Update Report
Period: 2/1/2012 - 1/31/2013

Quinn, Tom

Project: R/LME-7 - *Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity*

:: STUDENTS SUPPORTED

Thornton, Emily, ethorn10@uw.edu, University of Washington, School of Aquatic and Fishery Sciences, status:new, field of study:Aquatic and Fishery Sciences, advisor:Thomas Quinn, *no degree type*, *no degree date*, degree completed this period:No
Student Project Title:
Ecological interactions between resident, non-native brook trout and re-colonizing coho salmon in the Elwha River

Involvement with Sea Grant This Period:
Gradaute student supported by the grant

Post-Graduation Plans:
too soon to say

:: CONFERENCES / PRESENTATIONS

No Conferences / Presentations Reported This Period

:: ADDITIONAL METRICS

K-12 Students Reached:	**Acres of degraded ecosystems restored as a result of Sea Grant activities:**
Curricula Developed:	**Resource Managers who use Ecosystem-Based Approaches to Management:**
Volunteer Hours:	**HACCP - Number of people with new certifications:**
Cumulative Clean Marina Program - certifications:	

:: PATENTS AND ECONOMIC BENEFITS

No Benefits Reported This Period

:: TOOLS, TECH, AND INFORMATION SERVICES

Description	Developed	Used	Names of Managers	Number of Managers

Zooplankton key for Lake Sutherland used to quantify prey availability for recovering Elwha river salmon populations. R/LME-7	**Actual** (2/1/2012 - 1/31/2013) :	1	1	Lower Elwha Klallam Tribe	1
	Anticipated (2/1/2013 - 1/31/2014) :	0	1		

:: HAZARD RESILIENCE IN COASTAL COMMUNITIES

No Communities Reported This Period

:: ADDITIONAL MEASURES

Safe and sustainable seafood

Number of stakeholders modifying practices
Actual (2/1/2012 - 1/31/2013) :
Anticipated (2/1/2013 - 1/31/2014) :

Number of fishers using new techniques
Actual (2/1/2012 - 1/31/2013) :
Anticipated (2/1/2013 - 1/31/2014) :

Sustainable Coastal Development
Actual (2/1/2012 - 1/31/2013) :
Anticipated (2/1/2013 - 1/31/2014) :

Coastal Ecosystems
Actual (2/1/2012 - 1/31/2013) :
Anticipated (2/1/2013 - 1/31/2014) :

:: PARTNERS

Partner Name: Coastal Watershed Institute, type: NGO, scale: local
Partner Name: Department of Fish and Wildlife, type: government, scale: state
Partner Name: Lower Elwha Klallam Tribe
Partner Name: National Park Service, type: government, scale: federal
Partner Name: NOAA
Partner Name: Peninsula College
Partner Name: US Fish and Wildlife Service (US DOI, type: government, scale: federal
Partner Name: US Geological Survey
Partner Name: Western Washington University, type: academic, scale: state

:: IMPACTS AND ACCOMPLISHMENTS

Title: **Washington Sea Grant research leverages multiple partnerships to explore the ecological effects of a historic dam removal**

Type: accomplishment
Description:
Relevance: The removal of the Elwha and Glines Canyon dams and the restoration of what was one of the region's most productive river systems opens extraordinary opportunities to investigate how the nearly century-old dams have affected an unusually diverse fish community – including all five Pacific salmon and three anadromous trout species – and how their removal is now affecting it. This also affords fertile opportunities for cross-project collaboration, leveraging ongoing research to mutual benefit.
Response: The pace and range of changes underway require an unusually flexible, versatile approach incorporating multiple studies. Washington Sea Grant-supported researchers, in collaboration with state, federal, tribal, and nongovernmental agencies, are studying seven elements of the altered and restored Elwha ecosystem: (1) investigating the origins of and prospects for the kokanee of formerly landlocked Lake Sutherland, using

