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Redwood Creek Special Edition

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Project Aims to Double Salmon Habitat

Adult coho spawn in the gravel of Redwood Creek in the winter. Eggs hatch in the spring and juveniles stay in the freshwater stream for at least a year. In their second spring they migrate to the ocean.

A passerby at Muir Beach would be hard pressed to imagine this calm coastal sanctuary, sheltered from the roaring Pacific by lush green vegetation, as a harsh environment for fish. But in the face of steadily declining fish populations, NPS scientists planning the Redwood Creek restoration at Muir Beach are working to identify the hidden factors that have turned this gentle stream into unfavorable habitat for the endangered coho salmon.

Though not all West Coast coho are endangered, the population that lives in Redwood Creek is part of a legally defined "evolutionarily significant unit": a reproductively isolated group whose genes are a unique piece of the species' evolutionary puzzle. Although the coho range spreads north to Alaska, the southernmost continually-returning natural population of coho is found in Redwood Creek.

Human-induced changes, like channelization of the creek, sedimentation caused by roads, and the destruction of the floodplain, are posing often insurmountable challenges to this crucial fish population. Coho numbers have precipitously declined during the past several decades, with less than 6 adult fish seen in 2009. In March of 2010, the National Marine Fisheries Service put out a Draft Recovery Plan for coho. This document, along with analyses of coho behavior and habitat needs are guiding NPS planners as they aim to make the stream more hospitable for the fish that call it home.

The coho salmon, like the steelhead trout that also lives in Redwood Creek, is anadromous – it moves between fresh water and the ocean. A coho juvenile is hatched in fresh water, sticks around for approximately one year before migrating to the ocean, and then after two additional years of maturation in the ocean makes what can only be described as an epic return to the very stream in which it was born to reproduce. After the exertion of spawning the fish gracefully dies, returning nutrients to the ecosystem that feed everything from insects to redwoods to raccoons.

For years biologists have observed from stream banks the spawning preferences of coho adults. Coho are very choosy about where they dig their nests (known as redds) in the streambed's gravel because water has to be moving just right to deliver oxygen to the eggs without washing them away. After the eggs have hatched into juveniles, scientists such as Ethan Bell (of Stillwater Sciences) have literally immersed themselves in coho, snorkeling to observe fish abundance and the habitat preferences of the young fish.

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Juvenile coho stay in their native stream all through the winter after their birth. In periods of high precipitation and flooding, young fish are often fatally swept away. Ideal winter habitat for juveniles includes deep slow water with cover from large wood or dense **vegetation during** normal winter flows; with adjacent side-channels and floodplains to escape to under high flows. “When you have a degraded system you can have very high mortality rates during winter,” explained Bell, “It’s a problem, but it’s also an opportunity to restore habitat and bring populations back.”

Using winter habitat for juveniles as a critical piece, hydrologists used computer models to map the areas of Muir Beach with suitable water depth and flow velocities for use by coho during the winter. Scientists again used this method of hydrodynamic modeling to see into the stream’s future. They modeled features drawn in the preliminary restoration designs, such as floodplain connectivity, backwater channels, and sheltering deep pools.

Models revealed that after the restoration, coho in Redwood Creek will have access to more than twice the current amount of winter habitat. “There are a lot of projects in California and Oregon that are focused on helping coho during the winter, but few are as extensive as this one,” Bell said, “It’s ambitious, and based on what’s being done I’m optimistic.”

The intent of the restoration is to create an unobstructed floodplain, where water from winter storms that comes rushing down the main creek channel is able to diffuse as a shallow, slow-flowing, braided network. Also, large tree trunks will be inserted directly into the creek during habitat construction so that coho don’t have to wait for trees and branches to naturally fall down in order to have refuge.

This habitat will be self-sustaining and will not need constant human maintenance once it forms because the restoration will open the creek up to natural processes that have been disabled by human structures and land uses. NPS scientists and planners are hopeful that after restoration, coho life in Redwood Creek will be a little easier.

Creek Flows Freely Again

The murky waters of sedimentation have greatly diminished Redwood Creek over the past century. At Muir Beach, what was 150 years ago an expansive lagoon with 12 acres of open water is now walkable solid ground due to human-induced sedimentation (entry of dirt and rocks into the creek bed). The geomorphic aspects of Redwood Creek - its shape, its size, how much sediment it carries, and how this sediment comes and goes - affects everything from the breeding success of the fish that populate its waters, to the ability of humans to pass through often flooded nearby roads. Evaluating the stream’s geomorphology is a crucial step towards restoring it to a sustainable, livable condition for all creatures that interact with it.

