Proceedings of the 2011 Elwha River Science Symposium

A word cloud of the 35 most commonly used words from the abstracts provided in these proceedings. After filtering common words and prepositions, the algorithm gives greater prominence to words that appear more frequently. www.wordle.net.

September 14-16, 2011
Peninsula College
Port Angeles, Washington

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Preface

Jeffrey J. Duda

U.S. Geological Survey, Western Fisheries Research Center, Seattle, WA

After years of anticipation, volumes of Environmental Impact Statements, multiple mitigation projects, and the multidisciplinary collection of predam removal data, the deconstruction phase of the Elwha River restoration officially began on September 17th, 2011. With their simultaneous decommissioning, the removal of the 64 m tall Glines Canyon Dam and the 33 m tall Elwha Dam represents one of the largest such projects of its kind in North America. It's also an excellent opportunity to study large-scale ecosystem restoration, as the majority of the reconnected habitat that will become available to recolonizing salmon occurs in the protected wilderness areas of Olympic National Park. As part of a week-long series of 'Celebrate Elwha' events, which culminated with a moving ceremony commemorating the official launch of dam removal, I was proud to work with a number of dedicated people, listed below, to organize the two day 2011 Elwha River Science Symposium.

Many of the scientists working on the Elwha project have regularly met, since around 2004, for annual meetings. Loosely organized under the auspices of the Elwha Research and Elwha Nearshore consortia, the annual meetings have been informative for many reasons, including the sharing of study plans, field schedules, and preliminary results. It has been a great way for groups of physical scientists and groups of biologists to learn about the questions of interest to each group and to explore areas of overlap. In some cases, these meetings have spawned new collaborations, synergies, and research directions. In planning for the 2011 Elwha River Science Symposium, we sought to retain this *espirit de corps*, but realized that the start of dam removal heralded an important new phase of the project and called for an event that celebrated this special occasion.

We held the two-day symposium on the beautiful campus of Peninsula College on September 15-16, 2011, with a goal of providing the over 350 participants with many diverse perspectives about the Elwha River and the meaning of the historic dam removal project. The first day was dedicated to sharing the results of science activities across many fields of study to document the effects of the dams, the baseline conditions of the ecosystem, and the expected responses to dam removal. A total of 32 science presentations were organized into three concurrent sessions with topics covering Fish and Wildlife, Physical Science of the River and Nearshore, Vegetation, Nearshore Biology, and the Cultural/Human dimensions of the project. A keynote presentation by Dr. James R. Karr and a project update by Dr. Brian Winter helped set the stage for the rest of the symposium. A poster session with over 30 submissions, as well as a film and photography exhibit, gave participants additional views and perspectives of the Elwha River. The first day ended with a presentation by a team from the outdoor equipment and clothing company Patagonia, featuring a talk by the company's founder and noted conservationist, Mr. Yvon Chouinard.

Our goal for the second day was to foster a conversation about the broader meaning and context of the Elwha River dam removal and ecosystem restoration project. We accomplished this by asking a distinguished list of plenary speakers to address this topic in their lectures, which led into question and answer sessions moderated by Dr. Gordon Grant, an expert in the geomorphic responses of rivers to dam removal. We were fortunate to have noted experts discuss their views on the broader context surrounding dam removal, river and salmon restoration, and species conservation. Dr. Martin Doyle, Dr. Thomas Quinn, Dr. David Montgomery, Dr. Robert Young, and Dr. Thomas Lovejoy (keynote) delivered compelling and insightful lectures that elicited a good deal of conversation and great questions from the audience. We were also treated to a glimpse of the knowledge, insight, and seven decade institutional memory of the Elwha River by conservationist, angler, and long-time Port Angeles resident, Mr. Dick Goin. The hundred or so people who didn't want the event to end signed up for a three hour cruise from Port Angeles Harbor to the mouth of the Elwha River, run by Expeditions Northwest and emceed by Dr. Ian Miller and Dr. Jon Warrick, who provided interpretation and background information about the nearshore ecosystem.

Because we were celebrating an occasion of such significance — leaving the pre-dam removal phase of the project and embarking on dam decommissioning — it is important to have a record of the various activities that occurred during the 2011 Elwha River Science Symposium. Thanks to a grant by the Clallam County Marine Resources Committee and the leadership of Anne Shaffer, we have compiled all of the abstracts and summaries of each of the plenary talks into this proceedings document. All authors were provided the chance to append relevant citations to their submitted abstracts.

Two students, Tara Morrow and Kiley Barbero, deserve special recognition and thanks for their efforts to compile the information herein, as well as for their work to record and summarize the lectures by our distinguished speakers. Each of the summaries provided were based on the remarks of the speaker as presented and then slightly edited as appropriate for readability. In most cases, unless otherwise noted, the summaries were reviewed and edited by the speakers themselves. The intent of the plenary session summaries is to provide the general themes and context of each presentation, but it should be noted that most presentations also contained a great deal of visual information, which is not necessarily captured in the written summary.

Glines Canyon Dam during deconstruction, February 1st, 2012. Photo by the National Park Service

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Featured Speakers

Olympic National Park: Elwha River Ecosystem and Fisheries Restoration.

Brian Winter

National Park Service, Olympic National Park, Port Angeles, WA

Synthesized by Kiley Barbero, Tara Morrow, and Barb Maynes

As we celebrate the beginning of dam removal, it's appropriate that we look back and consider how we got here. It's important to recognize the years of collaborative planning, preparation and hard work that many partners have provided.

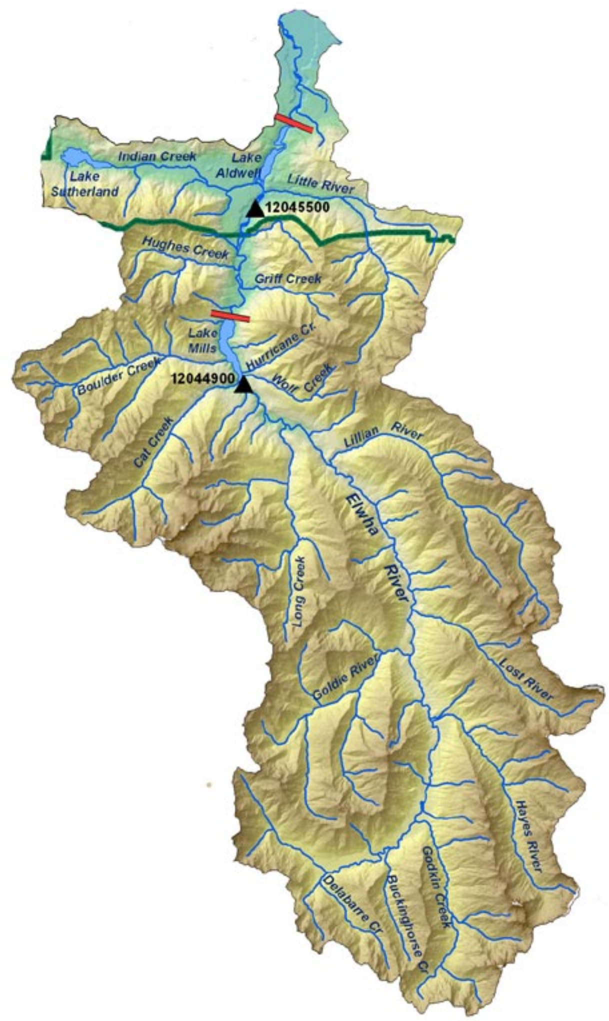
Construction of the Elwha Dam began in 1910, over the objections of the Lower Elwha Klallam Tribe, who with others, understood the impacts the dam would have on the river's anadromous fish runs. Built five miles upstream of the river's mouth, the dam began operating in 1913. Although a Washington State law required fish passage to be included in new dam construction, the builders did not provide a way for fish to pass around the 108-foot high dam and the runs were blocked at river mile five.

In 1927, 210-foot high Glines Canyon Dam was completed eight miles upstream of the Elwha Dam. It too was built without fish passage.

Because the Elwha dam preceded the Federal Power Act, the owners were not required to seek a license. In 1926, prior to establishment of Olympic National Park, a license for the Glines Canyon Dam was issued by the Federal Power Commission. Olympic National Park was dedicated in 1938, and the Glines Canyon Dam and its reservoir were included within its boundaries.

In the late 1960s, the dams' owner began the process of applying for a license to operate Elwha Dam and a renewed license for Glines Canyon Dam. As the future of the two Elwha dams was evaluated and reexamined during the licensing process, many voices were added to the debate. To settle the controversy and resolve the conflicts, Congress passed the Elwha River Ecosystem and Fisheries Restoration Act (P.L. 102-495) in 1992.

The Elwha River Restoration project includes 43 separate project components distributed over about 16 miles of the river's length, from the mouth of the river to the south end of Lake Mills. In accordance with the Elwha Act, most of these projects are designed to mitigate for impacts associated with dam removal, such as providing water quality protection and flood protection.



A map of the Elwha River watershed. Cartography by Theresa Olsen, U.S. Geological Survey

The first major construction project associated with Elwha River Restoration was building the municipal water treatment plant for the City of Port Angeles. Completed in 2010, this facility provides clean drinking water for the City of Port Angeles and will protect the City's water supply during and after dam removal.

The Elwha Water Facilities, completed in 2010, include a water treatment plant to protect the industrial water supply for the City of Port Angeles, the Washington Department of Fish and Wildlife's fish rearing channel and the Lower Elwha Klallam Tribe's fish hatchery. A new surface water diversion and intake structure were also constructed, replacing the old design with a new fish-friendly system, along with improvements to the Crown "Z" Water Road, and area flood protection.

A replacement fish hatchery for the Lower Elwha Klallam Tribe was completed in May 2011, as mitigation for impacts associated with rising groundwater levels near the river mouth. Flood protection projects on both sides of the river mouth were completed by September 2011. Dam removal began in September 2011, with completion scheduled for September 2014.

Ecosystem restoration plans are in place and restoration activities have begun. As of March 2012, over 30,000 native plants have been installed in the Lake Mills delta, with more under cultivation that will be planted in the coming years.

About 600 adult coho salmon were passed above Elwha Dam in October 2011, the first adult coho salmon in that area in over 100 years. Some of these fish spawned, and their progeny will pass downstream in 2013.

Sediment monitoring is also ongoing, both in the field and through the use of webcams and field gauges.

More information about Elwha River Restoration can be found on the Olympic National Park website at www.nps.gov/olym, where over 100 web pages provide information about the project. These include a weekly Elwha blog, links to webcams where the public can watch dam removal and sediment transport and a five-minute web video. The Elwha River Restoration Facebook page has over 3,000 fans and is growing weekly. New exhibits can be seen both within Olympic National Park and outside the park in partner locations. Increased summer interpretive staffing in the Elwha Valley is present to inform and educate visitors.

Elwha River Restoration has been covered widely by regional, national and international media, including repeated articles in the Seattle Times, several in the New York Times and articles in the Los Angeles Times, Washington Post, National Public Radio, Al Jazeera, the London Daily Mail, Smithsonian magazine and Audubon magazine.

The Elwha Restored: Not Only a River.

James R Karr

University of Washington, School of Aquatic and Fisheries Sciences, Seattle, WA

Synthesized by Kiley Barbero and Tara Morrow

Human attitudes about water resources have evolved over time. In his recent book *Elixir: A History of Water and Humankind* (2011), archaeologist Brian Fagan recognizes three stages in the history of human interactions with water. During the remote past (Stage one), water was scarce and unreliable but always valuable. Daily access to water was as essential then as it is now. Because water was so precious, it was considered sacred by most societies. The Bushmen of the Africa's Kalahari capture the essence of their dependence on water in their saying: "We don't govern water, water governs us."

Stage two began perhaps 2000 years ago and became the dominant theme through the industrial revolution. Human control of water made water a commodity. We pumped it, we plumbed it, we harvested it, and we allocated it with little concern for how we use water, how much we use, or the diverse consequences of that use. Damming of the Elwha River early in the 20th century is one obvious manifestation of this control of water. Collapses of populations of the iconic anadromous fishes of the Pacific Northwest are only one of the effects of dam construction. Forests, wildlife populations, coastal ecosystems, and human cultures too have been changed by twentieth century treatment of the waters of the Elwha River.

Stage three emerged in the later half of the twentieth century with recognition that water is a finite resource. It is something to be conserved, something to be treated with respect, even reverence. The ongoing effort to restore the Elwha by removing two century-old dams is clear evidence of the emergence of Stage three thinking.

For tribal members, some political leaders, and other local residents, the dream of dam removal and river restoration began decades ago. That dream took the first step toward reality when enabling legislation for dam removal and restoration of the Elwha River was passed in 1992 (PL 102-495, Elwha River Ecosystem and Fisheries Restoration Act). Nearly twenty years later, an interdisciplinary team with representatives from diverse constituencies is implementing a comprehensive plan to remove the dams and restore the river and associated resources. Their plan is visionary in three major ways.


The former Lake Mills reservoir in transition. Photo by the National Park Service

First, integration today replaces the fragmentation that resulted from dam construction of the early 20th century. Dam construction was largely driven by the rules of a single discipline: civil engineering. Planning for dam removal and river restoration now incorporates the wisdom of many disciplines: ecology, hydrology, geology, engineering, social sciences, and many more. As a university professor for 40 years, I have seen many departments become more open to interdisciplinary training of their students. The merging of disciplines in the Elwha restoration project is a manifestation of that trend.

Second, collaboration replaces fragmentation. A business and development advocate was able to literally create the environment under which the two Elwha River dams were constructed, including circumventing some legal requirements that might have reduced the catastrophic effects on anadromous fish in the Elwha. The sharp contrast in planning for the dam removal and river restoration initiated in late 2011 includes the efforts of institutions and agencies from local to national levels, tribal nations, and diverse citizen groups. By seeking common ground, they produced and are implementing a pioneering restoration program for the region and nation. One disadvantage of bringing all these disciplines together is that all groups do not always agree about everything that is to be done. But they also are willing to accept compromises to attain the higher goal of river restoration. These differences must eventually be resolved through a process of adaptive management discussed in more detail later in this presentation.

Third, ecological restoration (Stage 3) replaces water control plumbing (Stage 2). The Elwha River Restoration plan sees water and associated resources in an integrative context across the entire Elwha River watershed, from small streams and watersheds high in the Olympic Mountains to the coastal environments of the Strait of Juan de Fuca. Although much is said about the iconic salmon of the region, the Elwha plan is about more than salmon and river. The plan is also about forest and near-shore areas; it is about the wildlife of the region and the diverse human communities than live or vacation in the region. It is about the larger living system of the Elwha River watershed and the adjacent coastal environment.

Why does modern society undertake this kind of restoration program? Restoration of the Kissimmee River in Florida was mandated about the same time (1990, PL 101-640) as the enabling legislation for the Elwha. Enabling legislation for the Kissimmee River called for restoration of “the lost natural values of the land,” language quite similar to that used for the Elwha. Considerable time and energy was devoted to the effort in Florida with limited success until the interdisciplinary team settled on the overarching goal of restoring the ecological integrity of the watershed. Elwha River restoration planning has followed a similar trajectory. These two restoration efforts and many more across the nation are driven by a convergence of scientific advances, changing societal values, and increased understanding of the relationships between ecology, economy, and society. These programs are justified by widespread evidence that water management is about much more than plumbing. We cannot continue to misuse water and the broader array of natural resources upon which our society depends.

As a result, modern planning processes are adapting new ways of thinking, new approaches to defining societal goals. The core goal of the Elwha Restoration Program is to restore the regional ecosystem and associated fisheries. The best way to do that is through an integrative transition to "ecosystem-based management" (EBM). EBM emphasizes the need to manage human activities within the constraints and opportunities provided by ecosystems, as opposed to managing the ecosystems themselves. Management decisions should place emphasis on sustaining ecosystems to ensure that they continue to provide the full array of ecological services to human and non-human residents of our regional environment.

A foundational component of successful EBM is flexible, adaptive implementation of a project that will ensure success, a process referred to as adaptive management. Descriptions of adaptive management often descend into technical jargon. Simply stated ,adaptive management can be boiled down to four simple words and associated actions: plan, do, check, and adapt.

For the Elwha River project, the plan is complete and the do—dam removal and associated activity—begins as we speak at this conference. Early efforts to check, to monitor and assess the project, have been initiated in studies to provide baseline information about current conditions in the watershed. Many years of check lie ahead as the dams are removed and monitoring and assessment continue to track the changes that result from those efforts. One of the major lessons of past EBM projects is the reality of surprises. The complexity of projects make it a certainty that not all things will go as expected. Recognition of this fact creates the need for the "adapt" component of adaptive management, the modification of practices and actions in response to information gained in the check, or monitoring, phase.

The most frequent reason for EBM project failure is probably the unwillingness of program participants to adapt their thinking and change their approach when that is indicated by data and observations collected during careful checking of project progress. And the sad thing is, that much of the work of planning, doing, and checking can be negated by an unwillingness to change the thinking, to adaptively manage project actions to ensure that attaining over-arching project goals is still the centerpiece of decision making.

If a plan does not work as expected, project managers must have the will-power, the openness of mind, to say "what was previously thought to be the best thing to do is not the best thing to do." In the history of these kinds of programs, people are reluctant to revise their original conception of what ought to work. A reluctance to accept that cherished concepts and theories must be altered because of the facts at hand is so common that many, even most, adaptive management programs fail.

The Elwha project is very likely to improve the Elwha watershed in many ways, from the tops of the Olympic Mountains to the coastal environment at the mouth of the Elwha. Populations of anadromous and resident fishes will be healthier and supplies of sediment to coastal areas near the mouth of the Elwha will be replenished. The Elwha plan improves the river by removing dams and controlling harvest for a period. It is moving to improve physical habitat and connectivity within the river. But it is also about more than the river.

Even the best adaptive management program cannot work miracles because success also depends on the actions of bureaucracies, organizations, institutions, and special interest groups that drive decisions in the region. Unsound harvest practices inside and outside the watershed could be a major impediment to salmon recovery within the Elwha system. The controversial operation of hatcheries for release of fish into the Elwha can damage or even prevent recovery of healthy populations of wild fish. To be truly successful, the Elwha project must be supported by decision making across the larger Pacific Northwest landscape.

Quoting Harvard University landscape architect D. W. Meinig, "Landscapes mirror and landscapes matter. They tell us much about the values we hold and at the same time affect the quality of the lives that we lead." I look forward to the day when the mist in the Elwha Valley is not from water pouring over the dam but from water flowing freely down the forest lined valley of the Elwha River. The project is about restoration of more than the Elwha River and its salmon; it is about the Elwha landscape, including the well being of the people that occupy that landscape.

Conservation and Patagonia.

Yvon Chouinard

Founder and CEO, Patagonia, Ventura, CA

Synthesized by Kiley Barbero and Tara Morrow

We are on a roll. In addition to these two dams on the Elwha, three big dams on the Penobscot, the largest river in Maine, are slated to come down beginning next year. Their removal provides our last hope to restore Atlantic salmon in the United States. I never thought I'd see these dams come down in my lifetime. Maybe we can even do something about the Hetch Hetchy! These newly free-flowing rivers benefit the people, especially our children — and other wild things — as well as the fish that are key to being a salmon nation.

Some people may wonder how we make the connection making clothes and saving fish. Anyone who makes anything should worry about what they do to the health of the planet. We opened a store in Boston about twenty years ago, in a restored older building. Within three days of stocking the place, my employees started complaining about getting sick, having headaches. I closed the store down and brought in an environmental chemist who said, "Your ventilation system is not working properly. You're recycling the same air."

I asked, "Well, what's making them sick?"

"Formaldehyde poisoning," he said. Formaldehyde is used as a finish on all cotton clothes, to keep them from wrinkling and shrinking. I had no idea what kinds of chemicals went into my clothes.

But employees getting sick turned the lights on for me. I began to wonder about other evils we were doing, that we didn't even know about. So we started an environmental assessment program, and started asking questions. We compared the four leading fibers that go into our clothing to find out which was worst — you would think nylon or polyester. But the worst turned out to be "natural" cotton, industrial grown. Conventional cotton growing represents 15% of all chemical insecticides used in agriculture and 10% of all pesticides, yet only 2.5% of the land. The cancer rate in cotton growing areas is ten times above normal. This was a surprise.

We decided we would never again use industrial-grown cotton and switched to organic. That wasn't the end of it. You know about the formaldehyde. We also had to check out dyes to make sure they weren't toxic, and yes, some of them were. This led us down the path of trying to find out what we were doing. If you want to be a responsible business, you have to follow your supply chain, both processes and resources, all the way to the end. At the end is usually a farmer, a miner or driller, or a fisherman. When you find that evil is being done in their name on behalf of your company, stop doing it.

I challenge fishery people that they probably have no idea where their fish come from. Take Pacific salmon, for example. If you catch a sockeye with a gill net at the mouth of the Columbia River, it could be one of ten sockeye slated to go to Idaho to Red Fish Lake. A

Coho may come from a stream that has a pulp mill at its mouth and be full of dioxin. There is a good chance that the Chinook you catch was bred in a hatchery, with all the accompanying problems for wild fish.

Everything anyone makes affects the natural world. That's why Patagonia is working with Wal-Mart and other large apparel companies to develop a sustainability index for clothing. Ultimately, you will be able to walk into a store, zap the bar code on a jacket with your cell phone and learn the entire life history of that product, and its environmental report card, so you can compare two products and make an intelligent decision, so we can behave like real citizens instead of just consumers.

