Proceedings of the

7th Annual Elwha Nearshore Consortium Workshop

14 February 2011, Peninsula College, Port Angeles, Washington

DRAFT FINAL

Tara Morrow[1], Student Editor

Barbara Blackie[1], Anne Shaffer[2*],Dwight Barry[3], Faculty and Mentor Editors

[1]Huxley College of the Environment on the Peninsulas, Western Washington University, 1502 E. Lauridsen Blvd. Port Angeles, Washington 98362-6660

[2 *]Coastal Watershed Institute, P.O. Bx 2263 Port Angeles, Washington 98362. anne.shaffer@coastalwatershedinstitute.org

[3] Peninsula College, 1502 E. Lauridsen Blvd. Port Angeles, Washington. 98362

*Proceedings contact

Workshop and proceeding sponsored by:

Coastal Watershed Institute
Port Angeles, Washington
www.coastalwatershedinstitute.org

SURFRIDER FOUNDATION
OLYMPIC PENINSULA CHAPTER

WESTERN WASHINGTON UNIVERSITY
HUXLEY
COLLEGE OF THE ENVIRONMENT

PENINSULA COLLEGE

CLALLAM COUNTY
MARINE RESOURCES COMMITTEE

Table of Contents

Contributors and Contact Information

Name	Affiliation	Email
Anne Shaffer, Elwha nearshore coordinator	***Coastal Watershed Institute (CWI)***	anne.shaffer@coastalwatershedinstitute.org
Brian Winter, Elwha project manager	***Olympic National Park (ONP)***	brian_winter@nps.gov
Cathy Lear	***Clallam County***	Clear@co.clallam.wa.us
Dwight Barry, Elwha Research Coordinator	***Center for Excellence, Peninsula College***	DwightB@pcadmin.ctc.edu
Helen Berry	Washington Department Natural Resources (DNR)	helen.berry@dnr.wa.gov
Michelle D'Hemecourt	North Olympic Land Trust	michele@northolympiclandtrust.org
Jane Dolliver	University of Washington	dolliver@u.washington.edu
Amy Draut	USGS	adraut@usgs.gov
Guy Gelfenbaum	USGS	ggelfenbaum@usgs.gov;
Karen Gustin	ONP	Karen_gustin@nps.gov
John Hicks	Army Core of Engineers	John.A.Hicks@usace.army.mil
Ian Miller	University of California Santa Cruz	immiller@ucsc.edu
Beth McCasland	Army Corps of Engineers	Elizabeth.L.Mccasland@usace.army.mil
Kathryn Neal	City of Port Angeles	kneal@cityofpa.us
Tim Nelson	Seattle Pacific University	tnelson@spu.edu
Chuck Nittrouer	University of Washington	nittroue@ocean.washington.edu
Jim Norris	Marine Resources	jnorris@olympus.net
Andrea Ogston	University of Washington	ogston@ocean.washington.edu
Dave Parks	Washington Department Natural Resources (DNR)	dave.parks@dnr.wa.gov
Julia Parrish	University of Washington	jparrish@u.washington.edu
Steve Rubin	USGS	Steve_rubin@usgs.gov
Jamie Valadez	Lower Elwha Klallam Tribe	jv1033@gmail.com
Brian Winter	Olympic National Park	Brian_winter@nps.gov
Jacilee Wray	Olympic National Park	Jacilee_wray@nps.gov
Jon Warrick	USGS	jwarrick@usgs.gov

Students – WWU-Huxley College of the Environment on the Peninsulas

Kiley Barbero
Nancy Bell
Christine Butler-Minor
Tony (Charles) Duarte
Kristen Farley
Anthony Grim
Nora Haider
Michael Hank
Dayna Rose Hernandez
Tiffany Howell
Renee Johnson
Laura Jungbauer
Staci Kaufmann
Kari Klaas
Cindy LaRue
Christina LaVelle
Gary Massey
Dave McConnell
Tamara Neuffer
Seth Peterson
Joseph Ray
Joseph Richardson
Valli Sanstrom
Meggan Uecker
Sara Witczak

Executive Summary

Puget Sound Research ESTU 445 is a biennial course offered through WWU's Huxley College of the Environment on the Peninsulas and taught by adjunct faculty member Barbara Blackie. The purpose of this class is to provide students majoring in environmental science and environmental policy access to forums important for professional dialog, including professional workshops and conferences. As part of the requirements for the winter quarter 2011 ESTU 445 course, students attended the 7th annual Elwha Nearshore Consortium Workshop, held on February 14th in Port Angeles, and helped prepare these proceedings. WWU students prepared by reading and critically evaluating a series of journal articles covering research related to the Elwha Nearshore Consortium, as well as other topics related to water quality in Puget Sound, the Strait of Juan de Fuca, and the outer coast. Students also conducted their own independent review of scientific literature on a topic of interest, attend the one day workshop, and then each wrote a short synthesis of a presentation given at the workshop. The students interacted with the individual project Principle Investigators as a part of their student assignment. Another senior student intern, with modest funding from the Clallam MRC and guidance from the ENC coordinator and WWU faculty, then synthesized the write ups and consolidated them into this Proceedings, which, when finalized, will be posted on the Clallam MRC website, as well as WWU and CWI web pages.

The ENC workshop was co-sponsored by the Coastal Watershed Institute, Olympic Peninsula Chapter of the Surfrider Foundation, Peninsula College, WDFW, and the Clallam MRC.

In these days of ever diminishing financial resources researchers, managers, and educators are developing new ways to continue important research, management, and citizen dialog, as well as educate our next generation of resource managers. We feel the collaboration embodied in this Proceeding is a powerful example of how well we can work when we work together. We are very proud of our science, our natural resources, and our students, and are excited about the restoration that has finally begun. We hope you will find the information of use.

Anne Shaffer, ENC Coordinator, Coastal Watershed Institute.

Barbara Blackie, Professor, Western Washington University

Dwight Barry, Professor, Western Washington University

Cathy Lear, Clallam County

Karen Gustin, Olympic National Park

Overview and Introduction

Topic: Nearshore Overview
PI: Anne Shaffer, Costal Watershed Institute, anne.shaffer@costalwatershedintstitute.org
Student: Sara Witczak

The Elwha Nearshore Consortium (ENC) is made up of scientists, citizens, and co-managers dedicated to understanding and promoting the nearshore restoration associated with the upcoming Elwha Dam removals. The ENC was first convened in 2004, and is coordinated by the Coastal Watershed Institute. The annual ENC workshop, which began in 2004, is co-sponsored by the Coastal Watershed Institute, the Clallam Marine Resources Committee, Surfrider Foundation, Peninsula College, and the Lower Elwha Klallam Tribe, among others.

The Elwha nearshore is defined as extending from the area of tidal influence- including the riparian zone- out to 30 meters Mean Lower Low Water (MLLW) depth. It also includes the Elwha drift cell, which stretches from the west entrance of Freshwater Bay east to the tip of Ediz Hook and includes approximately 12 linear shoreline miles and five geomorphic habitat landform types of lower river and estuary, embayed shoreline, feeder bluffs, and spit. Both the Elwha Dam (1913) and the Glines Canyon Dam (1926) block important fish access to the Elwha River and affect many marine features below the dams.

The Strait of Juan de Fuca is a major conduit to the Salish Sea and the Puget Sound. Sediment processes define the Elwha nearshore and are currently significantly disrupted. The feeder bluffs and the Elwha River are the normal inputs of sediment for the Elwha nearshore. However a modified shoreline with armoring, diking, and the dams has prevented this sediment deposit for many years. As a result the Elwha nearshore is significantly impaired (Shaffer et al 2008).

Created in 2004, the ENC nearshore restoration strategy uses a Before, After, Control, Impact (BACI) framework. Comparative areas include Crescent Bay and the Dungeness drift cell (Figure 2). The Dungeness drift cell has similar sediment processes however those processes are completely intact. Thus the ENC can look to the Dungeness drift cell as a potential model.

Management of the Elwha nearshore is complex: it is completely out of the Olympic National Park (ONP) and includes multiple jurisdictions and ownerships. As an example, in 2006 the city of Port Angeles added more armoring to help protect municipal landfill on the feeder bluffs, preventing more sediment movement. Lower river alterations are also significant impediments to the Elwha nearshore. For example, the Place Road dike, also known as 'west levee', has just been raised and widened to mitigate potential flooding risk associated with dam removal. No fish passage was included in this modification.

The contract to begin removal of the dams begins September, 2011. We have a lot to do and a very short time in which to do it. Welcome to the Elwha Nearshore Consortium.

Annotated Bibliography

Shaffer, J. A., and D. Barry. 2009. The Elwha Nearshore: Linking Management, Education, and Research to Achieve Ecosystem Restoration. Priority Recommendations of the Elwha Nearshore Consortium. Published in the Proceedings of the 2009 Puget Sound Georgia Basin Research Conference, Puget Sound Partnership, Olympia Washington.

The Elwha Nearshore Consortium (ENC) is trying to identify and address additional priorities from the ENC annual meeting held in 2009. Attempts are made to link management, education, and research to achieve ecosystem restoration. Cross cutting common issues between the ENC, Puget Sound Partnership, and the West Coast Sea Grant.

Shaffer, J. A., P. Crain, B. Winter, M. L. McHenry, C. Lear and T. J. Randle. 2008. Nearshore restoration of the Elwha River through removal of the Elwha and Glines Canyon dams: an overview. Northwest Science 82 (Special Issue):48-58.

The Elwha dams have completely changed the habitat and ecosystems in the Elwha River and estuary. Removal of the dams will not only restore the habitat and ecosystems, but also provide a unique opportunity to study the relationship of dam removal to the adjacent nearshore area.

Shaffer J.A., L. Ward, P. Crain, B. Winter, K. Fresh, and C. Lear. 2005. "Elwha and

Glines Canyon dam removals: nearshore restoration and salmon recovery of the central Strait of Juan de Fuca." Proceedings, Puget Sound Research Conference 2005, Puget Sound Water Quality Action Team, Olympia, Washington.
The nearshore of the central Strait of Juan de Fuca is a critical component to the marine ecosystem of Washington. The nearshore is defined by sediment processes which have been severely degraded by shoreline armoring and damming of the Elwha River. Paper provides an overview of the researcher's approach to monitoring the nearshore response to removal of the Elwha River dams.

Figure 1. Elwha nearshore by landform type.

Model linkages between current habitat extent, use and sediment processes in lower river and shoreline to predict post dam removal sediment fate and anticipated near and long term habitat

Number	Landform	Length	
		km	miles
1	Elwha River (north to south)	0.5	0.3
	Elwha estuary (total area):		90 acres
	Elwha west estuary (both sides of dike)		27 acres
2	Elwha Embayed shoreline (Freshwater Bay)	7	4
3	Elwha bluffs	6	4
4	Ediz Hook (spit)	5	3
	Total	**18.5**	**11.3**

function response.

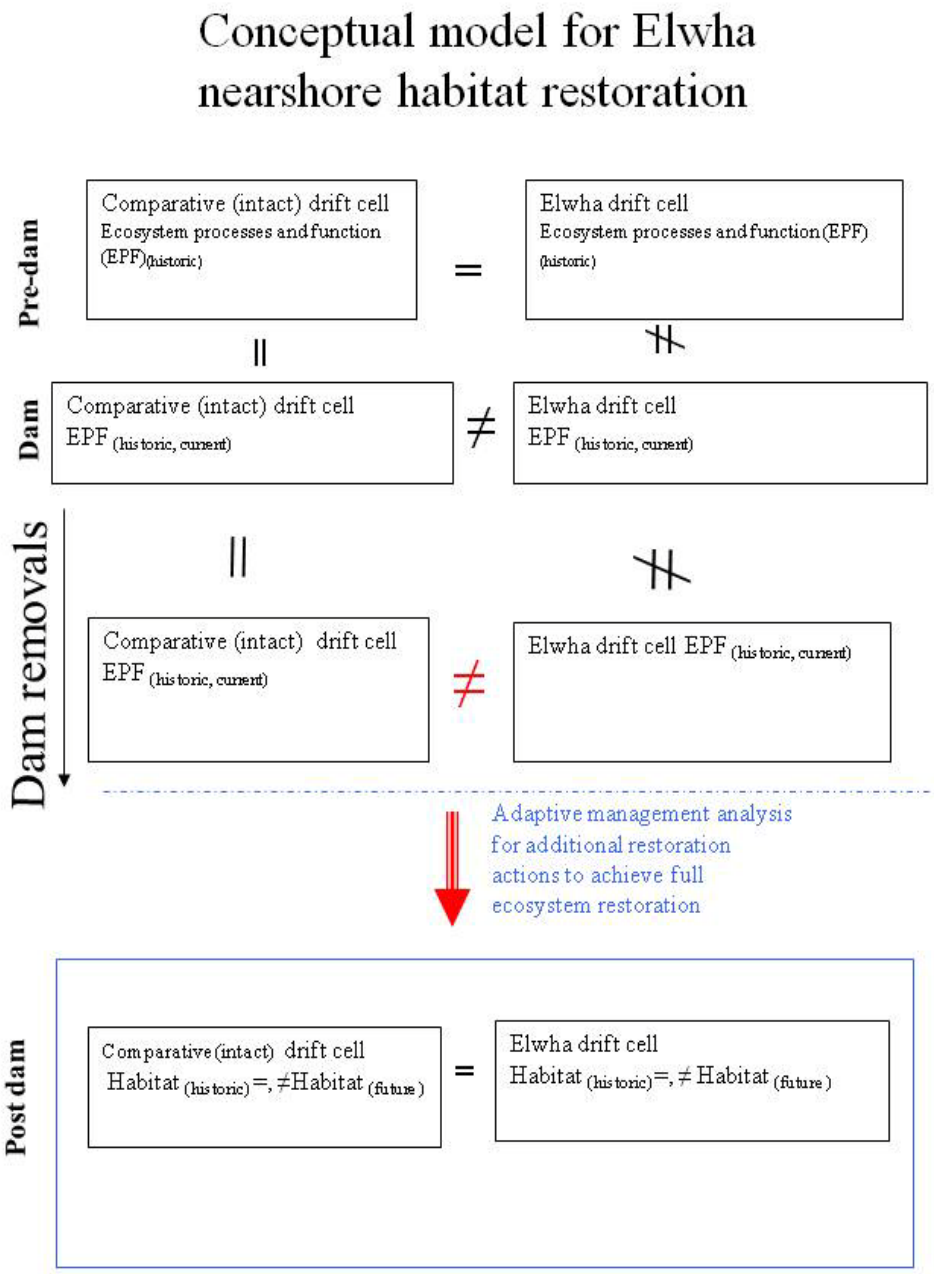


Figure 2. Elwha nearshore restoration strategy conceptual model.

Topic: Elwha Dam Removal Project Overview and Status

Principle Investigator: Karen Gustin, Superintendent, Brian Winter*, Project Manager Elwha Dam Removal, Olympic National Park. *Project Contact: brian_winter@nps.gov

Student: Kiley Barbero

Removal of the Glines Canyon and Elwha dams will begin in September 2011 with Barnard Construction Company Incorporated (BCCI), based out of Bozeman, Montana, hired as the contractor for dam removal. They have never removed a dam before but they have experience with dam construction and repair (BCCI n.d.). There will be a couple hundred people working on the Elwha Project. It is the largest construction project in the Olympic National Park and the second largest ecosystem restoration project in the National Park Service.

Of 43 total projects related to the Elwha River Restoration Project, only 6 remain. Mitigation measures have been accomplished. The west side levee was completed over two years ago. A two-foot raising of the east side federal levee, to account for rising water levels during deconstruction, is 95% complete, overall the levee project is 50% complete. The new fish hatchery is completed and the tribe will begin operations in May 2011. This hatchery replaced the old hatchery that is sitting in the ground and will not make it through the anticipated two-foot rise in water column. It was moved upstream to a better location where it will track individual fish families.A waste water system is beginning to unfold. Since tribal septic systems will be inoperable, the city and tribe have agreed on a least-cost scenario for the tribe, involving a collection system by the city of Port Angeles. The Park Service is funding the First Street Stormwater Separation Project, as a part of the Elwha Restoration Project This will begin in March 2011. This project is a collaboration between the City of Port Angeles and the National Park Service. The project installs infrastructure that will convey and treat stormwater before it enters Valley Creek. This removes enough stormwater from the sewage system to allow for the introduction of sewage from the Lower-Elwha Klallam Reservation (Mahulm 2011).

As for public education, a webmaster has been hired to update information on the park service

website regarding the status of dam removal. The public will also be able to access webcams to track sediment on the Elwha during dam removal. Dean Butterworth is the project contact.

Annotated Bibliography

Barnard Construction Company, Inc. > Who We Are (BCCI) [Internet]. n.d. Barnard Construction Company, INC.; [2011; March 2011] Available from: http://www.barnard-inc.com/WhoWeAre/tabid/58/Default.aspx.Overview of Barnard Construction Company Inc. Lists previous projects and experience.

Mahlum, Jim. 2011. First Street Stormwater Separation Project. City of Port Angeles, Public Works and Utilities Department. [2011; March 2011] Available from http://www.cityofpa.us/FirstStreetStormwater.htm.
Provides information to the public regarding downtown Port Angeles operations and closures during the First Street Stormwater Separation Project. The objective for the project is to disconnect stormwater from entering the sewage system as the LEKT reservation sewage is diverted to the City of Port Angeles.

