RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress
Thomas Quinn
[revised] - Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity
R/HCE-9
Submitted On: 03/23/2016 09:25:26 PM

METRICS & MEASURES

Metric/Measure	Value	Note
Acres of coastal habitat	0	The Elwha River itself has expanded coastal habitat markedly, and this is under study, but it was not a Sea Grant accomplishment per se.
Fishermen and seafood industry personnel	0	The project was not designed to have this outcome.
Communities - economic and environmental development	0	The project was not designed to have this outcome, though Port Angeles and the Olympic Peninsula likely have seen considerable tourist development related to Elwha dam removals.
Stakeholders - sustainable approaches	0	Not planned as an outcome of this project, though many stakeholders are heavily invested in the dam removal project, including the Lower Elwha Klallam Tribe and the community of Port Angeles.
Informal education programs	0	Not designed as an outcome of the project.
Stakeholders who receive information	100	presentations
Volunteer hours	0	Not a goal of this project.
P-12 students reached	0	Not a goal of this project.
P-12 educators	0	Not a goal of this project.

REQUESTED INFORMATION

Publications

Levels of stored energy but not marine foraging patterns differentiate seasonal ecotypes of wild and hatchery steelhead trout, O
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: accepted pending revisions
Publication Authors:
Publisher Info: Canadian Journal of Fisheries and Aquatic Sciences
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: Lamperth, J., T. P. Quinn and M. Zimmerman. Levels of stored energy but not marine foraging patterns differentiate seasonal ecotypes of wild and hatchery steelhead trout,

Oncorhynchus mykiss, returning to the Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences
Citation for Coverpage:
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Restoration potential for sockeye salmon in the Elwha River, Washington after dam removal: rearing capacity of Lake Sutherland f
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: in review
Publication Authors:
Publisher Info: Transactions of the American Fisheries Society
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: Hansen, A. G. J. R. Gardner, D. A. Beauchamp, R. Paradis, and T. P. Quinn. Restoration potential for sockeye salmon in the Elwha River, Washington after dam removal: rearing capacity of Lake Sutherland for landlocked and anadromous Oncorhynchus nerka. Transactions of the American Fisheries Society
Citation for Coverpage:
SG can post PDF online?:
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Influence of species, size, and relative abundance on the outcomes of competitive interactions between brook trout and juvenile
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2016
Publication Authors:
Publisher Info: Ethology, Ecology and Evolution
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: Thornton, E. J., J. J. Duda and T. P. Quinn. Influence of species, size, and relative abundance on the outcomes of competitive interactions between brook trout and juvenile coho salmon. Ethology, Ecology and Evolution
Citation for Coverpage:
SG can post PDF online?:
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Experimental determination of the limits of using stable isotopes to distinguish steelhead and Rainbow Trout offspring
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015
Publication Authors:
Publisher Info: North American Journal of Fisheries Management
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: Thornton, E. J., R. W. Hardy and T. P. Quinn. 2015. Experimental determination of the limits of using stable isotopes to distinguish steelhead and Rainbow Trout offspring. North

American Journal of Fisheries Management 35:810–817.
Citation for Coverpage:
SG can post PDF online?:
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Use of egg size differences in anadromous (sockeye salmon) and non-anadromous (kokanee) forms of Oncorhynchus nerka to infer anc
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015
Publication Authors:
Publisher Info: Ecological Research
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: Quinn, T. P., M. H. Bond, and H. Berge. 2015. Use of egg size differences in anadromous (sockeye salmon) and non-anadromous (kokanee) forms of Oncorhynchus nerka to infer ancestral origins of the Elwha River's landlocked population. Ecological Research 30: 547-554.
Citation for Coverpage:
SG can post PDF online?:
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Using redd attributes, fry density and otolith microchemistry to distinguish the presence of steelhead and Rainbow Trout Oncorhy
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015
Publication Authors:
Publisher Info: North American Journal of Fisheries Management
Notes:
Related URLs:
Keywords:
Publication URLs:
Abstract:
Citation: McMillan, J. R., G. R. Pess, M. Liermann, S. A. Morley, M. L. McHenry, L. A. Campbell, and T. P. Quinn. 2015. Using redd attributes, fry density and otolith microchemistry t distinguish the presence of steelhead and Rainbow Trout Oncorhynchus mykiss in the Elwha River dam removal project. North American Journal of Fisheries Management 35: 1019-1033.
Citation for Coverpage:
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Students Supported