Obama and other politicians say that the problem with our economy is that people aren't buying enough. We cannot go on like this forever, behaving only as consumers who, by definition, destroy by using up. That's why we need to educate consumers to be citizens first, to buy fewer things but of higher quality. I used to think designers were the most powerful people in the market because they decide what color of car you are going to drive or what your clothes are going to look like, all of that. But the consumer has the last word and the right not to buy any of that stuff. There are more than 400 indexes now in the works to educated consumers. And if the consumer starts making responsible choices, corporations will have to change. If corporations change, so will the government. Every dollar you spend is a vote, a much more important vote than the one you put in a ballot box.

There is only one form of leadership and that is by example. As a lifelong entrepreneur, I smelled an opportunity to make a profit, do some good, and show the industry how I thought it should be done. So this spring, Patagonia, with a Canadian partner, built a state-of-the art fish processing plant along the banks of the Skeena River in British Columbia. It is sixty miles from the ocean. Why there? We want to use mostly river-caught fish, caught upstream from any tributaries that have endangered runs.

These fish are going to be caught by the Gitxsan, the Witsuwit'en, the Carriers, and the Tsimshian First Nation people using fish wheels, fish traps, dip nets and beach seines. It is a very selective fishery; non-targeted fish like steelhead are released alive. Wild steelhead fishing by sports fishermen in the Skeena River system contributes $110,000,000 a year into the local economy, way more than the entire commercial fishery. Steelhead sports fishing is sustainable because it is all catch and release. Because the pink and sockeyes are caught alive, they are immediately killed and bled. Not only can the eggs be used, but the salmon itself is a superior product.

A fish that is bled can be kept in a fridge for twenty days. One that is not bled and cleaned right away will smell after six to eight days. First Nations people are paid more for their river caught pink salmon because it is a superior product and the eggs can be sold from $3 to $16 per pound. Moreover, the plant employs local people. We have no intention of ever buying genetically engineered "frankenfish", or farmed salmon. If Wal-Mart and Target will not sell farmed salmon, there must be a good reason. We will not be dealing in any hatchery-bred Chinook or steelhead. We will push to list hatchery-bred fish as a farmed fish, to add the "not recommended" listing on your seafood card. We will be buying fish caught at sea where there are no mixed stocks, like the Bristol Bay sockeye fishery, or caught by the tangle-tooth method, which uses a very small, light monofilament net. This catches fish

The official start of dam removal in the Elwha River, September 17th, 2011.
Photo by Jeffrey Duda, U.S. Geological Survey

by their teeth and keeps them alive. Every few hours you can pull up the net to harvest the catch, and release nontargeted fish. It is a very selective way to fish, far better than the gill nets.

Will we be successful in our river wild salmon runs? Does the consumer care where the salmon comes from? You go to many high-end restaurants these days and the menu will list the farm where the chicken was born and the name of the farmer who grew the lettuce. Of course the consumer cares. These days, given enough of that information, they prefer to do the right thing. I can tell you, I know we are doing the right thing when I see a widow mother with two children that have the support of $350 a month, helping to pull in a beach seine on the Babine River, singing her traditional Carrier songs with her family. Thank you very much for having me speak here.

The River I Know.

Dick Goin

Port Angeles, WA

Synthesized by Kiley Barbero and Tara Morrow

The Elwha River was a river like no other, one I came to know 75 years ago in 1936 as a lad of six. It was a beautiful river, a river of canyons and huge salmon. The depression started in 1929 and never ended until the war started in 1942. Until then very few people had jobs. At lot of people were like my family, lived on the land. We subsisted largely off salmon, and salmon were easy to come by. We didn't really know anything about salmon … they didn't have salmon in Iowa! We learned fishing techniques that were helpful. We went to tribal school and a lot of tribal folks went there.

We were soon able to go down into the valley to Bosco Creek, which was three times as big as now, and water came right out of the ground and it had a lot of fish. As tribal families moved into the area, we came to know them and learn ways of fishing and hunting. During that time the river had a big estuary. We would paddle to the estuary to hunt ducks when we were older. Tribal people fished halibut and there were many lingcod in the kelp beds. When the tide came in at the right time of year we would watch the bottom turn grey with salmon. We gaffed them with a flying gaff. But non-tribals could only fish in certain sites, where we would find pinks and some silvers along with dogs and humpies, but tribals had a place where they fished Chinook. During the snow melt the water would get turbid and in the riffles the tribe would gaff salmon. They would use fifteen foot long poles and they would sweep for the fish. Some were giant fish needing two men on the pole. It could be very dangerous with the snow melt, the river very high, swift and cold, and with no beach.

We fished the Elwha later on and caught kings up to seventy pounds with home-made spinners, but a lot of really big ones were lost. One guy would jump in and partially swim after the fish. There was little beach so they would climb down on the bank known as the Clay Bank. There were very few non-tribal fisherman, but we had been fishing there a long time. The fishing holes were named by fisherman — Dam Hole, Big Bend Hole, Three Major Canyon Holes, Junction Hole, Line Hole and Doty's Riffle. But we sometimes didn't give information about where we got fish … some of us lied not to give it away. There were a lot of places where we fished. One place I fished so much it came to be called Dick's Riffle. On the beach there were lots of clams, mostly butter, but some little necks and horse clams too. We didn't know anything about clams either, because there were no clams in Iowa! And, we didn't use them.

Pinks came to the dam, but chums did not. Pinks went up only to the edge of the dam but stopped in the big hole, but Chinook would come up to the dam and jump and bang themselves against the wall. Roy, a friend and co-worker we called Stumpy because he was short, with some friends attempted the first restoration of the Elwha. They, three or four guys, took wet gunny sacks and they carried them up the canyon and tossed them in the lake. The weight of the salmon made it hard. And the flopping didn't help!

There were wonderful trout in the lower Elwha too, wonderful rainbow trout. There were four-stripers with some attributes of a cutthroat. We went to the fisheries department and they said it was a rainbow with heavy cutthroat characteristics. I think maybe they also didn't know. I believe we have a natural hybrid in the Elwha. There were arguments in tackle and sporting goods shops. Just a kid, I was able to identify [the fish that went to the ocean] because [I] learned about the sea lice mark above the anal fin and if it was there, it had been to sea, if not, it had not been. And also the ones who had been to sea where bright with color. At the tackle shop there was a guy named Chick and he knew everything. Long weighty discussions took place at those shops.

No one could afford a tailor made rod, or split bamboo. We looked in a bundle of raw cane for the pole we wanted and each would cost about 25 cents. You looked around to find what you wanted, lighter ones for steelhead and heavier for king. We bought guides with porcelain liners and taped them on with black friction tape. We made spinners out of brass sheeting.

That was then, so many things to talk about. The manipulation of the dam was awful and was very destructive to the fishery. Fish were being stranded, mostly fingerlings and fry. They over generated during the week and shut it down on the weekend because the mill was not running. This killed so many fish, and they did not care. It used to sparkle like decorations on a Christmas tree … sometimes it was so abrupt they killed adults. Just above the bridge was a spawning riffle, and there they were, [stranded fish] just flopping. It was early in October, and still in the Chinook spawning season. People were sacking them up, but some got wasted. Some people cared and some did not. It was an atrocity! I once measured a 30 inch drop [of the water level] in about four minutes. Millions of fish were killed with the operation of the dam.

Male and female Elwha River Chinook salmon. Photo by John McMillan, NOAA

We saw mergansers, otters, gulls. They would peck the eyes out as [the fish] came by and it does not matter for spawning. At a place under the bridge where we fished, the bears were everywhere and were incredibly nosy. They were highly desired by people. They were a source of protein and their tallow was used for pastry. Bears came mainly after dark. They left the blackberries and salal berries when the salmon came, as did the herons and eagles. There were not too many eagles back then. They were overhunted. Once on Clay Bank there was a log jam with a cougar that was after carcasses. I remember thinking that wasn't the most desired catch for such a predator. There were so many steelhead, oh my, the steelheads, sockeyes and the natural hybrids. We could catch rainbow in April, those hybrids were not at sea long enough to get sea lice. We had all these surf smelt — lots— an enormous school of smelt got caught and every cormorant, merganser, and gull was there. There was eulachon, smelt that ran up river to spawn, and lampreys, oh, we had lampreys. The river was open year round. It was fairly common to see sturgeon three feet long. A very large one was caught on rocks at the power house.

No longer do we see the hundreds of salmon, no fish jumping, not bears, no huge redds, kings, no hatches of aquatic insects … it is quiet river now.

The Elwha Restoration Project: An Example of What Large-Scale Ecologial Restoration Should Be.

Robert Young

Program for the Study of Developed Shorelines, Department of Coastal Geology, Western Carolina University, Cullowhee, NC

Synthesized by Kiley Barbero and Tara Morrow

Listening to talks today, I was reminded how important long-term knowledge is to understanding ecological restoration and the natural world.

In many cases, scientists do a very poor job of talking to the general public about science. We think the facts are so readily obvious that everyone should just understand. Yet, in reality these systems have a level of complexity that we are just not very good at communicating. In order to help people understand the science, we need real stories and real examples of the change we anticipate. This is true if we are talking about global climate change or the benefits of dam removal. If we cannot talk to Americans in the way that Dick just spoke to us, about what is changing in the environment, we are never going to reach that larger audience.

Native Americans have a strong tradition of communicating the importance and relevance of environmental change and "scientific" lessons through stories and oral tradition. Sadly, Native Americans are terribly underrepresented in the sciences including my field, the geo-sciences. There are fewer Native American geoscientists and environmental scientists than there are African American, Asian American, and Hispanic American. Yet, Native Americans are heavily involved in environmental restoration as a means to cultural restoration. To help reverse this trend, we have a grant from the National Science Foundation (NSF) to initiate a geosciences education program with the young people of the Lower Elwha Klallam Tribe. Last year, partly because of this project and the dam removal, the Lower Elwha Klallam tribe had their highest high school graduation rate ever. It is our hope that the dam removal will not only restore the environment within the Elwha River Valley, but that it will also provide hope for the youth of the Lower Elwha Klallam Tribe. We hope that some of them may want to become environmental professionals so that they may one day lead their people in the science of restoration, just as Rob Elofson does so well today.

Many projects across the country are often referred to as "restoration" projects. In my opinion, the word "restoration" is often thrown around too easily. But, The Elwha Restoration Project meets the definition of ecological restoration—from an academic and scientific viewpoint—perfectly. Good restoration should return an ecosystem to its historical trajectory. It should reassemble a characteristic assemblage of species found in the native ecosystem by reestablishing physical environments. It should be sustainable over the long term and integrated into a larger matrix. There should be physical and biological connections with surrounding environments. It should also be as resilient as a natural ecosystem would be to disturbance. Interactions between native people and the environment play an important role in painting a landscape that has been maintained by cultural use over millennia.

Many shortcomings exist in projects around the country, either underway or proposed, that are dubbed "restorations." The dredging of sand to rebuild eroding beaches in front of oceanfront property is referred to as "beach restoration" by the Army Corps of Engineers and most coastal communities. Annually, this costs up to $300 million in federal and state tax dollars. In other words, we spend almost the full cost of Elwha River Restoration every year on "beach restoration." In this process, one pumps up beach in front of what is usually a very developed shoreline, then smoothed by land-moving equipment. It can be incredibly economically effective, but it is not environmental restoration. What they are doing is not sustainable. It is easily removed in storms. The main goal is not to restore habitat, but to offer storm protection for building and recreational habitat for people.

One cannot compare "beach restoration" to the Elwha River restoration.

The Army Corps of Engineers is preparing to "restore" the undeveloped Mississippi Gulf Islands, a part of Gulf Islands National Seashore. They would like to reconfigure the islands to a pre-Hurricane Camille condition. They intend to fill a naturally formed inlet that breached one of the barrier islands during Hurricane Camille, and then widened during Katrina. Remember, ecological restoration returns an environment to its historical trajectory. Well, these islands are in their natural trajectory! Barrier islands often erode and change form during storms. This is a natural response.

They argue that this "restoration" will provide increased storm protection for the Mississippi coast. The amount of storm protection to be gained by this will be minimal and it certainly is not environmental restoration.

The National Park Service commissioned us to document all restoration and engineering activities in coastal parks. We were stunned to find how much manipulation had gone on within our country's most protected environments. It was difficult to find areas, even on national seashores, that had not been impacted by some kind of coastal engineering or well-intended restoration what was not really restoration.

Right now, the monster in the closet is the many proposals to "restore" southern Louisiana. It is a beautiful place and important resource for everyone in the United States. They have the highest rate of land loss in the US. The disappearance of Louisiana's wetlands and coast is truly a tragedy of national importance, and there are too many culprits to discuss tonight. Over the last several decades, there have been multiple proposals for large-scale "restoration" of southern Louisiana to preserve the ecosystems and in an effort to provide some storm protection.

The Elwha River coast showing the U.S. Geological Survey's R/V Karluk on a data collection cruise. Photo by Miles Logsdon, University of Washington.

Louisiana has the highest rate (9mm/year) of sea level rise in the US. Yet, we are going to spend billions of dollars on multiple efforts to “restore” at least portions of coastal Louisiana. Sea level rise is the enemy to that “restoration.” Most projections call for a meter of sea level rise over the next hundred years. What sense does it make to spend huge amounts of money to restore an ecosystem that will be gone in a hundred years? How many Elwha projects could you have for those billions? How many smaller-scale, high quality ecosystem projects could we have for that kind of price tag? In light of what is going on in Louisiana, the cost of the Elwha project and its potential sustainability, certainly stack up very nicely.

The political establishment in the state of Louisiana has not had the will to say, “South of New Orleans is going to look very different fifty years from now, whether we do anything or not, so it is time to start planning for how that could happen.” Yet, the irony is that the best chance for restoring Louisiana is to let the Mississippi River reoccupy as much of that floodplain as it possibly could, but that is the one plan that is viewed as impractical because communities would have to move and some livelihoods would be threatened. It would mean the map of southern Louisiana would have to change. Folks are trying to protect the map, not the ecosystem. They want to use ecological restoration for storm protection. There are, of course, good proposals for restoring portions of the Louisiana wetlands, but they are often clouded by the large-scale desire to keep people in place.

The Everglades restoration is still a very important and well-intentioned large-scale ecological restoration trying to replace the natural slow flow of water to the south and to the Everglades. This project, which out of all that I have mentioned, has the best chance for some successes. In 2008, the National Academy of Sciences recommended a review of the entire long-term plan for Everglades Restoration because of sea-level rise. That portion of south Florida is one of the top three areas in the United States most vulnerable to sea-level rise. Even the $13 billion Everglades Restoration Project, no matter how well intended and how well it will do through the next few decades is not sustainable over the long run. Many scientists working on the project have switched to maintaining high quality ecosystems for as long as possible in response to the rising sea level.

The Elwha project, on the other hand, has a good chance at becoming self-sustaining; for returning the river to its historical trajectory and restoring that native ecosystem and the physical environment. This is a project that eventually will not need immediate hands-on work. If we initiate restoration in southern Louisiana, we are going to have to maintain every single barrier island, levee, and river diversion forever. That is engineering not restoration.

Taking these dams down will reconnect the river to the ecological matrix in the watershed and beyond. This project will be resilient, unlike beach nourishment projects that can be destroyed in a storm and are gone. On top of all that, it has that cultural connection. It is not just connecting the river to the watershed, it is connecting people to the river. I love to picture the first fish coming through the canyon to where the river valley opens up at Goblins Gate.

This is a long-term restoration project that has fabulous prospects for success. The large number of scientists here, the breadth and depth of scientific interest in this project is amazing. The price of this project is nothing compared to typical large-scale restoration projects.

The Elwha River Restoration should become one of the signature ecological restoration projects in the USA, and could be the poster child for the definition of what true ecological restoration should be. This project is a bargain for what we are getting out of it and for the likelihood of long-term success of that restoration.

Come to southern Louisiana a hundred years from now. You will see an engineered coast. Come back to this place a hundred years from now and you are going to see something wonderful.

Elwha and the Emerald Planet.

Thomas E. Lovejoy

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Often we talk about our planet as a blue planet, but it is also a green planet. The ability of green plants to trap energy from the sun has a great deal to do with how the entire planet works.

The Elwha is a metaphor for how we should manage the emerald planet. The eastern half of our country is littered with thousands and thousands of dams from the 19th century; they were built for industrial purposes with most having no entity responsible for their maintenance or safety. That is basically, in one sense, a recipe for disaster, and in another, a recipe for repeating what is happening right here at Elwha today. Globally today there are so many dams and so much water behind them, the rotation of the earth has actually slowed by a tiny fraction of a second.

Dams continue to be built. People still tend to think about them just in the narrow terms of their direct impact. In most cases, the indirect impact will be much greater because of the population they will attract, and the associated development. Dams and the future of energy for humanity is a big complex topic.

So where does Elwha fit in with what is happening today? Looking back, at the time of construction there were some really big issues that nobody had any idea about, like acidification of the oceans or the marine debris problem. One can only conclude that there are a lot of surprises ahead. Rather than give you an exhausting and discouraging list of all the bad trends going on in the world, one of the real issues is being able to distinguish between linear change and exponential change. At the outset, it is really hard to separate the two. And in terms of the climate change, I believe we are just at the point where those are beginning to diverge. In looking at what climate change means for the biology of this living planet, this talk will also consider what the biology of this planet may mean for climate change and the importance of ecological restoration.

In 1896, the Swedish scientist Arrhenius asked a really important question, 'why is the earth a habitable temperature for humans and other forms of life? Why isn't it too cold?' The answer in that really important paper was the greenhouse effect caused by greenhouse gasses. Miraculously, with pencil and paper he calculated what doubling preindustrial levels would mean to the global temperature: the result was very close to what modern day super computer models project.

What Arrhenius did not know is that for the last 10,000 years, the climate of the planet has been unusually stable. That means a significant portion of human history including the origins of culture and of human settlements all occurred during this period, such that the entire human enterprise is based on the assumption of a stable climate. For that same ten thousand years, ecosystems have been adapting to a stable climate. That, of course, is now changing. We have reached close to 400 ppm CO_2 in the atmosphere as compared to 280 ppm at pre-industrial levels. The earth's climate system is responding and on average, the planet is about 0.8 degrees Celsius warmer than in preindustrial times.

There are a whole series of physical changes particularly around the solid and liquid states of water. There is a dramatic reduction in sea ice on the Arctic Ocean. Continental glaciers are retreating in most places and in the tropics glaciers atop high peaks are retreating at such a rate that they might all be gone in 15 years. That has immediate implications for the ecosystems down slope from those glaciers.

There are a lot of biological changes, changes in phenology, the timing of the life cycles, the nesting times of birds, the migrating times of birds. There are similar changes in blooming times of flowering plants. Already some species are changing where they occur as they track their required conditions. In the western United States, Joshua trees are already marching out of Joshua Tree National Park and the Edith's Checkerspot butterfly is moving northward and upward in altitude.

Science is also beginning to record decoupling events that occur when two species have tightly linked timing in their interactions, but with one using a temperature cue and the other using daylight. The consequence is those two tightly coupled species begin to draw apart. For example black guillemots nesting on the northern shores of Alaska fly to the edge of Arctic ice to feed on Artic cod. The distance they have to fly gets farther and farther year after year. There are already are a couple of those colonies that have failed. What has been observed so far represents relatively minor ripples in the natural history of our planet. The more disturbing things are what could lie ahead.

Floodplain forest of the Elwha River valley. Photo by Pat Shafroth, U.S. Geological Survey

Already at 0.8 degrees we are seeing forms of abrupt change, namely ecosystem collapse. This was first noticed in 1983 with tropical coral reefs: with only a slight increase in temperature and not for any particularly long period of time, the fundamental partnership between the coral animal and the alga breaks down. The coral animal ejects the alga and the wonderful, diverse, productive and Technicolor world of the tropical coral reef essentially goes black and white in what are termed “bleaching events”. The diversity and productivity and the benefits to adjacent communities crash.

In western North America, a similar tipping point is occurring in coniferous forests in relation to native bark beetles with up to 70% tree mortality in most cases. This is widespread from Southern Alaska through Colorado. Such abrupt change is looming in the southern and eastern part of the Amazon rainforest. About 5-6 years ago, the Hadley Center in the UK, which runs one of the five major global climate models, projected that at a 2.5 degrees increase in global temperature, there would be insufficient moisture for the southern and eastern Amazon to maintain tropical rainforest. It would convert to a form of savannah vegetation in a transition termed Amazon dieback. A later run of the model moved the temperature threshold to 2.0 degrees increase. About a year ago, a World Bank study modeled the effects on the vegetation of climate change, fire and deforestation together for the first time and indicated there could be a tipping point to Amazon die-back at about 20% deforestation. The overall point is that two degrees increase in global temperature – which is the limit involved in current negotiations – is too much for the planet’s ecosystems.

I worry that policy makers in desperation will grasp at planetary geo-engineering to engineer the planet’s climate system. Most such schemes are inappropriate because they treat the symptoms (temperature) and not the cause — CO_2 concentrations in the atmosphere. They are quite dangerous because by definition their down sides will be planetary in scale.

So, how do we get down to a lower CO_2 level than we currently have in the atmosphere — down to 350 ppm (which equates to 1.5 degrees increase) — and how might we be able to get there? A major flaw in most policy discussions about climate change is they treat the planet just as a physical system when it actually operates as a biophysical system. Although it is rarely stated this way, roughly half of the excess CO_2 in the atmosphere at the moment comes from three centuries of ecosystem destruction and degradation. If we set our minds to it as a global society, a substantial amount of that former ecosystem carbon could be pulled back from the atmosphere through ecosystem restoration at a planetary scale. That is why Elwha is such a great metaphor as we think about this great global environmental challenge.

