from mouth (m)
- Arbitrary elevation (m)

Legend:
- Boulder: Turquoise
- Cobble: Light grey
- Gravel: Black
- Sand: Brown
- Silt: Green
Physical response of floodplain channels – middle Elwha

- January 2013
- H2O surface
- September 2012

Ave sediment depth 0.41m
How will stream productivity change?

**Primary Producers**
- Periphyton
- Indirect (nutrients)
- Direct (tissue & eggs)

**Secondary Producers**
- Invertebrates

**Consumers**
- Resident Fish

**Spawners**
- Anadromous

**Water Chemistry**

**Physical Habitat**

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
Benthic Invertebrate Densities – Results from Year 1

- Lower
- Middle
- Tributaries
Drift Invertebrate Densities – Results from Year 1

<table>
<thead>
<tr>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
</tr>
<tr>
<td>Spring</td>
</tr>
<tr>
<td>Summer</td>
</tr>
</tbody>
</table>
Juvenile Salmonid ( ) Diet – % Terrestrial

Before = 2011

Lower

Middle

Tributaries

Winter Spring Summer
How has stream productivity changed with increased sediment in year 1?

High level of fine sediment deposition on river cobbles
Benthic invertebrate densities reduced 95%
Drift invertebrates also reduced – especially in spring
Juvenile relying more on terrestrial prey sources
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

- Cedar River: ~300
- Glacier Bay: ~11,500
- S.F. Skykomish: ~22,000
- Fraser River: ~1,800,000
What habitats and locations will different salmon species colonize?
How many more salmon will there be?

\[ \ln \left( \frac{A^2}{2} \right) \]
= drainage area (km²)

<table>
<thead>
<tr>
<th>Elwha Chinook Estimate</th>
<th>Equilibrium Population Size</th>
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<tbody>
<tr>
<td>Stream type</td>
<td>4,589</td>
</tr>
<tr>
<td>Ocean type</td>
<td>10,099</td>
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How will we measure change?

• Adults
  – SONAR
  – Redd surveys
  – Snorkel surveys
  – Genetics

• Juveniles
  – Snorkel surveys
  – Seining
  – Electrofishing

• Smolts
  – Smolt traps
Elwha Adult Residence

- Bull trout
- Steelhead
- Chinook
- Coho
- Pink
- Chum
- Chinook

Spring: Bull trout
Summer: Steelhead & Coho
Fall: Pink
Winter: Chum & Chinook
Elwha Adult Residence

- **Bull trout**: Spawner surveys, SONAR, Genetic Mark-recapture
- **Steelhead**: Spawner surveys, SONAR
- **Chinook**: Spawner surveys, SONAR, Genetic Mark-recapture
- **Coho**: SONAR
- **Chum**: SONAR
- **Pink**: Spawner surveys, SONAR
- **Chinook**: Spawner surveys, SONAR, Genetic Mark-recapture

**Seasons**
- Spring
- Summer
- Fall
- Winter
Elwha SONAR location
Elwha SONAR Results – Chinook 2012
Elwha SONAR Results – Chinook 2012

Estimated Chinook salmon

- SONAR
- Middle Elwha redd survey
- Weir (L&D)
- Seining, hatchery returns

Total (other methods) vs. SONAR
Adult Recolonization – Results from Year 1

Steelhead

Coho
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

Photos John McMillan
Relocation of adult coho salmon in the middle Elwha
Fall of 2011

<table>
<thead>
<tr>
<th>Release Location</th>
<th>Male Coho</th>
<th>Female Coho</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainstem Elwha</td>
<td>260</td>
<td>223</td>
</tr>
<tr>
<td>Little River</td>
<td>102</td>
<td>70</td>
</tr>
<tr>
<td>Indian Creek</td>
<td>28</td>
<td>43</td>
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</table>

Photo by John McMillan
Coho salmon redds in the middle Elwha
Fall of 2011

<table>
<thead>
<tr>
<th>Location</th>
<th># Redds</th>
</tr>
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<tbody>
<tr>
<td>Little River</td>
<td>58</td>
</tr>
<tr>
<td>Indian Creek</td>
<td>43</td>
</tr>
<tr>
<td>Floodplain channels</td>
<td>3</td>
</tr>
<tr>
<td>Madison Creek</td>
<td>2</td>
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</tbody>
</table>
Relocation of adult steelhead in the middle Elwha Spring of 2012

<table>
<thead>
<tr>
<th>Release Location</th>
<th>Male Stlhd</th>
<th>Female Stlhd</th>
<th>Rainbow trout</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little River</td>
<td>11</td>
<td>39</td>
<td>15</td>
</tr>
</tbody>
</table>

Photo by John McMillan

Map showing Elwha Steelhead Distribution with Little River indicated.
Natural colonization of adult steelhead in the middle Elwha
Spring & summer of 2012