Volunteers plant small trees and shrubs into the expanded floodplain in 2010 (top). Fast-moving storm waters flood the Muir Beach levee road in 2004. High flows have the potential to sweep away juvenile salmon (bottom).

To understand the extent of recent human impacts on Redwood Creek, restoration planners dug into archives spanning decades and sometimes centuries. Scientists used aerial photographs taken periodically since 1947 to see how the lagoon surface has changed over time. Historic maps from as far back as the 1850s also help give a feel for what kind of impact humans have had on the area. Of course, maps and pictures only reveal superficial factors like the surface area of the water. To understand long-term geomorphic processes, hydrologists depend on past data. Restoration scientists considered data including measurements of water flow from U.S. Geological Survey (USGS) studies at Redwood Creek dating to the 1960s, and rainfall records from National Oceanic and Atmospheric Administration (NOAA) dating to the early 1940s.

More recent measurements of water flows have been taken by NPS scientists since the early 1990s. In the field, scientists use equipment to measure turbidity (how much sediment is suspended in the water) as well as other geomorphic factors like the width of the stream and the steepness of its banks. Features like vegetation, contours, pieces of woody debris, and locations of different types of substrate (the type of rock on the creek bottom) are recorded and sometimes hand-drawn on a gridded map in the field. In the lab, mapping software is used to analyze field data. Computer models process the data to predict how the stream will flow under different conditions both before and after planned restoration. With the help of such studies, NPS has developed a sediment “budget,” a measurement of how much sediment goes into the creek and how much comes out.

From this research, the story of how humans have changed sedimentation in the creek has been pieced together. Logging of redwood trees and other woody plants along the creek in the early 1900s increased erosion. As late as the 1970s, land filling to create grazing pastures increased sedimentation. Scientists estimate that after these land use changes there was ten times as much sediment in the creek as before. More easy for the naked eye to see is how the

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shape of Redwood Creek has been affected by humans. During its agricultural years part of it was channelized, carved into a straight "bowling alley," by people managing it for irrigation and flood control. The creek was often dredged to remove sediment. Today, a different mindset guides creek management, freeing natural processes.


Juvenile coho seek shelter in woody debris. Photo by Stillwater Sciences.

The plan for the Redwood Creek restoration aims to eliminate the need for channelization and dredging. By digging a naturally-shaped channel and limiting obstacles, the restoration will create a self-sustaining system that doesn't require much human involvement. The creek will meander, moving on its own in a dynamic way.

Current land uses in the watershed are largely recreational, but also include several residential communities and an organic farm. Remnant roads, levees and a parking lot still obstruct the flow of Redwood Creek, causing it to slow and drop the sediment it carries. Local roads are easily flooded during winter storms. As sediment piles up, the creek can become a labyrinth, and endangered coho salmon have trouble finding an upstream passage. By better understanding the effects of human interventions, restoration scientists are prioritizing effective solutions that will sustainably manage Redwood Creek's geomorphology.

Uncovering People and Plants

One of the most direct methods for determining landscape history is by drilling soil cores. First, intact layers 10 to 20 feet deep are extracted. Then layering, composition, and age of soil types reveal sequences of landscape features and watershed events. The cores also suggest areas used by humans hundreds or thousands of years earlier. Using these soil cores, scientists have identified past ecological processes that dominated the Redwood Creek watershed, and areas where archaeological investigations should be done.

This type of subsurface investigation was conducted at Muir Beach to guide restoration design. As geoarchaeologist Jack Meyer of Sonoma State University explained, "It's important to do the homework and know about any relevant studies," to guide the selection of coring locations. The goal is to identify target areas where the soil is likely to contain evidence of human existence. To plan the Redwood Creek coring, Meyer reviewed historical studies and other published literature on local archaeology dating back to the early 20th century. He even looked to coring that had been done at comparable sites for inspiration. A certain kind of surface soil called "Blucher-Cole complex" is found at both lower Redwood Creek, and in other nearby valleys where cultural remains have been found. By assuming that the soil history of the Blucher-Cole complex is similar in both places, Meyer could infer likely locations of cultural remains in the lower Redwood Creek site.