Emily Thornton (Continuing Student)
ethorn10@uw.edu
No institution, School of Aquatic and Fishery Sciences

Field of Study:
Advisor: Thomas Quinn
Degree Type: MS
Degree Year: 2015

Student Project Title:

Involvement With Sea Grant This Period (capstone, fellow, intern, etc.): Completed her

M.S. degree with Sea Grant support

Post-Graduation Plans (employer, grad school, etc.):

Was this thesis/dissertation supported by Sea Grant?: No

Thesis / Dissertation: Competition between non-native brook trout and coho salmon in the Elwha River, WA during dam removal

New or Continuing?: continuing

Degree awarded this reporting period?: Yes

Financially supported?: Yes

Narratives

Annual Report for 2015
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Partners This Period

US Geological Survey
Types: Government
Scale: FEDERAL or NATIONAL
Notes:

Northwest Fisheries Science Center (US DOC, NOAA, NMFS, NWFSC)
Types: Government
Scale: FEDERAL or NATIONAL
Notes:

US Fish and Wildlife Services (US DOI, FWS)
Types: Government
Scale: FEDERAL or NATIONAL
Notes:

US National Park Service (US DOI, NPS)
Types: Government
Scale: FEDERAL or NATIONAL
Notes:

Lower Elwha Klallam Tribe
Types: Government
Scale: INTERNATIONAL
Notes:

Coastal Watershed Institute
Types: NGO
Scale: LOCAL
Notes:

Washington Department of Fish and Wildlife
Types: Government
Scale: STATE
Notes:

STANDARD QUESTIONS

Impacts and Accomplishments

(1)

Type	accomplishment
Title	Washington Sea Grant research chronicles the real-time recovery of complex fish communities as a once-great salmon river returns to life
Relevance	The removal of the Elwha River dams is the most long-sought and important salmon restoration project ever undertaken. With all five Pacific salmon species plus freshwater and sea-run bull and steelhead/rainbow trout below, the recovering Elwha also affords a matchless natural laboratory. How will landlocked populations above the dams and remnant anadromous populations below merge, compete and use this rejoined habitat? What ranges and abundance will they regain? How will their life histories change? This real-time recolonization promises new insights into keystone species and guidance for future restorations. But the speed of change and complexity of fish populations demand an unusually quick, flexible, collaborative and multi-targeted response.
Response	Washington Sea Grant-supported researchers have met this challenge since 2012, chronicling the Elwha ecosystem’s transformation by measuring fish numbers, movements, redds (spawning nests), genetics, body and egg size, and stable-isotope composition.
Results	The team made several important findings in 2015. They determined how to distinguish redds made by steelhead and rainbow trout and thus determine whether sympatric breed occurs. They found that summer-run steelhead have much more fat than winter-run. Wild and hatchery-origin steelhead also differ in fat level, and isotopes revealed they feed differently in the ocean. Kokanee in upriver Lake Sullivan descended from pre-dam anadromous sockeye rather than coming from elsewhere. Despite fears that nonnative brook trout might suppress returning coho salmon, the coho seem to be competing successfully.
Recap	Washington Sea Grant researchers have documented rapid ecological change as salmon and trout recolonize the Elwha River following dam removal.
Comments	
Primary Focus Area	Healthy Coastal Ecosystems

Secondary Focus Areas	Sustainable Fisheries and Aquaculture
Goals	Ocean and coastal habitats are protected, enhanced and restored.|Fisheries are safe, responsibly managed and economically and culturally vibrant.
Partners	Coastal Watershed Institute Lower Elwha Klallam Tribe Northwest Fisheries Science Center (US DOC, NOAA, NMFS, NWFSC) US Fish and Wildlife Service (US DOI, FWS) US Geological Survey (US DOI, USGS) US National Park Service (US DOI, NPS) Washington State Department of Fish and Wildlife
PI Draft	