sockeye salmon from other lake systems as references; (2) examining the unusual spawning pattern of cutthroat trout in a section formerly blocked to salmon, to see whether it will shift following dam removal; (3) exploring differences in adaptation between winter and summer, and wild and hatchery, steelhead runs; (4) developing a noninvasive procedure using stable isotopes to distinguish anadromous steelhead from resident rainbow trout fry; (5) analyzing NOAA data and otolith (ear stone) samples from trout redds before dam removal, as benchmarks for monitoring steelhead recovery; (6) measuring zooplankton in Lake Sutherland by enlisting tribal biologists who were already monitoring water quality there, to determine, among other questions, whether returning salmon will find enough food; and (7) assisting the Coastal Watershed Institute in monthly beach seining to gauge the role of the Elwha estuary in salmon ecology and the river system.
Results: Studies are ongoing and data are still incoming. Researchers have already reorganized the tribe's lake data into readily analyzable form, providing valuable assistance to its fisheries management.

Recap:
Washington Sea Grant leverages multiple partnerships to explore changes in fish habitat, biology, and populations before and after the removal of the Elwha River dams.

Comments:
Primary Focus Area – OCEH (HCE)
Secondary Focus Area – LME (SSSS)

Associated Goals: Protect and restore marine, coastal and estuarine habitats (HCE Restore).
Support conservation and sustainable use of living marine resources through effective and responsible approaches, tools, models and information for harvesting wild and cultured stocks and preserving protected species (SSSS Supply).

Related Partners:

Coastal Watershed Institute
Lower Elwha Klallam Tribe
Northwest Fisheries Science Center (US DOC, NOAA, NMFS, NWFSC)
Peninsula College
University of Washington, School of Aquatic and Fishery Sciences, College of the Environment (UW)
US Fish and Wildlife Service (US DOI, FWS)
US Geological Survey (US DOI, USGS)
US National Park Service (US DOI, NPS)
Western Washington University (WWU)

:: PUBLICATIONS

Title: **Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2012
Uploaded File: *none*
URL: *none*
Abstract:
Captively reared animals can provide an immediate demographic boost in reintroduction programs, but may also reduce the fitness of colonizing populations. Construction of a fish passage facility at Landsburg Diversion Dam on the Cedar River, WA, USA, provided a unique opportunity to explore this trade-off. We thoroughly sampled adult Chinook salmon (Oncorhynchus tshawytscha) at the onset of colonization (2003-2009), constructed a

pedigree from genotypes at 10 microsatellite loci, and calculated reproductive success (RS) as the total number of returning adult offspring. Hatchery males were consistently but not significantly less productive than naturally spawned males (range in relative RS: 0.70-0.90), but the pattern for females varied between years. The sex ratio was heavily biased toward males; therefore, inclusion of the hatchery males increased the risk of a genetic fitness cost with little demographic benefit. Measurements of natural selection indicated that larger salmon had higher RS than smaller fish. Fish that arrived early to the spawning grounds tended to be more productive than later fish, although in some years, RS was maximized at intermediate dates. Our results underscore the importance of natural and sexual selection in promoting adaptation during reintroductions.

Citation:
Anderson, J. H., P. L. Faulds, W. I. Atlas, and T. P. Quinn. 2012. Reproductive success of captively bred and naturally spawned Chinook salmon colonizing newly accessible habitat. Evolutionary Applications 6:165-179. doi:10.1111/j.1752-4571.2012.00271.x

Copyright Restrictions + Other Notes:
Reported in AR2012

Journal Title: Evolutionary Applications
Title: **A Model for Estimating the Minimum Number of Offspring to Sample in Studies of Reproductive Success**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2011
Uploaded File: J_Hered-2011-Anderson-....0.pdf, 611 kb
URL: *none*
Abstract:
Molecular parentage permits studies of selection and evolution in fecund species with cryptic mating systems, such as fish, amphibians, and insects. However, there exists no method for estimating the number of offspring that must be assigned parentage to achieve robust estimates of reproductive success when only a fraction of offspring can be sampled. We constructed a 2-stage model that first estimated the mean (μ) and variance (v) in reproductive success from published studies on salmonid fishes and then sampled offspring from reproductive success distributions simulated from the μ and v estimates. Results provided strong support for modeling salmonid reproductive success via the negative binomial distribution and suggested that few offspring samples are needed to reject the null hypothesis of uniform offspring production. However, the sampled reproductive success distributions deviated significantly ($\chi 2$ goodness-of-fit test p value < 0.05) from the known simulated reproductive success distribution at rates often >0.05 and as high as 0.24, even when hundreds of offspring were assigned parentage. In general, reproductive success patterns were less accurate when offspring were sampled from cohorts with larger numbers of parents and greater variance in reproductive success. Our model can be reparameterized with data from other species and will aid researchers in planning reproductive success studies by providing explicit sampling targets required to accurately assess reproductive success.