Looking at the numbers, there is probably about 50 ppm of CO_2 that could come back out of the atmosphere through the process of ecosystem restoration over a 50-year period. That would be a half billion tons of carbon sequestered annually through reforestation and the way we manage our forests, and a half billion tons a year through restoration of grasslands and grazing lands (which brings better grazing). A third half billion tons a year could be sequestered by modifying our agro-ecosystems so they restore carbon to the soil rather than practicing agriculture in ways that release carbon to the atmosphere.

There is a whole blue carbon piece to this too, although the numbers are a little less obvious. But the point is that we could, if we got it together as a global society, we could begin to actually manage the planet as the biophysical system that it is.

Twice in the history of life on earth there have been exceedingly high levels of CO_2 brought down to pre-industrial levels by biological processes. The first time was with the emergence of the plants on land and the flourishing of that vegetation. It was also accompanied by the creation of soil and development of soil carbon that involves a lot more biodiversity than green plants. Actually, the lowering of atmospheric carbon dioxide was the consequence of a biodiversity symphony although photosynthesis was obviously central to it. The second time was with the arrival of modern flowering plants essentially doing the whole process but more efficiently.

So it is not such a wild idea that we could actually manage the biology of our planet to bring atmospheric CO_2 down but at a faster rate than in those two previous instances because of active human intervention. Since we are responsible for roughly half of the excess CO_2 in the atmosphere from ecosystem destruction and degradation, it is perfectly possible to do the reverse and manage/operate that system to restore some stability to the biosphere.

There is now a human population of seven billion, and there are likely to be at least a couple billion more. That means society has to worry about feeding them. Scientists are now trying to think through how to feed that kind of number without destroying/converting any more ecosystems into agro-ecosystems. Improving agricultural productivity without downsides (such as further distortion of the nitrogen cycle) is clearly part of the challenge. Using the biology of the planet to address the problem of climate change would simultaneously fortify the ecological systems of the planet to deal with the other stresses taking place including climate change. Basically this is a proposition to re-green the emerald planet and use the living planet to make the planet more habitable.

We should essentially use the inspiration of Elwha as the springboard to reach for planetary scale restoration. The planet is going to be here long after we are gone, but in the mean time why treat it in such a way that we are just going to have to turn it over to the sulfur bacteria? After all, nature bats last, so let's join her team.

A National Park Service snorkeler counts fish during a survey of the Elwha River. Photo by John Gussman, Doubleclick Productions

America's Rivers and the American Experiment.

Martin Doyle

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Synthesized by Kiley Barbero and Tara Morrow

September 17, 2011 will mark more than the new beginning for the Elwha River. September 17th, 1787 — 244 years ago — was the closing day of the Constitutional Convention. Two events separated by two hundred years. Two centuries that have a lot more in common that we might think. Let's look at some of the underlying original themes and notions and then trace our way back to the overlying layers of the present.

First, the American government was, by intent and by design, an experiment. And it works better this way. Second, many of the problems America's rivers now face are due to a period of time when the notion of experiment was set aside due to scientific and political hubris. Third, the removal of the Elwha dams marks the return and embodiment of the American experiment.

America's government was formed at the closing days of the Enlightenment. Thomas Jefferson, Joseph Priestly and Benjamin Franklin were as much scientific philosophers as they were political thinkers and tinkerers. Our founding fathers saw science as progress. It is critical to note that the characteristic, or the novelty of science, during the Enlightenment was the experiment. Science was synonymous with the experiment. Contrast that idea with that of science in the early 20th century, the progressive era, when we saw science as a tool of optimization and efficiency.

The Constitution and the authors of the Constitution were enchanted by the notion of the experiment. The Federalist papers, the scaffolding of the Constitution itself, mentions democracy only ten times, yet it mentions the word experiment 45 times. The notion of experiment was prominent in the thinking of many founders. George Washington stated in his farewell address to the nation, "even if the nation itself should fail, it is well worth the experiment." Both Andrew Jackson and Abraham Lincoln mentioned the nation as an experiment. It's provocative to think this notion of experiment seems to have been largely lost from the modern view of governments.

What exactly is it that makes government an experiment? First: trial and error. In science, we try something, we look at the results and then we honestly go back and try something else to see what works. Empiricism and honesty, looking at the results, these are the hallmarks of science and the experiment. Second, we don't assume we are right. We operate with multiple hypotheses, we engage with ideas. Competition of ideas is what makes science vibrant. That new data, new observations, can cause paradigm changes in the way we view our society and ourselves. We are not right because of our ideas nor are we right because our ideas are noble. We are right because data support our ideas at the end.

In one of the most critical of Federalist papers, Federalist No. 38, James Madison advocates taking a purely experimental approach to government, to conduct an actual trial, let the government run, note its defects and then adapt. Abandoning the Articles of Confederation is the first notable example of the willingness of the founders to admit mistakes, to change things and go back to try again. The provision for constitutional amendment shows that the founders did not expect to have built a perfect government from the start; rather the form of government was designed to be malleable, adaptable and able to change. Government was set up to promote competing hypotheses. Separation of power is formally requiring redundancy of decision-making and competition for decision-making between competing branches. In this simple formulation the American system of government was intended to be, by design, inefficient.

By looking at the American experiment and at American river governance, redundancy is clearly abundant. The National Research Council in 1996 identified 19 different federal agencies for watershed related tasks. Competition is also abundant. Two notable examples

The Glines Canyon dam power house. Photo by John McMillan, NOAA

are the use of one agency actually regulating another agency as happened with the Endangered Species Act, with the U.S. Fish and Wildlife Service and other agencies. While the Corps of Engineers is responsible for issuing permits under section 404 of the Clean Water Act, the Environmental Protection Agency is actually given veto authority over the Army Corps of Engineer decisions. Whether or not they choose to exert that authority is another question. Too often we see redundancy or competition between agencies as a sign of bad policy or bad legislating; in reality, competition is a very powerful tool. Checks and balances are as valuable in river management as they are in balancing the branches of our government; legislative, executive and judicial.

Finally, river management has also changed. The number of roles and the changes in mandates of river agencies at the state and local levels has increased dramatically over the past century. As water historian Peter Rogers has said, "water policies simply reflect the priorities of society at the time." We've had very significant pendulum swings in the past few centuries.

In the colonial era of the 1800s, there was a large federal restraint on spending any money on rivers. Federal expenditure was a minor fraction of total spending on rivers. Rivers lost their prominence for navigation by the later part of the 19th century as railroads carried people and their products ever deeper into the interior west. The demand for government work on rivers shifted from navigation towards irrigation and hydropower and flood control, dispersed between a limited federal government and more active states.

In 1908, Teddy Roosevelt, a harbinger of Progressive Era politics, saw rivers as providing the core of the future of the 20th century and he created the inland waterways tradition. He argued that rivers, if managed more efficiently would be the reason for natural resource conservation, cheap transportation and would provide renewable, clean power for a growing economy. Rivers with a strong federal backing would provide competition for the railroad monopoly as well.

If Teddy Roosevelt was the Progressive Era's riverine prophet, FDR was its messiah. The jewel of FDR's progressive era crown, the Tennessee Valley Authority, showed what could be done with rivers if one entity was given enough authority. Dammed rivers were essential to flood control and to drag the truly impoverished Appalachian region out of the Great Depression. The TVA took the region from 10% to 80% electrified in the blink of an eye. After World War II our population was being exceeded by the baby boomer generation who needed infrastructure. Engineers and planners, still grasping at the concept of efficiency, took on the task with religious zeal.

The TVA was synonymous with hydropower multipurpose management and agency cooperation. Integrated, multi-purpose river management navigation, flood control and conservation were its justifications for existence but now this task seems quaint in comparison to providing electricity rates far below the national average. The competition of ideas and the possibility of actual debates had been replaced by latitudes of multi-purpose management. Critical thinking and hard decisions were replaced by simply building a larger budget.

Within two decades of completing its final batch of dams, the TVA produced more power from coal than it did from rivers. Moreover, this multi-purpose federal agency was a vicious opponent to the Endangered Species Act. It remains important to acknowledge the growing hazard of coal hash piles strewn along its creeks and rivers.

Dams have played and will continue to play an active, central role in our society and in our economy. Now faced with over 80,000 dams, the hydroscape of geriatric infrastructure, we are faced with what to do with many of these end-of-life decisions. Do we continue them on life support, justifying their existence with decades-old rationale potentially flawed by benefit-cost-analysis? Or do we look for new information, new priorities and make changes?

We have tried turning the America Nation into the Dam Nation and the benefits have not been as they were promised. Removing the Elwha dams is the opposite. It is the antithesis of the mid 20th century. Along with all dam removals, it represents the epitome, the culmination of the founding fathers. It is the admission that we were wrong, that the expectations of what we could do to rivers were unrealistic, that the benefits of damming the river were just too small, too short-lived to justify the continuation of the structure. To wrestle our rivers back from their concrete sarcophogi requires embracing the humility of the scientific experiment.

In the closing of the constitutional convention on this day in 1787, Ben Franklin captured this when he said, "To change opinions on even important subjects which I once thought rigid or right, but found to be otherwise. It is therefore as I grow older the more apt I am to doubt my own judgment and pay more respect to the judgment of others". That's right, Benjamin Franklin, probably the greatest luminary in our history, was a flip-flopper. For the moment of dam removal, it is not just inspiring because of the benefits to the river and to river ecosystems, but also for what it symbolizes for the future — the power of admitting being wrong and changing our course.

Lest I leave you with the notion that all has gone terribly wrong, in many ways it has, there are some examples that we are learning. I see a movement afoot to reconcile river management with the great American experiment. First is the increasing adoption of adaptive management. Yes it isn't really done well; yes it isn't perfect. It is the acknowledgement that we do not know everything. This is a noble acknowledgement that we have to constantly learn to change our minds as new information becomes available — it is in essence, managing as an experiment. One of the main challenges and one of the lessons for the future is that too many decisions from the past will not easily be reversed. Development and decisions around our rivers made over the past decades have dramatically restrained our future options; they make any changes painful if not impossible.

And so this offers a lesson for engineers, leaders, planners and environmental managers in general. Consider whether your decisions and actions are changeable. The next generation of scientists and engineers will inevitably be smarter and better trained than we are. They will have more data and better models than we can possibly imagine. The next generation of river managers will also be faced with new challenges, society with different priorities. The founders of the United States gave us a government that we could adapt; we could change, as we needed to. We should give future river users the same gift — make our decisions, our actions, changeable. The way rivers are meant to be managed is chaotic, inefficient, and competitive. In times when it has not been this way we have been too often lured into creating immoveable monstrous mistakes. We have made unchallenged and unchangeable decisions; in so doing we have made many of our rivers into ecological tombs. Like a scientific experiment, America's river management has tended to be and will hopefully continue to be an untidy, competitive and inefficient affair.

The system, so initially unappealing to the engineer and planner in all of us, has the characteristics to be more resilient and better able to meet the unpredictable demands of society in the future. As we set forward to remove the dams on the Elwha River, in reality, we don't know what we are doing. No one has ever done anything like this before. Our models, our predictions, our expectations will almost certainly in some ways be wrong. And that's just the way it should be. In closing, I believe it is probably most appropriate to leave you with the words of Thomas Jefferson, which were as true in 1804 when he wrote them as they are true for the series of events in the Elwha this weekend: "No experiment can be more interesting than that we are now trying".

Changing Themes in Salmon Conservation: A Brief 35-year, Personal Perspective.

Thomas Quinn

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Synthesized by Kiley Barbero and Tara Morrow (not edited by Dr Quinn)

Several interesting things were happening in my youth. Rachel Carson's book, "The Sea Around Us," made a tremendous impression on many people in my generation. It turned us on to this new science, a new perspective of marine biology. In addition, Jacque Cousteau's movies were coming out. The impact that this man and woman had on marine biology and conservation biology is not to be underestimated. It was a really important shaping period of time as a young person for me and many other people of that generation.

Twenty-five years ago, a couple of conservation themes dominated the conferences, meetings and everybody's thoughts and now those have changed. Today, some things that none of us back then were talking about or thinking about are now absolutely prominent. The point is, things will change. We should anticipate the changing perspectives and the changing paradigms and be alert to those and program some of those kinds of interesting future patterns into our management.

If you went to a conference about salmon back then, it was all about logging. Logging symposia, there were books, controversies: Is logging bad for salmon? How bad for salmon is logging? How can we possibly continue to log and have salmon? And I don't mean to denigrate the effects of logging on salmon, because undoubtedly practices were harsh and we have seen over a long period of time a lot of those effects playing out.

In that period of time there was very extensive fishing by the Japanese on the high seas. The Japanese actually fished on the high seas prior to World War II. After the world war was over they resumed fishing and the Japanese were fishing a tremendous amount of salmon on the high seas. The International North Pacific Fisheries Commission in the US, Canada and Japan was essentially formed largely to figure out how many large fish they were catching. The effect of the research would essentially move the Japanese fleet farther and farther over until they eventually gave it all up. That was one of the preeminent concerns, endeavors in the period of time that has basically gone away. Oceans are a home free zone for salmon out there on the high seas and that is a huge change in their conservation and management. However, there are a number of things that were not on our radar screens at that time and they are now prominent.

Elwha River Chinook salmon. Photo by John McMillan, NOAA

Laws have changed. The Marine Mammal Protection Act in 1972, certainly now taken for granted by a lot of people, had to be passed. The Endangered Species Act had a huge and profound effect. Another was the United States vs. Washington in the Boldt decision. The Magnuson Fisheries Conservation Act, a 200-mile limit, had huge ramifications not just for salmon, but all kinds of fisheries. All of these things were playing out and defined a new transition in salmon conservation management as I arrived here.

Back then no one was talking about aquaculture and net pens. Salmon migrate thousands of miles, you can't put them in a pen. Net-pen aquaculture has had huge effects, especially on Atlantic salmon. There have been huge effects on salmon as a commodity worldwide with more people buying salmon and very important implications from the globalization of salmon as a commodity. You can buy your salmon from Ireland, Chile or from Canada. People perceive salmon differently because salmon used to come from Alaska and BC, where they are grown naturally. So in interaction with shoreline practices we have concerns about PCBs and about whether they are safe to eat. We have concerns about transmission of disease, sea lice in particular. Controversies associated with aquaculture, separation of price from supply and demand, and where the fish are caught as wild animals, nobody was talking about that back then.

About invasive species, we knew back then that there were non-native species. If you rounded up a bunch of salmon biologists and salmon conservation types and asked them their highest priorities, it is doubtful invasive species would have been on the top of their lists. So now we have disease, with tremendous affects on trout. Rock snot was transported down to New Zealand where it forms a sort of wet soggy mass that covered the substrate there. They traded us by giving us mud snails back. I hadn't realized how small these mud snails are but they soak up a whole lot of primary production. These are examples of the tremendous exchange of organisms and now most people concerned with salmon and river conservation would regard invasive species as something very important. Again, not that no one mentioned it back then, but it was certainly not prominent as one of the issues we were concerned about.

About predation, when I came to Seattle it was unusual to see seals and sea lions in Puget Sound because they had basically been harassed and shot. The population has rocketed up; the resident harbor seals, migratory sea lions, California sea lions came in. Then came an increasing series of fisheries-marine mammal conflicts. We see this now with sea lions, Stellar sea lions we are seeing, ironically, federally listed at the remote edge of their range at the bottom of the dam are going through and eating sturgeon. There are conflicts, they are eating our fish, now it turns out there are conflicts because we are eating their fish. Certainly not something we would have worried about 30 years ago.

We also didn't think so much about salmon as fertilizer. People knew that fish died and stank on the edge of the bank; like most ecological discoveries, it was hiding in plain view. The whole idea of the linkage between the inevitable death of salmon and the processing of their carcasses by wide variety of organisms from caddis flies to shrews to eagles to bears who are then urinating in the woods producing marine derived nutrients, stable isotopes. Those were not things that anyone was talking about. There were a few people who knew about those things and I give them full credit. Jeff Cederholm was among them, but it was certainly not prominent. There was not talk about modifying salmon escapement goals to provide drift eggs for dolly varden and rainbow trout, lots of fish for bears to eat. This is now become very prominent; in fact you couldn't go to a salmon conference these days without lots of talks about these types of ecosystem connections. This is a really big change in our perspective.

Salmon biologists used to work on just salmon, now things have become much more holistic. We also didn't talk about what is now referred to as bio-complexity and the portfolio effect. Salmon management tended to be about biomass, not biodiversity. Large population complexes were kept track of and considered important. The smaller ones were rolled into fishery management plans, typically not enumerated, and as long as the big ones were ticking along fine we assumed that everything was nice. It is clear now that in both wild fisheries and wild-hatchery fisheries, we will have wiped out small populations collectively which probably add up to a lot of fish and also provide a lot of buffering. Complex, diverse populations cause the most overall production because as environmental conditions change, what is favorable to one population may become something unfavorable for another. Now you couldn't go to a conference without talking about population structure, diversity of life history patterns and the ways in which that provides much more sustainable fishing.

There were no interactions with Russians. The International North Pacific Fisheries Commission (INPFC) was the United States, Canada and Japan. Russia was not a part. We now recognize Russia has a tremendous diversity of resources, essentially unknown to us before. We did not read the literature or translations; most of us knew nothing about what they had over there. A few intrepid people ventured there, but not many. Now it is routine to consider the lessons from Russia, a very big and positive change.

Climate change. Today you couldn't go to a salmon conference anywhere without hearing the theme of climate change. People used to measure the temperature and flow; they didn't put it in that context. We also have the concept of regime shift. For example, the 1983 El Niño event took the term from oceanographers to the common language. We realized there were other historical events of this kind. The three perceptions of oceans were all important. Limitation was in freshwater, for spawning and rearing, yet the ocean was a limitless pasture. The ocean didn't change in any important way and it didn't matter. We could throw our trash in there because it is so large we would never see it again. All of these notions were wrong. In 1977, this changed. There were periods of time, regimes under which climate conditions, ocean temperature and patterns of survival and abundance of salmon changed. The ocean has important limitations for salmon. It changes in extremely important ways and we can learn really important things from these changes.

Salmon are full of surprises. In Washington, many of the streams that pink salmon swim through are heavily degraded habitat with estuaries of the worst possible condition. Survival for coho, Chinook and steelhead in the Puget Sound has been dismal lately. Under any computer model these species would be toast but in truth they are going through the roof. Two years ago about 6 million pink salmon came back to Puget Sound. Contrary to many predictions and models they are showing us wrong. Bear in mind that salmon are a wildly devious bunch.

Human population pressures salmon: habitat, harvest, hydro, and hatcheries. Most of the species rely on freshwater for rearing and all of them rely on freshwater for breeding. Some things we do degrade or eliminate that habitat; we have fished them competitively to a critical point without feedback. This got things rolling. Stocks with fewer returning adults are less able to cope with human pressures. Artificial mortality is going up and we are also losing the fish in freshwater.

Dams were impassable. Even the passable dams have large effects on sediment transport, temperature and so forth. We have dams, fishing and habitat loss. We get this endless blame game. Fishermen blame loggers; they blame someone else — and around and around it goes. Unfortunately, the only solution seems to be artificial propagation. [Hatcheries] made problems. In many cases the problem was that they worked too well. We can cut through life history stages and improve the overall survival by putting a fish in a hatchery. Wild populations are subject to uncontrollable fishing rates and down they go.

The stronghold approach has been pointed out by a lot of people here; protecting the best remaining salmon populations throughout their range, where salmon can not only survive, but thrive for generations to come. The largest threat to salmon conservation in our country is happening in Bristol Bay, Alaska. If you take just the escapement from Iliamna Lake from 1960 to 2009 , it exceeds the total number of wild and hatchery production above Bonneville dams six-fold, all species combined. Over 45 million sockeye have been documented in the Iliamna Lake alone. That is at least five times an optimistic estimate of the peak pre-industrial fishing of the whole Columbia River system, all species combined. It is a salmon stronghold, the strongest of the strong.

What would we be worried about? The largest open-pit mine in North America proposed in this area dwarves the ones in Montana, where pits are over 1500 feet deep; we have blockaded up to five thousand feet deep. We would have a tailing 'pond' 745 feet high so you could sink the Space Needle in this pond holding the reactive acid-generated tailings from this open-pit copper and gold mine. Over 80% of local residents see it as threat and oppose it strongly. If that isn't worth saving, what is? If that doesn't constitute a threat, what would? And, if you do not draw a line in the sand there, there is simply no line to be drawn anywhere.

The Elwha is a good start. It is absolutely right for restoration like this. It is going to cost a lot of money and a lot of eyes will be on us. It is worth bearing in mind our goals and expectations; is it a fish factory that needs to gear up, part of a National Park that needs to be restored, an injured ecosystem to heal itself? It is much more than any of those things. It is more than justifiable in those terms itself, but the potential to be much more symbolic, not just to salmon biologists, river freaks and kayakers, but also to those who are interested in the restoration of natural systems across the whole country. It has tremendous symbolic value and would be a standard barrier for a period in this country where we are making a difference in the values. The benefits will ripple out.

Be patient, there will be ups and there will be downs. That is part of the natural system. If you expect rock-steady ten thousand fish of one species and five thousand fish of another species, you will be disappointed. Emphasize things that will allow the river to heal itself. Look for things where the river and the processes reveal themselves, where we don't need a continuing input from ourselves. Expect surprises, salmon may be riding high and then they may be tanking. That will go down as part of what you should

Adult coho salmon released into the Little River, an Elwha River tributary, in November, 2011. Photo by John McMillan, NOAA plan for. "If you can't be with the one you love, love the one you're with." If you can't have the fish you want, love the fish you have. Finally, I was looking out my window this morning, and the sun was just rising and the seas were calm and I thought, "It is a wonderful day to be alive."