Tools, Technologies, Information Services / Sea Grant Products

No **Tools, Technologies, Information Services / Sea Grant Products** information reported

Economic Impacts

No **Economic Impacts** information reported

Community Hazard Resilience

No **Community Hazard Resilience** information reported

Meetings, Workshops, Presentations

(1)

Type of Event	Public or professional presentation
Description	American Fisheries Society Annual Meeting, Portland, OK
Event Date	08-18-2015
Number of Attendees	100

Leveraged Funds

(1)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - field sampling
Source	Lower Elwha Klallam Tribe
Amount	15000
Start Date	02-01-2015
End Date	01-31-2016

(2)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - field sampling, data management, sample processing
Source	National Park Service
Amount	7500
Start Date	02-01-2015
End Date	01-31-2016

(3)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - field sampling, data management, sample processing
Source	US Fish and Wildlife Service
Amount	5000
Start Date	02-01-2015
End Date	01-31-2016

(4)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - sampling
Source	Dungeness River Hatchery
Amount	5000
Start Date	02-01-2015
End Date	01-31-2016

(5)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - field sampling, sample processing, data analysis
Source	NOAA
Amount	12500
Start Date	02-01-2015
End Date	01-31-2016

(6)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - sample processing, data analysis
Source	USGS
Amount	5000
Start Date	02-01-2015
End Date	01-31-2016

(7)

Purpose	Recovery of Elwha River Salmon and Trout after Dam Removal: Recolonization and the Awakening of Dormant Life History Diversity - field sampling, data analysis
Source	Trout Unlimited
Amount	5000
Start Date	02-01-2015
End Date	01-31-2016

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

Thomas P. Quinn
School of Aquatic and Fishery Sciences
University of Washington
Seattle, WA 98195

Proposal Objectives

The removal of two large dams on the Elwha River, on the Olympic Peninsula of Washington, is the most long-awaited and important salmon restoration project undertaken. The success of the project, not only for salmon and trout but for the ecosystem as a whole, will hinge on the full use of the habitat by a variety of species, each with the entire suite of life history traits that can be expressed. The objective of this study is to study the ways in which the salmon and trout populations of the Elwha River system will expand in abundance and spatial use of the basin, and in the diversity of their life history traits after the dams are removed. Pink salmon exist only as a remnant anadromous populations below the dams and are expected to expand upward in the watershed. In contrast, sockeye salmon exist only as a landlocked non-anadromous population but they are expected to expand into a sea-run population. Finally, rainbow trout and bull trout currently exist is both landlocked forms above the dams and sea-run forms below the dams but the forms are isolated from each other. We will use a variety of non-lethal and non-invasive approaches to assess the past and current life history diversity in these species, and set the stage for long-term sampling that will determine the future trajectories of these species towards their full potential in this re-connected river system.

Proposal Methodology

Our approach to this system is multi-tiered, as appropriate for the differences among the species, the special considerations necessitated by the fact that three salmonid species in the basin are protected under the US Endangered Species Act, and the co-management of the fisheries between state and tribal entities. In addition, full restoration of the system will take many years and so we will look backward at records from the past, sample in the present, and develop techniques and approaches that will serve in the future. The core of the proposed sampling was to be a weir across the river designed to allow capture, handling, and release of upstream migrating adult salmon and trout. The weir was set up and maintained by cooperators on this project but for practical reasons (high river flows, sediment transport, log jams, etc.) it was removed and replaced with an acoustic counter (DIDSON) and on-site sampling of fish for size, sex, and species composition. As before, we supported this effort with data analysis (e.g., age, sex, length, date) and the collection of additional data on stable isotopes (to infer anadromy and patterns of trophic ecology at sea). We also proposed to also measure redds and sample newly emerged fry to determine the extent to which steelhead are spawning in sympatry with rainbow trout. In the case of sockeye salmon, we will establish a baseline of life history traits and genetic population structure in the non-anadromous population for comparison with the anticipated anadromous population.