Citation:
Anderson J.H., E.J. Ward, and S.M. Carlson. 2011. A model for estimating the minimum number of offspring to sample in studies of reproductive success. Journal of Heredity 102: 567-576. doi: 10.1093/jhered/esr060

Copyright Restrictions + Other Notes:
Reported in both R/F-148 and R/F-159.
Reported in AR2012

Journal Title: Journal of Heredity
Title: **Juvenile coho salmon, Oncorhynchus kisutch, in the Elwha River estuary prior to dam removal:**

Seasonal occupancy, size distribution, and comparison to nearby Salt Creek

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2013
Uploaded File: TAFS_revision_to_the_j....l.pdf, 5610 kb
URL: *none*
Abstract:
In addition to the downstream migration of smolts in spring, coho salmon also enter estuaries throughout the year but especially in spring as fry and in fall as parr. The removal of two large dams on the Elwha River, Washington has increased the area accessible to salmon and is affecting many aspects of the system. For comparison with the post-dam period, when the estuary will likely expand in size and complexity, monthly sampling was conducted from 2007 – 2011 in the estuaries of the Elwha River and Salt Creek, a nearby undammed stream, to determine patterns of coho salmon presence and size. The spring smolt migration in the Elwha River included a large fraction of unmarked fish primarily of natural origin, as well as marked fish from a hatchery on the river. Sub-yearlings entered both estuaries during much of the year, with a peak in September. Coho salmon from the Elwha River (including wild and hatchery origin fish) were larger than those from Salt Creek and were more heavily represented in the fall, relative to the spring smolt migration. Future patterns in the Elwha River may include reduced pre-smolt use of the estuary if the center of distribution is farther upriver but improved estuarine habitat may make it more suitable for pre-smolts.

Citation:
Quinn, T.P., N. Harris, J. A. Shaffer, C. Byrnes, and P. Crain, Juvenile coho salmon, Oncorhynchus kisutch, in the Elwha River estuary prior to dam removal: Seasonal occupancy, size distribution, and comparison to nearby Salt Creek, Transactions of the American Fisheries Society (In review).

Copyright Restrictions + Other Notes:

Journal Title: Tranactions of the American Fisheries Society

:: OTHER DOCUMENTS

No Documents Reported This Period

:: LEVERAGED FUNDS

Type: influenced Period: 2012-02-01::2013-01-31Amount: $30000

Purpose:
Monthly beach seining in the Elwha River and Salt Creek estuaries, and data from previous sampling

Source: Coastal Watershed Institute (costs difficult to estimate as many people have been involved)
Type: influenced Period: 2012-08-01::2012-09-30Amount: $33844

Purpose:
Sampling salmon at a weir on the Elwha River.

Source: Washington Department of Fish and Wildlife

Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity

Funding from Sea Grant began in April 2012 and during that time we have recruited Emily Thornton as a master's student at the School of Aquatic and Fishery Sciences, University of Washington. She spent much of the summer living in Port Angeles and becoming familiar with the Elwha River system and the relevant agencies and people involved in salmon and ecosystem recovery. She is in the process of finalizing her research plans but will likely be studying interactions between resident (but non-native) brook trout and colonizing coho salmon.