Physical Processes

Topic: Sediment Dispersal Processes

Primary Investigator: Andrea Ogston, Chuck Nittrouer*, University of Washington School of Oceanography. *Project Contact: nittroue@ocean.washington.edu

Student: Brandon Massey

Currently a baseline study has been completed and will be compared to studies conducted after the dams come down. The work is being funded by WA Sea Grant and the National Science Foundation. The objectives for the baseline phase of 2007-2009 are to characterize the seabed and water column in the present river condition, estimate the impacts of high discharge events on the delta after dam removal, and determine when and where instruments should be deployed during dam removal to ensure the highest rate of return.

Several methods to determine the sediment processes in the Elwha nearshore were used. First a seabed characterization was done using Shipek Grab Samples. This method was used because of the large sizes of the gravels on the seabed. This method was also used to conduct macroinvertebrate surveys. This method allows measurement of sediment sizes in discrete locations that can be related to the organisms present in the samples. The water column was profiled in order to determine the overall net drift, the direction of the currents during ebb and flood conditions, and the magnitude of the currents. Having these data gives researchers the ability to determine how high flow events in the River, with their anticipated increase in sediment input, affect the system. The water-column profiling was undertaken with an Acoustic Doppler Current Profiler (ADCP), which is conducted using shipboard equipment and fixed monitoring tripods. The data gathered was then mapped in order to create a spatial representation of the dynamics that influence the sediment processes in the Elwha nearshore.

Once the dams are removed several processes will be studied. The first sediments that will come from the Elwha River are expected to be very fine. While the initial sediment plume will be visible, it is important to note that the majority of the sediments will not be visible. Typically, only a few percent (at most) of sediment transport will be in the surface plume. Many physical

processes (estuarine circulation, surface waves, tidal currents, density flows) will control the fate of the sediment reaching the ocean. The sediment that is on the bottom will be studied by a fixed instrument which is the best and most practical way to study the bottom sediment.

Other areas of interest are the changes in the bottom due to sediment deposition. The bathymetry will be measured and compared to the baseline bathymetric studies conducted 2007-2009. This will give new insight on how rivers affect marine processes and influence sediment morphology. Swath bathymetry is a highly detailed method of mapping the seafloor using acoustic equipment. This method can be used to evaluate the physical and sediment characteristics over large areas and allow the researcher to develop an overall picture of the sea floor.

The hydrograph of Elwha River is bimodal which indicates that the most sediment transport is during the winter rainy season and spring snow melts. The grain-size distribution was measured and compared to the biodiversity in the area. The areas with the greatest biodiversity were the areas with the most variable grain sizes. Currents have a direct effect in the sediment distribution and were measured using an Acoustic Doppler Current Profiler (ADCP) to determine the direction and magnitude of currents during changes in tides. It was determined that there is considerable variation in magnitude between the ebb and flood tide and there is an overall net eastwardly drift.

In the future, studies will be conducted to determine how physical-oceanographic processes affect the finer sediments released and transported in the boundary layer. This will give insight on the sediment dynamics of the nearshore and provide useful information about habitat characteristics. Mapping and base-line profiling will be compared to established bathymetry and sediment compositions. The general oceanographic processes in the nearshore are not expected to change, with the exception of the amount of sediment input into the system. Comparisons of new mapping and current profiling to established base lines will allow for explanation of changes occurring on the sea floor. Because working with other agencies, such as USGS, is essential the data collection and to determine the most effective placement of equipment to characterize the affects of the dam removal, relationships with other researchers will be fostered to help this integrated effort in determining the sediment dynamics of the Elwha

nearshore. Intense observations are expected to start 6 months to a year after dam removal because the sequestered sediment will not be released immediately and will take some time to travel out of the River.

The Army Corps of engineers is looking for funding to put in a long-term monitoring buoy at the mouth of the River to monitor conditions as the sediment inputs change. This Buoy will monitor wave height, intensity, and wave direction and will be deployed and monitored by Scripps Institute of Oceanography. This cooperative work will give new insight into how river sediments influence the habitats and morphology of the nearshore environments. In the research process student participation is essential, and this is why the University of Washington is planning to offer a unique opportunity for students through an immersion course at the Friday Harbor Lab. This course would give students the opportunity to be involved in oceanographic research through hands-on experience working on actual research projects. Students will be involved in intensive water-column profiling, seabed grab samples, and sub-bottom profiling. This course will give students an opportunity to conduct research and gain practical experience that will give them the understanding on scientific studies and ocean processes.

Money is also important in the research process, however, in 2009-2010 grant money was returned to the National Science Foundation because of the delay in the dam removal projects. Once the dates for the dam removal were finalized, the researchers reapplied for the grant and the NSF grant was reapproved and the projects continued.

Bibliography (no annotations available)

Nittrouer C.A. STRATAFORM: Overview of its design and synthesis of its result (1999) *Marine Geology*, 154 (1-4), pp. 3-12.

Goni M.A., Monacci N., Gisewhite R., Ogston A., Crockett J., Nittrouer C. Distribution and sources of particulate organic matter in the water column and sediments of the Fly River Delta, Gulf of Papua (Papua New Guinea) (2006) *Estuarine, Coastaland Shelf Science*, 69 (1-2), pp. 225-245.

Allison M.A., Lee M.T., Ogston A.S., Aller R.C. Origin of Amazon mudbanks along the northeastern coast of South America (2000) *Marine Geology*, 163 (1-4), pp. 241-256.

Topic: Baseline Surveys in the Elwha and Dungeness Drift Cells

Primary Investigator: Dave Parks, Washington Department of Natural Resources
dave.parks@dnr.wa.gov
Student: Tony (Charles) Duarte and Nora Haider

These surveys involve creating baseline data for the beaches and bluffs of the Elwha and Dungeness drift cells, which will later be compared to measurements taken after the dams are removed. Evidence was presented at the Elwha Nearshore Consortium that explains how sediment coming from the Elwha River and the beaches and bluffs near the river's mouth are being transported to areas east of the river. The work also shows that the bluffs overlooking the Elwha beaches contribute a great amount of sediment to the nearshore environment. By studying erosion on the beach, the researcher's work will help in understanding how sediment movement and transport will change after the removal of the dams on the Elwha River.

The project consists of creating beach profiles at 16 different sites near the mouth of the Elwha and Dungeness Rivers. The beach profiles are constructed by measuring topography and grain sizes of the sediment in the Elwha Delta. These baseline surveys will be used to show when or if accretion of sediment is occurring in the Elwha nearshore, or to show when sediment from the river starts to rebuild the shore, if it does at all. Mapping of historic landslides and measuring bluff texture and recession rates will identify what sediments will remain on the Elwha beaches after the dams are removed. Bluff texture is determined by taking bulk samples of sediment from each bluff and conducting sieve analysis, which shows how much of each grain size is present in the sediment column. Recession rates of the bluffs are based on estimates of lateral bluff erosion, comparisons of aerial photographs of the nearshore area taken from 1939-2009, and the use of software such as ArcGIS. The research also compares the armored beaches of the Elwha nearshore to the unarmored beaches of the Dungeness nearshore. A digital image of the bluff's edge was created that shows the position of the bluff in 1939 and its present position. Work on this project is scheduled to continue until the summer of 2011.

Annotated Bibliography

Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at *http://pugetsoundnearshore.org*. This article ties in the basic knowledge of geomorphology with established knowledge of Puget Sound beaches. It serves as a summary of peer-reviewed literature that was based on these beach ecosystems.

Folk Robert, Ward William. 1957. Brazos River Bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology. Vol 7 (1): 3-26. http://jsedres.sepmonline.org/cgi/content/abstract/27/1/3. This research was used to determine the geologic meanings of grain size dispersion. It helps to explain the logic behind the sorting of riverbed sediments.

Shipman, H. 2008. A Geomorphic Classification of Puget Sound Nearshore Landforms. Puget Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington. Available from http://www.pugetsoundnearshore.org. This study describes and classifies the nearshore landforms found in the Puget Sound. These are divided into four main categories: rocky coasts, beaches, protected areas and lagoons (embayments), and large river deltas.

Wallace, R. Scott. 1988. Quantification of Net Shore-Drift Rates in Puget Sound and the Strait of Juan de Fuca, Washington Journal of Coastal Research 4 (3): 395-403. Published by: Coastal Education & Research Foundation, Inc. Available from: http://www.jstor.org/action/showPublisher?publisherCode=cerf. (Stable URL: http://www.jstor.org/stable/4297427). Twenty-six sites were selected for quantitative analysis for their respective net shore drift. 3 types of analysis were used to determine this: field measurements of sediment accumulation, extrapolation of spit growth using aerial photographs and historic maps, and evaluating maintenance dredging volumes at navigation channels.

Wolman, Gordon. 1954. A method sampling coarse river bed material. Transactions, American Geophysical Union. Volume 35 6): Available from http://relicensing.pcwa.net/documents/Library/PCWA-L-161.pdf. Outlines the basic use of a grid system that can be used to determine the average grain size in rivers that are capable of being waded through at low flow periods. Its advantages are that it can be used on coarse materials and it can be used over the entire reach of a stream.

Topic: Geomorphology and physical process

Primary Investigator: Jon Warrick*, Guy Gelfenbaum, United States Geological Survey.

*Project Contact: jwarrick@usgs.gov

Student: Dayna Rose Hernendez

The United States Geological Survey (USGS) has a research and monitoring program for the Elwha River Restoration Project, for which surveys and physical sampling are conducted in the lower river, estuary and coastal zone. In 2005 and 2010, Swath Sonar surveys were conducted to provide high quality bathymetry of the Elwha nearshore (Figures 1 and 2). These surveys were intended to serve as a baseline so that changes in the nearshore zone could be evaluated. Notable changes within the past five years include coarse sediment piles directly offshore of the river's mouth.

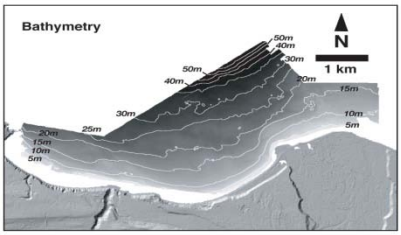


Figure 1. USGS. Bathymetry of the Elwha River delta in 2005.

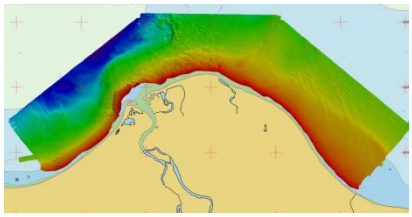


Figure 2. USGS. Bathymetry of the Elwha River delta in 2010.

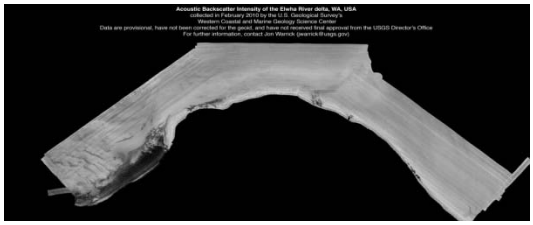


Figure 3. USGS. Acoustic Backscatter of the Elwha River delta in 2010.

Acoustic backscatter is also collected during the Swath surveys and is shown in the image to the left (Fig. 3). These backscatter data assist in estimating grain size, appoximate hardness of grains, and grain distribution of the seafloor. The lighter colors show areas that contain harder substrate; the darker-colored areas signify lighter substrates. These data correspond with the offshore sediment mapping presented by Chuck Nittrouer from the University of Washington.

The USGS has developed methods to determine grain size from a digital photographs. This methodology is to be applied to the shallow bottom of the nearshore and the beach. Using an underwater video sled, which is a mapping vehicle, digital photographs are taken and used to establish mean grain size (Figure 4). The vehicle covered sixteen, 100 m^2 sites.

Figure 4. USGS. Digital photographs from the downward-facing camera used to determine grain size.

The vehicle contains downward-facing and forward-facing cameras. The forward-facing cameras were monitored by biologists in the 2005 survey to determine aquatic organisms.

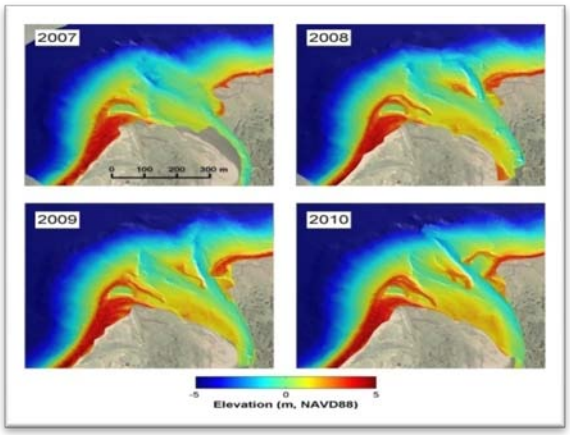


Figure 5. USGS. Annual bathymetric surveys of the Elwha River delta from 2007 to 2010.

The USGS has conducted annual topographic and bathymetric surveys of the Elwha nearshore since 2004. In 2011, as the start of the project draws closer, the frequency of the surveys will increase to semi-annual. The focus of the surveys since 2004 has been the delta; and since 2007 the surveys have been expanded to include the river's mouth. The data collected from these surveys are available to the public through the internet in [USGS Data Series Report No. 288](#).

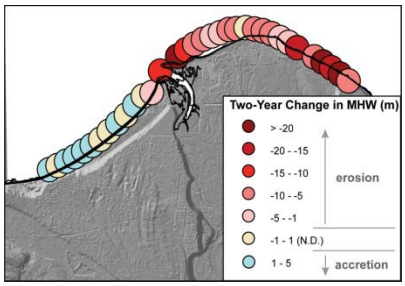


Figure 6. USGS. Rate of erosion or accretion of the Elwha River delta in two years.

The topographic surveys indicate that high erosion rates exist along the delta's shoreline. For example, the rates of erosion or accretion are demonstrated by the image shown in Figure 6 (Warrick et al., 2009). Shoreline change is characterized by erosion to the east of the mouth (shown in warm tones) and accretion to the west of the mouth (shown in cool tones).

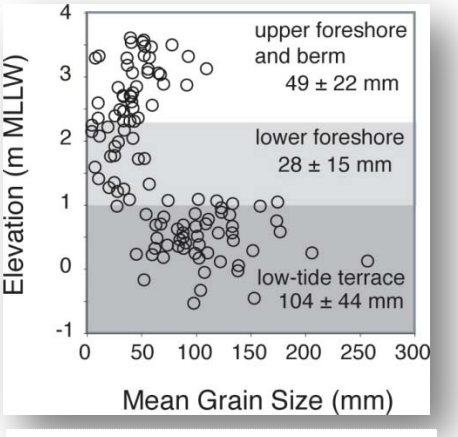


Figure 7. USGS. Profile of beach: elevation by mean grain size.

A beach grain size mapping methodology ("Cobble Cam") was designed to determine the mean grain size of sediment from a digital photo to characterize patterns on the beach. The graph to the right (Fig. 7) demonstrates that the mean grain size decreases as elevation increases, and this is an atypical finding for beaches in the Puget Sound and Strait of Juan de Fuca.

The USGS has also characterized the physical features and patterns in the Elwha River outflow plume (Warrick and Stevens, 2011). This plume changes abruptly over the tidal cycle, although the plume is most commonly observed bending over toward the east and hugging the eastern shoreline. These plume observations will be important in characterizing the initial transport and settling of river suspended sediment.

As resources and time allow, the USGS is developing a numerical model to simulate coastal hydrodynamics and sediment transport around the Elwha River delta. An intial evaluation of the model was provided in Gelfenbaum et al., (2009), which suggested that sand would be transported largely to the east of the river mouth, while silt and clay would go both east and west.

Channel migration is being investigated by Amy Draut and colleagues of the USGS. This research has used both historical aerial photographs and semi-annual surveys of the river channel topography and bed grain size. Results suggest that although some bed armoring is shown in the lower river, the lateral migration rates of the channel have been sustained, and this channel migration provides an important source of coarse sediment to the river (Draut et al., 2008, 2011).

Figure 8. USGS. Sediment tracers were used to produce a numerical model of sediment movement under variable tidal conditions.

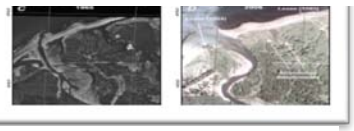


Figure 9. USGS. Lower river channel evolution.

There are also potential projects that the USGS may contribute to in the future. The USGS will be working with the University of Washington to characterize physical processes in the nearhshore zone, with an emaphasis on understanding plume dynamics and suspended sediment distribution. Presently,two sets of current meters and wave sensors are deployed offshore of the Elwha River delta by the USGS. Additional instrumented tripods and buoys for plume

monitoring will be deployed during the peak sediment outflow rates from the river. Lastly, the USGS may install cameras to gather quantitative measurements of beach position and plume conditions. The high resolution cameras would record shoreline change and plume pattern information before and after the removal of the dam.

