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Science Partnership Between U.S. Geological Survey and the Lower Elwha Klallam Tribe: Understanding the Elwha River Dam Removal Project

The Elwha River Dam Removal and Ecosystem Restoration Project

After nearly a century of producing power, two large hydroelectric dams on the Elwha River in Washington State were removed during 2011 to 2014 to restore the river ecosystem and recover imperiled salmon populations. Roughly two-thirds of the 21 million cubic meters of sediment—enough to fill nearly 2 million dump trucks—contained behind the dams was released downstream, which restored natural processes and initiated important changes to the river, estuarine, and marine ecosystems. A multidisciplinary team of scientists from the Lower Elwha Klallam Tribe (LEKT), academia, non-governmental organizations, Federal and state agencies, and the U.S. Geological Survey (USGS) collected key data before, during, and after dam removal to understand the outcomes of this historic project on the Elwha River ecosystem.

Glines Canyon (left) and the Elwha (right) dams before (top) and after (bottom) they were removed from the Elwha River. Photographs by John Gussman, private citizen.

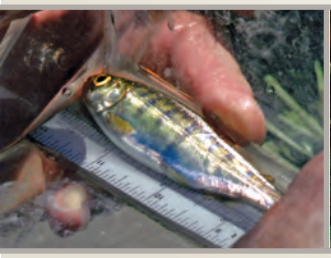
USGS — Lower Elwha Klallam Tribe Science Partnership

Since time immemorial, the Lower Elwha Klallam Tribe has depended on the Elwha River for spiritual, cultural, and economic sustenance. Natural resources staff from the Lower Elwha Klallam Tribe have partnered with scientists from USGS for decades, with a particular emphasis on monitoring the Elwha River and its coastal zone where the Tribal Reservation is located. This ongoing and mutually beneficial science partnership created an information legacy that will help the Lower Elwha Klallam Tribe understand the changes resulting from dam removal and manage their coastal resources into the future.

Key Lessons Learned So Far

- The river adjusted to the sediment release faster than scientists anticipated.
- With restored hydrologic connectivity, the Elwha River now more closely resembles other wild rivers of the Olympic Peninsula.
- Salmon are returning to the main stem and tributaries upstream of the former dams.
- The estuary and coastal beaches are expanding, with communities of plants, aquatic organisms, and bird life using the new habitats.
- Marine environments off the river mouth have fundamentally shifted toward a restored state.

Photographs (left to right): Measuring a juvenile salmon, a clown nudibranch (*Triopha catalinae*), a candy striped shrimp (*Lebbeus grandimana*) with a sand rose anemone (*Urticina columbiana*), kelp (*Pterygophora californica*) in new sediment, and Tribal canoes. Tribal canoes photograph by John Gussman. All other photographs by U.S. Geological Survey.





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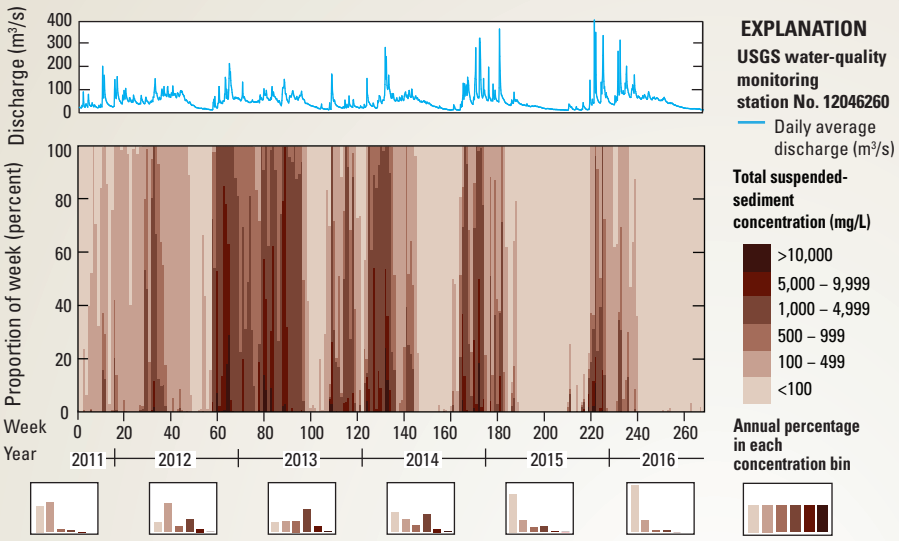


River Sedimentation

Dam removal on the Elwha River released a massive amount of sediment into the river, similar to observations of rivers following the eruption of a moderately sized volcano (Foley and others, 2015). In the first 3 years after dam removal, the river was choked with sediment that filled pools and, at times, created a sand-bedded channel (East and others, 2015) that was much different from the more typical cobble-gravel river bottoms in natural sections of the river upstream. After passage of the large sediment pulse, the shape and character of the riverbed downstream of the dams started to resemble pre-dam conditions. Monitoring of the river upstream and downstream of the dam removal projects (Magirl and others, 2015) indicated high suspended-sediment concentrations during dam removal, with progressively decreased sediment concentration in later years (fig. 1).