In addition to Emily's work, we have made progress on many fronts. The pace is exceptionally fast as the river is changing constantly, and the agencies are making rapid decisions and taking quick action. This is revealing the wisdom in our proposal's broad approach rather than rigidly defined studies. The report below is in outline form to facilitate review but our success in research, local involvement, and education has been above our expectations. In addition to the project co-investigators, all of whom have contributed greatly, special mention should be made of John McMillan, an exceptionally talented and dedicated biologist who has contributed a great deal in terms of data collection and insights. Many biologists working for the Lower Elwha Klallam Tribe (LEKT, e.g., Rebecca Paradis, Matt Beirne and Raymond Moses) have also been tremendously helpful, reflecting their expertise and dedication. Without the efforts of such skilled and motivated people, on-site, a project of this kind simply could not be carried out.

Steelhead – rainbow trout

1) **Title**: Characterization of redds by made steelhead and rainbow trout.
   Leads: John McMillan and George Pess (NOAA), Thomas Quinn (UW)
   Goal: Find ways to correctly classify redds by origin of mother to facilitate assessment of spatial distribution of breeding by the two forms, relative abundance, progress of colonization, and habitats used when sympatric.
   Method: Measure redd area and gravel at known rainbow and steelhead redds.
   Results/status: Data have been collected with excellent classification success indicated by univariate analyses. We will likely combine these data with #2 below in one paper.

2) **Title:** Use of steelhead and rainbow trout fry size for classification, and otolith chemistry for validation of maternal origins.
   Leads: John McMillan and George Pess (NOAA), Lance Campbell (WDFW) and TQ (UW)
   Goal: Determine whether steelhead fry (spawned earlier and from larger eggs) differ enough in size from rainbow trout for use to assess distribution, relative abundance, and in-stream ecology of age-0 fish after dam removal.
   Methods: Measure fry from areas occupied by rainbow and steelhead prior to dam removal as a function of date, develop a classification system, and then validate it with "unknown" fish collected in the post-dam period, identified with otolith micro-chemistry.
   Results/status: The pre-dam-removal data show excellent classification success, and samples of "unknown" fish are being prepared for otolith analysis. A draft MS has been started.

3) **Title**: Use of nitrogen stable isotope signal to distinguish steelhead and rainbow trout fry.
   Leads: Emily Thornton, Erica Curles, Lindsay Hart (UW) and Ron Hardy (U of Idaho)
   Goal: Develop and test methods to classify *O. mykiss* fry by maternal origin from stable isotopes to facilitate in-stream sampling and identification of mixed origin fish.
   Method: Obtain eyed eggs from steelhead, rear some fry on non-marine derived food and some on a diet with marine sources, and sample fry periodically as they grow for stable isotopes in fin tissue to see the decline in ^{15}N enrichment from the marine maternal signal to baseline.

Results/status: UW animal care permits have been obtained, eyed eggs have been transported to the UW hatchery and the experiment will be run in spring 2013.

4) **Title**: Wild and hatchery steelhead life history inferred from archived scale data.
Lead: Patrick Crain (NPS, formerly WDFW), George Pess (NOAA), Michael McHenry (LEKT) and TQ (UW)
Goal: Test the hypothesis that wild and hatchery steelhead in the Elwha River were similar with respect to return timing against the alternative that wild fish returned later, as would be expected if they retained ancestral traits. The secondary goals are to describe the return timing of wild steelhead in the past for evidence of summer vs. winter runs, and to determine the basic life history of the wild fish in the period prior to dam removal.
Method: Examine data from Elwha River gill-net caught steelhead from 1981 – 2001 (N = 18212 in total), including freshwater and marine age, capture date, and wild/hatchery origin and length.
Results/status: The data are in well-organized spread-sheets. Preliminary analysis (TQ) suggests some interesting patterns of overall arrival timing and linkage between freshwater age and return date, etc. There are some uncertainties regarding the nature of the fisheries (i.e. possible sampling bias) so analysis must be cautious.