King of Fish: Looking 1,000 Years Back to See 100 Years Forward.

David R. Montgomery

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Synthesized by Kiley Barbero and Tara Morrow

Why would a geologist write a book about salmon and a book about dirt? If you look at the commonalities between the way human societies treat natural resources there is actually strong parallels that can be drawn between the history of salmon fisheries and the history of agriculture. Many of those parallels do not paint us as a species in a very flattering light, but they make for interesting history and great reading. Why would a geologist try and bring that kind of insight of information to the general public? It is important for decision-making and for how we look at the future, especially as we remodel the landscape as our population increases.

A geologist thinks about broad scale things — like the physiographic evolution of the Olympic Mountains. While working on mountain rivers and the evolution of mountain ranges, a fundamental thing struck me about the rivers in the northwest and the salmon that were in them. Why were there so many species of Pacific salmon and yet only one species of Atlantic salmon? Twenty million years ago there was a common ancestral salmon. By six million years ago all the species of Pacific salmon that we know today were in existence. This period of time between twenty million years ago and six million years ago, the Miocene period, is a very special period of time. The Atlantic salmon did not change much during that time and was close to the ancestral salmon.

Turns out that the Olympic Mountains were not here twenty million years ago, they evolved into the mountain range we know today in that same period of time, the Miocene. The salmon of the Pacific Northwest coevolved with the region's topography. The radiation of Pacific salmon, its diversification into the species we know today, happened at the same time that the topography we know today evolved. And as a geomorphologist, a geologist who studies topography, I was interested in the connection between these two seemingly separate events. Of course the fish did not drive the evolution of the mountains, but I think the inverse did happen. A strong case can be made that the Pacific salmon evolved in response to the changing landscape of the Pacific Northwest. Why is this interesting? The fundamental importance to bear in mind when one thinks about salmon conservation in the big picture is that the salmon and the landscape they evolved in have been intimately connected at the most fundamental level, as far back as either existed.

There is a site at the southern end of the Olympic Peninsula along the Skokomish River where you can see fossil salmon eroding out of a river bank. There are not a lot of fossil salmon anywhere in the world because salmon die in mountain streams, which are not preserved in the geological record. The Skokomish salmon were about two feet long and isotopic analyses of their beautiful fossils indicate they went out to sea. These were four-year-old spawned-out fish, as indicated by their telltale worn out tails. They lie entombed in sediments deposited about a million years ago. The species of salmon that we know today were in existence around Puget Sound and the Olympic Peninsula by a million years ago. Salmon coevolved with the landscape, and have thrived in a world full of natural disturbances. They have been able to do pretty well for a very long period of time and have adapted to living in disturbance prone environments, which is part of why they go out in to the nutrient rich marine environments for a few years. They survived repeated ice ages. Will they survive the human age?

There is a very similar pattern to changes in the salmon rivers of England, New England, and California and those of the Pacific Northwest. What do the lessons that played out in salmon crises before in other regions mean for salmon conservation efforts in the Pacific Northwest? Basically it was the same story retold in different environments with different contexts. In researching *King of Fish*, my environmental history of salmon, I traced the history of a thousand years to very early Scotland and a statute dated from the reign of Richard the Lionhearted, in the 12th Century. Even back then, they knew that if you block a river the salmon would not come back because the juvenile fish needed to make it to the ocean and then adult salmon eventually needed to make it back to their spawning grounds to perpetuate the cycle of fish.


The re-emerging floodplain of the former Lake Aldwell delta. Photo by John Gussman, Doubleclick Productions.

In the 1830s, Scottish gamekeeper Alexander Frasier discussed the social and political salmon crisis that was plaguing England, and triggering widespread concern over loss of their commercial salmon fisheries. Frasier basically hit on a 3-point plan to not block the ability of salmon to migrate up or downstream, limit fishing intensity so as to not take a majority of spawners, and prevent habitat degradation that could damage the fishery. In other words, manage the hydro H, the harvest H and the habitat H. There is a lot of science and natural history understanding that we have known about salmon for a long time that is not actually used in salmon management, salmon conservation, and river management. What happened to the Atlantic salmon? By the late 19th century something like 90% of the river miles that had been physically accessible to salmon were either blocked by dams or had habitat no longer capable of supporting fish due to lack of oxygen as a result of pollution. All of those dams that blocked salmon from their habitat were in violation of long established, though poorly enforced laws.

Problems were not unnoticed in other areas. In 1848, the Oregon territorial constitution proclaimed that the rivers and streams of the new territory, in which salmon are found, should not be obstructed by dams or otherwise in ways that would not allow salmon to pass freely. In other words, the laws had been on the books for centuries in England and New England, were incorporated into the earliest documents establishing American territories in the Northwest. Meeting in its first session a few years later, the newly formed Washington State legislature also passed laws making it illegal to block salmon from running up or down a stream because that is what salmon needed to perpetuate their lifecycle.

The opportunity to produce power for markets not yet in existence led Thomas Aldwell, a Canadian with backing by Chicago investors, to dam the Elwha. Built between 1910 and 1913, Aldwell's first dam lacked both provision for fish passage and a solid foundation. It failed because of engineering shortcomings, but was soon rebuilt again without the required fish passage. The illegal fish barrier created a political problem for the newly elected Governor of Washington, Ernest Lister. His creative fish commissioner, Leslie Darwin came to the rescue. Darwin proposed Aldwell's company build a fish hatchery instead of a fish way. Although this would not satisfy the law, Darwin saw a novel way around this technicality. He suggested that if the company built a fish hatchery that was physically connected to the dam then the dam could be considered an official state sanctioned fish obstruction for the purpose of supplying the hatchery with eggs. Governor Lister liked this idea so much that he persuaded the state legislature to endorse building hatcheries instead of providing for fish passage at new dams.

As a geomorphologist, I find it fascinating how the rivers of this region work, how they sustain fish, how the fish influence the rivers and how they have changed historically. There has been a lot of progress in our understanding of rivers in the Pacific Northwest, and the rivers of Olympic National Park have really served an incredibly important purpose in learning about how rivers in the region functioned historically, particularly regarding the role of large wood on big rivers. The rivers of Olympic National Park have provided a natural laboratory. Seeing first hand how, on the Hoh River during a storm, an old growth log with a full root wad ground out and spun around and basically dug itself into the river bed during a high flow influenced my own thinking about the role of different kinds of inputs and processes that structure forest river systems.

Water and sediment have always been in the geomorphic textbooks as things that fundamentally structure rivers, the interplay between them, how the flows move the gravel around, how the gravel steers the flow. But large woody debris, something we have learned a lot about in the last few decades, has changed the way we think about the processes of sediment transport, erosion and floodplain inundation and how those processes form the floodplains, the bars, pools and riffles that create the salmon habitat for rearing and spawning dependent fish. Today we have to think about how all of these things interconnect.

We have physically lost a lot of the salmon habitat that we had historically. At the close of the 19th century, Livingston Stone predicted what would happen to salmon in the Northwest based on his experience growing up seeing the New England salmon's demise in Maine. He wrote, "Provide some refuge for the salmon and provide it quickly before complications arise which may make it impracticable or at least very difficult … If we procrastinate and put off our rescue mission too long, it may be too late to do any good. After the rivers are ruined and the salmon gone they cannot be reclaimed…" But we can actually restore the Elwha — its being done and it really is a historic moment. It demonstrates that we can restore habitat. Opening up some of the best habitat in the world will also directly test the contention that habitat loss is not a dominant limiting factor to salmon production in Pacific Northwest rivers.

This is a major historical event in the history of humanity's relationship with salmon. Taking out a very large dam with a very long history behind it to restore a major salmon run really does have the opportunity of being identified as a turning point in this thousand year long history where we have gradually shut off salmon from much of their habitat. How much of a turning point will this be? It's certainly a turning point for the Elwha River; there is no way to argue that one. But how much of a turning point will it be for salmon in the Northwest? That remains an arguable point.

The history of salmon runs in the English-speaking world also speaks to how well we are using the science we know to protect salmon in relation to land use in the Northwest. The question is very pertinent to thinking about land use around the northwest. The problem is that scientific knowledge of basic processes is not well used in our decision-making. While this obviously reflects a policy call, as a scientist I cannot help but feel disappointed when I think about the way a lot of what we know about landscape management, about the role of land use and its effect on say storm water runoff, slide-prone hill slopes, physically blocking of salmon access has not been used to prevent damage to once-thriving salmon fisheries. All too often there is blind faith in the idea that if we have good information, we will make good decisions, that if we just do one more study, if we just understand things a little bit better then we could better manage things.

If you look back to history it is replete with examples where we have not made good decisions based on the information we had. Why not? Other short-term priorities often come into play; the word politics comes into mind. But if we look into the future, what does the future hold for salmon in the Northwest? What we can see is that we can turn things around. And if we can turn around a single river like the Elwha, could we possibly turn it around for the Puget Sound and the entire Northwest?

I reject Livingston Stone's idea that salmon and civilization cannot coexist. The answer depends on how we live on the land. We actually could bring back major salmon fisheries throughout Washington State if we did what it took to get there. Taking the strategy, ideas, energy, and emotions behind the Elwha restoration and taking it to other rivers could be a very good start. Rising to the challenge of river restoration — and salmon recovery — compels us to explore how we look at nature and how much can we learn from her world. These are fundamental questions and the Elwha is a good example of people stepping back and thinking maybe we do have more of a responsibility to future generations than we have been meeting in the past. It is an absolutely wonderful experiment.

An aerial view of the Glines Canyon dam during deconstruction. Photo by John Gussman, Doubleclick Productions

Oral Presentations

Fish and Wildlife I

A Riverscape Perspective of Fish and Habitat Throughout 45 Miles of the Elwha River Prior to Dam Removal.

Samuel J. Brenkman, Jeffrey J. Duda, Christian E. Torgersen, Ethan Welty, George R. Pess, Roger Peters and Michael L. McHenry

Olympic National Park, Port Angeles, WA (SB), U.S. Geological Survey, Western Fisheries Research Center, Seattle, WA (JD), Forest and Rangeland Ecosystem Science Center, Cascadia Field Station, U.S. Geological Survey and University of Washington, Seattle, WA (CT and EW), Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA (GP), U.S. Fish & Wildlife Service, Lacey, WA (RP), Fisheries Department, Lower Elwha Tribe, Port Angeles, WA (MH)

The removal of dams on the Elwha River provides a unique opportunity to restore 10 anadromous fish populations in a wilderness river. A key to understanding watershed recolonization is the collection of spatially continuous information on fish and aquatic habitats. In 2007 and 2008, 20 biologists conducted concurrent snorkel and habitat surveys throughout the Elwha to provide baseline information before dam removal. The riverscape approach characterized spatial extent, community structure, abundances, and densities of Pacific salmonids from the headwaters to the sea. Species richness was highest below the dams where anadromous salmonids still have access. Each year, the percent composition of salmonids over 65 rkm was nearly identical for rainbow trout (89%; 88%), Chinook salmon (8%; 9%), and bull trout (3% each year). In 2007, 7,312 trout, 687 Chinook, 215 bull trout, and 26 pink salmon were observed. Spatial patterns of abundance for trout (r = 0.76) and bull trout (r = 0.70) were consistent in 2007 and 2008. There were clear differences in major habitat features along the river profile. Longitudinal patterns of river fish in the Elwha were markedly different when compared to results from riverscape surveys in the nearby and undammed Quinault River. The riverscape approach in the Elwha provided a spatially comprehensive view of what fish and corresponding habitats were like before dam removal. The riverscape surveys highlighted species-specific biological hotspots and revealed high numbers of rainbow trout that may contribute to steelhead restoration. After dam removal, riverscape surveys can be used to identify the spatial extent of salmonid recolonizers and assess the proportion of, and habitat use by, hatchery (marked) and wild fish. In light of many upcoming dam removal projects in the western U.S., riverscape surveys that focus on collecting spatially continuous biological data will provide landscape context for understanding changes expected in fish communities.

A biologist searching for fish during a 2007 'riverscape' survey. Photo by Jeffrey Duda, U.S. Geological Survey

Brenkman, S.J., J.J. Duda, C.E. Torgersen, E. Welty, R. Peters, M. McHenry, and G. Pess. 2012. A riverscape perspective on distributions and abundances of Pacific Salmonids in Washington State's Elwha River prior to large-scale dam removal and ecosystem restoration. Fisheries Management and Ecology 19:36-53.

Use of a Floating Weir to Assess Salmonids in the Elwha River Prior to Dam Removal.

Kent Mayer, Mara Zimmerman, Sam Brenkman, Jeffrey J. Duda, Mike McHenry, George Pess, Roger Peters

Washington Department of Fish and Wildlife [WDFW], Port Angeles, WA (KM), WDFW, Olympia, WA (MZ), Olympic National Park, Port Angeles WA (SB), USGS Western Fisheries Research Center, Seattle, WA (JD), Lower Elwha Klallam Tribe, Port Angeles, WA (MM), NOAA Fisheries, Seattle, WA (GP), U.S. Fish and Wildlife Service, Lacey, WA (RP)

Removal of the Elwha and Glines Canyon Dams on the Elwha River is scheduled to begin in the fall of 2011. Most salmonid species in the Elwha River are ESA-listed (Chinook, steelhead, bull trout), at critically low levels (pink, chum), or extirpated (sockeye). Enumeration of anadromous salmon, trout, and char is needed to assess fish response to dam removal and the floating weir provides data to help adaptively manage the recovery of salmonid populations in the Elwha. The main goal of the Elwha weir project is to evaluate trends in abundance and diversity of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) in the Elwha before, during and after dam removal. In 2010, we installed and operated the first resistance board floating weir in the Elwha River. Biological information was collected from all salmon, trout, and char captured at the weir, which was fished between September 9 and October 9, 2010, at river kilometer 5.9 (river mile 3.7). Over this 30-day period, Chinook salmon, pink salmon (*O. gorbuscha*), steelhead, sockeye salmon (*O. nerka*), bull trout (*Salvelinus confluentus*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), and coastal cutthroat trout (*O. clarki clarki*) were captured. All eight species were captured within the first two weeks of weir operation. The majority (70.0%) of the female Chinook salmon captured were 5 years of age, whereas the majority (78.3%) of males were 2, 3, and 4 years of age at spawning. Scale data indicated that most (98.3%) of the spawning Chinook salmon migrated to the ocean as sub-yearlings. Mean fork length of male Chinook salmon was longer than that of females in the same age class. A combination of weir and SONAR technology should result in abundance estimates for winter steelhead. The weir was operated in April-May 2011 and we began the 2011 summer/fall trapping season in August.

Resident Rainbow Trout Populations are Genetically Divergent From One Another and From Downstream Anadromous Steelhead in the Elwha River.

Gary A. Winans and John Baker

NOAA Northwest Fisheries Science Center, Seattle, WA (GAW), Salmonmetrics, Mukilteo, WA (JB)

We highlight a study of the levels and patterns of genetic variability in rainbow trout collected above the two Elwha dams using 14 microsatellite markers. Data were available from fish tissues collected by various agencies from 2004 to 2007. Significant differences were seen between small, neighboring streams of rainbow trout; and between upstream trout and the extant population of anadromous steelhead downstream. We make comparisons with other dammed populations of rainbow trout studied in the Pacific Northwest. The contribution of resident rainbow trout to recolonization of the upper Elwha River by steelhead can be studied with these markers. Variation at major histocompatibility loci and parr mark patterns is discussed.

Where We Are Today: A Quantitative Baseline for Assessing Response of Elwha River Chinook Salmon to Dam Removal.

Mara Zimmerman, Kent Mayer, Randy Cooper, and Mike McHenry

Washington Department of Fish and Wildlife, Olympia, WA (MZ), Washington Department of Fish and Wildlife, Port Angeles, WA (KM), Washington Department of Fish and Wildlife, Port Townsend, WA (RC), Lower Elwha Klallam Tribe, Port Angeles, WA (MM)

Removal of two hydroelectric dams on the Elwha River, slated to begin in fall 2011, will provide salmonid populations access to 130 km of pristine habitat. The Elwha Fish Restoration Plan relies heavily on hatchery supplementation to rebuild a self-sustaining wild population of Elwha Chinook salmon. The success of efforts to rebuild this population will depend on the abundance and productivity of wild and hatchery-origin Chinook salmon following dam removal. Until recently, relative contributions of wild and hatchery-origin fish could not be assessed because spawner origin was not detectable. Beginning with the 2004 brood year, an origin-specific comparison of the survival and age-at-return was enabled by a hatchery program that fully marks or tags hatchery releases and a smolt trap study that estimates the number of wild Chinook out-migrants. All Elwha River Chinook salmon from the 2004 brood year and later were recognizable as one of three out-migrant types: wild sub-yearling, hatchery sub-yearling, or hatchery yearling. Chinook out-migrants during this period were predominantly (84-93%) sub-yearling hatchery fish. In order to compare survival and age-at-return among out-migrant types, Chinook spawner carcasses were collected from the Elwha River during spawner surveys, brood stock collection, and operation of a floating fish weir. For the 2004 brood year, survival-to-return of wild out-migrants was 3 times greater than sub-yearling hatchery releases and 2 times greater than yearling hatchery releases. Age-at-return also differed among out-migrant types. Wild out-migrants returned primarily as age-4 spawners (61%), whereas hatchery yearling releases returned primarily as age-3 spawners (55%). Returns of hatchery sub-yearling out-migrants were evenly distributed among age-3 and age-4 spawners. The survival-to-return and age-at-return of wild- and hatchery-origin Chinook prior to dam removal should be useful for evaluating future changes in abundance and productivity and for adaptively managing the restoration of self-sustaining wild populations in the Elwha River.

Aerial view of the Lake Mills delta, December 15th 2010. Photo by the National Park Service

River Physical Science

Elwha River Restoration: Adaptive Sediment Management and Monitoring Program.

Jennifer Bountry, Tim Randle, Gary Smillie, Brian Cluer

Sedimentation and River Hydraulics Group, Technical Service Center, Bureau of Reclamation, Denver, CO (JB and TR), Water Operations Branch, National Park Service, Fort Collins, CO (GS), NOAA Fisheries, Santa Cruz, CA (BC)

The U.S. Department of the Interior is removing Elwha and Glines Canyon Dams on the Elwha River near Port Angeles, Washington to restore anadromous fish and the natural ecosystem. Elwha Dam, completed in 1913, forms Lake Aldwell. Glines Canyon Dam, completed in 1927, forms Lake Mills. These dams will be removed in controlled increments over a two to three-year period, beginning in September 2011. Reservoir sedimentation is estimated at approximately 24 million yd^3. The sediment release impact period associated with dam removal is projected to last 3 to 5 years.

The sediment effects of dam removal were predicted based on a 1994 Lake Mills Drawdown Experiment, numerical modeling, and physical laboratory modeling. These predictions informed the design of mitigation measures for water quality and flood protection, including water treatment plants, new wells, a new surface water intake, raising the height of existing levees, and the construction of new levees.

During the first portions of dam removal it is expected that only fine grained sediments (silt and clay size range) will be released from the reservoir. Fine grained material will primarily be transported as suspended sediment and will cause spikes in turbidity concentration downstream. As the lakes are drawn down and the reservoirs become smaller and smaller, turbidity concentrations are expected to become larger with each increment of dam removal. Once dam removal is complete, turbidity levels downstream of the reservoirs are predicted to return to background levels relatively quickly. Coarse grained materials (sand size and larger) in the deltas of each reservoir are predicted to behave differently. No coarse grain sediment is predicted to leave the reservoirs until well into to the dam removal project. Delta sediments are predicted to advance downstream by eroding and redepositing in the remaining lake beds following dam removal increments. Only after the delta propagation downstream reaches the dam and attains a height equal to the remaining dam structure can coarse material be released from the reservoirs. Once introduced to the river downstream, the coarse sediments will primarily travel as bedload and may take a year or more to reach the sea depending on hydrology following dam removal.

These two dams are the largest yet removed in the world. Although the predictions from field tests, numerical modeling, and physical modeling converge, there is still uncertainty in river sedimentation and water quality. An adaptive management plan for sediment was developed to reduce uncertainty of the predicted results and ensure that the planned mitigations are adequate. In addition, reservoir drawdown will be halted during approximately 5 ½ months each year to minimize sediment impacts to adult fish entering the river as well as emigrating smolts.

The adaptive management plan relies on real-time and near real-time monitoring to verify if actual results agree with predictions within a certain tolerance. If necessary, additional actions would be taken to ensure that sediment impacts remain within tolerance. System-wide impacts would be addressed by slowing or temporarily halting dam removal until impacts are reduced within tolerance.

Monitoring will initially focus on the sediment erosion within the two reservoirs and on turbidity downstream from the two dams. Measures will be taken to ensure that the reservoir deltas are not incised by a single erosion channel along a reservoir margin. If necessary, delta erosion channels will be modified to erode and redistribute the delta sediments within each reservoir at the pace of dam removal. This will help ensure that sediments left in the reservoir after dam removal will be in a stable condition. Because of extensive vegetation growth, large wood deposits, and the delta channel being trapped along the right margin of Lake Mills, a center pilot channel was constructed in September 2010 to ensure two erodible banks. Monitoring of downstream riverbed aggradation will begin once sand and gravel-sized sediment eroded from the reservoirs are released into the downstream river channel.

The Morphodynamics of Sediment Movement Through a Reservoir During Dam Removal.