Figure 1. River discharge (top) and suspended-sediment concentration at low to high concentration on weekly (middle) and annual (bottom) basis. Sediment concentration values based on turbidity measurements collected every 15 minutes and a series of suspended-sediment concentrations from across a range of streamflow conditions (photographs). Data based on Magirl and others (2015).

Estuary — Physical

The Elwha River efficiently transported more than 90 percent of the eroded sediment from the reservoirs to the coastal zone (Warrick and others, 2015). Accumulation of sediment at the mouth of the river led to rapid and persistent changes to the estuary, as measured by water-quality instruments installed by USGS and Tribal scientists (fig. 2). Before dam removal, the river mouth routinely fluctuated as tidal and river flow conditions mixed fresh and salt water in the estuary. After dam removal, large sediment deposits formed, eliminating the tidal influence and turning most of the "old estuary" into freshwater-dominated habitat (Foley and others, 2015).

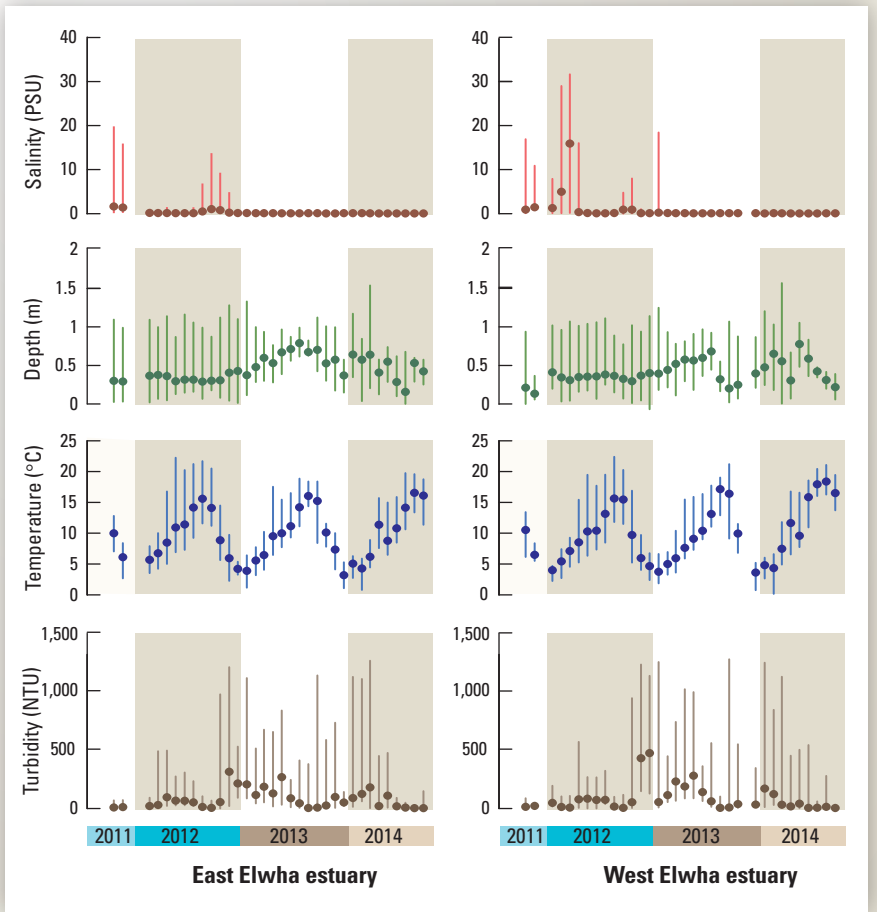


Figure 2. Water-quality samples collected from the east and west sides of the Elwha River estuary during dam removal. An increase in turbidity (bottom) and decrease in salinity (top) began when sediment load increased beginning in 2013. Images (left) and graphic from Foley and others (2015).

Estuary — Biological

New habitat and landforms were created in the estuary, reversing decades of erosion and habitat loss (fig. 3). This shifting habitat mosaic, caused by the changing landforms and a new water regime, has prompted responses in estuarine plant and animal species. Although total plant species richness and relative density was stable, the amount of pioneer vegetation increased in response to the newly forming habitat. Benthic invertebrates declined due to dam removal across seasons, likely due to sediment deposition. The estuarine fish community changed in the former estuary, favoring freshwater adapted species, while still functioning as a nursery for juvenile salmon. As the river mouth delta expanded seaward, new estuarine habitat was created and used by salmon, shorebirds, and their invertebrate prey.