5) **Title**: Wild and hatchery steelhead life history inferred from body fat content
Lead: Mara Zimmerman and Jamie Lamperth (WDFW), TQ (UW)
Goal: Test the hypothesis that body fat of adult steelhead varies with return date, seasonal run (winter vs summer) and between wild and hatchery origin fish. Do fish adapted to return early (i.e., summer steelhead) arrive with more body fat than winter steelhead? Given the variation in return date observed from gillnet catch data (#4) and recent weir counts, are there remnant summer steelhead in the Elwha River or just early fish on the edge of a normal distribution?
Method: Test native wild and hatchery summer and winter steelhead at the Kalama River to quantify the variation in long-established populations for subsequent comparison with Elwha River fish. Scales are also being taken for age determination and stable isotope analysis.
Results/status: The meter has assessed fat content in 109 steelhead and work is on-going. Wild fish tend to have more body fat than hatchery fish of the same run and on the same date, and summer and winter runs seem to differ as well but we will get year-round data from the Kalama River before shifting the equipment to the Elwha River.

6) **Title**: Wild and hatchery steelhead marine ecology inferred from stable isotope analysis
Lead: Mara Zimmerman (WDFW), Larry Ward (LEKT) and TQ (UW).
Goal: Use stable isotopes from scales to determine whether wild and hatchery fish make different use of the ocean for feeding, as an indirect inference method.
Method: Take scales from wild and hatchery steelhead on the Elwha and also from Kalama River fish to determine whether stable isotopes of N and C indicate differences in marine ecology.
Results/status: Planning stages, some scales being taken from wild and hatchery Elwha steelhead, and from Kalama River fish.

Sockeye salmon - kokanee

1) **Title**: Life history of Lake Sutherland kokanee: Implications for ancestral origins
Lead: TQ and Morgan Bond (UW) and Hans Berge (King County)
Goal: The first goal is to characterize the current life history and phenotypic traits of *O. nerka* in Lake Sutherland as a baseline against which anadromous fish can be compared. The second goal is to be able to determine, in the future, whether anadromous sockeye originated from non-anadromous parents or whether they were colonists from elsewhere, with the eventual goal of determining the mix of anadromous and non-anadromous fish in the lake. The third goal is to help determine whether the sockeye salmon are descended from native or stocked fish.

Methods: Obtain specimens of adult *O. nerka* from Lake Sutherland, process for length, weight, egg size and fecundity if possible, measure body shape, take digital photos, sample muscle for stable isotopes, and remove otoliths for age determination and later micro-chemical analysis. Augment these data with data from sockeye and kokanee from other populations for comparisons.
Results/status: Marcia House (NWIFC) and Rebecca Paradis (LEKT) provided us with adult samples from 2010 and 2012 (n = 190). The results show patterns of life history suggestive of anadromous ancestry (large egg size for a given body size) and local origin (deep bodies in males, consistent with beach spawning). Completion of the analysis awaits processing of data obtained from other kokanee populations in BC and Washington but a draft MS has been started.

2) **Title**: Ecology and nutrient cycling of Lake Sutherland
Lead: Rebecca Paradis and Matt Beirne (LEKT), TQ, Morgan Bond, David Beauchamp (UW)
Goal: Characterize the current ecology and nutrient base in Lake Sutherland as a baseline against which future years, when anadromous fish enter the system, can be compared. The question is whether (or when) the sockeye salmon will make detectable contributions to the ecosystem of the lake, and what the carrying capacity would be for anadromous rather than resident fish.
Methods: LEKT limnology sampling provides monthly depth-specific data at six stations in the lake. We have initiated monthly zooplankton sampling and processed the first series for species identification and stable isotope analysis, and plan on regular processing. We will also use bioenergetics models to estimate the eventual carrying capacity for sockeye rather than kokanee, based on volume of water, thermal and oxygen conditions, and plankton density.
Results/status: The limnology data have been examined and indicate a possible temperature-DO squeeze in late summer. Zooplankton species have been identified and stable isotope analysis indicated sufficiently low ^{15}N levels that an increase in the future from salmon carcasses should be detectable.

Cutthroat trout

1) **Title**: Life history and breeding timing of Indian Creek cutthroat trout
Lead: John McMillan and George Pess (NOAA), Michael McHenry (LEKT) and TQ (UW)
Goal: Cutthroat trout were observed spawning in Indian Creek, the outlet of Lake Sutherland, in fall rather than the more normal spawning period in spring. This is a most unusual trait and worthy of full documentation. It is not clear how this trait might change in the post-dam removal period but change is certainly possible as the "fall-spawning" coho salmon will likely spawn later than the cutthroat, reversing the normal patterns, and perhaps disturbing the redds from the smaller trout. The goal is to more formally document this phenomenon, and deploy temperature loggers to estimate developmental rates and emergence based on thermal sums models.
Methods: Direct observations of courting and redd construction, and positive ID of the fish (from photos) were obtained, redds were measured for size, and temperature loggers deployed.
Results/status: Data are collected and a draft MS has been started.