Chris Bromley, Colin Thorne, Gordon Grant, Timothy Randle

University of Nottingham, Nottingham, UK (CB, CT), Scottish Environment Protection Agency, Stirling, Scotland (CB), USFS PNW Research Station, Corvallis, OR (GG), USBR Sedimentation and River Hydraulics Group, Denver, CO (TR)

The imminent removal of the Glines Canyon and Elwha dams from the Elwha River, WA, provided the inspiration for a series of physical modeling experiments whose objective was to further our understanding of the morphodynamics of sediment movement through the Glines Canyon Dam reservoir (Lake Mills) during dam removal. Each experiment involved hydraulically growing the delta and removing the dam (dropping local baselevel) in equal-sized increments, allowing the delta to erode and prograde to a static, or near-static, equilibrium between each increment. The size of the increments varied between experiments, as did the starting position of the delta surface channel. Results show that the volume of eroded delta sediment increased as the initial position of the incising channel moved from the left and right delta margins towards the center of the delta. This occurred because the evolution of the central channels was less affected by interaction with the asymmetrical reservoir basin boundary in the delta area and, as a result, was able to develop a more sinuous planform that eroded laterally into the delta terraces to a greater extent than the marginal channels. The volume of eroded delta sediment also increased with the magnitude of drop in baselevel, since a larger amount of potential energy was introduced to the delta surface at one time, thus more easily overcoming the resistance to erosion imparted by the armor layer. While the larger volumes of delta erosion associated with the central channel experiments reduced the size and height of the delta terraces, they also resulted in greater volumes of sediment being transported out of the model reservoir.

An Overview of Elwha River Hydrology and Its Role in Ecosystem Restoration.

Christopher P. Konrad

U.S. Geological Survey, Washington Water Science Center, 934 Broadway, Suite 300, Tacoma, WA 98402

The hydrology of the Elwha River has been investigated for over a century. While the motivation for hydrologic investigations has evolved over time from basic characterization of streamflow regime to prediction of river responses to dam removal, the cumulative result is a rather complete understanding of streamflow and its role in transporting sediment out to the Strait of Juan de Fuca. Annual runoff from the basin averages about 2 m. The river has a bimodal hydrologic regime, with storm flow and floods in late autumn and winter in response to large Pacific storms and sustained high flows as the snowpack melts during spring and summer. Most of the runoff from the basin is generated above Glines Canyon where about 70 percent of the basin area produced about 85 percent of streamflow. Historically, operations of the dams have had little effect on the magnitude of floods, which generally are about 16 percent larger as much as 45 percent larger at McDonald bridge gage than above Lake Mills. Upstream of Lake Mills, the annual sediment load of the river is about 330,000 Mg/yr with over 90 percent of the load delivered by flows greater than 85 cms, which occur only 10 percent of the time. Only about 15 percent of the sediment load from the upper river passes through Lake Mills – all of which is fine-grained material in suspension. The river has ample capacity to transport the sediment deposited in the reservoirs provided it can continue to access these deposits once the dams have been removed from the channel. Channel incision and progressive migration of the channel will isolate some of the reservoir sediments leaving terraces. The river will routinely transport and deposit more sediment in the channel restoring a fluvial process fundamental to the structure and dynamics of the river ecosystem.

U.S. Geological Survey scientists deploy an isokinetic sampler to collect water samples from a bridge spanning the Elwha River. Photo by John Gussman, Doubleclick Productions

Monitoring of Suspended-Sediment Load in the Lower Elwha River, Washington, USA, During the First Two Years of Dam Removal.

Christopher S. Magirl, Christopher A. Curran, Christiana R. Czuba, and Mathieu D. Marineau

U.S. Geological Survey, Washington Water Science Center, 934 Broadway, Suite 300, Tacoma, WA 98402, United States (CM, CC, CC, MM).

An understanding of the movement and redistribution of sediment during and after the removal of two large dams on the Elwha River, Washington, will be needed to explain how the restoration project affected the biological and physical processes of the river system. The U.S. Geological Survey (USGS) and collaborating partners have installed a suite of sediment-monitoring instruments at a new USGS gaging station (#12046260, Elwha River at Diversion near Port Angeles, Washington) located at the water-diversion weir downstream of Elwha Dam. Turbidity will be monitored continuously using two instruments designed to provide measurements under both low- and high-turbidity conditions. A laser in-situ scattering and transmissometry instrument will measure both the mean suspended-sediment grain size and the total suspended-sediment concentration. Finally, a side-scanning hydroacoustic instrument will quantify both acoustic backscatter and acoustic attenuation. Correlations between suspended-sediment concentrations from discrete physical measurements and turbidity, acoustic backscatter, and acoustic attenuation data will be developed to produce a continuous record of suspended-sediment load carried by the lower Elwha River during the dam-removal process through 2013. Although knowledge of suspended-sediment concentrations and transport will be of considerable value during the early stages of the dam-removal project, this sediment-monitoring strategy will not involve quantifying bedload transport. In addition, the strategy will not quantify background sediment load in the Elwha River upstream of the removal project or sediment load in the river between the dams. Ideally, these additional datasets would be collected to determine a complete sediment budget for the duration of the dam-removal project.

A spotted skunk from the upper Elwha valley photographed using a wildlife camera. Photo by Kurt Jenkins, U.S. Geological Survey

Fish and Wildlife II

Riparian Mammal and Amphibian Communities Prior to Dam Removal and Ecosystem Restoration in the Elwha Valley, Washington.

Kurt Jenkins, Nathan Chelgren, Michael Adams, Patricia Happe, Kimberly Sager-Fradkin, Steven Perakis

USGS Forest and Rangeland Ecosystem Science Center, Port Angeles, WA (KJ , KS), USGS Forest and Rangeland Ecosystem Science Center, Corvallis, OR (NC, MA, SP), Olympic National Park, Port Angeles, WA (PH), Lower Elwha Klallam Tribe, Port Angeles, WA (KS)

Removal of two hydroelectric dams and restoration of anadromous fishes in Washington's Elwha River Ecosystem provides a unique opportunity to improve understanding of habitat and trophic effects associated with dam removal on riparian faunal communities in the Pacific Northwest. Dam removal beginning this week is expected to alter channel dynamics and habitat characteristics in the riparian zone, and restoration of salmon that have been missing from the upper river for 100 years is expected to alter nutrient dynamics in riverine and riparian ecosystems. We developed a multi-species monitoring program to document current and future patterns in species occupancy, community composition, and species richness of mammal and amphibian communities in the Elwha River riparian zone. We examined patterns in species occupancy and community richness across unregulated (above dams) and regulated (below dams) river segments that also lack (above dams) or support (below dams) anadromous fishes. Species richness was derived from Bayesian multi-scale occupancy models. We will discuss present patterns in the distributions of individual species and species richness and discuss potential changes in species distributions following river restoration.

Enaging Birds in Elwha Vegetation Restoration.

John McLaughlin

Huxley College, Western Washington University, Bellingham, WA

Establishing native vegetation in the two drained reservoirs represents both opportunities and challenges to Elwha restoration. Draining the two reservoirs will expose nearly 800 acres of accumulated sediment, which may provide area to restore native forest, substrate for exotic plant invasion, or unstable terraces of eroding sediment. Terrestrial animals often are considered beneficiaries of vegetation restoration, but some may act as agents of restoration. This presentation focuses on one of the most important restoration roles of terrestrial animals: dispersal of native seeds by birds. Birds are potentially important to Elwha forest restoration due to their flight and foraging behaviors. Birds are known to disperse seeds of 23 (59%) of 39 native woody plants common in the Elwha's early seral communities. Although many bird species are active in floodplain habitats, American Robins appear to be the most important potential seed disperser for restoration. Robins fly frequently between seed sources in established forests and open habitats, while most other birds remain within a particular habitat type. My objective was to evaluate several hypotheses for bird-dispersed seed distributions. Causal factors in these hypotheses included: proximity to existing forest, distance from river channels, floodplain vegetation characteristics, and large woody debris (LWD) characteristics. I measured avian scat deposition along randomly located transects in the Geyser Valley Floodplain and in the Lake Mills reservoir delta. I fit linear and nonlinear models to scat data, and evaluated model fit using Akaike's Information Criterion. Most bird-dispersed seeds were found on or adjacent to LWD, particularly large logs and debris piles. I found little empirical support for other hypotheses. These results suggest birds can increase the anticipated slow rate of natural vegetation establishment in reservoir beds. Revegetation programs can leverage birds as restoration agents by locating or retaining LWD where fruit-bearing plants are desired.

Elwha Aquatic Foodweb Research: Baseline, Experimental, and Future Datasets.

Sarah Morley, Jeffrey Duda, Holly Coe, Michael McHenry, Kristopher Kloehn, Brian Beckman, Schuyler Dunphy, and George Pess

NOAA Northwest Fisheries Science Center, Seattle, WA (SM,HC,BB,GP), USGS Western Fisheries Research Center, Seattle, WA (JD), Lower Elwha Klallam Tribe, Port Angeles, WA (MM), University of Victoria (KK), University of Washington (SD)

Primary and secondary producers are vital to the structure and function of aquatic ecosystems, are sensitive to changes associated with river impoundment, and have rapid response and recovery timelines well suited to capturing ecological response to dam removal. Over the last decade we have conducted a series of related studies examining how the Elwha dams have affected primary and secondary producers, how these patterns may change following dam removal, and what such changes will mean to fish. From 2004-2006, we collected data on water chemistry, stable isotope ratios, and periphyton and benthic invertebrate assemblages from 52 study sites distributed across the river basin. Water chemistry analyses confirmed earlier reports that the river is oligotrophic, while $\delta^{15}N$ was significantly higher in fish, stoneflies, black flies, and algae where salmon still have access. We found that periphyton biomass was consistently higher in regulated than unregulated sections and that benthic invertebrate composition at sites above both dams was distinct from sites between and below. From 2006-2008 we conducted a nutrient limitation and salmon carcass addition experiment to better understand how future re-colonization by salmon will affect river productivity. We found that nitrogen and phosphorus co-limit aquatic primary productivity during most times of the year. Following carcass placement, periphyton growth rates and $\delta^{15}N$ values of juvenile salmon were significantly elevated in treatment reaches relative to reference reaches. In 2010, we began incorporating data on invertebrate drift and juvenile salmonid diet into our overall monitoring plan to better track short and long-term foodweb responses to dam removal. The extended timeline predicted for Elwha River recovery and the complexities of forecasting ecological response highlights the need for more long-term assessments of dam removal and river restoration practices in general.

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A Genetic Analysis Comparing Pink Salmon in the Elwha and Dungeness Rivers.

Maureen P. Small, Alice E. Fry, Jennifer Von Bargen, and Sewall Young

Molecular Genetics Laboratory, Conservation Division, Washington Department of Fish and Wildlife, Olympia WA

We assessed genotypes at 15 microsatellite loci in four collections of pink salmon from the Elwha and Dungeness rivers. Early and late run pink salmon from the Elwha River were genetically differentiated from each other and differentiated from early and late run pink salmon from the Dungeness River, suggesting that the Elwha River supports a native population of pink salmon. However, the like-timed run groups from the two rivers were more similar to each other than they were to the different-timed run group in the same river – e.g. early run pink salmon from the Elwha and Dungeness rivers were more similar to each other than early and late run pink salmon in the Elwha River. This indicates that, at least at this geographic scale (roughly 15 miles between river mouths), genetic structure in pink salmon is more influenced by run timing than by spatial distance.

University of Washington scientists prepare to deploy equipment into marine waters offshore from the Elwha coastal zone. Photo by Ian Miller, Washington Sea Grant

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Nearshore Physical Science

Dispersal of Fine Sediment From the Elwha River – the Potential Effects of Dam Removal on Coastal Turbidity and Sedimentation.

Guy Gelfenbaum, Jonathan Warrick, and Andrew Stevens

USGS Pacific Coastal and Marine Science Center, Santa Cruz, CA

Dam removal on the Elwha River will increase suspended-sediment concentrations and turbidity of river outflow to the coastal waters of the Strait of Juan de Fuca. Here we combine observations of the currents, waves, and the buoyant river plume of the Elwha River with numerical modeling of the region's hydrodynamics to evaluate the extent and implications of the restoration of sediment discharge to the coastal waters. Currents offshore of the river mouth are adequately strong to influence the direction of the buoyant river plume – and thus the initial dispersal direction of fine sediment – from the Elwha River. Currents are also strongly influenced by the coastal headland of the delta; during both flooding and ebbing currents ~1 km scale eddies develop on the downstream side of the delta headland. These regular eddies strongly influence the initial outflow direction of the river discharge, which is toward the east much more frequently than toward the west. The sediment discharged toward the east of the river mouth will likely stay in suspension or move frequently, however, owing to the strong currents east of the river mouth. The fine sediment discharged toward the west, in contrast, should be more likely to deposit and accumulate on the seafloor, owing to the relatively weak currents between the river mouth and Freshwater Bay. These predictions will be evaluated and tested with observations of sediment transport and seafloor change during and following the dam removal.

The mouth of the Elwha River where it enters the Strait of Juan de Fuca at low tide. Photo by John Gussman, Doubleclick Productions

The Elwha Delta: Shrinking or Growing?

Ian Miller, Jon Warrick, Andrew Stevens, and Guy Gelfenbaum

UC Santa Cruz, Santa Cruz, CA and WA Sea Grant, Port Angeles, WA (IM), USGS Pacific Coastal and Marine Science Center, Santa Cruz, CA (JW), USGS Pacific Coastal and Marine Science Center, Menlo Park, CA (AS and GG)

Chronic erosion on the sub-aerial shoreline fringing the Elwha River delta on the Strait of Juan de Fuca in Washington State is well documented. Mean beach erosion rates of 0.6 m/yr (measured between 1939-2006) are frequently attributed to the emplacement of two dams on the Elwha River in 1913 and 1925. The impending removal of the two dams, slated to begin in September 2011, could provide an additional 28,000 to 80,000 m^3/yr of coarse sediment to the coastal zone. Here we present the results of an analysis of annually collected topography and bathymetry data set. Data were collected on the beach and in the near-coastal zone with an RTK-DGPS system, mounted either on a backpack or on a jet-ski. Digital elevation models were constructed and annual differences calculated. Results suggest that the Elwha River typically delivers more sediment to the coastal zone than is transported away from the river mouth, and that sediment is retained in the river mouth bar and accretion is primarily sub-tidal. Rates of volumetric change in the Elwha River mouth region range from -21,000 ± 24,000 m^3/yr to 30,000 ± 24,000 m^3/yr, with the total change between September 2007 and May 2011 estimated to be 54,000 ± 12,000 m^3. Our results, which point to accretion in the river mouth area even as adjacent beaches and sub-tidal areas erode, suggest that a simple model of coastal response to dam removal (i.e., remove the dams and the sub-aerial shoreline responds) may need to be revised. This large dam-removal provides an exceptional natural laboratory in which to test models of coastal response to new additions of sediment.

Fine-Grained Sediment Dispersal from the Elwha River, Present and Future, and Expectations for Seabed Changes Near the Mouth of the Elwha River in the Coastal Strait of Juan de Fuca.

Andrea S. Ogston, Charles A. Nittrouer, Kristen M. Lee

School of Oceanography, University of Washington, Seattle, WA 98195

The 72-km Elwha River originates in the Olympic Mountain Range and dams at 8 and 22-km from its mouth are about to undergo removal. We hypothesize that prior to damming, sediment gravity flows were a dispersal mechanism for sediment and associated chemical constituents, and a dominant progradation process of the delta. Baseline observations of present sediment-transport processes were obtained under various river discharge conditions, and include seabed characterization, nearshore currents, water-column structure and suspended-sediment concentrations. The time series of sediment resuspension and transport in ~20-m water depth explored relationships between sediment delivery by the Elwha River and oceanic processes (including winds, waves, tides, and currents) operating in the Strait of Juan de Fuca. We deduce that sediment dispersal under present, restricted supply is broad and most of the fine-grained sediment likely leaves the vicinity of the delta topset. The little that does get temporarily deposited during floods is resuspended and moved away from the nearshore during storms. The active processes have winnowed the seabed creating a coarse lag layer ranging from sand to cobble size. This layer is ubiquitous over much of the subaqueous delta, although regions with some fine-grained sediment are found near the river mouth and trapped between the paleo-spits on the eastern delta topset. And thus, anthropogenic changes in the sediment supply to the nearshore have led to a new phase of delta evolution - specifically one of net erosion. This baseline research provided a framework for future coring and process studies to understand sediment budgets offshore of small mountainous rivers. It also allows us to develop predictions for seabed changes near the mouth of the Elwha River during the dam removal period when river-supplied sediment concentrations are expected to be elevated enough to induce sediment gravity flows in the Strait of Juan de Fuca.

Lower Elwha Klallam Tribe scientists install equipment to monitor sediment dynamics in the Elwha River Estuary. Photo by the Lower Elwha Klallam Tribe

The Elwha River Estuary – An Overview of Its Morphology and Hydrology.

Jonathan Warrick and Matt Beirne

USGS Pacific Coastal and Marine Science Center, Santa Cruz, CA (JW), Lower Elwha Klallam Tribe, Port Angeles, WA (MB)

At the mouth of the Elwha River, freshwater from the river mixes with saline waters of the Strait of Juan de Fuca creating estuarine habitats across a complex of coastal ponds, channels and nearshore waters. In this presentation we will introduce the recent history and geomorphic evolution of the Elwha estuary and present hydrologic data collected by the USGS and Lower Elwha Klallam Tribe (LEKT) that reveals patterns of water mixing within this estuary. The present estuary has been established through avulsions and meandering of the river and through direct manipulation of the channel by humans. Humans have altered the estuary directly through the construction of levees that have cut off the exchange of water, sediment and biota, and also through the two Elwha River dams that have reduced sediment discharge to this estuary. Coastal erosion – which is likely related to the dams – has resulted in the reduction in the size and extent of the estuarine wetlands. The Elwha River estuary continues to change through channel movement and redistribution of sediment from waves and other coastal processes. These changes in the morphology of the river mouth alter the hydraulics of water exchange throughout this estuary. For example, the exceptional river discharge event of December 2007 resulted in 7-8 m of lateral migration in the channel at the river mouth (Draut et al., 2011), and this resulted in much greater exchange of fresh and saline water through the eastern portion of the estuary. Future changes to the estuary will be monitored with continued sampling of the water, sediment and geomorphogy of the river mouth estuary by the USGS and LEKT.

Cultural / Human

Archeological Research in the Elwha Valley: How River Restoration Has Contributed to Understanding Native American Use of the Elwha Watershed.

Dave Conca and Kim Kwarsick

National Park Service, Olympic National Park, Port Angeles, WA

Olympic National Park Cultural Resource staff, with assistance from contractors and the Lower Elwha Klallam Tribe, has been working on archeological projects associated with removal of the Glines Canyon and Lower Elwha Dams since the mid-1990s. These studies, including inventory, test excavations, construction monitoring and analysis have added substantive knowledge regarding pre-contact and historic period use of the Elwha Valley. Data categories include archeological site distribution, lithic technological organization, and raw material procurement. Because these investigations were focused on a single watershed, these data provide an opportunity to discuss how Native American groups like the Lower Elwha Klallam Tribe have used the entire Elwha River Valley corridor throughout the Holocene. Additionally, these data are also used as a template for understanding pre-contact land use within other watersheds in the Olympic Mountains. Future archeological work associated with dam removal and restoration efforts will be discussed as it relates to these and other research domains.

Manufacturing a New Hydroscape Era: Semantics of restoration in the Elwha Waters.

Enrique Lanz Oca

Graduate Center, City University of New York (C.U.N.Y.), New York, NY

Dams have made America. Through dams, private and public agencies have manufactured new landscapes and ideologies of nature. In the 1840s, Lowell, Massachusetts became the first place in the country with a concentration of industry when its first hydropower system was installed. But it was Hoover Dam, built in the 1930s, that signaled the beginning of a massive physical transformation of the river landscape. Franklin D. Roosevelt envisioned it as a modern and nationalist symbol with which America could control nature, overcome its enemies, and propel the economy out of a depression. When the Glen Canyon Dam was built, 30 years later, however, public opinion had changed about dams. And nowadays, dams are removed in a similar public spirit in which they were once built. The Elwha Project in Washington State is the largest dam removal in history, and its removal may spur other demolitions such as the Condit, Klamath, or Snake River dams. Although many dams will remain, I demonstrate the dam removals are part of a new radical transformation of the American energy landscape. Based on interviews, primary and secondary sources, and direct observation, this paper examines how this new waterscape is being constructed and imagined. If the Federal Government represented Hoover as a tool of domination and nationalism, the Elwha Project is posited as an ecological restoration. Although the concept of restoration is not appropriate, the Government perpetuates it, I argue, to convince Americans that if we built the colossal Hoover during an economic depression, we, as a nation, are still capable of such largess.

Dignitaries arrive at the Elwha River restoration project ceremony, September 17th, 2011. Photo by the National Park Service

Removal of Elwha and Glines Dams – Revisiting Benefits.

Philip Meyer

Meyer Resources, Inc., Davis, CA

The Elwha Project Human Effects Team (1995) identified benefits from removal of Elwha and Glines dams. These included 507,000 added visitor trips per year to Clallam County and up to 2,000 jobs during construction phases of the project – another 446 long-term jobs for county workers.

Updating to July, 2011 dollars, annual economic benefits associated with dam removal are:

- Annual net business benefits associated with commercial and sport fishing: $5.1 million.
- Annual business revenue from recreation and tourism: $42.2 million.
- Annual business profits associated with recreation and tourism: $5.7 million.