Annotated Bibliography

Draut A, Logan J, McCoy R, McHenry M, Warrick J. 2008. Channel evolution on the Lower Elwha River, Washington 1936-2006. USGS Scientific Investigations Report 2008-5127. USGS.gov [Internet]. Available from: http://pubs.usgs.gov/sir/2008/5127/.
Historical aerial photos of the Lower Elwha River show patterns and rates of change between 1936 and 2006 due to anthropologically made dams. During those years, annualized active floodplain margins usually exceeded 50 m; recently, the margins have exceeded 400 m due to new channel formations caused by human alteration of the floodplains in the 1940s to 1980s. Analysis of patterns and change were used to characterize the river's evolution of most of the time since the dams' genesis. Channel morphology and channel velocity are anticipated to change due to the removal of the dams and the sediment load associated with the restoration.

Draut A, Logan J, Mastin M. 2010. Channel evolution on the dammed Elwha River, Washington, USA. *Geomorphology* 127:71-87.
This paper describes the historical and recent changes in the lower Elwha River channel morphology and documents channel armoring and change.

Gelfenbaum G, Stevens A, Elias E, Warrick J. 2009. Modeling sediment transport and delta morphology of the dammed Elwha River, Washington State, USA. Worldscinet.com [Internet]. Available from: http://eproceedings.worldscinet.com/9789814282475/9789814282475_0109.html.
This paper describes a numerical model that was implemented to predict hydrodynamics and sediment transport pathways offshore of the Elwha River delta.

Warrick J, Cochrane G, Sagy Y, Gelfenbaum G. 2008. Nearshore substrate and morphology offshore of the Elwha River, Washington. *Northwest Science* 87:153-163.
Seafloor characterization near the Elwha River mouth was produced using sonar and video mapping methodologies,. Results indicated that no fine sediment was present on the seafloor, that the substrate was highly variable, including sand waves and gravel beds,

and that coarse sediment was dominant. The sand waves and gravel beds are indicative of active sediment transport. Bull kelp is located along boulder and bedrock substrates.

Warrick J, George D, Gelfenbaum G, Ruggiero P, Kaminsky G, Beirne M. 2009. Beach morphology and change along the mixed grain-size delta of the dammed Elwha River, Washington. *Geomorphology* 111:136-148.
Changes in the Elwha River's shoreline position and beach morphology were examined over time to evaluate the effects two dams had to sediment supply. The delta's beach was observed to be erosional on the eastern side of the river mouth, and stable on the western side of the river mouth. This is largely due to the littoral transport direction that is strongly eastward. Due to atypical grain-size patterns on the beach, the low-tide terrace was determined to be "a geomorphological feature caused by coastal erosion of a coastal plain and delta".

Warrick J, Rubin D, Ruggiero P, Harney J, Draut A, Buscombe D. 2009. Cobble cam: grain-size measurements of sand to boulder from digital photographs and autocorrelation analyses. *Earth Surface Processes and Landforms* 34:1811-1821.
Autocorrelation techniques were applied to the determination of sediment grain-size through digital photographs and found to be an accurate method. The methodology was accurate for grains ranging in size from sand to boulder. Compared with other methods, the autocorrelation created less need for camera adjustment and lighting correction.

Warrick J, George D, Stevens A, Eshleman J, Gelfenbaum G, Kaminsky G, Schwartz A, Beirne M. 2010. Beach morphology monitoring in the Elwha River littoral cell, 2004-2006 [Report]. USGS.gov [Internet]. Available from: http://pubs.usgs.gov/ds/288/.
With support from the Lower Elwha Klallam Tribe, the USGS with the Washington State Department of Ecology to collect both topographic and bathymetric data around and within the Elwha River delta. The data were obtained with Real Time Kinematic Differential Global Positioning Systems which have precision of ~10 cm. This report provides a description of the data collection and analysis methods and access to the data files.

Warrick J, Stevens A. 2010. A buoyant plume adjacent to a headland- Observations of the Elwha River Plume. *Continental Shelf Research* 31:85-97.
The buoyant plume of freshwater leaving the Elwha River mouth and flowing into the coastal waters of the Strait of Juan de Fuca will be the initial pathway for fine sediment from the river. This buoyant plume was investigated and found to respond strongly to the tidal currents near the river mouth. These currents are influenced by the coastal

topography caused by the shape of the delta, and result in currents near the river mouth that a eastward much more frequently than they are westward. This results in a buoyant plume that is directled eastward much more frequently than it is westward.

Topic: Lower Elwha River Bathymetry

PI: Dwight D. Barry: DBarry@pencol.edu

Student: Kari Klaas

Director of the Center of Excellence for Peninsula College, Dwight D. Barry has been aggressively developing strategies to improve stream flow forecasting for the Dungeness River. His project on the Dungeness has been and is being funded by a grant from NASA. With some extra funds from the Dungeness project, Dr. Barry was able to initiate a pilot project on the Elwha River. Together with some Huxley on the Peninsulas students, Barry is attempting to characterize sediment transfer on the ground using a computer program to compare it to sediment data collected from satellite images. Several methods were used to compile a database. Turbidity data was gathered at random points along the lower Elwha River; temperature, salinity, etc. were also gathered in the river and at other points throughout the estuary.

Dungeness River (Dungeness River Inc.)

Barry and his team found single beam sonar to be especially useful and important for measuring areas of influence in the river. Such areas of influence include places like the entrances to the western and eastern estuary, and transition points. These factors can have adverse effects on marine activity; it is necessary to monitor changes in bathymetry to observe changes in the habitat of local marine populations. To gather these data, sonar was attached to either a raft or a

kayak, which was then steered back and forth across the channel. In this way, the team was able to get a detailed portrayal of the river mouth floor. This will be critical when tracking how sediment movement affects bathymetry.

With their methods, findings, and proceedings, Barry will be able to design a website where other teams and researchers can access that data and create their own forecast. With the databases and programming, others will have access to an online resource to upload data, pictures and videos of the site and anything else spatially represented. The website will be a portal, accessible upon creation of a username and password. Once in the user's account, the website will allow access to dropdown USGS data files, and anything spatially represented can be downloaded as an html file and saved. This will be an invaluable tool for planning and tracking, not only with the Elwha Dam being so close to dismantlement, but also with the projection of many more dams being dismantled. The Elwha supports 5 different salmon species and is integral for the health of the Sound.

Annotated Bibliography

Barry, D. D. (Presentor). (2011, February 14). *Lower Elwha River Bathymetry.* Peninsula College, Port Angeles, WA.Dwight D. Barry is the Director for the Center of Excellence for Peninsula College Dwight D. Barry. He has been aggressively developing strategies to improve stream flow forecasting for the Dungeness River based on a pilot study on the Elwha River.

Dungeness River Inc. (n.d.). *The Dungeness River*. Retrieved Marcy 9, 2011, Dungeness Community Web Site: Available from: http://www.dungeness.com/river/index.htm.This is a community-created resource to inform the public on the Dungeness River and the surrounding area. It provides a succinct overview of the river, the lighthouse, and local wildlife.

Topic: Course Sediment Movement

PI: Ian Miller, University of California, Santa Cruz immiller@ucsc.edu

Student: Christina LaVelle, Laura Jungbauer

One of the goals from the 2004 Marine Research Committee (MRC) meeting was to find base line information on the rate and direction of the course sediment movement in the Elwha River delta's diverse and complex foreshore, which is the seaward-sloping area of a shore that lies between the average high tide mark and the average low tide mark. Ian Miller, who is completing his doctoral work at UCSC, designed a study to measure course sediment movement and delta erosion prior to the Glines Canyon and Elwha dams' removal.

Tracers (native rocks to the delta about the size of a fist, fitted with 23mm Radio Frequency ID (RFID) chips drilled into the center and capped with epoxy) were deployed on the surface at three different locations (two to the east and one to the West) to determine the along shore movement. The first eastward location is just east of the Elwha mouth (middle site) and the other is around the bend to the east of Charles Road (east site). The west location is just west from the mouth of the Elwha River (west site). The tracer movement was east at the east site, dominantly east at the middle site, and bi-directional at the west site. These tracers were used to determine where the waves would deposit coarse sediment within the delta.

To study erosion from the wave energy within the delta; seven tracers were buried at seven relative positions at the middle foreshore terrace (surface, flush, 10, 20, 30, 40, and 50 meters) and were evaluated over ten different sampling days. To understand how wave energy and tidal height affect coarse sediment deposition within the delta, a pressure sensor was placed twenty meters off shore. The sensor is used to correlate the wave size with the movement of the tracers.

The surface tracers that were located within the high energy zone traveled farther than within the zone of low action. On the days that the waves were the highest (largest at two meters) and the energy was the strongest, the tracers moved the fastest and farthest. It can be concluded that the size and energy of the waves will determine how far coarse sediment will be deposited.

In the bed deployment tracer, the wave energy and the tidal height varied within these sampling days and can be correlated with the beach erosion along the shoreline. Erosion of the shoreline varied with energy and wave height as well. The low energy wave broke further up the beach past the low tide terrace, excavating about five to ten centimeters into the foreshore, while the high energy wave broke on the terrace and excavated thirty-five to forty centimeters into the foreshore.

Sea Grant is continuing its effort to study sediment transport in the Elwha nearshore. Ian Miller and other researchers are trying to apply the model of sediment transport to the anticipated movement of the river after the dams are removed. Preliminary estimates show the amount of sediment moving past the site ($4000m^3$) is exceeding the amount of sediment that is being eroded ($1035m^3$) from the low tide terrace during the highest tidal cycle.

Annotated Bibliography

Warrick JA, George DA, Gelfenbaum G, Ruggiero P, Kaminsky GM, Beirne M. 2009. Beach morphology and changes along the mixed grain-size delta of the dammed Elwha River, Washington. Coastal Dynamics. Accessed on March 2011. Available from: EBSCO Academic Search Complete. DOI: 10.1016/j.geomorph.2009.04.012. The study predicted sediment transport against water levels and current orientation within the Strait of Juan de Fuca and the Elwha delta. Using GIS and mapping the authors found that strong tidal currents transport fine grained material across the Elwha delta eastwardly. The delta is currently dominated by a hard bottom and coarse sediments due to sediment starvation from the Elwha Dams. Post Elwha dam removal large amounts of mixed grained sediments are expected to be released into the nearshore potentially renewing the delta and nearshore. The study also proposed that the Elwha delta has been modified by erosion due to low sediment flows and strong wave action since the creation of the Elwha Dams. The eastern beach is characterized by a low-tide terrace, which has coarsened over the last twenty years. It is speculated that the dam removal will potentially reverse the damage and restore the delta.

Warrick JA, Stevens AW. 2010. A buoyant plume adjacent to a headland: Observations of the Elwha River plume. Continental Shelf Research 31 (2): 85–97. Accessed on March 2011. Available from: EBSCO Academic Search Complete. DOI: 10.1016/j.csr.2010.11.007. Using GIS mapping the authors concluded that the Elwha river plume is strongly influenced by the topography of the Elwha nearshore. As the Elwha River discharges out of its delta it flows Westerly in a strong oscillatory flow. This produces short term eddies which modifies the river plume by causing it to bend over during strong along shore

flows in an Easterly direction. This information is critical in assessing how sediment will be distributed within the coastal zone of the Elwha post dam removal.

Biological

Topic: Subtidal Surveys

Primary Investigator: Steve Rubin, US Geological Survey Steve_rubin@usgs.gov

Student: Tamara Neuffer

Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) methods are designed to sample a large number of ecologically important species in a specific study area. The methods include swath surveys and uniform point contact methodology. In addition to species information these methods enable the divers to quantitatively characterize seafloor relief and substrate composition. These data are used to better understand the relationships between substrate composition, species richness and density. This baseline study will be used for comparison once the dam is removed.

In total there were 33 study sites in 2008 and 31 in 2009. The benthic communities were surveyed and documented. The results indicate that a lot of plant material will be right in the line of fire for sediment deposition after dam removal. There is a concern about fine sediments like sand and silt burying the cobbles and preventing kelp attachment. Kelp is an important part of the food chain in the area most likely impacted by dam removal.

Future plans are to set up fixed transects with markers on the seafloor bottom at regular intervals and come back annually for data retrieval. The transects will be located in areas being monitored for sediment grain size by other researchers using photographic techniques, thus fostering coordination among disciplines. Jon Warrick of USGS is leading the effort. They will also use previous data from 1994 collected by US Fish and Wildlife. The challenge will be getting the data out of the old GIS format to make it comparable with current methodologies.

Annotated Bibliography

Berry HD, Mumford T, Dowty P. 2005. Using historical data to estimate changes in floating kelp (*Nereocystis leutkeana* and *Marcrocystis integrifolia*) in Puget Sound: Unpublished Report." edited by Washington Department of Natural Resources. Olympia: Washington Department of Natural Resources. Floating kelp beds are important nearshore habitats for many species. Understanding the changes that have occurred over time due to natural and human factors will be helpful in understanding the impacts of the Elwha Dam removal. This paper investigated long-term temporal trends in the floating kelp canopy along the Strait of Juan De Fuca.

Cochrane GR, Warrick JA, Sagy Y, Finlayson D, Harney J. 2008. Sea-floor mapping and benthic habitat GIS for the Elwha River Delta nearshore. edited by U.S. Geological Survey. The USGS mapped more than 252 km of seafloor off the Elwha River Delta in order to obtain high resolution bathymetry, record geologic characteristics of the seafloor and construct maps of sea-floor geomorphology and habitat. This information will provide important baseline data in order to identify future changes that occur after dam removal.

Mumford TF. 2007. Kelp and eelgrass in Puget Sound. In *Puget Sound Nearshore Partnership Report*. Seattle: Seattle District, U.S. Army Corps of Engineers. A comprehensive report on the importance of kelp and eelgrass beds in Washington's waters as they are highly productive and fuel nearshore food webs. This information provided valuable information on a critical ecosystem component that could be impacted by the removal of the Elwha Dam.

Shaffer JA. 2000. Seasonal variation in understory kelp bed habitats of the Strait of Juan De Fuca. Journal of Coastal Research 16: 768-75. Kelp resources in the state of Washington are prodominately found in the Strait of Juan De Fuca and provide critical habitat for federally listed and declining stocks of salmon, rockfish, surfsmelt and sandlance. Unfortunately little data exitsts on kelp habitat community structure for the Strait of Juan De Fuca. This study defined understory composition of two dominant kelp habitats in the Strait, providing important baseline information for USGS to identify potential habitat disruption after dam removal.

Additional Resources:

PISCO monitoring methodology information can be found at the following website:

http://www.piscoweb.org/research/science-by-discipline/ecosystem-monitoring/kelp-forest-monitoring/subtidal-sampling-protoco (Accessed 6 March 2011).

Topic: Long-term fish use of the Elwha west estuary

Primary Investigator: Anne Shaffer, Coastal, Watershed Institute, anne.shaffer@coastalwatershedinstitute.org and Chris Byrnes, WDFW

Student: Kristen Farley

The Elwha dams have been disrupting salmon spawning for nearly a hundred years and as the dam removal project nears the final stages of research prior to dam removal,, there has been extensive research theorizing the potential benefits to the dwindled salmon population. The sediment that would naturally replenish the estuaries and shorelines has been blocked by the dams and has led to extensive loss of salmon habitat.

The purpose of this project was to determine the long-term fish use of the Elwha west estuary. The project began with an 18-month study assessing fish use of the Elwha nearshore, including the Elwha estuary. Three areas of the lower river were studied, the impounded west estuary, the connected west estuary, and the east estuary. This work included beach seining at a minimum of once a month and was a collaborative project with WDFW, Peninsula College and WWU.

Key findings are given in the final report. Highlights include that the Elwha nearshore is functioning at a lower level ecologically than comparative areas. Within the Elwha estuary, the connected west side of the estuary has only 15% of the available habitat, however it has 40% of all the fish, 91% of the salmon, and over 94% of the salmon . The west estuary also had the highest species richness (see Shaffer et al. 2009). Results have indicated 1) There have been significant physical changes to the Elwha nearshore ecological function due to lower river alterations, shoreline armoring, and the dams; 2) The Elwha drift cell supports numerous federally listed species; 3) The drift cell is impaired and functioning lower, ecologically, relative to comparative areas, and; 4) Even though impaired, the Elwha nearshore, including the estuary, is still extremely important for fish use.

Long term monitoring has continued for over four years in the Elwha west estuary and comparative (Salt Creek) estuary. Seining is conducted monthly. Results of the 2010 seining are being worked up and an annual report analysis is provided in Brown et al. 2011. Findings include consistent seasonal trends in fish use of the Elwha and comparative areas. Relative proportion of

individual species differs by site, but is generally consistent within each site (Figure 1-3). Significant spikes in juvenile Chinook densities in the Elwha west estuary in June 2010 were attributed to hatchery release when over 3 million juvenile Chinook salmon were released into the lower river in 24 hours (WDFW pers comm; Figure 3). These hatchery releases may overwhelm the west estuary and should be considered in light of such a heavy dependency on a small area of the estuary. They should also be considered in light of sediment changes in the Elwha estuary that may occur as a result of dam removals.

Figure 1. Species composition as a percent of total CPUE per month for the Elwha west estuary May 2010-2011. All specimens intercepted are counted as individuals. Data reprinted from Brown et al 2011.