<table>
<thead>
<tr>
<th>Natural colonizers</th>
<th>Male Stlhd</th>
<th>Female Stlhd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little River</td>
<td>6(?)</td>
<td>?</td>
</tr>
<tr>
<td>Indian Creek</td>
<td>13(?)</td>
<td></td>
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</table>
Steelhead redds in the middle Elwha
Spring & summer of 2012

<table>
<thead>
<tr>
<th>Location</th>
<th># Redds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little River</td>
<td>43</td>
</tr>
<tr>
<td>Indian Creek</td>
<td>7</td>
</tr>
</tbody>
</table>

• = location of steelhead redd(s)

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

<table>
<thead>
<tr>
<th>Location</th>
<th># Redds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>14</td>
</tr>
<tr>
<td>Middle Elwha</td>
<td>105</td>
</tr>
<tr>
<td>Middle Elwha Tributaries</td>
<td>98</td>
</tr>
</tbody>
</table>

Data courtesy of Pat Crain, NPS
Number of redds above former Elwha dam 2012 to 2014

- Steelhead
- Chinook salmon
- Coho salmon
Number of actual & estimated redds above former Elwha dam 2012 to 2014

Assumed population growth rate of 1.61 (Pess et al. 2014)
Elwha Juvenile Residence

- Bull trout
- Steelhead
- Chum
- Coho
- Pink
- Chinook

Seasons:
- Spring
- Summer
- Fall
- Winter
Elwha Juvenile Residence

- **Bull trout**: Smolt trap
- **Steelhead**: Smolt trap, end of summer population estimate, snorkeling
- **Chum**: Smolt trap
- **Coho**: Smolt trap, end of summer population estimate, snorkeling
- **Pink**: Smolt trap
- **Chinook**: Smolt trap, seining

Seasons:
- Spring
- Summer
- Fall
- Winter
Little River coho salmon 2012 redd & juvenile snorkel surveys

Coho salmon redds

Juvenile coho salmon

River Kilometer
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

Red = tributary sites
Light blue = floodplain channels
2012 Juvenile salmon composition between the dams

- Brook trout
- Bull trout
- Rainbow/Cutthroat
- Chinook
- Coho

Floodplain:
- Brook trout: 40%
- Bull trout: 60%
- Rainbow/Cutthroat: 20%
- Chinook: 0%
- Coho: 0%

Tributaries:
- Brook trout: 40%
- Bull trout: 60%
- Rainbow/Cutthroat: 20%
- Chinook: 0%
- Coho: 0%

J. McMillan
Middle Elwha River

Ave end of summer salmon population estimate (all locations)

Error bars = 95% C.I.
Elwha River smolt trap locations

Data collection since 2005

Data collection since 2012

Data collection since 2013

Glines Canyon Dam

Elwha Dam

Indian Creek

Little River

Main stem Elwha

Strait of Juan De Fuca

RKM 22

RKM 12

RKM 0
Chinook salmon productivity
Little River v. Indian Creek

Chinook salmon smolts/spawner

Indian Creek

Little River
Coho productivity
Little River v. Indian Creek

Average smolt/spawner
Zimmerman et al. 2012

Average outmigrating fry/spawner
Bradford et al. 2000
Middle Elwha tributaries estimated juvenile coho salmon survival

- Egg to smolt survival
- Egg to fry survival

Indian: 20% Egg to smolt, 10% Egg to fry

Little: 10% Egg to smolt, 20% Egg to fry
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

Photo by John McMillan
2013 Fish recolonization highlights

- First documented lamprey above Elwha dam.
- First documented sockeye salmon in Indian Creek
- First documented summer steelhead in Little River

Photo courtesy of WDFW
2013 Fish recolonization highlights

- First documented lamprey above Elwha dam.

- First documented sockeye salmon in Indian Creek

- First documented summer steelhead in Little River

Photo by John McMillan
Fish recolonization summary

- Adults are making it past old Elwha Dam site
- Coho, steelhead & Chinook salmon redds are throughout the middle Elwha
- Juveniles are dispersing to colonize new areas
- Coho salmon and Chinook salmon ~20% of 2012 summer parr population estimate
- Average summer population estimates decreased in 2013 v. 2012 but within same range.
- Salmon productivity (i.e. smolts/spawner) varies as a function of local environmental conditions.
- New species (lamprey) and life history strategies (sockeye and summer steelhead) are being documented.

Photo by John McMillan
Sediment Impacts to Fish

- Peak turbidity event April 6-8\textsuperscript{th} 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 in the process of prograding into the Strait of Juan De Fuca.

- ~10 to 20% of sediment stored in-river.

- Main stem pools filled/evacuated/filling again with sediment.

- Floodplain channels filling with sediment & becoming more connected to main stem.

- 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 reds are in the middle Elwha and tributaries.

- Juveniles are dispersing to colonize new areas.

- New species and life histories are being documented.

- High turbidity levels can and has resulted in a fish kill in the Lower Elwha.
Where to Find Additional Information


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

www.elwhainfo.org

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

Thanks!

Photo by John McMillan