Loomis identified that Washington residents associated an additional $94 million in annual "satisfaction" benefits, above monies paid or received, with removal of the Elwha dams. In 2011 dollars, this increases to $139 million. The Elwha Human Effects Team concluded, "Crediting even miniscule proportions (one half of one percent or more) of the non-market benefits from removing both dams reported by Loomis (1995) yields a positive benefit-cost ratio under all (dam removal) discounting scenarios." The Lower Elwha Klallam Tribe, suffering from high rates of unemployment will benefit substantially from return of the salmon. But tribal values transcend the statistics presented above. The Elwha is a salmon Treaty river – and stands at the center of tribal life in many ways. "Our Creator gave us the fish to live on ... and we cherished it, and we respected it, we used every bit of it... I may not see the abundance of fish come back in my lifetime, but I would like to see it come back for my grandchildren, my great-grandchildren, and the rest of my people, the following generations to come. It was a gift from our Creator, it was our culture and heritage" — Beatrice Charles, Lower Elwha Klallam Elder.

The Elwha River: Its Human History

Jacilee Wray, Adeline Smith, Beatrice Charles, Gretchen Luxenberg, Alice Alexander, Phrania Jacobson, Bud Hanify, and Orville Campbell

Elwha Klallam Elders, Port Angeles, WA (AS, BC), Olympic National Park, Port Angeles, WA (JW), National Park Service, Seattle, WA (GL), Elwha homestead family, Port Angeles, WA (AA, PJ), Elwha ranger and CCC employee, Port Angeles, WA (BH), James River Resident Engineer, Port Angeles, WA (OC)

Klallam Indian territory extended all along the Strait of Juan de Fuca and into Hood Canal, but populations were highest along the Elwha River, from its mouth upriver for at least 12 miles. The Treaty of Point No Point preserved to all of the Klallam their aboriginal fishing rights and before the Elwha dams were constructed, this was the major fishing source for the Elwha Klallam. Soon after 1860, small numbers of settlers began homesteading in the lower part of the Elwha Valley. They claimed land on the broad flood plain near the river's mouth and continued to settle upriver. The Klallam were not permitted to homestead under the General Homestead Act of 1862 because a homesteader had to be a citizen of the United States. The Elwha Klallam became "squatters" in their traditional territory until the first Indian homestead law was enacted in 1875, allowing Klallam families to acquire legal title to land in the Elwha Valley. In the early 1900s, the free-flowing Elwha River was blocked with two hydroelectric dams. The hydroelectric projects were major power suppliers to the paper and pulp industry in Port Angeles and other residential and commercial power users on the peninsula in the 1920s and have helped make Port Angeles the city it is today. Vignettes of the human history of the Elwha River Valley reveal the relationship of land use against this backdrop of a rugged and newly settled area and shifting federal land management boundaries. Land use presented conflicts between preserving natural grandeur, human use and occupation, and industry seeking to fulfill its development potential.

An orange sea pen photographed in the Elwha River drift cell of the Strait of Juan de Fuca. Photo by Ian Miller, Washington Sea Grant

Nearshore Biology

Nearshore Sediment Dynamics and Benthic Invertebrate Communities in Elwha and Dungeness Drift Cells.

Helle Andersen, David Parks, and Jeff Cordell

Coastal Watershed Institute, Port Angeles, WA (HA), Department of Natural Resources, Port Angeles, WA (DP), University of Washington, Seattle, WA (JC)

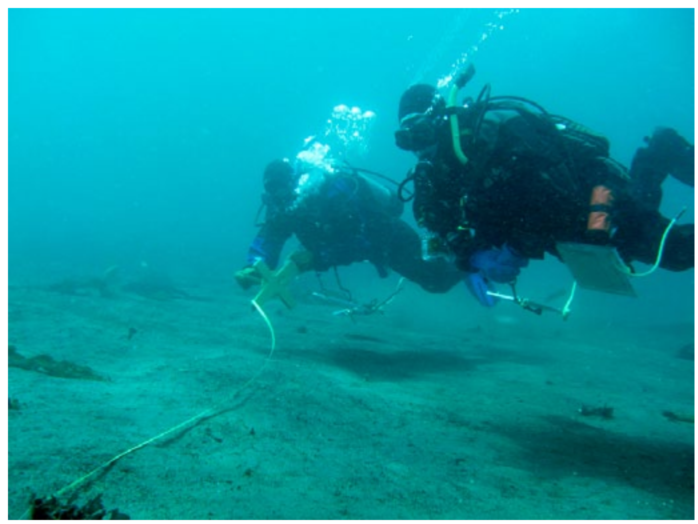
Hydrodynamic and sediment processes are important drivers of nearshore processes of the Salish Sea, including the invertebrate communities that form the basis of the complex food web that supports numerous species of salmon, forage fish, and birds deemed critical to Pacific Northwest ecosystems. Disruptions of sediment processes, a significant limiting factor of the region, can change substrate size, significantly impacting invertebrate communities and the larger marine ecosystem. Two studies are currently being conducted in the marine nearshore that characterize the seasonal changes in beach particle size distribution and topographic profiles. The purposes of the studies are to estimate changes in beach sediment storage in Elwha and Dungeness drift cells and the effects the sediment changes and dynamics have on the benthic invertebrate communities. These data will provide important information on how sediment and sediment dynamics define habitat functions for the benthic community and also establish a present-day baseline of the nearshore benthic invertebrate communities. The results will be available to compare to changes in community structures that may occur after the dam removal and the expected influx of sediment to the marine nearshore. The presentation will provide a short summary of the current status and preliminary results of the benthic invertebrate project, future sampling efforts, and data analyses.

Evaluating Implications of Removal of the Elwha Dams on Fish Associated With Intertidal and Shallow Subtidal Habitats in the Strait of Juan de Fuca.

Kurt L. Fresh, Anna N. Kagley, Josh Chamberlin, Larry Ward, Doug Morrill, Nichole Sather, and Kinsey Frick

NOAA Fisheries, NWFSC, Seattle, WA (KLF, AK, JC, KF), Lower Elwha Klallam Tribe, Port Angeles, WA (LW, NS), PNNL, Sequim, WA (NS)

Removal of two dams on the Elwha River, Washington will help restore natural sediment processes to the coastal environment near the river mouth. The goal of our research investigation is to evaluate responses of fish associated in shallow subtidal and intertidal habitats because these areas function as spawning and rearing habitat for many fish species, including ecologically important forage fish and federally protected species of Pacific salmon. Since 2006, our data collection efforts have focused on species composition and size distribution of the intertidal/subtidal fish community in the Eastern and Central Strait of Juan de Fuca. Potential reference sites and impacted sites (where sediment changes are expected to occur) were sampled on a monthly basis from April to September using a beach seine and collections will continue following dam removal. We found over 45 species of fish, mostly juvenile stages, using this portion of the Strait of Juan de Fuca. Species composition can be segregated into two primary groups-species occurring in the water column and species associated with the benthos. The water column species tended to be very abundant and included both migrants (e.g., juvenile salmon) and residents (e.g., surf smelt). Although the same species tended to be present each year, they often exhibited dramatic interannual variability in abundance, suggesting the importance of using multiple years of data to evaluate changes in the nearshore fish community. Impact and reference areas exhibited some significant differences and we found strong seasonality in the fish assemblage structure. Our results suggest the useful indicators of changes in the nearshore fish community following dam removal include: 1) numbers of species, 2) species diversity, 3) composition and sizes of benthic species, 4) abundance by life history stage of surf smelt, and 5) presence of migratory species such as juvenile salmon.



U.S. Geological Survey divers set up a survey transect in the Strait of Juan de Fuca. Photo by Ian Miller, Washington Sea Grant

Scuba Surveys to Assess Effects of Elwha Dam Removal on Shallow, Subtidal Benthic Communities.

Steve Rubin, Ian Miller, Nancy Elder, Reg Reisenbichler, Jeffrey Duda, Rob Pedersen, Mike McHenry, and Matt Beirne

USGS Western Fisheries Research Center, Seattle, WA (SR, RR, JD), UC Santa Cruz, Santa Cruz, CA and WA Sea Grant, Port Angeles, WA (IM), USGS Western Fisheries Science Center Marrowstone Marine Station, Nordland, WA (NE), USEPA Region 10 Environmental Cleanup Office, Seattle, WA (SS), Lower Elwha Klallam Tribe (MM, MB)

The impending removal of the Elwha River dams will affect marine habitats when sediments that have accumulated behind the dams for nearly 100 years are transported to the Strait of Juan de Fuca. Deposited and suspended sediments can have a variety of effects on marine plants and animals including burial, inhibition of propagule settlement, light reduction affecting plant growth, damage to animal gills and filter feeding structures, and alteration of interactions among species with different tolerances and responses to sediment. The initial large sediment influx from release of accumulations in the reservoirs may stress nearshore communities, but in the long run communities may benefit from reestablishment of sediment delivery from the upper watershed. Scuba surveys were initiated in 2008 to characterize nearshore biological communities prior to dam removal. Community structure in the Elwha nearshore (west Freshwater Bay to the base of Ediz Hook) was partly controlled by substrate composition and seafloor relief. Kelp density was low in sandy areas, intermediate on gravel-cobble substrates, and highest on bedrock or boulder reefs. Taxa richness (number of kelp, invertebrate, and fish taxa) was more strongly associated with seafloor relief than with substrate. Scattered boulders perched on top of mixed sand and gravel-cobble substrate usually provided relief. On average, 12 (59%) more taxa occurred where boulders were present compared to areas lacking boulders but with similar base substrate. The presence of boulders allowed species adapted to rocky reefs to coexist with species that inhabit sand and gravel-cobble substrates, thereby increasing species richness. These results highlight the importance of seafloor characteristics and suggest that different habitats and associated communities may respond differently to sedimentation. Elwha nearshore communities will continue to be surveyed during and after dam removal. Measuring community responses to short and long term changes in deposited and suspended sediments offers an unprecedented opportunity to gain insight relevant to managing these important marine resources.

Long Term Fish Use of the Elwha Nearshore.

Anne Shaffer, Chris Byrnes, Justin Brown, Tara Morrow, and Patrick Crain

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The nearshore is a complex and critical component of the Elwha ecosystem. Extending from the area of tidal influence, including the riparian zone, and out to 30 meters MLLW, the Elwha nearshore drift cell comprises approximately 11 linear miles of shoreline. Variability and sediment processes, severely disrupted due to shoreline armoring, lower river alterations, and in-river dams, are two signature features of the Elwha nearshore. Detailed information on each, and a clear understanding of the linkages between the two are needed. Fish use in the Elwha nearshore has been documented to vary with season, geomorphic landform, and species. Evidence suggests that at the drift cell scale, the Elwha nearshore is functioning at a significantly lower ecologic level for fish use than other comparable intact drift cells. Habitat function has also been documented to be partitioned across the estuary. To better understand inter-annual variation in fish use of the Elwha nearshore as well as define sediment linkages to nearshore Elwha ecological functions, we initiated a long-term fish use monitoring study of the Elwha west estuary and a comparative area. Beginning in 2005 and continuing to present we have conducted monthly beach seining in the Elwha west estuary. In this presentation we provide an overview of results to date, including seasonal trends in species richness, diversity, and densities of the Elwha west estuary, and how these results compare to observations in the comparative area. We also provide a discussion on key features of the Elwha estuary that will need to be closely monitored before, during, and following dam removal, as well as potential adaptive management for future restoration actions.

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River Physical Science II

Influence of Dams on Floodplain Dynamics and Grain Size Distributions in the Elwha River, and Expected Responses to Dam Removal.

Tim Beechie, Kris Kloehn, Sarah Morley, Holly Coe, and Jeffrey Duda

NOAA Fisheries, Northwest Fisheries Science Center, Seattle, WA (TB, KK, SM, HC), USGS Western Fisheries Research Center, Seattle, WA (JD)

The historical record of floodplain dynamics and the longitudinal pattern of grain size distributions in the Elwha River provide a baseline against which to measure key physical responses to dam removal. Based on historical aerial photography we found that the percentage of floodplain surfaces >75 years old increased through time in reaches below the dams, was relatively stable in the Quinault reference reach, and fluctuated considerably in the upper Elwha reach (above both dams). Increasing age of the floodplain indicates decreased channel dynamics and channel narrowing downstream of the dams, and recent bank full channel widths below the dams are approximately half that in the upper Elwha and Quinault reference reaches. The stable floodplain age structure in the Quinault reach reflects a long-term stability in channel migration rate, whereas fluctuations in the upper Elwha reach were primarily a result of a large landslide and dam-break flood in ~1968. Bed particle sizes in the main channel and side channels were much coarser immediately downstream of the dams than in reference reaches. However, particle sizes decreased rapidly with increasing distance from the dams, and particle sizes were within the natural range only 5 to 10 km downstream of the dams. Removal of the two Elwha dams will initially release fine sediment stored in the reservoirs, and in subsequent decades gravel bed load supply will increase and gradually return to natural levels. The release of fine sediments will initially create bi-modal grain size distributions in reaches downstream of the dams, and will likely result in considerable pool filling for a few years. Eventual recovery of natural sediment supply will likely widen channels to near reference reach widths, significantly increase lateral channel migration and erosion of floodplain surfaces, and gradually shift floodplain age distributions towards younger age classes.

Channel Evolution on the Dammed Elwha River, 1939 to 2010.

Amy E. Draut, Joshua B. Logan, and Mark C. Mastin

USGS Pacific Coastal and Marine Science Center, Santa Cruz, CA (AED, JBL), USGS Washington Water Science Center, Tacoma, WA (MCM)

Like many rivers in the western U.S., the Elwha River, Washington, has changed substantially over the past century in response to natural and human forcing. In preparation for studying the effects of dam removal, we present a comprehensive field and aerial photographic analysis of dam influence on this anabranching, gravel bed-river. Over the past century with the dams in place, loss of the upstream sediment supply has caused spatial variations in the sedimentary and geomorphic character of the lower Elwha River channel. Bed sediment is armored and better sorted than on the naturally evolving bed upstream of the dams. On time scales of flood seasons, the channel immediately below Elwha Dam is fairly stable, but progresses toward greater mobility downstream such that the lowermost portion of the river responded to a recent 40-year flood with bank erosion and bed-elevation changes on a scale approaching that of the natural channel above the dams. In general, channel mobility in the lowest 4 km of the Elwha River has not decreased substantially with time. Enough fine sediment remains in the floodplain that—given sufficient flood forcing—the channel position, sinuosity, and braiding index change substantially. The processes by which this river accesses new fine sediment below the dams (rapid migration into noncohesive banks and avulsion of new channels) allow it to compensate for loss of upstream sediment supply more readily than would a dammed river with cohesive banks or a more limited supply of alluvium. Dam removal will provide a valuable opportunity to evaluate channel response to the future restoration of natural upstream sediment supply.

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Engineered log jams installed in the lower Elwha River. Photo by Mike McHenry, Lower Elwha Klallam Tribe

Results of 12 Years of Habitat Restoration in the Lower Elwha River and Preparation for Dam Removal.

Mike McHenry and Tim Abbe

Lower Elwha Klallam Tribe, Port Angeles, WA (MM), Cardno ENTRIX, Seattle, WA (TA)

Over the last century the lower 3 miles of the Elwha River have been impacted by deforestation, channelization, dike construction and construction of the Elwha and Glines Canyon dams that interrupted the supply of wood and sediment to the lower river. In the 1990s the lower Elwha River was characterized by a single large meandering channel with little or no in-stream structure, a very coarse cobble substrate and few perennial side channels. Beginning in 1999, the Lower Elwha Klallam Tribe began to place engineered logjams (ELJs) into the river to create pools with complex cover to provide refugia for both juvenile and adult salmonids. The ELJ restoration strategy expanded as the ELJ structures demonstrated their ability to partition shear stress and locally decrease the bed material grain size to sizes more conducive to spawning, an effect particularly of interest when we were uncertain about when the dams would be removed. As of 2011 a total of 44 ELJs have been constructed in the river between River Mile 1 and 3. The ELJ placements have induced some very positive changes in the river that include: 1) creation and maintenance of pools, 2) an increase in shaded complex cover, 3) reduced bed material grain size, 4) retention of sediment within bars and islands created by the structures, 5) an increase of invertebrates where ELJs have been placed, 6) retention of more organic material, 7) increases in local water elevations that have improved floodplain and side channel connectivity, 8) transformation from a single thread to an anabranching channel, and 9) triggering of natural wood recruitment by deflection of river flow and creation of new channels.

The Importance of Floodplain Channels in the Elwha River Dam Removal.

George Pess, Mike McHenry, Sarah Morley, Martin Liermann, John McMillan, Keith Denton, Tim Beechie, Jeffrey Duda, Roger Peters, and Sam Brenkman

NOAA-NWFSC, Seattle, WA (GP), Lower Elwha Tribe (MM), NOAA-NWFSC, Seattle, WA (SM), NOAA-NWFSC, Seattle, WA (ML), NOAA-NWFSC, Seattle, WA (JM), NOAA-NWFSC, Seattle, WA (KD), NOAA-NWFSC, Seattle, WA (TB), USGS Western Fisheries Research Center, Seattle, WA (JD), USWFS, Lacey, WA (RP), NPS-ONP Port Angeles, WA (SB)

On September 17 of 2011, a 2.5-year deconstruction of two long-standing, high-head dams will begin on the Elwha River of the Olympic Peninsula, Washington State. Over the past decade, a variety of ecosystem related information (e.g., fish, riparian, in-stream habitat, and stream productivity) has been collected in the Elwha River basin to establish baseline conditions prior to one of the largest watershed and salmon restoration projects in North America. The design of these studies is based upon the geomorphic template of the watershed, as different channel types are expected to respond differently to the large amount of sediment that will be released as a result of dam removal. For example, we anticipate that floodplain channels will attenuate the impacts of sediment and provide biological refuges after dam removal. Over the last decade the group of scientists from several state, federal, and tribal organizations have collaborated to identify the most important questions and develop adequate study designs that can answer these questions such as how will salmon populations respond to the removal of large-scale, long-term barriers to migration and utilize these floodplain channels? How will these same populations react to the large amount of sediment that will be released in combination with the large amount of pristine habitat that will be re-connected? Our ultimate goal is to quantify the ecological "signal" following dam removal in the Elwha River basin, in order to better tell the story of this unique watershed restoration and share critical findings with other dam removal projects.

Vegetation Science

Potential Vegetation Development in Two Drained Reservoirs After Dam Removal on the Elwha River: Implications for Revegetation.

Joshua Chenoweth, Steve Acker, Kern Ewing, Rebecca Brown, Pat Shafroth

Olympic National Park, Port Angeles, WA (JC), Olympic National Park, Port Angeles, WA (SA), University of Washington, Seattle, WA (KE), Eastern Washington University, Cheney, WA (RB), USGS Fort Collins Science Center, Fort Collins, CO (PS)

The removal of Glines Canyon and Elwha dams will expose over 300 hectares of land. The disturbance caused by 100 years of inundation and sedimentation is severe. The reservoirs have accumulated more than 19 million m^3 of fine and coarse-textured sediments. Dam removal will expose valley slopes covered in fine sediments, newly deposited terraces of coarse sediments, and developing floodplains. On most of these surfaces we anticipate the rate of recovery to be slow due to the size of the disturbed landscape and the lack of developed soil, seed banks, or other biological legacies. The density and diversity of seed rain should be high within 50 meters of the forest edge but is expected to diminish with distance. Species that regenerate successfully on valley slopes will need to be capable of establishing on fine sediments 0.3-1.5 meters deep, such as graminoids. On newly formed coarse terraces 6 to 18 meter deep, regeneration likely will be limited by sparse seed rain and low water availability. In the future floodplain, hydrochorous seed dispersal, water availability, and the deposition of vegetative fragments of willow and cottonwood from upstream should facilitate natural regeneration. At sites expected to regenerate slowly, a variety of revegetation prescriptions can accelerate native plant establishment. For example, native grasses will be seeded on fine sediments. During dam removal, in situ growth trials will determine which native woody species will succeed on fine-textured sediments. Species with fleshy fruits will be planted to attract birds, enhancing zoochorous seed rain. Large woody debris abundant along the dewatered shorelines will be re-distributed to create safe sites for seedlings. Dense plantings of fast-growing, early seral woody species will be planted to create the foundation for future forest development (facilitation patches). This project provides an opportunity to test revegetation methods derived from our understanding of plant succession.

Seed Rain and Revegetation of Exposed Substrates Following Dam Removal on the Elwha River.

James Michel, James Helfield, and David Hooper

Huxley College of the Environment, Western Washington University, Bellingham, WA

Scheduled to begin in 2011, the removal of two dams on the Elwha River, Washington, will be one of the largest dam removal and river restoration projects undertaken in the United States. One challenge associated with this project is to understand how exposure and downstream deposition of sediments presently detained behind the dams will influence patterns of revegetation and invasive species colonization following dam removal. We conducted two greenhouse experiments assessing the potential effects of reservoir sediments on germination success and growth of (1) propagules dispersed naturally via seed rain, and (2) seeds of selected native and invasive species. Observed summer seed rain density was relatively low (<125 seeds m^{-2}). This suggests slow recolonization in the initial years following dam removal, although these results may have been influenced by sampling methods and timing. In the selected species experiment, four out of five tested species exhibited reduced germination and growth on fine reservoir sediments, while the invasive forb *Cirsium arvense* was unaffected. Though reduced compared to more typical alluvial sediments, germination and growth of the natives *Artemisia suksdorfii* and *Rubus parviflorus* were comparable to that of *C. arvense* on reservoir sediments. These native species may be useful for revegetating exposed sediments. However, depending on such factors as source population sizes, seed production and dispersal rates, growth rates, water

A biologist prepares plant specimens for identification and pressing. Photo by Pat Shafroth, U.S. Geological Survey availability and competition during establishment, control of *C. arvense* and other exotics in the years following dam removal may be necessary to prevent a relative increase in invasive species populations on the new post-dam substrates.