Common Name	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Total Annual Catch	Annual % Composition
Chinook	51.36%	99.82%	50.52%	7.43%	0	0	3.13%	0	0	0	0	50.78%	2.72%	13,863	73.68%
Coho	33.82%	0.08%	0	4.77%	1.25%	0	0	0	0	1.61%	2.70%	0	19.05%	278	1.48%
Chum	1.88%	0	0	0	0	0	0	0	2.04%	16.13%	5.41%	7.03%	13.61%	51	0.27%
Smelt (adult = >120)	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Smelt (juv = 50-120)	0	0	0	0	0	0	0	0	2.04%	0	0	0	0	1	0.01%
Smelt (pl = <50)	0	0	0	0	0	0	0	0		0	0	0	0	-	-
Herring (juv = 50-120)	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Sticleback(<30)	0	0	0	51.47%	72.43%	83.17%	87.50%	94.19%	61.22%	24.19%	8.11%	0.78%	1.36%	3,008	15.99%
Starry Flounder	0.84%	0	0	0.37%		0.55%	3.13%	0.83%	4.08%	4.84%	0	6.25%	5.44%	37	0.20%
Crescent gunnel	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Saddleback gunnel	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Penpoint gunnel	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Tubesnout	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
3-Spine stickleback	1.46%	0.05%	27.77%	23.30%	21.10%	6.42%	0	2.90%	6.12%	12.90%	32.43%	3.13%	14.29%	918	4.88%
Shiner perch	0	0	0	0	0	8.08%	0	0	0	0	0	0	0	73	0.39%
Staghorn sculpin	9.19%	0.06%	14.41%	3.39%	4.95%	1.77%	6.25%	1.24%	10.20%	22.58%	45.95%	22.66%	19.05%	367	1.95%
Cottids Unknown	0	0	0	0	0	0	0	0.41%	0	0	0	0	0	1	0.01%
Buffalo Sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Cottids <30mm	1.04%	0	4.38%	0.09%	0	0	0		12.24%	16.13%	5.41%	9.38%	24.49%	93	0.49%
Cutthroat	0.21%	0	0	0	0	0	0	0	0	1.61%	0	0	0	2	0.01%
Unkown trout	0	0	2.30%	3.58%	0.10%	0	0			0	0	0	0	52	0.28%
Steelhead	0.21%	0	0	0	0	0	0	0.41%	2.04%	0	0	0	0	3	0.02%
Prickley Sculpin	0	0	0.63%	5.60%	0	0	0	0	0	0	0	0	0	64	0.34%
Arrow Goby	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Northern Anchovie (Adult)	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
N. Shad	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Fluffy Sculpin	0	0	0	0	0.16%	0	0	0	0	0	0	0	0	3	0.02%
Sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Total CPUE	479	13,248	479	1,090	1,919	903	32	241	49	62	37	128	147	18,814	

.

Figure 2. Species composition as a percent of total CPUE per month for the Salt Creek estuary May 2010-2011. All specimens intercepted are counted as individuals. Data reprinted from Brown et al 2011

Common Name	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	Apr-11	May-11	Total Annual Catch	Annual % Composition
Chinook	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Coho	47.62%	14.78%	2.62%	4.84%	6.46%	9.63%	0.95%	0	25.93%	2.94%	2.06%	9.43%	38.92%	474	8.81%
Chum	32.38%	0	0	0	0	0	0	0	0	0	19.59%	7.55%	1.23%	62	1.15%
Smelt (adult = >120)	0	0	0	0	0	0	0	0	0	2.94%	0	0	5.67%	24	0.45%
Smelt (juv = 50-120)	0	0	0	0	0	0	0	0	0	8.82%	1.03%	0	0.25%	5	0.09%
Smelt (pl = <50)	0	0	0	0	0	0	0	0	0	5.88%	0	0	0	2	0.04%
Herring (juv = 50-120)	0	0	0	0	0	0	0	0	0	0	0	0	0.25%	1	0.02%
Sticleback(<30)	0	0	0	0.20%	1.25%	2.63%	0	0	0	0	5.15%	0	0.25%	32	0.59%
Starry Flounder	0	1.85%	0.20%	0.87%	1.47%	4.16%	0.32%	0	7.41%	5.88%	6.19%	7.55%	0.74%	73	1.36%
Crescent gunnel	0	0	0.40%	0.40%	0	0	0	0	0	0	0	0	0.25%	9	0.17%
Saddleback gunnel	0	1.58%	7.04%	7.59%	4.87%	7.22%	0.21%	0	0	0	0	0	0	232	4.31%
Penpoint gunnel	0	0	2.82%	0.47%	0	0	0	0	0	0	0	0	0	21	0.39%
Tubesnout	0	0	0	0.07%	0	0.22%	0.11%	0	0	0	0	0	0	3	0.06%
3-Spine stickleback	0.95%	42.74%	0	2.15%	0.34%	0.22%	0	0	0	2.94%	1.03%	0	0.74%	204	3.79%
Shiner perch	2.86%	27.70%	80.28%	47.72%	75.20%	36.76%	97.05%	0	0	0	0	0	0.74%	2973	55.25%
Staghorn sculpin	0.95%	9.50%	6.04%	24.46%	10.08%	38.73%	0.53%	100%	44.44%	29.41%	9.28%	45.28%	43.84%	941	17.49%
Cottids Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Buffalo Sculpin	0	0	0	0%	0	0	0	0	0	0	0	0	0	1	0.02%
Cottids <30mm	2.86%	0	0	0.07%	0	0	0	0	22.22%	41.18%	51.55%	30.19%	7.14%	119	2.21%
Cutthroat	0	0.53%	0.40%	0.20%	0.34%	0.44%	0.74%	0	0	0	4.12%	0	0	23	0.43%
Unkown trout	0	0	0.20%	0.07%	0	0	0	0	0	0	0	0	0	2	0.04%
Steelhead	12.38%	0	0	0	0	0	0	0	0	0	0	0	0	13	0.24%
Prickley Sculpin	0	0	0	0.07%	0	0	0	0	0	0	0	0	0	1	0.02%
Arrow Goby	0	0.53%	0	0	0	0	0	0	0	0	0	0	0	2	0.04%
Northern Anchovie (Adult)	0	0	0	10.75%	0	0	0	0	0	0	0	0	0	160	2.97%
N. Shad	0	0	0	0	0	0	0.11%	0	0	0	0	0	0	1	0.02%
Fluffy Sculpin	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Sardine	0	0.79%	0	0	0	0	0	0	0	0	0	0	0	3	0.06%
Total CPUE	105	379	497	1488	883	457	949	6	27	34	97	53	406	5381	

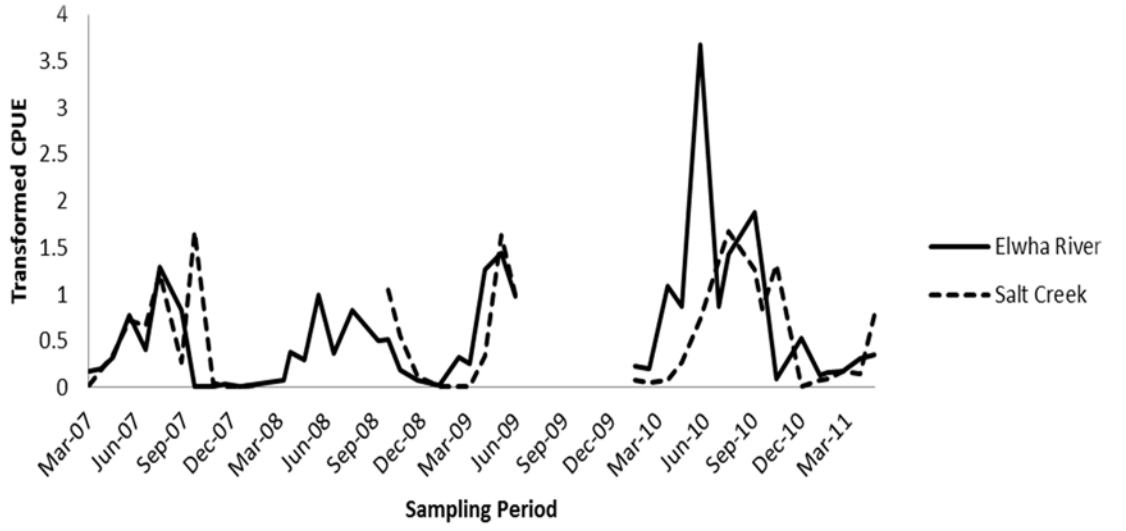


Figure 3. Transformed annual CPUE's for the Elwha west estuary and Salt Creek. Values represent $Ln\ (standardized\ mean\ CPUE\ +\ 1)$. Unfilled data represents periods without sampling (reprinted from Brown et al 2011).

Bibliography (no annotations available)

Peters, R. 1996. Emigration of juvenile chum salmon in the Elwha river and implications for timing hatchery coho salmon releases. USFWS, Olympia, Washington**.**

Shaffer, J.A., T. Ritchie, P. Crain, M. Beirne, and C. Lear. 2008. Nearshore function of the central Strait of Juan de Fuca for juvenile fish, including Puget Sound Chinook salmon. Strait Juan De Fuca Nearshore Assessment Report No. 06-2279. Available from: http://hws.ekosystem.us/prun.aspx?p=Page_e7e0ad79-17d5-489b-9ed8-cb76f1f7c879&m=1&text=juan+de+fuca+nearshore&cols=2

Shaffer**,** J. A. M. Beirne, T. Ritchie, R. Paradis, D. Barry, and P. Crain. 2009. Fish use of the Elwha estuary and the role anthropogenic impacts to physical processes play in nearhore habitat function for fish. Hyrdogiologia 636:179–190

Brown, J., A. Shaffer, and C. Byrnes. 2011. Long term monitoring, nearshore Elwha and Salt Creek Beach Seining and Ichthyofauna Assessment of the Nearshore Environment: 2010-2011. Draft Final Report. Coastal Watershed Institute, Port Angeles, Washington. Available from: www.coastalwatershedinstitute.org;

Topic: COASST in the Elwha overview/highlights
Primary Investigator: Julia Parrish*, Jane Dolliver, University of Washington.
*Project contact: jparrish@u.washington.edu
Student: Nancy Bell

The Coastal Observation and Seabird Survey Team (COASST) and its research related to the Elwha nearshore, was presented by Jane Dolliver, Program Coordinator for COASST. Jane explained the key to COASST is "Citizen Science," with volunteers cataloging dead bird finds on beaches from Humboldt County in California, to Shishmaref (the Chukchi Sea) in Alaska. Jane discussed the COASST process, including the strategy to "collect, verify and report" and how data gathered is sent to the University of Washington School of Aquatic and Fishery Sciences for verification. Data are then compiled into a variety of reports, to be subsequently used by studies related to the health of the marine ecosystem. Of the 300 beaches covered, 200 are in Washington State, including San Juan Islands, Puget Sound, Hood Canal, the Pacific Coast and Strait of Juan de Fuca, with four in close proximity to the Elwha River.

One primary aim for COASST is to involve the general public in collecting beach-based data. These monthly surveys include documentation of the presence of oil, humans, dogs, and vehicles on the beach, and dead bird species including measurements, age, sex and plumage. Referred to as "Citizen Science," the data collected provides temporal and spatial baselines of mortality not collected through other seabird monitoring efforts. Additionally, when a large die-off of a bird species (referred to as "a wreck") is observed, COASST supplies the data across disciplines to provide clues to the cause of the wreck. Monthly surveys by about 600 participants provide baseline data to establish seasonal norms. Other special projects COASST data have been used for include testing for avian influenza; oil spill impacts, remote community involvement, and a population-genetics study of Western Grebes. [Some published studies on nearshore health using COASST data include: (Hamel et al. 2009) on fisheries impacts and (Litle et al. 2006) on oil spill impacts.

The data gathered by COASST volunteers is uniquely useful for understanding long-term trends. Because the program is designed with professional verification as a component, the data are

effective for peer-reviewed studies. The importance of volunteer involvement in maintaining marine health should not be underestimated. Bringing science into the communities that impact sensitive areas may be one of the best forms of public education available. One aspect of COASST's activity is directed at rewarding volunteers with stories of how their work is impacting science. In addition, COASST maintains the annual "dead-bird Christmas card," tradition, and offers a variety of effort-based prizes to volunteers (water bottles, clipboards, raincoats etc.).

At the end of the presentation, Jane Dolliver invited scientists to incorporate COASST data into a study or project or to collaborate on a peer-reviewed paper or US government report. Collaborative studies, such as those profiled in the annual report, "COASST Reports 08-09" provide further support and recognition of the value of citizen science.

Annotated Bibliography

Parrish, J. Editor,"COASST Reports 08-09", May 2010, This annual newsletter highlights species, reports on activity of participants, and publishes scientific studies relating to COASST's survey activity during the year.

Hamel, N.J., Burger, A.E., Charleton, K., Davidson, P., Lee, S., Bertram, D.F. & Parrish, J.K.. 2009. Bycatch and beached birds: assessing mortality impacts in coastal net fisheries using marine bird strandings. Marine Ornithology. 37: 41–60. Fisheries-associated strandings are compared to baseline data collected at beaches monitored by citizen science programs in Washington State and British Columbia, and to seabirds salvaged from gillnets during observer programs. The data shows a sharp drop in seabird bycatch after 1999, when seabird bycatch mitigation rules went into effect in the Sockeye *Oncorhynchus nerka* and Pink Salmon *Oncorhynchus gorbuscha* non-treaty gillnet fishery in Washington State.

Litle, K; Parrish, J. K.; Dolliver, J.2006. The Coastal Observation and Seabird Survey Team – Citizens Monitoring Coastal Environmental Health in Alaska, *in* "Community based coastal Observing in Alaska: Aleutian Life Forum, Page 19-35, 2006. Baseline data is used with species counts of carcasses recovered from specific oil spills to chart which species are particularly vulnerable to oil spills. At high risk are Common Murres, scoters and true puffins – and low-risk species include fulmars, gulls and cormorants.

Parrish, Julia K.; Bond, Nicholas; Nevins, Hannah; Mantua, Nathan; Loeffel, Robert; Peterson, William T.; Harvey, James T. 2007. Beached birds and physical forcing in the California Current System. Marine Ecology Progress Series, Vol. 352: 275-288, . This article describes a study using beached-bird data to calculate the effect of poor

ocean condition on abundant species, including murres, auklets, and cormorants. Climate driven changes in currents, upwelling, and winter storms were determined as causes of unusual die-offs apparently due to malnourishment.

Historical

Topic: History of the Elwha Nearshore

Primary Investigator: Jacilee Wray, Olympic National Park Jacilee_wray@nps.gov

Students: Cindy LaRue, Meggan Uecker

In 2004, Jacilee Wray, anthropologist for the Olympic National Park, and Ann Shaffer, Coastal Watershed Institute, conducted interviews with numerous S'Klallam and other tribes' elders to gather information about Native American traditional and contemporary knowledge of the Northern Olympic Peninsula nearshore. The stories of nearshore cultural knowledge from elders such as Adeline Smith, and Beatrice Charles, members of the Elwha Klallam tribe, and Elaine Grinell, of the Jamestown S'Klallam tribe, can inform us about the historical experiences and processes of the nearshore.

The tribes that lived along the Strait of Juan de Fuca, both the Elwha Klallam whom resided predominantly near the mouth of the Elwha River, and the Jamestown S'Klallam whom maintained residence primarily near the Sequim Bay area, relied heavily on the bounty of the sea for survival. Surviving images show the nearshore habitat of the Elwha River to be very different from its current state; the estuary used to drain in a double-mouthed formation. There were also lakes, which varied in size and residency, east and west of the mouth, that were important gathering spots; they were even used to harvest ice. Indian homesteads were located both near the river mouth, and out onto Ediz Hook, a geological spit formed by the sediment deposits from the Elwha river flow.

Adeline Smith and Beatrice Charles, born in 1918 and 1919, respectively, grew up on a homestead a few miles upriver from the Elwha river nearshore; Adeline was Bea's aunt. One recollection of this area was a house west of the mouth that came to be known as "The Place". This house was written about in Popular Mechanics because the house was made out of huge logs cut in rounds; the windows were also cut out into log rounds. Adeline and Bee recalled that the reason it was named "the Place" was because somebody asked what it was called and the reply was: "I don't know it's the place where everyone camps and builds campfires; I guess it's

just called the place." In the late 1930s the home burnt down. A modern day road which leads to the Elwha estuary is called Place Road.

Adeline and Beatrice also were among the first to attend the Chemawa Indian Boarding School in the 1930s. Today Adeline is working on a Klallam language dictionary.

A variable record of access by the Elwha tribe punctuates the history of the Elwha nearshore in the 20th century. As European settlers moved in, Indian settlements were subject to upheaval under various agreements and orders. When European homesteaders came in and property values skyrocketed, native Klallam lost land because they couldn't pay the taxes on it. Another example of how Klallam people lost access to their native grounds occurred in the 1930s, when a land trust was purchased in the Elwha river mouth area, under the Indian Reorganization Act. The objective of this land trust was to move Indian families off of Ediz Hook to the nearshore. Until the 1950s, Klallam occupied areas from Ediz Hook along the entire nearshore to Freshwater Bay. This Act contributed to a severe reduction in Klallam nearshore access. Today, due to industrialization and privatization of the nearshore, access for native peoples is very limited.