Proposal Rationale

Pacific salmon and trout are the most important fishes in the region for commercial, recreational, and ceremonial fishes. In addition, they are keystone species for the stream and riparian ecosystems, bringing vast quantities of energy obtained from the ocean to nourish the otherwise nutrient-poor stream system when they did. In addition to the value of salmon in fisheries and ecosystems, they have great symbolic value to the native peoples of the region and the more recent settlers as well. They are, in many ways, the icon of the region. The reductions in Pacific Northwest salmon populations have many causes but the construction of impassable dams in rivers is among the main ones. For decades, the removal of the two dams on the Olympic Peninsula's Elwha River has been the goal of fisheries professionals, tribal, commercial and recreational fishermen, ecologists, and citizens at large. After a protracted legal process, the dam removal began in fall 2011 and is now complete. It is essential that scientific sampling be conducted to determine the extent to which the system responds. In particular, how will the salmon and trout, isolated from the sea or from populations below the dam, expand in not only numbers for spatial extent and the diversity of life history that is so crucial to their long-term productivity.

Annual Report

Funding from Sea Grant began in April 2012 and we recruited Emily Thornton as a master's student at the School of Aquatic and Fishery Sciences, University of Washington. She selected and completed her thesis and defended it in spring 2015. In addition, as proposed, we directed efforts towards a variety of species and questions in an effort to accomplish as much as possible, given the funding in hand and the complexity of the task. We feel very good about what has been done, though inevitably there are many things still in progress or that could not be attempted for one reason or another. Overall, we have established very strong links to all the major collaborators in the Elwha River system and project begun under this grant will continues into the future.

The pace of work in the Elwha River system is exceptionally fast as the river is changing constantly, and the agencies are making rapid decisions and taking quick action, sometimes with little notice to groups outside the circle of decision-makers. These challenges are revealing the wisdom in our proposal's broad approach rather than rigidly defined studies, notwithstanding the skepticism of the proposal reviewers. 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. In addition, Emily Thornton has been a wonderful graduate student, contributing new ideas and hard work to the tasks, and already accomplishing much.

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: paper published:

McMillan, J. R., G. R. Pess, M. Liermann, S. A. Morley, M. L. McHenry, L. A. Campbell, and T. P. Quinn. 2015. Using redd attributes, fry density and otolith microchemistry to distinguish the presence of steelhead and Rainbow Trout *Oncorhynchus mykiss* in the Elwha River dam removal project. North American Journal of Fisheries Management 35: 1019-1033.

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 were processed as well. These data were integrated into the MS #1 above.

3) **Title**: Use of nitrogen stable isotope signal to distinguish steelhead and rainbow trout fry.
   Leads: Emily Thornton, and Ron Hardy (U of Idaho) and Thomas Quinn (UW)
   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: Obtained eyed eggs from steelhead, reared some fry on non-marine derived food and some on a diet with marine sources, and sampled fry periodically as they grew for stable isotopes in fin tissue to see the decline in ^{15}N enrichment from the marine maternal signal to baseline.
   Results/status: The experiment was a success and the paper is published:

Thornton, E. J., R. W. Hardy and T. P. Quinn. 2015. Experimental determination of the limits of using stable isotopes to distinguish steelhead and Rainbow Trout offspring. North American Journal of Fisheries Management 35:810–817.

4) **Title**: Wild and hatchery steelhead life history inferred from body fat content
   Lead: Mara Zimmerman and Jamie Lamperth (WDFW), Thomas Quinn (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: Sample wild and hatchery summer and winter steelhead at the Kalama River to quantify the variation in long-established populations in body fat content at arrival for subsequent comparison with Elwha River fish. Scales were also taken for age determination.
Results/status: The meter was used to assess fat content in wild and hatchery summer and winter steelhead at the Kalama River for an entire year. All the data are now in, and we submitted a paper combined with objective #6 (below). The paper was accepted pending minor revisions, which we are working on that this time:

Lamperth, J., T. P. Quinn and M. Zimmerman. Levels of stored energy but not marine foraging patterns differentiate seasonal ecotypes of wild and hatchery steelhead trout, *Oncorhynchus mykiss*, returning to the Kalama River, Washington. Canadian Journal of Fisheries and Aquatic Sciences

5) **Title**: Wild and hatchery steelhead marine ecology inferred from stable isotope analysis
Lead: Mara Zimmerman (WDFW), Jamie Lamperth, (WDFW) and Thomas Quinn (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 from Kalama River fish to determine whether stable isotopes of N and C indicate differences in marine ecology.
Results/status: Full sets of scales were collected from wild and hatchery summer and winter steelhead from the Kalama River for an entire year. They have been processed for stable isotopes and the data examined. A paper combining these data and the fat content data is being revised and finalized for publication (see above).