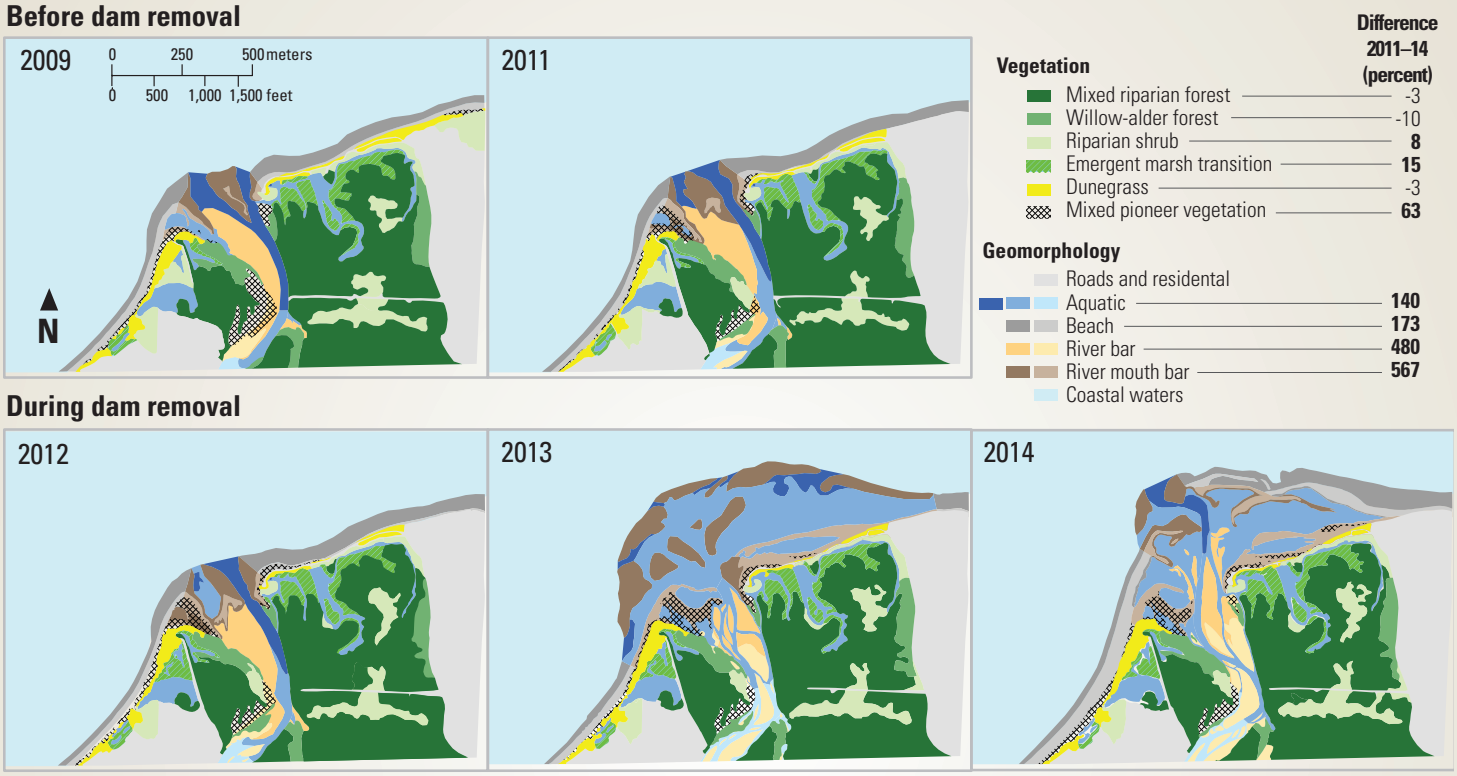


Figure 3. Time series of coastal habitat change of the Elwha River estuary during dam removal. Modified from Foley and others (2017).

Coastal — Physical

Before the dam removal project, the beaches around the Elwha River mouth—including those fronting the Lower Elwha Klallam Tribal Reservation—had been eroding at more than 1 foot per year, a rate that was increasing with time (Warrick and others, 2009). This coastal erosion resulted in the loss of Reservation lands, including coastal wetlands. Dam removal changed this erosional trend and resulted in the creation of broad, new beaches and a new estuary complex near the river mouth (fig. 4; Gelfenbaum and others, 2015). Although the coastal waters remained turbid, or cloudy with sediment, during the dam removal project, this condition has improved considerably in the years following dam removal.

Seafloor mapping.