Interesting memories of the earlier Elwha culture include competitions in which Elwha youth would attempt to carry boulders across the river to prove their strength. Klallam literally means "strong people". This name comes from a tale of a gathering in which the Klallam people showed their strength by lifting a giant log to place on a roof, using the property of buoyancy in water to get it onto their shoulders. Another memory includes trading canned goods for seafood out on Ediz Hook.

Elaine Grinell, born in 1936, was raised by her parents David and Elizabeth Prince. She was a professional fisher and crabber. She grew up on Sequim Bay, the name for which literally means "the place where the birds go in the direction of the fire". This name stems from the practice of setting a fire in order to lure ducks toward it, only to be caught by nets held up between two canoes. Other place and organism's names have interesting stories behind them as well. In a place where sea urchins still proliferate, the Klallam name for that location (undisclosed in lecture due to harvesting sensitivity) means "a place of spiritual healing."

Nearby locations also retain S'Klallam mythology in describing geological formations and processes. Mt. Baker, which can be viewed across the Strait from the nearshore, was depicted as a mean father and his little girl. Another story told of a sea witch with long hair of eel grass, whose location was denoted by a constant bubbling from underwater, actually a result of the tide mixing over that particular seafloor formation.

Elaine would hunt octopus in the bay. Her technique to catch one was to find an octopus hole at low tide. Octopus holes have front and back doors; splashing water at both doors would make the octopus irritated until it came out. She would grab it by the head and turn it inside out, take out its membrane with a sharp stick, and then cook in a dutch oven with no water, else it would get chewy.

Seafood tales abound from the peoples who survived on and relished the nearshore edible offerings. Gooseneck barnacles, known as boots or Sutsin, which translates to 'the waves coming' in the Klallam language, were thought to be more tender if harvested under the kelp. Children were warned not to eat them unless they would risk getting boils, but this was realized to be an adult trick to keep the difficult to harvest delicacies to themselves. Other cherished edibles included lingcod eggs, boiled in water, but difficult to take from the protective lingcod. Chitons, cockles, crabs, fish, seals, whale, octopi, anemones and kelp were eaten. Each type of clam was said to have its own taste; strings of smoked butter clams were a great snack for Indian children on the go. Fried salmon eggs and sea mussels were cheap and nutritious foods. Tricks to avoid red tide poisoning included touching the shellfish to one's lip to check for irritation; one man, Lyle Prince, would give clam necks to his cat and monitor it for effects. The Klallam used dogfish oil as well, for lights in early lighthouses. Cattails were used as camping mats and salmonberry spouts were nutritious edibles gathered from the nearshore habitat. Seaweeds such as surfgrass and eelgrass, shellfish shells, and rocks were used in basketry, rattle making and other cultural items.

The partitioning of the beaches in modern times has led to the loss of seafood populations, as well as access to food and other resources, with ensuing immeasurable detrimental effects on the traditional peoples' health and culture. Ancestors, it was felt, could find everything they needed

to eat and survive right in this area; the loss of the productivity, access, and functioning of this habitat is still deeply felt.

Annotated Bibliography:

Olympic Peninsula Intertribal Cultural Advisory Committee**.** Wray, J, ed. 2002. Native Peoples of the Olympic Peninsula: Who We Are. Norman, OK: University of Oklahoma Press.A collection of writings about cultural and geographical history of the native peoples of the Olympic Peninsula, from the perspective of a representative member of each tribe.

Charles, Beatrice (Elwha), Cooke, Vince (Makah), Grinnell, Elaine, (Jamestown), Morganroth, Chris III (Quileute), Morganroth, Lela Mae (Quileute), Peterson, Melissa (Makah), Riebe, Viola (Hoh), Smith, Adeline (Elwha), and Wray, Jacilee. 2004. When the tide is out. An ethnographic study of nearshore use on the northern olympic peninsula. (Olympic National Park and the Coastal Watershed Institute, Port Angeles, Washington

Habitat Mapping

Topic: Macrovegetation Survey Results

PI: Jim Norris, Marine Resources Council jnorris@olympus.net

Student: Michael Philip Hank

The purpose of this study is to define fish habitat use of subtidal vegetated habitat, and their effects within the Elwha River Nearshore drift cell. Research of fish habitat use within macrovegetation and its effects along the Elwha River has been ongoing for several years. It is looking to clarify and understand the mechanisms that help to structure the fish populations in the Elwha Nearshore drift cell, quantify the effects of macrovegetation on fish habitat, quantify the effects of changes in macrovegetation on fish habitat that will occur during and following dam removal, and determine whether or not the juvenile fish or forage fish are utilizing the macrovegetation..

Currently 715 acres of land are covered by the dams and reservoir that were previously covered with native vegetation. Post dam removal is hoped to recover and expose about 684 acres for replanting and aid in salmon recovery, but it is also expected that there will be less kelp forest in the nearshore area. The goal of this study is to determine the potential effects on fish from dam removal by determining the extent of the current kelp bed habitat (prior to dam removal), and to assess its importance for fish rearing.

Preliminary results of the current research survey have uncovered the following (in summary):

- Macrovegetation covers most of the survey area.
- Few small schools of fish were actually observed.
- *Frame Trawl* is not an efficient measuring device.
- Frame trawl was not capable of catching adult sandlance.
- No video surveys were conducted initially.
- Large amount of sand lance were seen in eelgrass in 2006.
- No large fish schools found.
- Not video survey was conducted in first week of September 2010.

- Successfully collected sand lance from bait balls using a dip net along the Dungeness Bluffs and midchannel Bank near Port Townsend.

Since construction of the Elwha and Glines Canyon dams, two main changes have occurred along the river. Downstream transport of sediment and wood has decreased dramatically. Migration of salmon above the lower dam has halted. Because wood and fish losses have occurred on certain reaches along the river, studies are being conducted to see how changes in sediment, wood, fish, flow influence, vegetation, and soils are affected in the Elwha River floodplain.

Sounding depths measured during day lights hours only and were taken at the -30 ft to the Mean Lower Low Water (MLLW) levels (see Figure 1). Data that was collected in the summer of 2010 in the Elwha River Nearshore . Locations of the random 3 transects were Freshwater Bay to the east, Elwha Bluffs in the center and Ediz Hook to the west. Additional soundings were conducted along the Crescent Bay area out towards Dungeness Spit taken out to the -15 ft MLLW levels. (see Figure 2).

Vegetation parameters were obtained and measured using the Department of Natural Resources (DNR) class schemes for the following type vegetation and classified in five separate categories. They were: 1) Seagrasses, predominantly *Zostera marina* (eelgrass) 2) Big–Blades, includes kelps and broad bladed red-algae, 3) Fuzzy-Bushy, algae, 4) Greens, and 5) other Brown Seaweeds, including *Pterygophora californica, woody stemmed kelp.*

Research surveys based on *Hydro-Ecograph Acoustics* data conducted in 2006, have established that fish densities are greater around Ediz Hook.. This suggests that there are greater interactions between algae and fish than initially introduced. Since very few fish were uncovered or observed during the surveys, the data are inconclusive. Kelp found in the study area has been increasing due to less sediment release from the dams, exposing more rock and cobble in the intertidal region. Many macroalgae need larger substrate to hold on to with their holdfasts.

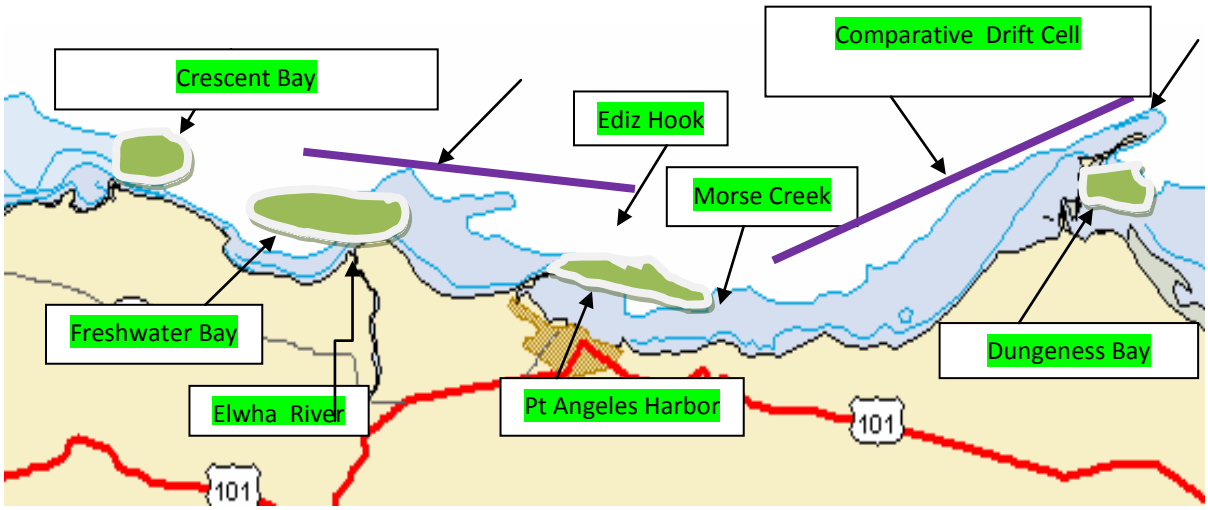


Figure 2: Map of study areas from the 2006 survey (purple lines) and 2009 survey (shaded green lines).

Annotated Bibliography

Elwha Nearshore Consortium, 2005. Elwha Watershed Information Resource. Boise, ID: , University of Idaho.The Elwha Watershed Information Resource is an online resource center which integrates ecological and socioeconomic information that describes the physical environment, biological and human communities, and management issues within the Elwha watershed. The Elwha Watershed Information Resource was developed to support the management and recovery of the Elwha Watershed after dam removal. The online resource complements ongoing activities related to dam removal, including those of the National Park Service, the Elwha Research Consortium and NOAA Fisheries.

Norris, James G. 2009 Eelgrass Mapping in Crescent Bay, Freshwater bay, Port Angeles Harnor, and Dungeness Bay. Report submitted to Cathy Lear, Clallam County Planning Biologist, and Port Angeles, WA. This report was conducted by Marine Research Consultants in June 2009 for Clallam County by James Norris. It describes the total eelgrass mapping project that was conducted along Freshwater Bay, Crescent Bay, Port Angeles Harbor and Dungeness Bay. Site selection, sampling plan, survey equipment used along with results and tidal parameters are detailed and shown. Survey transect locations including depth of soundings, ecograph acoustic technologies, fish abundance and vegetation parameters were inserted and annotated on this latest round of collaborations and research.

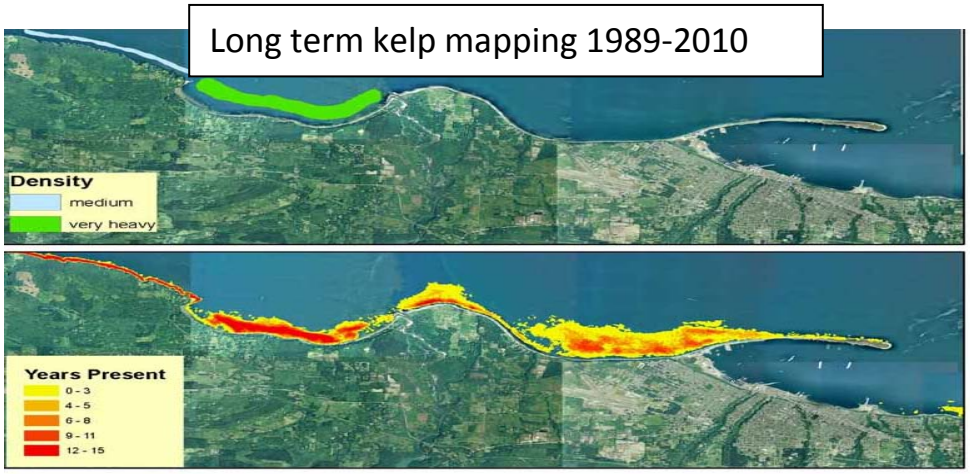
Shafroth, P. (2006). Riparian Vegetation Research along the Elwha River. Washington, D.C.: US Geological Service. This article proceedings, which were published during the Elwha Consortium Nearshore Conference 2005-2006, generally describe what vegetation research has taken place, the locations of survey transects, who is conducting the research and techniques used to determine data. The baseline used is sediment load and its effects on salmon restoration.

Washington Sea Grant. . 2009. West Coast Regional Marine Research and Information Needs. Portland, OR: Oregon State University.As part of the California Current Large Marine Ecosystem (CCLME) this document has a primary goal is to present, for the West Coast planning process, identification of continuing or new research on outreach information related to the CCLME that would contribute to the transition toward an ecosystem-based approach to ocean and coastal management.

Topic: Long term kelp mapping

Primary Investigator: Helen Berry, Department of Natural Resources
helen.berry@dnr.wa.gov
Student: Christina LaVelle

The Nearshore Habitat Program at the Department of Natural Resources (DNR) has been studying kelp bed distribution since 1989 within the Strait of Juan de Fuca. The purpose of the long-term mapping is to assess trends in kelp species distribution over temporal time scales. Kelp beds are critical habitats that support commercial and recreational fishing, marine mammals, marine birds, and invertebrates (Berry et al 2005). Using aerial photography and regression analysis, conclusions can be made about what natural or human induced impacts have changed distribution and composition of kelp canopies on a temporal scale. (Map 1)



Map 1: Density of Nereocystis luetkeana (bull kelp) and Macrocystis interifolia (giant kelp)
Slide Courtesy of the Department of Natural Resources

Historical to Current Kelp Distribution in the Elwha River Study Area, the top image shows canopy-forming kelp beds mapped by Rigg (1912) prior to Elwha Dam Placement. The bottom image summarizes DNR monitoring data and shows persistence of Canopy-forming Kelp between 1989-2004

The Nearshore Habitat Program in the Department of Natural Resources is continuing a detailed study mapping kelp beds within the Elwha nearshore. Using baseline data from a kelp bed survey from 1989-2010 the group will assess the before and after effects to nearshore macro-algal populations from the dam removal along the Elwha River. Annual aerial photo-based

monitoring of species of kelp that form extensive surface canopies is currently ongoing. The study mainly focuses on *Nereocystis luetkeana* (bull kelp) and *Macrocystis pyrifera* (giant kelp) within the Elwha nearshore. The study was based on bed mapping from Port Townsend to the Oregon Border. The group is completing a detailed trend analysis of 1989-2010 data and will produce a report in the summer/fall of 2011.

The survey hopes to determine if this information will be useful to evaluate the before and after conditions related to the dam removal and kelp bed trends throughout the study area. This work is based on previous kelp mapping studies of kelp bed distribution within the Puget Sound and Port Angeles coastlines. These studies have been ongoing since 1989 and are a compilation of long-term kelp mapping.

Scientists with the Nearshore Habitat Program in the Department of Natural Resources have inventoried canopy-forming kelp beds using aerial photography annually since 1989, with the exception of 1993. (Berry et al 2005)

Color infrared aerial photographs are taken at low tides in the late summer when kelp beds are at the maximum growth. The photographs are then transferred to USGS 7.5 minute topographical maps, enlarged and then converted to datasets. The species are categorized as giant kelp, bull kelp or mixed. This information is then assessed to see if there were any changes over time in the extent of the kelp beds.

Preliminary analysis of kelp bed extent over the study area concluded that kelp bed extent changes annually. Over the eight years of study, giant kelp consistently had a higher annual study area wide density (0.34-0.53) as compared with bull kelp (0.17-0.39).

The results of the study found that kelp canopy has variable and high year-to-year distribution. (Berry et al 2005)The results of the study concluded that kelp canopies have increased significantly (roughly 1850 hectares) between the years 1997- 2000. However this increase in kelp bed canopy did not occur evenly throughout the study region. Two regions increased overall. This was the outer coast region and within the Strait of Juan de Fuca. Protection Island suffered a significant decrease from 10 hectares to 1 over the 1989-1990 periods and kelp continues to decline in this region.

The overall trend in kelp canopies was that they are increasing at a rapid rate. The reasons for this are currently unknown. Climate change, sea urchin decline from harvesting and/or sea otter proliferation, changes to habitat through anthropocentric means, and algal community shifts were considered in the assessment.

The Nearshore Habitat Program is continuing its efforts in mapping canopy forming microalgae in the Strait of Juan de Fuca to provide critical information about kelp bed distribution in the nearshore. These efforts can be used to make conclusions about stressors in the nearshore environment that can disrupt the nearshore food web.

Annotated Bibliography

Berry, Helen, Mumford, Thomas F.Jr, Dowtry, Peter. 2005. Using historical data to estimate changes in floating kelp (*Nereocystis luetkenea and Macrocystis integrifolia*) in Puget Sound, Washington. Department of Natural resources Nearhsore Habitat Program.[internet] [date cited 2011, updated 2005]; available from: http://bio.research.ucsc.edu/people/carr/publications/Nereo-lit/Nereo%20grey%20lit%20PDFs/Berry%202005.pdf (Accessed March 2011)
Using aerial photographs from 1989-2005, the Nearshore Habitat Program DNR studied change over time in the canopy forming *Nereocystis luetkeana* and *Macrocystis interifolia* in the Strait of Juan de Fuca. The study is a continuation of the 1989- 1999 canopy forming Kelp bed analysis performed between Port Angles and the Oregon border.