Sockeye salmon - kokanee

1) **Title**: Life history of Lake Sutherland kokanee: Implications for ancestral origins
Lead: Thomas Quinn 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. The results showed patterns of life history suggestive of anadromous ancestry (large egg size for a given body size). A paper reporting these data has been published:

Quinn, T. P., M. H. Bond, and H. Berge. 2015. Use of egg size differences in anadromous (sockeye salmon) and non-anadromous (kokanee) forms of *Oncorhynchus nerka* to infer ancestral origins of the Elwha River's landlocked population. Ecological Research 30: 547-554.

2) **Title**: Ecology and nutrient cycling of Lake Sutherland
Lead: Rebecca Paradis and Matt Beirne (LEKT), Thomas Quinn, Morgan Bond, Adam Hansen, 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 these data will be very valuable for assessing the productive capacity of the lake for sockeye salmon. 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. We examined the data and have a paper in review at this time:

Hansen, A. G. J. R. Gardner, D. A. Beauchamp, R. Paradis, and T. P. Quinn. Restoration potential for sockeye salmon in the Elwha River, Washington after dam removal: rearing capacity of Lake Sutherland for landlocked and anadromous *Oncorhynchus nerka*. Transactions of the American Fisheries Society

3) **Title**: Genetic identity of anadromous sockeye salmon in the Elwha River system
Lead: Ruth Withler (DFO, Canada), George Pess (NOAA), Michael McHenry (LEKT), and Thomas Quinn
Goal: Characterize the current genetic population structure of the non-anadromous sockeye salmon in Lake Sutherland, compare that baseline to the anadromous sockeye salmon that have entered the Elwha River, and determine whether these sea-run fish are the offspring of local Elwha River fish or are strays, and the origin if they are strays.
Methods: DNA samples were obtained from sockeye salmon in Lake Sutherland with Sea Grant support, and adult sockeye salmon from the ocean were sampled by NOAA, LEKT and other entities. Samples have been provided to Ruth Withler, a well-recognized scientist with a large baseline of sockeye salmon from the region, and she will lead the data analysis.

Status: Samples have been collected and the UW specimens provided to NOAA for transferal to DFO.

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, and Thomas Quinn (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: Papers on coho and Chinook salmon were published. Analyses of data on chum salmon, bull trout and cutthroat trout are on-going but we will likely include data from the post-dam period and so these papers will be prepared in the future.

Pink salmon

1) **Title:** Life history of odd-year and even-year pink salmon
   Lead: Krista Oke (McGill University), and Thomas Quinn (UW)
   Goal: Determine the patterns of body size of Elwha River pink salmon for comparison with conspecifics in the Dungeness River. Do the Elwha River odd and even year runs differ in size, and are they similar to the sizes of fish in the Dungeness River?
   Methods: Monitor body size in the two rivers and obtain historical data.
   Results/status: We hope to include the data on body size of even and odd year runs of pink salmon in a larger paper on life history differences between these lines, and data analysis is on-going.

Bull trout

1) **Title**: Tracking of anadromous bull trout
   Lead: Roger Peters (USFWS), Jeffrey Duda (USGS), Sam Brenkman (NPS), Michael McHenry (LEKT) and Thomas Quinn (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: This project is moving forward, albeit slowly, with radio tracking of bull trout being conducted each year, in coordination with the fence being operated to count and tag adult salmon. The results of this work will be building over the next several years but we will maintain this collaboration into the future.

2) **Title:** Resumption of anadromy by Elwha River bull trout
   Lead: Thomas Quinn, Samuel Brenkman (NPS), Roger Peters (USFWS), Rebecca Paradis (LEKT)
   Goal: To use stable isotopes of carbon and nitrogen to test determine the extent to which the present bull trout population in the Elwha River system is taking advantage of marine

food resources and so have effectively resumed anadromy after being land-locked for a century.