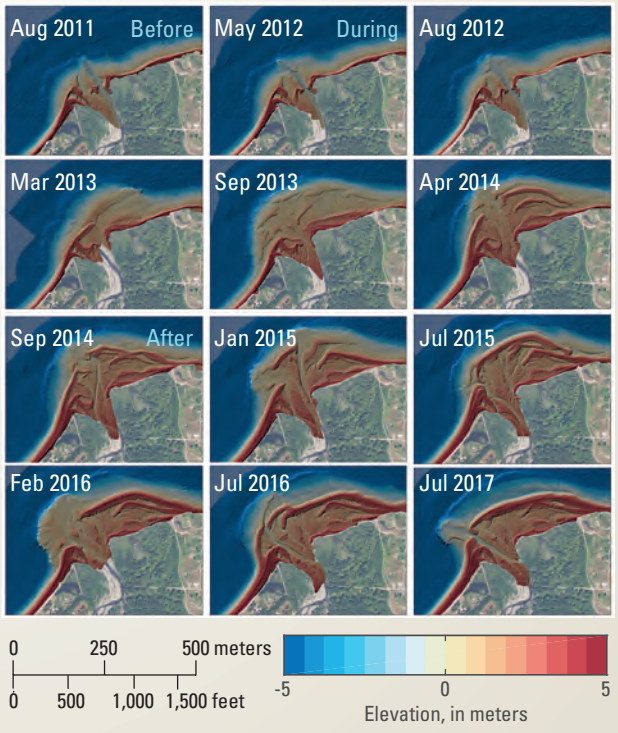


Figure 4. Time series of beach and seafloor mapping of the Elwha River mouth before, during, and after dam removal. For detailed methods, see Gelfenbaum and others (2015). Image courtesy of Andrew Stevens, U.S. Geological Survey.

Coastal — Biological

For 10 years, scuba divers from USGS, LEKT, and other partners monitored the ecosystem responses on the seafloor of the Strait of Juan de Fuca near the Elwha River (Rubin and others, 2017). The response of biological communities to dam removal varied with distance from the river mouth. In most places near the river mouth (sediment source), the increased turbidity decreased light availability to kelp and algae, which led to a significant decline in abundance. For other taxa like clams, tubeworms and some fish, significant changes were seen only when the sediment accumulated on the seafloor, and in some cases the changes attracted species such as the Pacific sand lance (*Ammodytes hexapterus*), which increased in abundance (fig. 5) in newly deposited sand after dam removal. Importantly for the Tribe, the return of abundant Dungeness crab along the new Elwha River delta allowed a productive fishery to resume for the first time in the memory of many Tribal fishers.

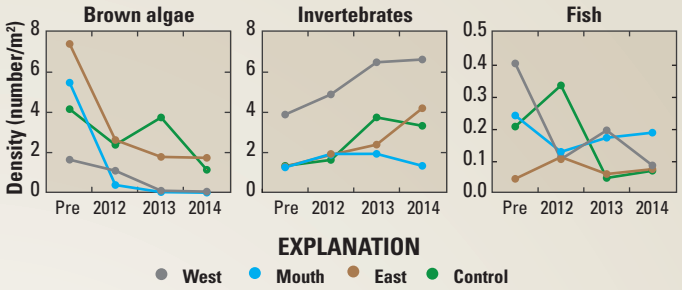
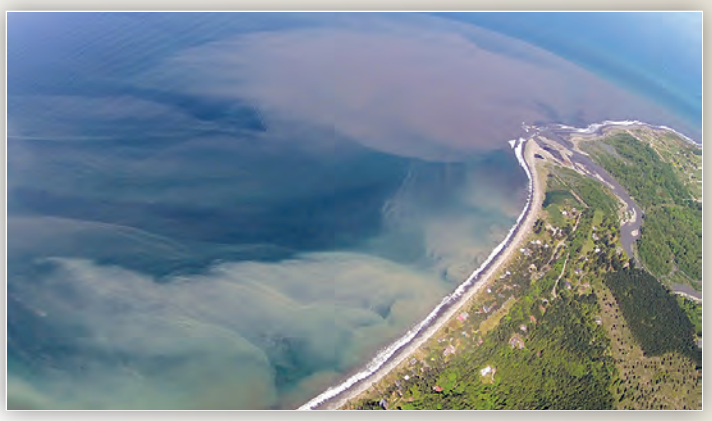


Figure 5. Response of seafloor biological communities to dam removal, Strait of Juan de Fuca near the Elwha River. Data represent average density of brown algae, invertebrates, and fish counted on permanently located seafloor transects over a 10-year period. Control location at Green Point is 21 kilometers east of the Elwha River. Data from Rubin and others (2017).



Photograph by Tom Roorda, private citizen, 2012.

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Partners

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