Berry, Helen, Sewell, Amy. 2001. Temporal trends in the aerial extent of canopy-forming Kelp beds along the Strait of Juan de Fuca and Washington's outer coast. Nearshore Habitat Program. Washington State Department of Natural Resources.[internet] [date cited 2011, updated 2001]: available from: http://bio.research.ucsc.edu/people/carr/publications/Nereo-lit/Nereo%20grey%20lit%20PDFs/Berry%202001.pdf (Accessed March 2011)
Using aerial photographs taken from 1989-1999, the Nearhsore Habitat Program DNR mapped kelp beds using aerial photography and converted them to datasets. These data sets were studied to evaluate change over time in kelp bed density and populations from Port Angeles to the Oregon border.

Topic: Pilot Study on Marcoalgae Bloom in the Impounded West Elwha Estuary

PI: Dr. Tim Nelson, Seattle Pacific University tnelson@spu.edu

Student: Dave McConnell

The study, entitled "Pilot Study on Marcoalgae Bloom in the Impounded West Elwha Estuary," examined the possible causes and effects of the macroalgae blooms in the impounded Elwha Estuary. Dr. Nelson and his marine botany class conducted the study on October 12, 2010. The class collected and processed algae samples from the study site and a control site and then analyzed the results. The study was conducted in the impounded section of the far west estuary shown in photos 1 and 2 below. The zone labeled 6.9A in photo 1 indicates the study area. Photo 2 is a close-up of the site from ground level.

Photo 1 – 6.9A indicates location of study area. (Nelson et al. 2008)

Photo2 - Close-up photo of the study area.
Source: Photo by Keith Thorpe/Peninsula Daily News

The impounded section of the west estuary is 9 acres in area and is impounded by an earth and rock dike referred to as the "Elwha Westside Levee." The dike was constructed along the west river channel and separates the impounded zone from the rest of the estuary. The dike was constructed in 1964 by a local flood control district for flood protection. The National Park Service further raised and armored the dike in July 2010 to prevent erosion of the dike and provide additional flood protection. As part of the dike retrofit, the improved sections were hydro-seeded and fertilized to restore their surfaces and to provide temporary protection to the altered surface. The seed mix used included Seaside Colonial Bentgrass, Red Fescue and Perennial Rye. The fertilizer used contained nitrogen, applied at 90lbs. per acre, phosphoric acid, applied at 70lbs. per acre, and soluble potash, applied at 70 lbs. per acre. The dike creates an effective fish barrier and contributes to increased algae blooms. Pictures 3&4 below show the dike in its original form before it was raised and armored and after it was modified and armored.

Photo 3 - Levee before armoring. Source: Photographer Rob Casey

Photo 4 - Levee after armoring July 2010. Source: Photographer Rob Casey

The population of algae present in the impounded section of the estuary consisted of Division *Chlorophyta,* Order *Ulvales* where many species are commonly known as "sea lettuce". The sea

lettuce grows vigorously and is abundant from April through August. In appearance sea lettuce is a bright green color with simple morphology. The leaves are flat, thin bladed, and one or two cells thick with high growth and decomposition rates. Sea lettuce is ubiquitous and present in almost every nearshore habitat and provides food and shelter for other organisms as well as recycling nutrients present in the aquatic environment. Sea lettuce growth is often limited by nitrogen availability so if excess nitrogen becomes present, large blooms often occur which reduces light and oxygen and creates an anoxic environment (Nelson et al. 2008).

The researchers believe that three factors have contributed to an increase in algae blooms. First, the dike has decreased water circulation substantially by cutting off the flow of water from the main estuary into and out of the study area. Second, nutrient sources such as failing septic systems from upstream of the estuary impoundment may be contributing nutrients to the water that drains into the estuary impoundment. Finally, increased nutrients have raised primary productivity and biomass of the sea lettuce population. The researchers had not positively identified the source(s) of nutrients by the time the presentation was given.

The collection of grab samples for this study was done in the field on October 12th 2010. The grab samples were taken to the laboratory of Dr. Tim Nelson at Seattle Pacific University, where they were dried and then analyzed for percent nitrogen and percent carbon using a CE Elantech 1112 elemental analyzer calibrated with aspartic acid. The results were as follows; (1) test values below 2% N are usually only seen in N-limited algae, (2) the C to N ratio in the Elwha is very high, which implies nitrogen limitation, (3) when nutrient sources are high, algae will use excess nutrients to create more growth and a larger bloom, (4) sea lettuce normally grows in nutrient limited conditions so a nutrient source is likely causing an increase in algae blooms. The primary conclusion of the researchers is that the sea lettuce population is normally nutrient limited and that a possible nutrient increase from one or more sources increased the sea lettuce bloom.

This study was a preliminary investigation designed to compare the algae bloom in the impounded portion of the west estuary with a control site to see if the sea lettuce algae bloom was abnormal and excessive. Since the study was a preliminary investigation, there are several next steps for future study that the researchers plan; (1) detailed study to determine nutrient

levels and sources, (2) monitoring water quality for nutrients, (3) defining nutrient sources such as groundwater, septic systems, dike, and (4) study to define historic macroalgae blooms and habitat changes. The researchers will conduct these steps in the next year or as time and funding allow.

Annotated Bibliography:

Nelson et al. 2008. Ecological and physiological controls of species composition in green macroalgae blooms. Ecology 89 (5): pp. 1287-1298.This is the published journal article on which the above presentation is based. It describes a comparative study of "sea lettuce", Division Chlorophyta, Order Ulvales, in the impounded west estuary of the Elwha River and a reference site. The primary conclusion of the researchers is that the sea lettuce population is normally nutrient limited and that a possible nutrient increase from one or more sources increased the sea lettuce bloom. The researchers also indicated that there was a need for follow up research in the following areas including; (1) detailed study to determine nutrient levels and sources, (2) monitoring water quality for nutrients, (3) defining nutrient sources such as groundwater, septic systems, dike, etc., (4) study to define historic macroalgae blooms and habitat changes.

Nelson, T.A., Haberlin, K, Nelson, A.V., Ribarich, H., Hotchkiss, R., Van Alstyne, K.L., Buckingham, L., Simunds, D.J., & Fredrickson, K. 2008. Ecological and physiological controls of species composition in green macroalgal blooms. Ecological Society of America. 1287–1298. This journal article examines ecological and physiological control factors in the growth of common species of green algae of several common types including *Ulva sp.* and *Ulvaria obscura*. The research relates to the Elwha estuary impoundment study by indicating possible growth control factors that could trigger rapid growth and lead to algae blooms.

Olympic National Park. No Date Given. Section 02920 Seeding. Olympic National Park (WA): National Park Service (US). PMIS No. OLYM 005375.This report is an internal National Park Service document written to describe the restoration treatment applied to the dyke that impounds the west estuary of the Elwha River. The document describes the hydro-seeding mixture used, the type of fertilizers applied, and the specific restoration techniques and processes to be implemented as the dyke surface is stabilized and restored after the improvements were made to the dyke. This was not a published report so not all of the citation information is available.

Nearshore Management

Topic: Port Angeles Landfill Update and Status

Primary Investigator: Kathryn Neal, City of Port Angeles Engineering Manager
kneal@cityofpa.us
Student: Anthony Grim

The property of the Port Angeles landfill has been transformed to accommodate many uses throughout the years. Initially it started out as a gravel pit and was converted into the county dump, once the resource extraction was complete, and eventually it became the Port Angeles landfill. Today the landfill is closed and is operated as a transfer station and waste water treatment plant. The landfill's bluff was graded with a slope cutback of 1.25:1 and the material removed was retained to support the closure plan's beach nourishment requirements. In addition to the slope cutback, an approximately 430 foot long and 10 foot high revetment wall was built in front of the landfill's bluff as part of a pollution control function designed to sequester garbage from eroding into the water.

As part of the 30-year landfill closure plan, the City of Port Angeles has been conducting beach profile measurements from the wall out 200 feet to monitor for any erosion that may be occurring due to the revetment wall. The first profiles were conducted in 2005 and served as the basis for the revetment wall's design and have continued since in the spring and fall. In October 2007, after the completion of the revetment wall showed that the beach had lain back very quickly but was not far from the profiles of the previous years. It is expected that the profiles will change from season to season and year-to-year since this is a dynamic environment. During the 2011 summer, the City will be placing, as beach nourishment, approximately 20% of the retained bluff material along the wall and will extend material out 100 feet to each side. This beach nourishment is "sacrificial" and designed not for the structural support of the revetment wall, but for the improved habitat of the beach and the redistribution of the sediments. Currently the closure plan has budgeted for 3 beach nourishment replenishments. The City understands that this process will most likely need to continue past the initial budgeted replenishments. As part of

the ongoing research, beach profiles will be conducted annually and will be used to evaluate requirements for further beach nourishment replenishment.

Another component of the landfill closure plan was to conduct a macro-algae survey. The most recent survey was completed in August 2010 and a draft report is being evaluated by the City and will be available in the near future (send email requests to Katheryn Neal: kneal@cityofpa.us). Due to better weather conditions, the survey conducted in 2010 was more comprehensive than the initial survey in 2006 and will act as the baseline in the future. The overall conclusion of the survey indicates that the micro-algae population and substrate were similar to those recorded in 2006.

Last, there was a question regarding leachate from the landfill and what the City is doing. There is a 24 inch perforated pipe behind the revetment wall designed to capture any leachate. This water is treated as waste water and is pumped to the waste water treatment plant for processing.

Photo courtesy of WA DOE

Topic: Army Corps of Engineers Five Year Control Program

Primary Investigator: Michael A. Giovannozzi, USACE Coastal Engineer, Beth McCasland, USACE Biologist

Student: Christine Butler-Minor

The Army Corps of Engineers became involved in the erosion control of Ediz Hook during the mid 1960s when the City of Port Angeles requested the Corps provide erosion control measures to protect the roadway and prevent breaching of Ediz Hook (figure 1). The purpose was to protect the sand spit from erosion, protect Port Angeles Harbor from direct wave action, and maintain access to the U.S. Coast Guard station at the tip of the spit. The Corps project, originally constructed in 1978, consisted of a beach nourishment of 160,000 tons of gravel/ cobble and approximately 450,000 tons of rock for the revetment. Subsequent repairs were performed to reinforce the revetment and provide additional beach nourishment material.

Figure 1: Project Location

Figure 2: Corps Revetment on North (Strait) side of Ediz Hook

The fiveyear erosion control project need arises from continuing erosion of Ediz Hook. The spit is a natural barrier without much applied engineering. As a berm of varying widths, rising 12+ meters above the mean lower low water (MLLW), the preliminary study identified wave transport as the greatest erosion factor. Long shore currents, shoreline armoring along the toe of feeder bluffs west of Ediz Hook, and two dams on the Elwha River create a reduction in sand, gravel, and cobble materials on Ediz Hook (figure 2).

Year	Metric Tons
1978	160,000
1985	45,300
1997	45,000
2002	45,000

During the original study, fortification required 450,000 tons of revetment stone and 160,000 tons of beach sand/gravel. Estimates indicated an additional 100,000 tons of beach sand/gravel should be added every five years to maintain the shoreline. However, on average only 50,000 tons of beach material has been placed in front of the revetment on a seven to eight year basis due to prioritization and reduced funding availability to the Corps. In 1985, the Corps rehabilitated the revetment. Emergency repairs of the revetment were performed in 1991. The most recent beach nourishment project was completed in 2002.

The Army Corps of Engineers' 2011 budget includes funds to re-nourish the beach during the summer months of the same year. In order to maximize damage control, surveys were conducted in 500 ft increments up to the outer 1/3 of the hook. No repairs will be attempted at or beyond the Coast Guard landing strip as it is outside the authorized project limits. Preliminary profile results identify large changes to the shoreline in prior fill placement areas. A great deal of erosion has occurred along the western edge. The landward half of the spit has two locations selected for priority repairs (Zones A and B in figure 3).

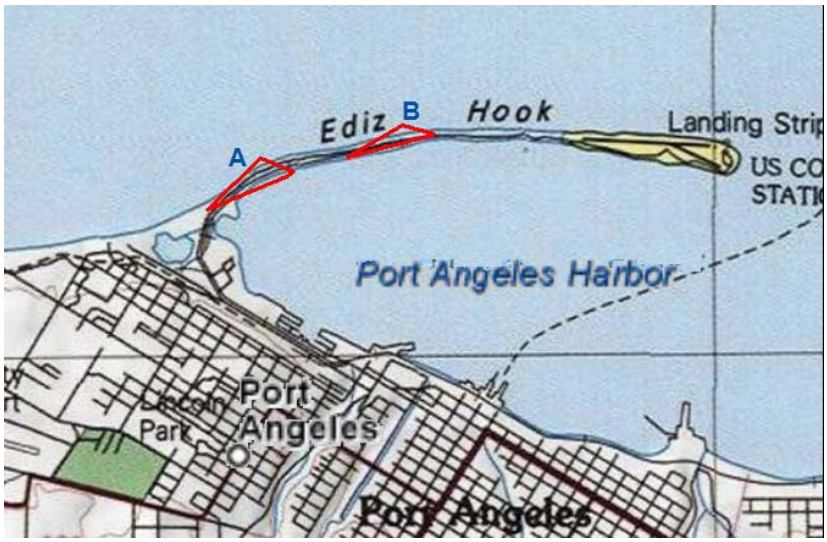


Figure 3 Ediz Hook project sites A and B

Of the two reaches, site A near the Nippon paper mill experiences higher rates of erosion due to energetic northwestern swells. Transport is oblique to the hook with an easterly net drift, leaving 6+-inch rounded cobbles on the shoreline. Site B commonly has 1-3 inch rounded cobbles. Some accretion occurs along the shoreline although largely due to displacement of existing fill. Approximately 2,000 feet will receive sand at site A and 3,000 feet will be amended in site B in front of the existing revetments as protection from further erosion.

The Corps will maintain engineering and operations on the western 2/3 of the spit. Renewed efforts in engineering will take place to develop a sediment budget and determine a critical threshold for beach nourishment. In addition, an increased understanding of wave action and sediment transport effects on the Ediz Hook will be pursued.

Various members of the Elwha Restoration Consortium have offered to provide their survey results to the Corps to assist engineering planning. For instance, the USGS is conducting sonar and camera bathymetry surveys to characterize sediments and to monitor morphology east of the Elwha River delta. Even with removal of the two Elwha River dams, nourishment of the beach will remain necessary in the near-term. This is due to plans for staggered sediment release after dam deconstruction. Allowing the river to transport sediment naturally will result in slow distribution towards the Ediz Hook. Current estimates calculate sediment delivery to the hook no sooner than five years after dam removals. In addition, the feeder bluffs will remain armored blocking that source of sand. When sediment reaches the Ediz Hook, sediment is unlikely to be retained due to the high wave action, lack of flat gentle beach and no large woody debris. Placement of engineered log jams (ELJ) to trap sand is presently out of the project scope. Reauthorization of a revised project and funding would be required to include ELJs or to place restoration materials in another location on the spit as exact specifications are mandatory in any project using federal funds.

This project, funded by federal monies requires compliance with National Environmental Protection Act (NEPA). When timeframes between projects exceeds one year, a new Environmental Assessment (EA) is necessary. Accordingly, a replacement to the 2005 EA has been compiled. Updates to the Endangered Species Listings have been incorporated, including

additions to critical habitat. This part of the revised document has been provided to the National Marine Fisheries Service. The Washington State Department of Ecology has been contacted for the water quality permit. The nearly completed EA is expected to be available for public review in the March-April timeframe. Work to bolster the existing revetment is anticipated to begin in July of 2011, which is a common start date for this particular project. Previous revetment restoration projects have been completed before October of the same year. This is the expectation for completion of the 2011 undertaking.

Annotated Bibliography

U.S. Army Corps of Engineers. 1972. Ediz Hook, Port Angeles, Washington 93rd Congress: Hose Document 93-101. The Secretary of the Army transmittal from the Chief of Engineers, Department of the Army, dated August 21, 1972 includes the survey report, together with accompanying research and illustrations, on Ediz hook, Port Angeles, Washington. The feasibility report on erosion control was requested by resolutions of the Committees on Public Works, United States Senate and House of Representatives., adopted September 13, and October 8, 1968. The transmittal also includes letters of support from various applicable federal and Washington State agencies Retrieved 16 Feb 2011. Available online at http://ftp.resource.org/gao.gov/93-251/00007d20.pdf

U.S. Army Corps of Engineers**.** 2002**.** Ediz Hook Beach Erosion Control Project, Washington**.** This publication is a comprehensive assessment of the project. It provides erosion control baseline information and approaches that will be taken by the USACE. Included are impact assessments on the environment and protected species as well as cumulative effects. to Retrieved 11 Feb 2011**.** Available Online at Http://El.Erdc.Usace.Army.Mil/Tessp/Pdfs/Ediz_Hook_Be.Pdf

U.S. Army Corps of Engineers. 2011. Fiscal Year 2011 Civil Works Budget for the U.S. Army Corps of Engineers summary. Retrieved 11 Feb 2011. The budget report confirms appropriation of funds for implementing the project in 2011. Available online at http://www.usace.army.mil/CECW/PID/Documents/budget/budget2011.pdf

Topic: Elwha Nearshore Ecosystem Acquisition and Restoration Plan

Primary Investigator: Michele d'Hemecourt, North Olympic Land Trust

Student: Staci Kaufmann

The North Olympic Land Trust has been protecting land in Clallam County for over 20 years (North Olympic Land Trust, 2011). Michele d'Hemecourt, the presenter, has been working with the North Olympic Land Trust (NOLT) as the Conservation Director and is partnering with the Coastal Watershed Institute (CWI) to develop an Elwha Nearshore Action Plan. This Action Plan will be a two-year project and will allow CWI and NOLT to partner with other agencies such as Clallam County and Peninsula College. The Action Plan will be to prioritize the restoration efforts of the Elwha nearshore environment based on the geomorphic habitat. This project includes the development of an ecosystem action plan for both acquisition and restoration of these critical nearshore habitats based on landform priorities.