Elwha River estuary

1) **Title:** Use of the Elwha River estuary by juvenile salmon and trout
Lead: J. Anne Shaffer (CWI), Nicole Harris (WWU), Justin Brown, Jon Wittouck and TQ (UW)
Goal: Determine the patterns of occupancy by salmon in the estuary of the Elwha River and nearby Salt Creek in the period prior to dam removal, for comparison to the future.
Methods: Monthly beach seining has been conducted at two sites in each estuary by the CWI since 2007, with all fish identified and counted, and a sub-set measured for length.
Results/status: A MS on coho salmon is in press at Transactions of the American Fisheries Society. A paper on Chinook salmon is nearly ready for submission and analyses of data on chum salmon and cutthroat trout are on-going.

Pink salmon

1) **Title:** Migration timing and life history of pink salmon
   Lead: Mara Zimmerman (WDFW), George Pess (NOAA), Michael McHenry (LEKT), TQ (UW)
   Goal: Determine the patterns of body size and return timing of Elwha River pink salmon for comparison with conspecifics in the Dungeness River. Does the Elwha River have early and late runs, as does the Dungeness? Is the timing similar or different between rivers? Are the fish of the same body size in the early and late components, and in the two rivers? Are the runs synchronous between rivers and between early and late or asynchronous, as might suggest that they are independent populations?
   Methods: Monitor arrival timing or live counts in the two rivers, especially on odd-numbered years. Measure body size of carcasses in both rivers throughout the run(s).
   Results/status: Preliminary data indicate bimodal run timing in the Elwha River, and we are planning sampling in 2013, when substantial numbers of fish are anticipated.

Bull trout

1) **Title**: Non-lethal sampling to develop migration chronologies for bull trout
   Leads: Roger Peters (USFWS), Sam Brenkman (NPS), Lance Campbell (WDFW)
   Goal: Refine non-lethal techniques for reconstructing the migration history of fish from fin rays as an alternative to otolith extraction, to determine whether fish from the above-dam area become anadromous, and the extent of anadromy by fish below the dam sites.
   Methods: Obtain and prepare pectoral fin rays from anadromous and non-anadromous bull trout to determine the success in detecting their recent migrations from Sr/Ca ratio.
   Results/status: Campbell has already demonstrated that pectoral fin rays can archive migration history and the techniques are being refined to minimize harm to the fish.

2) **Title**: Tracking of anadromous bull trout
   Lead: Roger Peters (USFWS), Jeffrey Duda (USGS), Sam Brenkman (NPS), Michael McHenry (LEKT) and TQ (UW)
   Goal: Characterize the timing of movement upstream and downstream by anadromous bull trout and the distribution along the marine shoreline.
   Methods: Catch fish within the river for implantation with radio tags, and deploy self-contained receivers at strategic locations.
   Results/status: Still in the planning stages but likely to commence in spring 2013.

Community Outreach

In addition to collaboration and outreach within the scientific community, we plan to organize educational and outreach activities to share Elwha River science with the public. The goal of these activities is to increase local and widespread knowledge about, and therefore interest in, the Elwha River restoration and salmonid populations. Communication has been established with Nature Bridge and the Fiero Marine Life Center, two Port Angeles-based environmental education organizations, as well as with the Port Angeles Public Library. These entities are interested in helping us coordinate and execute educational activities for school groups and community members and will serve as collaborators and hosts for future outreach events. Additionally, we have agreed to assist with the UW Undergraduate Honors Program's "Partners in the Parks" program. This program brings honor students with a variety of majors at different universities around the country to Olympic National Park for a week of interdisciplinary, experiential learning. Our contribution to the program will focus on Elwha River fish ecology and recolonization.