Methods: We obtained samples of fin clips that had been collected from juvenile bull trout in the Elwha River prior to dam removal above the dam, in the estuary after dam removal, and adults in the river after dam removal. We also obtained samples, for comparison, from bull trout in the Dungeness River (nearby, with no dam) including juveniles in the river, juveniles in the estuary, and adults.

Results/status: Stable isotope analysis is complete and preliminary data analysis clearly indicates that the Elwha River fish have resumed anadromy. More detailed data analysis is needed but a report is being prepared on these findings.

Brook trout – coho salmon interactions

1) **Title**: Influence of species, size, and relative abundance on the outcomes of competitive interactions between brook trout and juvenile coho salmon.

   Leads: Emily Thornton (UW), Jeff Duda (USGS), Thomas Quinn (UW)

   Goal: Determine the extent to which competitive dominance might affect behavioral interactions between colonizing coho salmon and established (but non-native) brook trout.

   Method: Conduct paired laboratory experiments to assess dominance using the USGS experimental facility at Sand Point.

   Results/status: Experiments have been completed, data analyzed, and a paper is accepted and soon to be published:

Thornton, E. J., J. J. Duda and T. P. Quinn. Influence of species, size, and relative abundance on the outcomes of competitive interactions between brook trout and juvenile coho salmon. Ethology, Ecology and Evolution

2) **Title:** Trophic overlap, habitat, and scope for competition between re-colonizing coho salmon and resident, non-native brook trout in the Elwha River system.

   Leads: Emily Thornton (UW), George Pess (NOAA), Thomas Quinn (UW)

   Goal: Determine whether juvenile coho salmon and brook trout occupy the same trophic position in the Elwha River system, in a manner that might lead to competition, affecting the success of recolonization by coho salmon.

   Methods: Fish were sampled for diet and stable isotope ratios in a series of habitat units, the diet samples were processed, as were the isotope samples, and these data were integrated with habitat use data for both species.

   Results/status: The data have been fully analyzed and a paper is under pre-submisison internal review at NOAA. This is the planned citation:

Thornton, E. J., G. R. Pess, and T. P. Quinn, Common resource utilization as an indicator of competition between brook trout and juvenile coho salmon in the Elwha River, WA during dam removal. Environmental Biology of Fishes

Conclusion

Data collected by collaborators in the pre-dam removal period have been examined and, in some cases, combined with data from the post-dam period, though the ecological processes and

responses will play out over many decades. In general, the pace of physical change (e.g., sediment transport in the areas that had been reservoirs, and deposition in the estuary) have been very rapid, and many changes in the salmonid community have been observed. There have been a variety of human interventions, including on-going hatchery production and also transportation of some adult individuals upriver to facilitate recolonization. Therefore, interpretation must be made cautiously because this is not an entirely natural recolonization process. Nevertheless, it is fair to say that species formerly limited to the area below the dam (Chinook, coho, chum and pink salmon) are moving upriver rapidly. Species formerly present both above and below the dams (rainbow/steelhead trout, cutthroat trout, and bull trout) and moving up and down, and showing signs that they are resuming anadromy (bull trout) and expanding their range (steelhead). Sockeye salmon, formerly found only above the dam, are still limited in their distribution and it may be years or decades before it is clear what their final condition will be.

The proposal to take a multi-species approach to the recolonization of the Elwha River system was met with some skepticism from the reviewers but I remain convinced that my approach was the correct one, rather than undertake a specific, narrow project with a tight hypothesis. So many unexpected physical, biological, and human processes have been at work that considerable agility is needed to maintain forward motion. We have successfully built collaborative relationships that will endure long after the funding has ended, and we have published or are in the process of publishing many papers, including work on adult and juvenile life history stages, in the river, lake, and estuarine habitats, and involving coho, Chinook, and sockeye salmon, cutthroat trout, and steelhead. Other projects on pink salmon and bull trout are ongoing, and a major review paper was published and another is planned. It is fair to say that no one of these individual papers encompasses the full scope of salmonid recovery in this system, but that was not really the intent. I think that we have more than fulfilled the promise of the proposed work, and there have also been notable successes in personnel training and capacity building.