The four main habitat types in the Elwha nearshore environment in order of restoration priority are, (1 the Elwha River and estuary, (2 the Elwha embayed shoreline, (3 the Elwha bluffs and (4 Ediz Hook. (see figure 1)

Number	Landform	Length	
		km	Miles /area
1	Elwha River (north to south)	0.5	0.3
	Elwha estuary (total area):		90 acres
	Elwha west estuary length (both sides of dike)		0.5/27 acres
2	Elwha Embayed shoreline (Freshwater Bay)	7	4
3	Elwha bluffs	6	4
4	Ediz Hook (spit)	5	3
	Total	**18.5**	**11.8**

Figure 1. Table of habitat types in the Elwha nearshore environment and their dimensions.

The main reason why the area needs this plan is because the nearshore Elwha environment is impaired. A huge impediment to the natural nearshore processes is the dike in the west estuary of the Elwha. The total land in this action plan encompasses 12 shoreline miles from Freshwater Bay to Ediz Hook (Elwha Watershed Information, 2009). The goal of this Action Plan will be to restore the Elwha nearshore sediment processes. The current state of the Dungeness spit is being used in this Action Plan as a model for how CWI theorize Ediz Hook would have looked like if the dams were never built on the Elwha.

To instigate this Action Plan, CWI will develop a property inventory in the four regions. The property inventory will then be prioritized, and CWI and the Land Trust will begin working with willing property owners. In return for their cooperation, the property owners will receive state tax benefits, and there may be grant funding for restoration and the purchase of development rights.

The North Olympic Land Trust hopes to employ conservation easements in this Action Plan. In three of the four action areas, (1) the Elwha River and estuary, (2) the Elwha embayed shoreline (3) and the Elwha bluffs, the action plan will utilize conservation easements as a way to help restore the habitat. Conservation easements are legal binding agreements with the landowner to restrict the use of their land in order to protect the habitat. The restrictions, which are voluntarily put in place by the landowner and North Olympic Land Trust and enforced by NOLT, are binding on all future owners of the property (North Olympic Land Trust, 2011). The use of conservation easements is preferable over outright ownership by the North Olympic Land Trust. In the Action Plan, the efforts on (4) The Ediz Hook habitat will be purely monitoring and restoration.

The Action Plan is comparable to the Greenbook action plan that was put in place in the Dungeness area near Sequim in 2003 (Clallam County, 2009). The Greenbook is the land protection strategy that included 13 miles of shoreline and focused on fish use, current land use and land development (Clallam County Environment, 2009). The cost of implementing the Greenbook action plan was $59,000. The Elwha nearshore action plan will cover 12 miles of shore and will focus on land use and development. The Coastal Watershed Institute has applied for a grant through Estuary and Salmon Restoration Program of $341,000 for this two-year

action plan (Elwha Watershed Information, 2009). The Estuary and Salmon Restoration Program provides funding to help restore the shorelines in the Puget Sound (Estuary and Salmon Restoration Program, 2011).

Annotated Bibliography

Clallam County Environment "Dungeness River Comprehensive Flood Hazard Management Plan" (2009). Retrieved from http://www.clallam.net/environment/assets/applets/Ch2.pdf The Dungeness Spit has been compared to Ediz Hook in 1884. The Flood Hazard Management Plan has details on the Greenbook, which was a restoration plan for the shoreline and Dungeness Spit near Sequim. In this presentation the current Action Plan is compared to Greenbook.

Elwha Watershed Information "River Restoration" 2009. Retrieved from http://www.elwhainfo.org/research-and-science/nearshore-consortium The Elwha Watershed Information promotes the nearshore restoration that is involved with the removal of the two Elwha dams. The consortium brings together scientist and managers to present their work and findings concerning the Elwha nearshore and related habitat.

Estuary and Salmon Restoration Program "Fact Sheet". Retrieved from http://www.pugetsoundnearshore.org/esrp.htm The grant that the NOLT is applying for is through the ESRP. The mission of the ESRP is to restore shoreline in the Puget Sound and this correlates with the goals of the NOLT Action Plan for the Elwha nearshore.

North Olympic Land Trust 2011. "Who We Are". Retrieved from http://www.northolympiclandtrust.org/index.html The NOLT website details the steps that are taken when a property is put in consideration for a conservation easement. Conservation easements are voluntary and the landowners involved are compensated. NOLT also owns land outright through donation or bequest. NOLT monitors the land in their care.

Topic: Clallam County Shoreline Master Plan

Primary Investigator: Cathy Lear, Clallam County Clear@co.clallam.wa.us

Student: Joseph Ray, Seth Peterson

The main goals for the shoreline master plan (SMP) is to reserve appropriate areas for water oriented uses, promote public access opportunities, identify areas appropriate for restoration and preservation of habitat, and help local governments avoid or lessen environmental damage as shorelines are developed. The Clallam county SMP has been in effect for 35 years and has gone through nine revisions. Within Washington State, the master plan applies to the jurisdictional boundaries of 200 cities in 39 counties that have "shorelines of the state". Clallam County has 800 miles of shoreline including tribal and public land that is covered by their SMP. Shorelines of the State encompass: 1) all Marine waters, 2) streams greater than 20 cubic ft. per second mean annual flow, 3) lakes 20 acres or larger, 4) shorelines/upland areas extending 200 ft. inland from the edge of these waters. And some of the following areas when they are associated with one of the below: 1) some or all of the 100 year floodplain, 2) all wetlands within the 100 year floodplain, 3) wetlands, 4) river deltas.

A number of new reports will be written that include information from sources such as flood management plans, critical areas ordinances, watershed plans, and other plans encompassed in the Puget Sound Action Agenda. These plans are meant to address erosion problems on our streams and beaches, increase flood protection, safeguard fish and wildlife habitat, improve water quality, increase water dependent uses, and promote public access. The significance of these plans should protect water quality for marine, lake, and stream systems. Increase protection of lives and property from flood and landslide damage, protect critical habitats as well as fish and wildlife, and promote recreational opportunities and public access within these shoreline areas. Key standards when implementing these plans should include the best available science, "No net loss" of ecological functions, assessment of the reasonably foreseeable cumulative impacts, and restoration plans.

The “no net loss of ecological functions” will be the most challenging standard to achieve. There are two challenges here, both with how this phrase is defined. What is “no net loss” and what is considered an “ecological function?” There is one thing that may help in finding common ground on this issue; the EPA is providing funding to implement “no net loss” policies. Currently, Clallam County is examining how Jefferson County has implemented “no net loss” policies.

Most plans are not created in a vacuum and this SMP is no different. To start, there are many data sources already available including WAC 173.26 Part III Guidelines, existing plans for watersheds, salmon recovery, and flood hazards and previous reports and studies. Another source of data comes from local experts. This includes shoreline owners, people who use shorelines for recreation and businesses that use the shoreline.

To gather these data there will be numerous meetings. This includes public meetings where stakeholders and the general public can provide input and give recommendations. These public meetings ensure that all stakeholder concerns are addressed in the SMP update process. Major stakeholders include:

- Federal Government
- Tribal Government
- State Government
- County Government
- City Government
- Non-government Organizations
- Watershed Planning Groups
- Local/Service Groups
- General Public
- Shoreline land owners

Contacts and further information

PROJECT MANAGER: Steve Gray – sgray@co.clallam.wa.us; 360.417.2520

PROCESS/PRODUCTS MANAGER: Cathy Lear – clear@co.clallam.wa.us; 360.417.2361

MAPPING GURUS:

Tom Shindler – tshindler@co.clallam.wa.us; 360.417.2232

Susan Lundstedt - slundstedt@co.clallam.wa.us; 360.417.249

PUBLIC OUTREACH GUIDE: Hannah Merrill – hmerrill@co.clallam.wa.us; 360.417.2563

Designated SMP Email Address: SMP@co.clallam.wa.us

Annotated Bibliography

Department of Ecology [homepage on the Internet]. Shoreline Management (WA): Department of Ecology; n.d. [cited 2011 Apr. 14]. Available from: http://www.ecy.wa.gov/programs/sea/sma/index.html.
Washington State participates in the national Coastal Zone Management Program and receives federal funding for managing our coastal shorelines. Local Shoreline Master Programs apply the Shoreline Management Act at the community level.

Clallam County Shoreline Master Program Update [homepage on the Internet]. Port Angeles (WA): Clallam County; 2011 Mar. 10. [cited 2011 Feb. 14]. Available from: http://www.clallam.net/RealEstate/html/shoreline_management.htm.
Clallam County is updating its Shoreline Master Plan (SMP), which regulates land use and development within 200 Ft. from rivers, lakes, streams, and marine shores. Shorelines in Clallam County are protected by Washington State Shoreline Management Act (SMA) and by the Clallam County SMP. This website provides SMP update information and links to local state shoreline related materials.

Priorities

Topic: Group Discussion on Priorities: Adaptive Management, Data Gaps and Next Steps

Contact: Anne Shaffer, Coastal Watershed Institute anne.shaffer@coastalwatershedinstitute.org

Student: Valli Sanstrom, Tiffany Howell

The group spent the last two hours of the workshop identifying priorities for the next year. Contributors included, researchers and managers from United States Geological Survey (USGS), North Olympic Land Trust (NOLT),the Environmental Protection Agency (EPA), the Army Corps of Engineers (CoE), the Department of Natural Resources (DNR), Department of Fish and Wildlife (WDFW), Coastal Watershed Institute (CWI), Clallam County, Western Washington University (WWU), University of Washington (UW), Peninsula College, City of Port Angeles, and the community came together to analyze the aspects that will assist in the advancement of the overall project. Nearly all researchers claimed that more progress on their research and data collection was needed as the effort heads into the next year. A comprehensive list of priorities identified is presented in Table 1. Highlights of the discussion follow:

Adaptive Management

- Needed is a specific management action plan for restoration response for sediment delivery on the Elwha nearshore.
- Future planning is needed for possible issues possibly associated with sediment blocking fish passage into estuaries. Because the west dike creates a fish barrier to the impounded west estuary, access to the remaining connected west and east estuary is crucial for salmon survival.
- The Army Corps of Engineers (CoE) have fallen behind in their refurbishment plan for Ediz Hook which is needed because of the industrial water pipeline that armors the shore from the Elwha, heading east, to Ennis Creek where the previous Rayonier

Mill was located. This year the CoE will add 400,000 tons of armor stone and 160,000 tons of sand to the outer beach on Ediz Hook to 'catch up'.

- The city of Port Angeles must stay on task with their beach refurbishment plan for the landfill/seawall shoreline. As the beach erodes hazardous old garbage is exposed. The city has a stockpile of material.

- Due to a lack of information that connects Ediz Hook and the Elwha River, there are several questions that are difficult to answer. Information that connects the two locations must be combined.
- Clallam County and Port Angeles's Shoreline Master Plans (SMPs) lack restoration plans for removing the industrial water pipeline and restoring ecological function to the Elwha drift cell. Restoration methods, obstacles that will be faced, and property issues all need to be addressed in the Port Angeles and Clallam County SMPs for the Elwha Nearshore Restoration.
- There is currently no active management plan for salmon and other fish in the Elwha nearshore. Specific management methods, as well as a contingency plan, and discussion of alternatives need to happen sooner than later to ensure healthy habitats in the future.
- Baseline measurements of Elwha and Dungeness drift cell feeder bluffs have been established. This allows a study in the differences between beaches fed by armored vs. non-armored bluffs. Additional benchmark sites at Ediz and Dungeness Hooks are needed. Also switching to a GPS differential system will lessen the problem of loosing physical benchmarks.
- USGS added a goal for the future, to use coastal cameras to observe shoreline changes and plume patterns, teaming up with UW, using an ARGIS camera.
- Researchers want to place a buoy for long term monitoring at the mouth of the river that would collect data on wave direction and height. This has been an ongoing goal from the beginning of the project.

Next Steps:

- An analysis of the cost/benefit of long term revetment of Ediz Hook needs to take place, also the cost/benefit of revetment of the industrial pipeline that armors the shoreline impeding the ecological function of the feeder bluffs.
- From a management perspective, there are numerous researchers with a lot of data that needs to be integrated and compiled to get the most out of the information.
- There needs to be a repository for any information that has been or could be used for projects. Currently, available data is difficult to find and access as it is stored in several different locations. The repository should be in an easily accessible area where researchers and the public alike can retrieve information on the Elwha River Restoration Project. Suggestions regarding where to compile that information included the Marine Resources Council (MRC) or a website.
- An updated shoreline atlas is needed and it should to be more local to include a comprehensive view of particular sections such as the Elwha nearshore. Also, upgrading the geographic information needs continuous upgrading and needs to be available.
- NOLT needs a plan so they can start action on identifying, inventorying, prioritizing which parcels to pursue putting in trust.

The group discussion allowed members of the community and researchers alike to express their concerns and ideas about the restoration project and it gave everyone an idea of what steps need to be taken over the next year.

Elwha Nearshore Consortium priorities, 2011

Category	Activity
Modeling	Model linkages between current habitat extent (for example west estuary extent), use (for example fish abundance) and sediment processes in lower river and shoreline to predict post dam removal sediment fate and anticipated near and long term habitat function response. Develop adaptive management actions to respond to nearterm restoration process. Prioritize additional nearshore long term restoration actions prior to dam removal. Specifically: 1. Augmenting of Elwha bluffs shoreline to optimize sediment delivery 2. Identify additional restoration actions
Monitoring	Monitoring (lower river, estuary, and shoreline of Elwha and comparative drift cells).
Sediment/Physical processes	1.More detailed and comprehensive sediment mapping and study of lower river and estuary; specifically: Extend current sediment mapping in the lower river north to include river mouth
	2. Definition of relative contribution of bluff erosion to sediment budget of Elwha, Dungeness drift cells. Ground based shoreline Lidar
	3.Expansion of 2009 Lidar study to include estuary, boat and land based Lidar for bluffs along lower river and shoreline, to and including Dungeness Spit;
	4.Wave buoys (CDIP)
	5.Continue and expand nearshore habitat report and sediment mapping (USGS) update to include: a. Further east and comparative areas; b. Offshore and inshore to

	include eelgrass area (MLLW-25-30')
	6. Comprehensive assessment of water quality in impounded, east, and west estuary including turbidity and nutrients (both CTD's and hand held YSI readings).
	7.Mapping of the historic Elwha nearshore (Brad Collins style study);
	8.Monitor of discharge of river from suspended sediments prior to dam removal
Biological and habitat	1.Continue long term monitoring of fish use of Elwha nearshore by CWI and PC/WWU, NOAA,LEKT, and others, including genetic composition of ESA stocks of salmon and forage fish-at a cross regional scale.
	2.Macroinvertbrate assemblage of Elwha and comparative
	3. Post process eelgrass data for macroalgae and fish presence.
	4.Conduct additional field surveys to define fish composition and extent in and of understory macro algae beds of Elwha and comparative nearshore
	5.LWD, riparian mapping, Elwha and comparative nearshore
	6.Bird surveys of Elwha nearshore for baseline info (both live and stranded birds) and linkages to other monitoring elements
	7.Marine mammal tracking (harbor seals)
Management	
	Develop and implement an Elwha nearshore restoration action plan. Priorities of plan; 1. Preservation of Freshwater Bay and lower river nearshore thru property CE/acquisition; 2. Ecosystem restoration of the Elwha estuary. 3. Restoration of Elwha feeder bluffs and Ediz Hook. Incorporate feed rate into bluff management.
	Analysis of sediment projections to estuary and development of adaptive management actions that might be anticipated;
	Preserve feeder bluffs of Dungeness drift cell, which are comparative sites and of extremely high ecological importance.
	Identify ELJ sites if any in Elwha nearshore
	Cost benefit analysis of changing pipeline alignment so not on beach along feeder bluffs
	Adaptive management priority actions (contingency actions) for sediment processes in river
	Data clearing house for data managers, data integration, shoreline atlas
Education	Continue working with citizens, local colleges and education groups

Public dialog

Topic: History of the Elwha Nearshore Public Presentation by Jacilee Wray, ONP and Public Discussion

Students: Renee Johnson and Joseph Richardson

Contact: Anne Shaffer, Coastal Watershed Institute anne.shaffer@coastalwatershedinstitute.org

After listening to a history of the Elwha by Jacilee Wray, Al Charles, Lower Elwha Klallam member born in 1942, spoke. He recalled fishing with his father in a canoe near the Elwha near shore at the age of seven. He described a long spit with two openings at the mouth of the Elwha River with the king salmon concentrated along the east fork (opposite of today's distribution). Another Native American recalled a proliferation of clams, and how the Natives would know the clams were ripe for picking on the beaches after a storm, because of the large number of seagulls present. The storm would literally "throw" clams up onto the beaches. Also mentioned was a "beautiful sandbar with flounder and halibut all around".