Structure, Composition, and Diversity of Floodplain Vegetation Along the Elwha River.

Patrick B. Shafroth, Chanoane Hartt, Laura G. Perry, Jeffrey B. Braatne, Rebecca L. Brown, Aaron Claussen

U.S. Geological Survey, Fort Collins Science Center, Fort Collins, CO (PBS, LGP), University of Idaho, Department of Fish and Wildlife Resources, Moscow, ID (CH, JBB), Colorado State University, Department of Biology, Fort Collins, CO (LGP), Eastern Washington University, Department of Biology, Cheney, WA (RLB, AC)

Floodplain vegetation dynamics and diversity in the Pacific Northwest are linked to flows of water, and fluxes of sediment and large woody debris. Dam removal on the Elwha River will alter these system drivers, inducing changes to floodplain vegetation. To evaluate these changes, we collected baseline data between 2003 and 2010 along five cross-valley transects in each of three reaches of the Elwha: above both dams (reference), between the dams, and downstream of both dams. Along each transect, we randomly selected nested tree, shrub, and herbaceous vegetation quadrats within different vegetation types and sampled the vegetation composition, structure, age, and diversity. From 2003-2005, we sampled 138 tree, 275 shrub, and 120 herbaceous/diversity plots. Most plots were resampled in 2010. Environmental data included transect topography, quadrat elevations, and surficial soil particle size. We encountered approximately 13 tree, 30 shrub, and 150 herbaceous species along the transects. Young bar surfaces (5-20 yrs) were dominated by *Salix* spp., *Alnus rubra*, and *Populus trichocarpa* and had the highest species richness. Young floodplains (<80 yrs) comprised much of the Elwha bottomland and were generally dominated by *A. rubra* and sometimes by *P. trichocarpa*. High floodplain surfaces and terraces (>80 yrs) were often dominated by *Acer macrophyllum* with an understory of *Acer circinatum* and *Abies grandis*. P*seudotsuga menziesii* occurred on young and older floodplains. Substantial geomorphic change has occurred recently within the mostly-braided reference reach, resulting in a large number of young *Salix*, *Alnus*, and *Populus* patches, as well as extensive, relatively unvegetated bars. The reach between the dams is quite stable with relatively few young vegetation patches and abundant, stable floodplain surfaces. The reach below both dams shows moderate channel and floodplain dynamics, especially as the valley widens in and near the delta. We conclude with predictions and hypotheses regarding post dam removal vegetation responses.

Predicting Spread of Invasive Exotic Plants Into De-watered Reservoirs of the Elwha River.

Andrea Woodward, Christian Torgersen, Joshua Chenoweth, Katherine Beirne, and Steve Acker

USGS Forest and Rangeland Ecosystem Science Center, Seattle, WA (AW, CT), Olympic National Park (JC, KB, SA)

The potential for dispersal of exotic invasive plants into the de-watered reservoirs following removal of two dams on the Elwha River, and consequent inhibition of native vegetation restoration, is of great concern. Because the reservoirs are not currently vegetated and adjacent locations of exotic plants have been treated, we focused on predicting long-distance dispersal rather than diffusive spread away from parent plants. We considered long-distance dispersal vectors (wind, water, birds, beavers, ungulates, and users of roads and trails) in relation to seven focal invasive taxa (*Cirsium arvense*, *Cytisus scoparius*, *Geranium robertianum*, *Hypericum perforatum*, *Lathyrus sylvestris*, *Phalaris arundinacea*, and *Rubus* spp.) These taxa were selected because they have great potential to do environmental harm and sufficient sample size in the area to support analysis. Using information about the surveyed or modeled spatial distribution of invasive species, vectors, and environmental variables we determined potential source areas and species-specific environmental relationships. We then identified high-priority areas within Olym-

pic National Park for Park staff to treat prior to dam removal, and areas outside of park boundaries that require collaboration with the community or other agencies to minimize the spread of invasive species. We also predicted areas of the dewatered reservoirs at greatest risk for establishment of invasive exotic plants following dam removal.

Poster Presentations

Cultural/Human

Valuing Ecosystem Service Benefits From Restoration Along the Elwha River.

Colleen Donovan, Anthony Dvarskas, Peter Edwards, David Chapman, Megan Lawson

NOAA Assessment and Restoration Division, Sandy Hook, NJ (AD), NOAA Office of Habitat Conservation, Silver Spring, MD (PE), Stratus Consulting, Boulder, CO (CD, DC, ML)

NOAA's Office of Habitat Conservation (NMFS) and Assessment and Restoration Division (NOS) have embarked on a pilot project to identify and value ecosystem services associated with the Elwha River Dam removal and floodplain habitat restoration. This study will explore the linkages between ecological functioning and societal values for ecosystem services. NOAA, in collaboration with project partners, is in the process of refining appropriate scenarios for describing current ecological functions and expected changes to those functions based on the proposed restoration activities. A choice experiment approach will be used to estimate consumer surplus associated with changes in key ecosystem services and environmental quality as a result of the restoration effort. The survey instrument is being developed and will integrate ecological and economic information into the design. The selection of appropriate ecosystem service attributes including, among others, wetland area, salmon production, and recreational opportunities, is currently underway. This poster will highlight the survey design elements being developed to elucidate public preferences for ecosystem services associated with the restored river and floodplain. The poster will focus on the attribute selection and policy scenario development steps, including linkages between ecological production function changes and ecosystem services endpoints. The study is expected to provide answers for relevant policy questions such as the effect on the public's welfare from dam removal and floodplain restoration, as well as the effect on potential resource users' welfare from the changes in ecological function and cultural and recreational opportunities, including the importance of tribal activities.

Results of Archeological Investigations Related to the Elwha River Restoration.

Matthew Dubeau and Davina Miller

Olympic National Park, Port Angeles, WA

From the restoration of natural phenomena in the Elwha River Valley an opportunity has arisen to investigate the valley's cultural history through archeology. In 2009 Northwest Archaeological Associates surveyed 209 acres of land along the Elwha River that will likely be impacted by removal of the Elwha and Glines Canyon dams. During the course of these investigations, three previously documented archeological sites were re-evaluated and seven new sites were recorded. These sites reflect historic use of the Elwha River Valley associated with dam construction and operation, as well as prehistoric use of the Valley by Native Americans. Six of these sites are recommended eligible for the National Register of Historic Places. Historic sites associated with dam construction, which contain a variety of domestic and industrial materials, can provide insight into daily life in construction worker camps in the early twentieth century, as well as the technological constraints of industrial construction during this period. Prehistoric sites in the interior Olympic Peninsula are primarily composed of the byproducts of stone tool manufacture, called lithic debitage. Formed tools, such as projectile points, knives and scrapers, are typically much less common. The sites recorded during the course of this study exhibit a high degree of variability in terms of overall site area, artifact density, artifact type, and stone tool material type. Prior to this project, discovery of sites in river valleys had been fleeting due to poor ground visibility and high soil deposition. Focused subsurface survey of the Elwha watershed has enhanced our ability to locate archeological sites in relation to dynamic river valley landforms.

Recreational Benefits of Rivers Restored Through Dam Removal.

Thomas O'Keefe and Megan Hooker

American Whitewater, Seattle, WA (TOK), and Portland, OR (MH)

Over the past five years a number of dams have been removed throughout the Pacific Northwest, reconnecting riparian ecosystems that include the Clark Fork (MT), Bear (ID), Rogue, Sandy, and Hood Rivers (OR), and Trout Creek (WA). The upcoming removal of Condit Dam on the White Salmon and the Elwha and Glines Canyon Dams on the Elwha River will restore additional river miles in the region. While the fishery and ecosystem benefits of restoring these rivers have been well documented, these projects also afford significant recreational benefits. American Whitewater has completed an overview of these projects throughout the region, which quantifies project size as a function of mean annual discharge relative to reservoir volume. Our overview also includes a photographic record of the dams and the resulting river channel following removal. Additionally, while dams throughout the Pacific Northwest and the country are coming down, many are here to stay. Full restoration through dam removal may not be an option in these cases, however there is still opportunity for restoration through modifying operating regimes. To illustrate this, we will present a conceptual model that demonstrates how recreational flows, fishery flows, and geomorphic process flows have been integrated to benefit river health. Overall, our review and related poster offers insight into the benefits of river restoration efforts throughout the region and how a comprehensive case, which includes recreation, can be built for dam removal or improved operations.

Deploying a beach seine in the Elwha River estuary. Photo by Pat Shafroth, U.S. Geological Survey

See link "http://www.americanwhitewater.org/content/Project/view/id/elwha/"

Using Archaeology at the Tse-Whit-Zen Site (Port Angeles) to Examine Animal and Human Response to Earthquakes and Other Environmental Changes

Virginia L. Butler, Kathryn A. Wojcik, Kristine M. Bovy, Sarah C. Campbell, Michael A. Etnier, Sarah L. Sterling

Portland State University, Portland, OR (VLB, KAW, SLS), University of Rhode Island (KMB), Western Washington University, Bellingham, WA (SCC, MAE)

Over the last decade, anthropological research on the impact of catastrophic environmental events has evolved from a relatively simplistic approach that assumed natural hazards such as earthquakes and volcanoes are disasters, to a more complex understanding of the social factors that affect cultural response such as food getting, settlement pattern, population density, sociopolitical complexity, technology, and experience with the event. Archaeology offers a unique opportunity to explore societal response to past environmental changes, through study of fine-scale changes in animal bone records, compared against independent records of environmental changes. The Tse-whit-zen archaeological site in Port Angeles provides an excellent test case to illustrate these values. The site was excavated with fine geo-stratigraphic control, faunal preservation is outstanding, multiple houses were documented that show human occupation for varying times over the past 2000 years, and regional seismic records show that the environment experienced sizeable earthquakes and more subtle changes (such as climate change associated with the Medieval Climate Anomaly, and Ediz Hook development). Our research team is in the beginning phases of a pilot project to study the fauna (fish, birds, mammals, shellfish) from this important site to better understand the dynamic linkages between the environment and humans/animals. Besides the scientific value in studying the degree of resilience of people and animals in coping with drastic and more subtle environmental changes, our project hopes to contribute to long-term goals of the Lower Elwha Klallam Tribe in developing a museum and cultural center that honors the past and takes to the future the records and stories from this exceptional archaeological site.

Communicating Science: Bridging the Gap

John R. McMillan

NOAA Northwest Fisheries Science Center, Seattle, WA.

Photography provides a means of distilling the otherwise complex results of contemporary ecological science into images that capture the essence and value of river restoration. Although quantitative science is certainly the most robust way to assess pre- and post-river restoration conditions, it is also difficult for non-scientific audiences to quickly visually assess and grasp the meaning of complex tables and figures. River restoration projects are ideal candidates for photographic documentation because they offer the opportunity to record pre- and post-restoration river characteristics and salmon abundance and diversity. Here photography was used as part of the pre- and post-dam removal monitoring on the Elwha River dam removal project. The photography focuses on documenting the small populations of spawning adult salmon that have survived in the lower five miles of river, waiting for two high dams to be removed and subsequent access to an additional 75 miles of available habitat. Despite a truncated distribution, reduced abundance and diversity, the fish have remained resilient in a consistently tenuous situation. During the fall of 2009 the salmon returned in relative abundance to the section of the lower Elwha River known as the Hunt Channel. For a brief period of time the Elwha was — being filled with spawning salmon and brimming with underwater life — as it was for thousands of years prior to the dams. Combining these types of images with data provides a means of integrating the beauty of ecology into the science of restoration.

Lower Elwha Klallam Tribe Chairwoman Francis Charles and Billy Frank celebrate during the dam removal ceremony, September 17th, 2011. Photo by John Gussman, Doubleclick Productions.

Leveraging River Restoration for Geoscience Education: The Elwha Science Education Project

Robert S. Young

Program for the Study of Developed Shorelines, Western Carolina University, Cullowhee, NC

Native Americans are poorly represented in all science, technology and engineering fields. This under-representation results from numerous cultural, economic, and historical factors. The Elwha Science Education Project (ESEP), initiated in 2007, strives to construct a culturally-integrated, geoscience education program for Native American young people through engagement of the entire tribal community. The ESEP has developed a unique approach to informal geoscience education, using the Elwha River Restoration Project as a centerpiece. Environmental restoration is an increasingly important goal for tribes. By integrating geoscience activities with community tradition and history, project stakeholders hope to show students the relevance of science to their day-to-day lives. The ESEP's strength lies in its participatory structure and unique network of partners, which include Olympic National Park; the non-profit, educational center Olympic Park Institute (OPI); a geologist providing oversight and technical expertise; and the Lower Elwha Klallam Tribe (LEKT). Lower Elwha tribal elders and educators share in all phases of the project, from planning and implementation to recruitment of students and discipline. The project works collaboratively with tribal scientists and cultural educators, along with science educators to develop curriculum and best practices for this group of students. Use of hands-on, place-based outdoor activities engage students and connect them with the science outside their back doors. Preliminary results indicate that most (75% or more) students were highly engaged approximately 90% of the time during science instruction. Recruitment of students has been particularly successful, due to a high degree of community involvement. Preliminary evaluations of the ESEP's outcomes indicate success in improving the outlook of the Tribe's youth towards the geosciences and science, in general. The project has also helped to raise the high school graduation rate for LEKT young people to record levels.

Nearshore

The Elwha Nearshore: An Overview.

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The Elwha nearshore encompasses approximately 12 linear shoreline miles including the Elwha drift cell which stretches from the west entrance of Freshwater Bay east to the tip of Ediz Hook. It consists of five distinct geomorphic habitat landform types of lower river and estuary, embayed shoreline, feeder bluffs and spit. It is defined as extending from the area of tidal influence, including the riparian zone, out to 30 meters Mean Lower Low Water (MLLW) depth. The Elwha River is one of the dominant rivers on the Olympic Peninsula and has functional linkages to the Strait of Juan de Fuca including providing rearing and migration for juvenile salmon and migration and spawning habitat for forage fish. The Strait is a major conduit linking coastal regions to the inner Salish Sea. Sediment processes from feeder bluffs and the river are defining features of the Elwha nearshore. These processes are currently disrupted by the dams, shoreline armoring and diking, which significantly disrupt sediment and wood delivery to the nearshore. Although approximately 7.5 million cubic meters of coarse and fine sediment is expected to be delivered to the Elwha nearshore after dam removal, this will only partially restore the function of the nearshore. Additional restoration plans such as augmenting the Elwha bluffs to optimize sediment delivery, restoring hydrologic connectivity to the estuary, and incorporating adaptive management actions are necessary for optimal restoration of the nearshore and successful recovery of the sediment starved central Strait of Juan de Fuca and the ecosystem it supports.

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Geomorphic Processes and Potential Restoration Actions in the Elwha River Estuary and Nearshore

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The last century has brought about dramatic loss of critical habitat in the Elwha River estuary and nearshore due to the construction of the Elwha and Glines Canyon dams, straightening of the river channel and placement of levees in the floodplain. These modifications resulted in beach erosion, coarsening river and shore substrates, decreased off-channel habitat, and simplification of tidal networks. Changes in the estuary were analyzed in the context of anticipated geomorphic response to dam removal and potential restoration opportunities. Beach profile surveys from 1996 to 2010 reveal that while overall trends are toward erosion, the foreshore position is very dynamic. Within cycles of accretion and erosion, large portions of river sediment discharge moved through the nearshore and into the Strait of Juan de Fuca, with a net loss of 51,000 cubic yards of material. The review of lower river channel dynamics was based on historical aerial photographs since 1939, 2009 LiDAR data, and previous channel migration studies. Overall lateral channel movement since 1939 was in the order of tens to hundreds of meters. Between 1939 and 2009 average channel width in the lower river decreased by 55 percent and outlet width was reduced by 65 percent due to levees and roads in the floodplain. Multiple historical river outlets to the shore were limited to a single outlet and the number of active side channels decreased. Restoration concepts were developed to address the cumulative effects of human alterations, to minimize short-term negative impacts during the initial geomorphic response period to dam removal and to make optimal use of the newly available upstream sediment and wood supply to the estuary and nearshore. The suite of options included activation of additional distributary river outlets to the delta, forested buffers for floodplain levees, engineered log jams, beach nourishment and structural driftwood enhancement.

Nearshore Biotic

Methods Used to Assess Effects of Elwha Dam Removals on Shallow, Subtidal Benthic Communities

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The impending removal of the Elwha River dams will affect marine habitats when sediments that have accumulated behind the dams for over 95 years are transported to the Strait of Juan de Fuca. To monitor changes in Elwha nearshore communities, a survey method was needed to quantify benthic macroalgae, macroinvertebrates, and fish, as well as substrate composition and seafloor relief. We adapted survey protocols developed by the Partnership for

The mouth of the Elwha River. Photo by John Gussman, Doubleclick Productions

Interdisciplinary Studies of Coastal Oceans (PISCO) for monitoring ecosystems associated with rocky reef habitats. Data were collected by scuba divers on 30 meter-long transects. Organisms were counted in swaths of fixed width to estimate the density of conspicuous, solitary and mobile invertebrates as well as specific macroalgae and fish. Data on presence or absence at uniformly spaced points were collected to estimate percent cover of encrusting or colonial species as well as sea floor attributes such sediment grain size. Surveys were initiated in 2008 at sites near the Elwha River mouth and at more distant reference sites expected to be minimally affected by dam removal.

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See link "http://pubs.usgs.gov/sir/2011/5120/seaLife/

Nearshore Physical

Coarse Sediment Movement on the Mixed Grain Size Beach of the Elwha Delta.

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The removal of two dams on the Elwha River is expected to deliver between 153,000 and 1.1 million m^3 of coarse sediment (sand, gravel and cobble) to the lower river and coastal zone within a few years. Predicting the transport of this material is important to understanding how the removal of the impoundments may influence beach and delta morphology. This investigation utilized a novel application of Radio Frequency Identifier (RFID) technology to track coarse sediment on the mixed grain size beach of the Elwha delta over weeks to months. Clasts implanted with radio frequency identifier (RFID) tags were released at an elevation of 1.9 m (MLLW) in August of 2009 at three sites on the Elwha delta and surveyed approximately monthly for >3 months. The distance travelled of tagged sediment over the study period varied from >500 m to < 1 m. Clast movements are paired with sediment characteristics across samples to evaluate the role of breaking wave angle in beach sediment transport.

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Baseline Observations of Beach Cross-Shore Topography and Sediment Grain-Size Distribution in the Elwha and Dungeness Drift Cells.

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Beach cross-shore topography and sediment grain-size distribution play an important role in habitat forming processes for many species of marine fish and invertebrates. Construction of two dams on the Elwha river and shoreline armoring of coastal bluffs between the Elwha River and Ediz Hook have reduced the supply of sediment to the nearshore resulting in shoreline erosion and coarsening of beach sediments. The pending removal of the two Elwha dams will likely restore a portion of the historic sediment supply to nearshore beaches. Evaluation of the role that future contributions of sediment from the Elwha River may play in changing beach topography and sediment size requires pre-dam removal observations of seasonal changes in beach topography and sediment grain-size distributions. Seasonal changes in beach topography and grain-size occur from seasonal changes in wind intensity and direction which in turn affect the size and direction of waves that transport sediment both across and along beaches. This study observes bi-monthly changes in cross-shore beach topographic profiles and grain-size distributions at eight respective locations in the Elwha and Dungeness drift cells between July, 2010 and July, 2011. Observation sites are distributed across a range of drift cell conditions (source, transport and sink) and include armored and un-armored beach profiles. The resulting data demonstrate the range and frequency of seasonal changes in beach profiles and grain-size distributions across the Elwha and Dungeness drift cells and will help inform a companion invertebrate study (Andersen et al. 2011) examining the relationships between nearshore sediment dynamics and invertebrate community composition. These data may also provide useful baseline observations with which to evaluate future contributions of sediment to the nearshore from the removal of two dams on the Elwha River.

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NOAA fisheries biologists sample juvenile fish in a side cahnnel of the Elwha River. Photo by John Gussman, Doubleclick Productions.

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The Coastal River Plume of the Elwha

Jonathan Warrick and Andrew Stevens

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The initial sediment dispersal from the Elwha River to the coastal waters of the Strait of Juan de Fuca will be influenced by the patterns and dynamics of the river's buoyant plume. The Elwha River provides a unique opportunity to study the effects of coastal topography on a buoyant plume, because it discharges into the Strait of Juan de Fuca on the western side of its deltaic headland. Here we show that this headland induces flow separation and transient eddies in the tidally-dominated currents (O(100 cm/s)), consistent with other headlands in oscillatory flow. These flow conditions are observed to strongly influence the buoyant river plume, as predicted by the "small-scale" or "narrow" dynamical classification using Garvine's (1995) system. Because of the transient eddies and the location of the river mouth on the headland, flow immediately offshore of the river mouth is directed eastward twice as frequently as it is westward. This results in a buoyant plume that is much more frequently "bent over" toward the east than the west. During bent over plume conditions, the plume was attached to the eastern shoreline while having a distinct, cuspate front along its westernmost boundary. The location of the front was found to be related to the magnitude and direction of local flow during the preceding O(1 hr), and increases in alongshore flow resulted in deeper freshwater mixing, stronger baroclinic anomalies, and stronger hugging of the coast. During bent over plume conditions, we suggest that significant convergence of river plume water toward the frontal boundary occurred in the initial 1 km from the river mouth. These results show how coastal topography can strongly influence buoyant plume behavior, and they should assist with understanding initial coastal sediment dispersal pathways from the Elwha River during the pending dam removal project.