This historic recollection of the beach environment caused another citizen to express interest in the release of silt and if it would "push the land forward". Anne Shaffer answered by explaining that the notching of the dam and the metered release of sediment, would allow only a portion of the sediment to be released over time. This means that if the land mass does increase, it will be done naturally and at a pace the environment can adapt to.

A photo of the mouth of the Elwha River was projected on the screen, leading one attendee to ask the question: "Can you see Hwy 112 in that photo?" Although no one could tell, this led to a discussion of an early road/bridge and stories of putting planks down to drive across the water. Elders in the audience recollected that a man named Sampson ran a ferry there at one time, and the toll was 25 cents.

Public discussion:

Question: Is there a time line for when we will see real changes?

Anne answered: The majority of sediment reaching the near shore is anticipated to arrive within

two to five years. There is a two to three year completion time for dam removal. One hundred years of sediment will be released.

Question: How do we know that the release won't be overwhelming?

Anne answered: Changes in the ecosystem will be noticed with the first pulse of sediment. After the stored sediment is all released there will be an annual contribution of sediment by natural processes of the river. Anne explained that the short-term ecological effects of the initial phase of restoration are temporary and trumped by the overall long-term ecosystem restoration of sediment processes. Anne added that "It's what we have to do to restore"—referring to taking the initial short-term consequences along with the long-term benefits (as with any engineering project).

Another citizen, Margaret Owens, asked: As the bottom goes from rocky to sediment, will there be seeding in (of plants and organisms) or will it just take over naturally?

Anne and group answered: The there is remnant eel grass out there now, and it is hypothesized that, due to sediment starvation, eelgrass distribution is substrate limited. So we are going to let things go naturally. But we have talked about things like engineered log jams to help get sediment to stick.

Question: Will there be an exchange? Will eelgrass come back, but kelp be smothered out?

Anne answered: The large increase in kelp is due to the cobblestone and low fine sediment. Snorkeling surveys revealed that kelp beds in the Elwha drift cell have lower fish abundance and species diversity relative to kelp areas outside the Elwha drift cell. The dam release should return the fine sediment and lower the kelp distribution back to closer to what it was historically

Question: Are the homes in the beach transitioning to city sewer and water?

Anne and the group answered: No there are no plans to change that (other than for the tribal land). Groundwater flow is so strong that salt water intrusion is not a concern.

Question: Will the amount of sediment and erosion be greater due to logging?

Group answered: Actually only nine percent of the Elwha watershed has been cut so that shouldn't pose too much of a problem. About 90% of the watershed is in the Olympic National forest, so logging is not a concern. Deposition is from glacial silt and the storms will clean it out.

Annotated Bibliography:

Mapes L, Charles F. 2009. Breaking Ground: The Lower Elwha Klallam Tribe and the Unearthing of Tse-whit-zen Village. Seattle (WA): University of Washington. 240 pages.

With the help of a Native American woman, this book is written by an award winning journalist with over twenty years experience. The story tells the tale of a dry dock excavation site and the discovery of the remains of a large Indian village, the Tse-whit-zen village. The social, economic, and political drama that unfolds is captured in the accounts of tribal members, archaeologists, historians, city planners, state officials, and local residents in the lower Elwha area. The book also contains a compilation of over 100 photos, which help tell the history of the lower Elwha area within the context of this excavation project.

Wray J. 2002. Native Peoples of the Olympic Peninsula*: Who We Are*. Norman: University of Oklahoma. 166 pages. Wray's book delves into real Native American stories previously unavailable to the public. There are many oral stories put into written form for the first time. The book elaborates on the history of the area and experiences of people throughout time. The book takes the reader through the years and enlightens on what the indigenous people have done in the area. Another aspect of the book is the pronunciation guide that helps readers understand the language. The author is a known historian and knowledgeable with the culture making this book credible. The book is directed toward a broad audience and would not be difficult for the average person to read or understand. During the Comments Section of the consortium many members of the community gave stories about how the Elwha used to be and what went on in the area. This book helps give a historical perspective and similar stories.

References

Allison MA, Lee MT, Ogston AS, Aller RC. Origin of Amazon mudbanks along the northeastern coast of South America (2000) *Marine Geology*, 163 (1-4), pp. 241-256.

Barnard Construction Company, Inc. Who We Are (BCCI) [Internet]. n.d. Barnard Construction Company, INC.; [2011; March 2011] Available from: http://www.barnard-inc.com/WhoWeAre/tabid/58/Default.aspx.

Barry, D. (Presentor). (2011, February 14). *Lower Elwha River Bathymetry*. Peninsula College, Port Angeles, WA.

Berry H, Sewell A. 2001. Temporal trends in the aerial extent of canopy-forming Kelp beds along the Strait of Juan de Fuca and Washington's outer coast. Nearshore Habitat Program. Washington State Department of Natural Resources.[internet] [date cited 2011, updated 2001]: available from: http://bio.research.ucsc.edu/people/carr/publications/Nereo-lit/Nereo%20grey%20lit%20PDFs/Berry%202001.pdf (Accessed March 2011)

Berry HD, Mumford T, Dowty P. 2005. Using historical data to estimate changes in floating kelp (*Nereocystis leutkeana* and *Marcrocystis integrifolia*) in Puget Sound: Unpublished Report." edited by Washington Department of Natural Resources. Olympia: Washington Department of Natural Resources.

Brown J, Shaffer A, Byrnes C. 2011. Long term monitoring, nearshore Elwha and Salt Creek Beach Seining and Ichthyofauna Assessment of the Nearshore Environment: 2010-2011. Draft Final Report. Coastal Watershed Institute, Port Angeles, Washington. www.coastalwatershedinstitute.org

Clallam County Shoreline Master Program Update [homepage on the Internet]. Port Angeles (WA): Clallam County; 2011 Mar. 10. [cited 2011 Feb. 14]. Available from: http://www.clallam.net/RealEstate/html/shoreline_management.htm.

Clallam County Environment "Dungeness River Comprehensive Flood Hazard Management Plan" (2009). Retrieved from http://www.clallam.net/environment/assets/applets/Ch2.pdf

Cochrane GR, Warrick JA, Sagy Y, Finlayson D, Harney J. 2008. Sea-floor mapping and benthic habitat GIS for the Elwha River Delta nearshore. edited by U.S. Geological Survey.

Draut A, Logan J, McCoy R, McHenry M, Warrick J. 2008. Channel evolution on the Lower Elwha River, Washington 1936-2006. USGS Scientific Investigations Report 2008-5127. USGS.gov [Internet]. Available from: http://pubs.usgs.gov/sir/2008/5127/.

Draut A, Logan J, Mastin M. 2010. Channel evolution on the dammed Elwha River, Washington, USA. *Geomorphology* 127:71-87.

Department of Ecology [homepage on the Internet]. Shoreline Management (WA): Department of Ecology; n.d. [cited 2011 Apr. 14]. Available from: http://www.ecy.wa.gov/programs/sea/sma/index.html.

Dungeness River Inc. (n.d.). The Dungeness River. Retrieved Marcy 9, 2011, from Dungeness Community Web Site: http://www.dungeness.com/river/index.htm

Elwha Watershed Information "River Restoration" (2009). Retrieved from http://www.elwhainfo.org/research-and-science/nearshore-consortium.

Estuary and Salmon Restoration Program "Fact Sheet". Retrieved from http://www.pugetsoundnearshore.org/esrp.htm North Olympic Land Trust (2011). "Who We Are". Retrieved from http://www.northolympiclandtrust.org/index.html

Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington.

Folk R, Ward W. 1957. Brazos River Bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology. Vol(7), no.1, Pg 3-26. http://jsedres.sepmonline.org/cgi/content/abstract/27/1/3. This research was used to determine the geologic meanings of grain size dispersion. It helps to explain the logic behind the sorting of river bed sediments.

Gelfenbaum G, Stevens A, Elias E, Warrick J. 2009. Modeling sediment transport and delta morphology of the dammed Elwha River, Washington State, USA. Worldscinet.com [Internet]. Available from: http://eproceedings.worldscinet.com/9789814282475/9789814282475_0109.html.

Goni M.A., Monacci N, Gisewhite R, Ogston A, Crockett J, Nittrouer C. Distribution and sources of particulate organic matter in the water column and sediments of the Fly River Delta, Gulf of Papua (Papua New Guinea) (2006) Estuarine, Coastal and Shelf Science, 69 (1-2), pp. 225-245.

Hamel NJ, Burger, AE, Charleton, K, Davidson, P, Lee, S, Bertram, DF & Parrish, JK. Bycatch and beached birds: assessing mortality impacts in coastal net fisheries using marine bird strandings. Marine Ornithology 2009, 37: 41–60.

Litle K, Parrish, JK, Dolliver, J.; The Coastal Observation and Seabird Survey Team – Citizens Monitoring Coastal Environmental Health in Alaska. Community based coastal observing in Alaska: Aleutian Life Forum, Page 19-35, 2006.

Mahlum, J. 2011. First Street Stormwater Separation Project. City of Port Angeles, Public Works and Utilities Department. [2011; March 2011] Available from http://www.cityofpa.us/FirstStreetStormwater.htm.

Mapes L, Charles F. 2009. Breaking Ground: The Lower Elwha Klallam Tribe and the Unearthing of Tse-whit-zen Village. Seattle (WA): University of Washington. 240 pages.

Mumford TF. 2007. Kelp and eelgrass in Puget Sound. In *Puget Sound Nearshore Partnership Report*. Seattle: Seattle District, U.S. Army Corps of Engineers.

Nittrouer CA. STRATAFORM: Overview of its design and synthesis of its result (1999) *Marine Geology*, 154 (1-4), pp. 3-12.

Nelson et al. 2008. Ecological and physiological controls of species composition in green macroalgae blooms. Ecology 89 (5): pp. 1287-1298.

Nelson TA, Haberlin K, Nelson AV, Ribarich H, Hotchkiss R, Van Alstyne KL, Buckingham L, Simunds DJ, Fredrickson K. 2008. Ecological and physiological controls of species composition in green macroalgal blooms. Ecological Society of America. 1287–1298.

Olympic National Park. Section 02920 Seeding. Olympic National Park (WA): National Park Service (US). PMIS No. OLYM 005375.

Olympic Peninsula Intertribal Cultural Advisory Committee**.** Wray, J, ed. 2002. Native Peoples of the Olympic Peninsula: Who We Are. Norman, OK: University of Oklahoma Press.

Peters R. 1996. Emigration of juvenile chum salmon in the Elwha river and implications for timing hatchery coho salmon releases. USFWS, Olympia, Washington**.**

Parrish J. Editor,"COASST Reports 08-09", May 2010, newsletter highlights species, reports on activity of participants, and publishes scientific studies relating to COASST's survey activity during the year.

Parrish J K, Bond N, Nevins H, Mantua N, Loeffel R, Peterson WT, Harvey J T. Beached birds and physical forcing in the California Current System. Marine Ecology Progress Series, Vol. 352: 275-288, 2007.

Quantification of Net Shore-Drift Rates in Puget Sound and the Strait of Juan de Fuca Washington R. Scott Wallace *Journal of Coastal Research* Vol. 4, No. 3 (Summer, 1988), pp. 395-403 (article consists of 9 pages) Published by: Coastal Education & Research Foundation, Inc. Stable URL: http://www.jstor.org/stable/4297427

Shaffer JA. 2000. Seasonal variation in understory kelp bed habitats of the Strait of Juan De Fuca. Journal of Coastal Research 16: 768-75.

Shaffer JA, Barry D. 2009. The Elwha Nearshore: Linking Management, Education, and Research to Achieve Ecosystem Restoration. Priority Recommendations of the Elwha Nearshore Consortium. Published in the Proceedings of the 2009 Puget Sound Georgia Basin Research Conference, Puget Sound Partnership, Olympia Washington.

Shaffer JA, Beirne M, Ritchie T, Paradis R, Barry D, Crain P. 2009. Fish use of the Elwha estuary and the role anthropogenic impacts to physical processes play in nearhore habitat function for fish. Hyrdogiologia 636:179–190

Shaffer JA, Crain P, Winter B, McHenry ML, Lear C, Randle TJ. 2008. Nearshore restoration of the Elwha River through removal of the Elwha and Glines Canyon dams: an overview. Northwest Science 82 (Special Issue):48-58.

Shaffer JA, Ritchie T, Crain P, Beirne M, Lear C. 2008 Nearshore function of the central Strait of Juan de Fuca for juvenile fish, including Puget Sound Chinook salmon. http://hws.ekosystem.us/prun.aspx?p=Page_e7e0ad79-17d5-489b-9ed8-cb76f1f7c879&m=1&text=juan+de+fuca+nearshore&cols=2

Shaffer JA, L Ward, P Crain, B Winter, K Fresh, and C Lear. 2005. "Elwha and Glines Canyon dam removals: nearshore restoration and salmon recovery of the central Strait of Juan de Fuca."

Proceedings, Puget Sound Research Conference 2005, Puget Sound Water Quality Action Team, Olympia, Washington.

Charles, Beatrice (Elwha), Cooke, Vince (Makah), Grinnell, Elaine, (Jamestown), Morganroth, Chris III (Quileute), Morganroth, Lela Mae (Quileute), Peterson, Melissa (Makah), Riebe, Viola (Hoh), Smith, Adeline (Elwha), and Wray, Jacilee. 2004. When the tide is out. An ethnographic study of nearshore use on the northern olympic peninsula. (Olympic National Park and the Coastal Watershed Institute, Port Angeles, Washington

Native American Traditional and Contemporary Knowledge of the Northern Olympic Peninsula Nearshore. Kingston, WA: Olympic Peninsula Intertribal Cultural Advisory Committee. Port Angeles, WA: Coastal Watershed Institute.

Shipman, H. 2008. A Geomorphic Classification of Puget Sound Nearshore Landforms. Puget Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

U.S. Army Corps of Engineers. 1972. Ediz Hook, Port Angeles, Washington 93rd Congress: Hose Document 93-101. The Secretary of the Army transmittal from the Chief of Engineers, Department of the Army, dated August 21, 1972 includes the survey report, Feasibility report, together with accompanying research and illustrations, on Ediz hook, Port Angeles, Washington. Retrieved 16 Feb 2011. Available online at http://ftp.resource.org/gao.gov/93-251/00007d20.pdf

U.S. Army Corps of Engineers. 2002. Ediz Hook Beach Erosion Control Project, Washington. The report includes erosion control baseline information, impact assessments on the environment and protected species. to Retrieved 11 Feb 2011. Available Online at Http://El.Erdc.Usace.Army.Mil/Tessp/Pdfs/Ediz_Hook_Be.Pdf

U.S. Army Corps of Engineers. 2011. Fiscal Year 2011 Civil Works Budget for the U.S. Army Corps of Engineers summary. Retrieved 11 Feb 2011. The budget report confirms appropriation of funds for implementing the project in 2011. Available online at http://www.usace.army.mil/CECW/PID/Documents/budget/budget2011.pdf

Warrick J, Cochrane G, Sagy Y, Gelfenbaum G. 2008. Nearshore substrate and morphology offshore of the Elwha River, Washington. *Northwest Science* 87:153-163.

Warrick J, George D, Gelfenbaum G, Ruggiero P, Kaminsky G, Beirne M. 2009. Beach morphology and change along the mixed grain-size delta of the dammed Elwha River, Washington. *Geomorphology* 111:136-148.

Warrick JA, George DA, Gelfenbaum G, Ruggiero P, Kaminsky GM, Beirne M. 2009. Beach morphology and changes along the mixed grain-size delta of the dammed Elwha River, Washington. *Coastal Dynamics*. < Gelfenbaum_CS09.pdf>. March 2011.

Warrick J, George D, Stevens A, Eshleman J, Gelfenbaum G, Kaminsky G, Schwartz A, Beirne M. 2010. Beach morphology monitoring in the Elwha River littoral cell, 2004-2006 [Report]. USGS.gov [Internet]. Available from: http://pubs.usgs.gov/ds/288/.

Warrick J, Rubin D, Ruggiero P, Harney J, Draut A, Buscombe D. 2009. Cobble cam: grain-size measurements of sand to boulder from digital photographs and autocorrelation analyses. *Earth Surface Processes and Landforms* 34:1811-1821.

Warrick J, Stevens A. 2010. A buoyant plume adjacent to a headland- Observations of the Elwha River Plume. *Continental Shelf Research* 31:85-97.

Wray J. 2002. Native Peoples of the Olympic Peninsula*: Who We Are*. Norman: University of Oklahoma. 166 pages.