A biologist processes a salmon carcass sample at the Elwha River weir. Photo by Jeffrey Duda, U.S. Geological Survey

River Biotic

Update on the Elwha River Mussel (*Margaritifera falcata*) Populations.

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pia, WA (MH), The Nature Conservancy, Lansing, MI (LC), Lower Elwha Klallam Tribe Fisheries, Port Angeles, WA (LW)

The Elwha River was surveyed in 2008 for the presence of freshwater mussels, which are potentially the largest invertebrates in the river. Several small remnant populations of the western pearlshell *Margaritifera falcata*, an environmentally sensitive species which has a life cycle closely tied to Chinook salmon, were found in the lower river where some salmon still migrate, and many more were found in a side stream near the fish rearing ponds. At the time, the large majority of the mussels in the side stream were in imminent danger of destruction due to ongoing construction related to dam removal. In fall 2008 9765 of the side stream mussels were moved to several small tributaries of the lower river by a team from the Lower Elwha Klallam Tribe, Olympic National Park, Washington Department of Fish and Wildlife, Jamestown S'Klallam Tribe, USGS, USFWS, Western Washington University, Oregon State University, Peninsula College, and Walla Walla University. The small remaining mussel populations in the river are vulnerable to scour and sedimentation once dam removal starts. In 2010, as many individuals as could be located (121 individuals) from the largest and likely oldest of these populations just below Elwha Dam were removed from the river and transplanted to one of the tributaries the earlier population had been moved to. Some mussels remain both in the main channel of the river and in the side stream near the fish rearing ponds. Both these and the transplanted populations will be monitored over the next several years as the river system reverts to its free-flowing state.

Thermal Regimes and the Distribution and Abundance of Native Bull Trout and Nonnative Brook Trout Prior to Dam Removal in the Elwha River Ecosystem.

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In anticipation of the Elwha River dam removals, we have been monitoring presence and abundance of fishes with a focus on native bull trout (a threatened species) and nonnative brook trout. How do these species influence each other? How will they respond to changes in the river's floodplain and colonization by salmon after more than a century of isolation? What habitats are most important for these species? To set the stage for addressing these questions and provide a baseline for evaluation of ecosystem responses to dam removal, we have completed an extensive survey of fish and habitat conditions in the river and its associated floodplain and tributaries. Study sites within the system include locations below both dams, between the dams, and upstream of dams. Fish sampling has involved a combination of electrofishing and daytime snorkeling. Fish surveys in 2009 and 2010 covered 59 sites sampled with repeat surveys to estimate probabilities of detection, presence, and abundance. We have also modeled relationships between these estimates and habitat conditions and potential for biotic interactions among species. In addition to fish, we analyzed water temperatures to evaluate their sensitivity to atmospheric versus hydrological influences. Our preliminary results suggest that temperatures in larger mainstream and fluvial floodplain channels are less sensitive to atmospheric influences, whereas tributaries are highly sensitive. In contrast to these habitat types parafluvial floodplain channels show high variability in their sensitivity. We suspect that subsurface influences often dominate the

The site of the former Elwha Dam on January 13th, 2012. Photo by John Gussman, Doubleclick Productions thermal regime of these habitats (e.g., hyporheic or groundwater fluxes). The relationship between floodplain habitats and thermal sensitivity, and influence of temperature on fish has helped us understand bull trout and nonnative brook trout in the system and set the stage for future evaluations of how the river, its thermal regime, and its fish fauna may respond to changes related to dam removal.

Imaging Sonar Based Escapement Estimation for Small Salmon Populations: The Elwha River as a Case Study.

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A piece of large woody debris on a beach near the Elwha River. Photo by John Gussman, Doubleclick Productions

Stock specific escapement estimates are an essential part of salmon and steelhead management in the Pacific Northwest. Popular visual escapement methods such as Area-Under-the-Curve (AUC), peak count expansion, and redd counts are widely implemented but are believed to often have high measurement error. Here we investigate the feasibility of imaging sonar-based escapement estimates for small salmon and steelhead populations in Washington State. While imaging sonar has been used for escapement estimation for large high value populations in Alaska and British Columbia for over a decade, it is not immediately obvious that this technology will be cost effective for small populations. However, with a steady improvement in the necessary technology and decrease in costs relative to other approaches, we believe that this escapement estimation approach may provide an attractive alternative for some small populations. We use the Elwha River as a case study along with characteristics of several representative Washington Rivers to investigate this hypothesis. Factors we consider include, 1) errors introduced through species identification in rivers with overlapping run timing for multiple species, 2) the availability of sites with good acoustic characteristics, access, security, and power options, 3) the estimated error in sonar based escapement estimates relative to the current visual approaches, and 4) the estimated cost of a sonar based approach relative to the alternatives. While the cost of buying and operating sonar for escapement estimation still limits its applicability in smaller systems, for cases where traditional methods fail (e.g., high turbidity during spawning) or the stock is of particular importance (e.g. index or ESA listed stocks) sonar may provide an attractive alternative.

Otolith Analysis of Chinook Salmon in the Elwha River Prior to Dam Removal.

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Puget Sound Chinook salmon have declined to precariously low levels (ESA threatened status) due to a variety of perturbations, including estuarine and coastal development. Juvenile fall Chinook salmon utilize a number of habitats as they migrate from their freshwater rearing areas to the open ocean. Estuaries are recognized as one important habitat because they provide a migratory corridor, protection from predators, and opportunity to forage, grow and adapt to seawater. However, the importance of the Elwha River estuary and nearshore to Chinook salmon populations is relatively unknown. We used otolith microstructure to examine the importance of the Elwha River estuary to juvenile Chinook by acquiring baseline information on habitat utilization, growth, and residence time prior to dam removal. The otolith microstructure revealed three distinct areas early in development associated with hatch, emergence and first feed, and two distinct areas associated with migration into estuarine and nearshore habitats. Growth, measured indirectly through mean increment width on the otolith, revealed an increase of 27 percent from freshwater habitat (3.20 microns) to lower estuary habitat (4.06 microns). The average size of juvenile Chinook salmon increased as they migrated successively among freshwater, estuary, and nearshore environments. The average estuarine residence time determined from Chinook captured in the nearshore habitat was 25 days. Wild-origin fish were mostly using the lower estuary habitat, whereas hatchery fish were mostly using nearshore habitat. Once in the Strait of Juan de Fuca, Elwha hatchery and wild juveniles migrated east and west. Seventy-six percent of the adult Chinook collected from the lower Elwha River in 2008 and ninety-six percent in 2009 were identified as hatchery fish (thermally marked otoliths).

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Carbon and Nitrogen Stable Isotopes in Elwha River Aquatic Food Webs Prior to Dam Removal

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We measured carbon and nitrogen stable isotopes ratios in Elwha River aquatic food webs to document the effects of two dams prior to their removal. Stable isotope methods are commonly used in freshwater and terrestrial ecosystems to document the movement and magnitude of marine-derived nutrients derived from spawning salmon and their carcasses. Our approach was two-fold. We conducted an assessment of stable isotope ratios in tissues of primary producers, benthic macroinvertebrates, and fish from areas above, between, and below the dams. We also conducted a field experiment by measuring stable isotopes in these same trophic groups before, during, and after the addition of salmon carcasses in side channels between the two dams and downstream of the lower dam. In the mensurative study, we found that in sites where salmon still have access, δ 15 N was significantly higher in fish, stoneflies, black flies, periphyton, and macroalgae. Fish and stoneflies were also enriched in δ13C, but these values were more variable than for δ 15N. For some taxa, there were also differences among areas between and above the dams – sections of the river that lack salmon – suggesting that other factors may be structuring longitudinal profiles of isotope ratios in the Elwha River aquatic food webs. In the carcass addition study, we observed elevated δ 15 N values in treatment reaches for multiple species, with the timing, magnitude, and persistence of this signal varying by trophic position. Periphyton δ 15 N was significantly elevated 1 and 2 months post carcass placement, algae-grazing mayflies from 1-3 months post placement, predatory stoneflies 2-3 months post placement, and juvenile Oncorhynchus mykiss 3 months post. The biggest increase in δ 15 N was observed for periphyton with values twice as high as for reference reaches, while O. mykiss δ 15 N increased 30%. The removal of these dams and the return of salmon populations to their former spawning grounds could alter the stable isotope values that we documented Additional studies following salmon recolonization will facilitate a more mechanistic understanding of how marine nutrients affect freshwater productivity, and do so in the context of monitoring a major watershed restoration effort.

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River Physical

Elwha River Sediments: Phosphorus Characterization and Dynamics under Diverse Environmental Conditions

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Two large dams on the Elwha River, Olympic Peninsula, Washington, are scheduled for removal in 2011. Sediments that have accumulated in reservoirs behind these dams will be exposed to new physical and chemical conditions that will affect P distribution and availability in the oligotrophic river system. Coarse sediments from a reservoir delta and fine sediments from a reservoir bottom were analyzed for physical and chemical characteristics relevant to P availability. The fine sediments had 20 to 200% greater concentrations of C, N, amorphous Fe, Fe-bound P, Ca-bound P and organic P. Both sediment types had relatively low P concentrations compared with published values for eutrophic systems. Both fine and coarse sediments immobilized large quantities of added P, but fine sediments maintained dissolved P concentrations at half the level of coarse sediments. A 300 h incubation of sediments under diverse environmental conditions indicated released P was not affected by short-term exposure to oxygen. For coarse sediments, P release was greater in freshwater than saltwater throughout the incubation, for fine sediments this occurred only initially. Results of sediment characterizations are important in understanding potential post-dam conditions. Release of P from eroded and resuspended sediments will likely be of sufficient magnitude to increase downriver P concentrations and stimulate primary production of the periphyton. Ca-bound P in non-eroded dewatered sediments will likely be sufficient to meet the P demand of vascular vegetation that establishes in the new riparian zone.

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Distribution, Density, and Potential Functional Linkages of Large Woody Debris in the Elwha Nearshore.

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Large Woody Debris (LWD) is an important part of the marine ecosystem in that it is a base component of physical processes that form critical habitats for numerous fish species such as endangered salmon and forage fish including smelt and sand lance. The Elwha drift cell, a naturally sediment rich system, has been sediment starved for close to a century as the dams, dikes and shoreline armoring along it have kept back not only sediment, but also the large wood that would have naturally made its way into the Strait of Juan de Fuca. Little is currently known about large wood in the nearshore system, including the Elwha. Given the upcoming dam removals there is a need to define baseline parameters of LWD in Elwha and comparable drift cells to establish benchmarks for what restoration might look like, and make predictions of the Elwha's future state. This study looks at the function of the current distribution and density of LWD deposition on riparian and nearshore ecosystems in the Elwha. This study aims to examine unmodified comparable landforms as well as accessing the historical information available about the Elwha's pre-dam state. Questions I am addressing are: 1.How much nearshore habitat would a normal volume of

The former Lake Aldwell reservoir reverts back to a floodplain river during dam removal. Photo by John Gussman, Doubleclick Productions.

Large Woody Debris provide, and; 2. What is the current LWD of the Elwha nearshore. Key sampling parameters include a qualitative description of LWD with an emphasis on location on the beach, general composition, configuration and size. Linkages between LWD's biological functions within the intertidal Elwha nearshore will be illustrated as well.

Vegetation

Longitudinal and Temporal Variation in Plant Species Richness Along the Elwha River: Effects of Dams and Recent Flooding.

Aaron Clausen, Rebecca L. Brown, Patrick B. Shafroth

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Riparian vegetation is heavily impacted by damming and, despite its ecological value and contribution to biodiversity, continues to be threatened. Plant diversity is dependent on seed transport, sediment supply, and particular flow and disturbance regimes. Because they interrupt or alter these processes, one might expect dams and floods to effect diversity. In 2005 we observed reduced vascular plant diversity below 64 m high Glines Canyon Dam and 33 m high Elwha Dam along the Elwha River, Olympic National Park, Washington; however, extreme flood events have since altered the system. To test whether the observed reduction in diversity persists, we studied the effects of these two dams again in 2010. In 2005, 61 100m^2 plots were established across a range of geomorphic landforms along 15 transects, located in river reaches upstream of, between, and downstream of the dams. Within each plot we noted each vascular plant species at various scales and recorded their percent cover, along with ground cover, sediment size, elevation, soil depth, and landform. These plots were resampled in 2010. Average species richness was compared among reaches and time periods. We observed 38% fewer native species downstream compared to upstream of both dams in 2005 ($P < 0.001$), and 26% fewer in 2010 ($P < 0.025$). In the intervening years there was an increase in exotic species richness of 220% downstream of both dams ($P < 0.01$) and 300% upstream ($P < 0.01$). These results suggest that dams may negatively affect native species diversity in the downstream reach. Further, this study shows that the pattern of decreased diversity we observed downstream from dams in 2005 persists, despite large flood events in the intervening years. Understanding pre-dam removal vegetation patterns over multiple years will provide baseline data to assess the effects of dam removal on riparian vegetation.

Vegetation of the Elwha River Estuary.

Patrick B. Shafroth, Tracy L. Fuentes, Cynthia Pritekel, Matthew Beirne, and Vanessa B. Beauchamp

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The Elwha River estuary supports one of the most diverse coastal wetland complexes yet described in the Salish Sea region, in terms of vegetation types and plant species richness. Using a combination of aerial imagery and vegetation plot sampling, we identified six primary vegetation types and 121 plant species in a 39.7 ha area. Woody vegetation types dominate most of the estuary, with mixed riparian forest being the most abundant (20 ha), followed by riparian shrub (6.3 ha) and willow-alder forest (3.9 ha). The shrub-emergent marsh transition vegetation type was fourth most abundant (2.2 ha), followed by dunegrass (1.75 ha) and emergent marsh (0.2 ha). We document the abundance, distribution, and floristics of these six vegetation types, including plant species richness, life form, species origin (native or introduced), and species wetland indicator status. Between 30 and 50 plant taxa occurred within each vegetation type, typically including several taxa unique to each type. Native species predominated, but approximately 37 percent of taxa were introduced. Introduced species were most common and abundant in the shrub-emergent marsh transition and dunegrass vegetation types. Plants in lower elevation plots were most likely to be categorized as obligately or facultatively occurring in wetlands. These data will serve as a baseline to which future changes can be compared, following the impending removal of Glines Canyon and Elwha Dams upstream on the Elwha River. Dam removals may alter many of the processes, materials, and biotic interactions that influence the estuary plant communities, including hydrology, salinity, sediment and wood transport, nutrients, and plant-microbe interactions. Understanding how physical processes and environmental gradients interact with species dispersal, establishment, and survival would greatly improve our understanding of how Elwha estuary vegetation may respond to dam removals, and could be linked to physical process models to predict biological responses over time.

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Photopoint showing the Lake Aldwell area before and after dam removal. Photo by John Gussman, Doubleclick Productions.

Wildlife

Impact of Elwha River Restoration on River-Dependent Species: River Otters and American Dippers.

Kim Sager-Fradkin, Peter Marra, Kurt Jenkins, and Patti Happe

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River otters (*Lontra canadensis*) and American dippers (*Cinclus mexicanus*) are both representative species of the river-obligate mammalian and avian taxa found in the Elwha River ecosystem on Washington's Olympic Peninsula. Both species are considered to be indicators of ecosystem health, yet we know very little about their populations in the Elwha. In anticipation of removal of the Elwha dams, we have commenced a study of otters and dippers designed to document distribution, seasonal movement patterns, and dietary composition of marine-derived nutrients. Specifically, we are in the process of capturing both species below, between, and above the dams for the purposes of applying radio-tracking devices and collecting biological samples for stable isotope analysis. It is widely believed that restoration of salmon to the Elwha River will substantially alter the nutrient composition of the ecosystem, and because river otters and American dippers are so closely tied to the riverine environment, we expect that both species will be important indicators of river restoration. We will present information gathered to date, and will discuss the potential implications of our work, both for salmon and river restoration as a whole.

River-Dependent Bird Surveys Prior To Elwha River Dam Removals

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The upcoming removal of the Elwha dams, with consequent return of anadromous fish, is anticipated to cause changes that reverberate through trophic levels. All life stages of salmon provide a direct food source to various species of birds. The presence of spawning fish leads to changes in populations of macroinvertebrates that further impacts benthic feeders. Surveys were conducted in the 1990s to estimate pre-dam removal densities of five species of birds (harlequin ducks (*Histrionicus histrionicus*) American dippers (*Cinclus mexicanus*) common mergansers (*Mergus merganser*), belted kingfishers (*Ceryle alcyon*) and spotted sandpipers (*Actitis macularia*)) using non-intrusive, easily repeatable survey methods. In 2009 a subset of surveys were repeated to a) reestablish a pre-dam baseline estimate of relative density, b) identify any major shifts in relative densities since 1997 and c) test the assumptions that the surveys will be able to detect changes in bird use during and after dam removal. We compare the 1996-97 survey data on the Elwha and Duckabush Rivers for two of the species surveyed, harlequin ducks and American dippers. Using our current method, we detected a statistically insignificant and small decrease in harlequin duck relative abundance over the 12-year time period and a slight increase in dippers on some reaches. These data are noisy but potentially useful as a monitoring tool for post-removal comparisons, especially if correlated with parallel studies of fish, macroinvertebrates and mesocarnivores. We briefly discuss alternative potential analyses and modification of survey methods that would improve the statistical analyses of future surveys.

A tagged black bear located in the Cat Creek basin of the Elwha Valley. Photo by Kurt Jenkins, U.S. Geological Survey

Movement and Habitat Selection Patterns of Black Bears Prior to Dam Removal and Ecosystem Restoration in the Elwha Valley, Washington

Patricia Happe, Kim Sager-Fradkin, Kurt Jenkins

Olympic National Park, Port Angeles, WA (PH), USGS Forest and Rangeland Ecosystem Science Center, Port Angeles, WA (KJ , KS), Lower Elwha Klallam Tribe, Port Angeles, WA (KS)

Removal of two hydroelectric dams and restoration of anadromous fishes in Washington's Elwha River Ecosystem provides a unique opportunity to improve understanding the role of anadromous fish runs in influencing black bear movement and habitat selection patterns. Dam removal is expected to restore 7 species of native salmonids, potentially providing a rich and predictable food resource for black bears during autumn prior to denning. We captured and equipped 18 black bears with transmitter collars that has GPS units and gathered detailed information on yearly movement patterns of bears from 2002-2006. In addition, we used hair snares and DNA analysis to estimate minimum number and sex of bears using riparian areas during the spring and fall, from 2006-

2008. We will discuss seasonal habitat selection and altitudinal movements and discuss potential changes in black bear use of the valley following fish restoration.

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An old growth stump, logged before construction of the Elwha Dam, re-emerges from the depths following the drawdown of Lake Aldwell. Photo by John Gussman, Doubleclick Productions

Multimedia

Return of the River (Film).

John Gussman

Doubleclick Productions, Sequim, WA. 360.808.6406. jgussman@dcproductions.com. http://www.elwhafilm.com

The Elwha River documentary film, "Return of the River" is the story of the people, politics and process of removing two dams, restoring the Elwha River to its natural free-flowing state, and bringing back the river's long-lost great salmon runs, a true Northwest treasure. Beginning in early 2010, I started devoting most of my time to documenting as much of this ongoing process as possible and anticipate filming this project for at least the next four years to document the planning, preparation, dam removal and initial phases of restoration.

Elwha Unplugged: The Opus of Dick Goin (Film)

Sachi Cunningham, Jennifer Galvin, and Emma Jones

Reelblue LLC, email: info@reelblue.net

A documentary film in progress about the quest of Pacific Northwest American hero, Dick Goin, who dedicates his life to set the Elwha River and its natural inhabitants — salmon — free. For a trailer of the film, visit http://vimeo.com/14138803, http://www.reelblue.net

Lake Mills Delta Reveals All (Film)

Brian Cluer

NOAA National Marine Fisheries Service, Southwest Region Habitat Conservation Division

A short film showing time lapse footage of the 1994 drawdown and refilling of Lake Mills.

Fish Weir on the Elwha (Film)

Jeffrey J. Duda, John Gussman, and Greg Brotherton

U.S. Geological Survey, Western Fisheries Research Center, Seattle, WA (JD), Doubleclick Productions, Sequim, WA (JG), Frenetic Productions, Seattle, WA (GB)

In 2011, an inter-agency team of biologists installed a fish weir in the Elwha River to help study and enumerate salmon populations. The film is intended to inform the public about an important tool being used to document the return of salmon to the Elwha River. To see the film, http://gallery.usgs.gov/videos/509

Denizens of the Elwha Nearshore Zone

(Photography)

Nancy Elder

U.S. Geological Survey, Western Fisheries Research Center,

Marrowstone Field Station, Nordland, WA

Nancy Elder is a fisheries biologist and long-time scuba diver the the U.S. Geological Survey's Western Fisheries Research Center. She is a member of the team conducting baseline assessments of the benthic marine communities inhabiting the Elwha River nearshore. The photographic slide show shows the incredible diversity and beauty that occurs on the seafloor near the Elwha River. To see a slide show of these photograhps, see http://pubs.usgs.gov/sir/2011/5120/seaLife/

Elwha Ecosystem - Valley, River, Fish

(Photography)

John McMillan

NOAA Northwest Fisheries Science Center, Port Angeles, WA

John McMillan is a fisheries biologist who uses photography as a tool to monitor conditions of the Elwha ecosystem as they change over time. He has studied Olympic Peninsula rives and their inhabitants for fifteen years. His photographic slide show shows beautiful landscapes, the Elwha River dams and associated structures, and incredibly candid views of the inhabitants of the Elwha River.

A silverspotted sculpin photograhed in the Elwha River nearshore. Photo by Nancy Elder, U.S. Geological Survey

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Links

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