Using this research, he was able to pinpoint "sensitive" areas where the likelihood of finding indigenous archaeological resources was high. In the fall of 2002 and 2003 a total of 23 cores were extracted from these locations. At each chosen site, a human-operated hydraulic coring machine was used to drive a two-inch-wide cylindrical core into the ground. When pulled out, the contents of a soil core were packed into a clear plastic liner. Next the core liners were cut in two, placed in wax-lined cardboard boxes, labeled and eventually transported to an NPS laboratory at the nearby Presidio in San Francisco for further analysis. Meyer noted that coring can be an "unglamorous and grueling part of the job. It can be a very hectic kind of day."

A well-practiced geoarchaeologist can read thousands of years of natural history from one soil core. At the Presidio, each stratum, or layer, of soil was labeled based on its properties and historical context. Scientists then used radiocarbon dating to figure out the ages of the layers. Like determining the history of the site from its strata, dating each layer depends on the skill of the scientist. In the Presidio lab, Meyer's work took on an almost surgical precision as he scrutinized particles of each soil layer. Through small changes in color or composition, he could determine ecological shifts at the soil core location. A layer of gravel, for instance, indicated a period of "high energy" where the path of the creek once flowed. Earlier sand dunes were found under today's visitor parking lot.

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A map of the restoration site from an 1859 coastal survey shows Redwood Creek and a large lagoon at the base of Frank's Valley, near Muir Beach (top). An aerial image shows the highly fragmented project site today (bottom).

Traditional Ecological Knowledge Guides NPS

In a continuing effort to protect national and indigenous cultural resources, NPS has partnered with the local tribe, the Federated Indians of Graton Rancheria (FIGR), to incorporate traditional ecological knowledge (TEK) into its revegetation strategy for the Redwood Creek restoration. TEK is knowledge accrued by native peoples over hundreds of years through direct interaction with the local environment. It frequently refers to plants, though TEK may also describe uses of animals or inorganic materials. Often TEK has been preserved over many generations in great detail and tells not only what a natural resource is used for, but exactly how and when it should be used. NPS scientists searched local anthropological evidence and worked with FIGR members to compile local TEK. The investigation yielded a list of hundreds of natural resources used in traditional ways by tribes such as the Coast Miwok and Southern Pomo. Researchers then narrowed the list down to a few particular plants that are native to the project site and that fit the project goals.

Many of the riparian plants in the project site like sedge, willow, buckeye, and red alder (pictured here) have traditional uses.

Approximately 17 plant species have been chosen for the revegetation plan for their traditional significance, mainly for basketry and construction uses. The integration of these plants in the project opens the door for future active and involved interpretation of Coast Miwok culture for the general public. There is also potential for collaboration between NPS and FIGR to allow tribe members to harvest and use traditional plants. Read more about FIGR at http://www.gratonrancheria.com/

NPS scientists paid careful attention to the cultural history of the coring site. Lower Redwood Creek was originally inhabited by the Huimen, one of over a dozen politically independent Coast Miwok tribes. As NPS historian Paul Scolari noted, coring is "a balance between doing science, and acknowledging that these sites represent human history and associations with current human cultures." Today the Coast Miwok are represented by the Federated Indians of Graton Rancheria (FIGR) who throughout the Redwood Creek restoration planning process have aided NPS in the investigation of potential buried cultural resources at the project site. "We planned the project with them, they worked as field monitors, and they took part in the lab work," said Scolari, "These archaeological sites are on park land today, but they're really associated with the Coast Miwok people." The partnership between FIGR and NPS in the restoration fulfills legal requirements for interaction between the federal agency and tribal governments. It also demonstrates sensitivity to the site's cultural past. "We're brought in through true consultation," explained Nick Tipon, chairman of FIGR's Sacred Sites Protection Committee, "Our primary purpose is to ensure that the human remains of our ancestors are not disturbed."

The coring at Redwood Creek revealed a 3,700-year history of significant landscape changes, ranging from natural sea-level rise to anthropogenic sediment deposition. "This lagoon has been very different at different times," explained Meyer. "These sites are evolving. They have a life of their own." Scientists identified three sites containing evidence (e.g., marine shell fragments, charcoal, and heat-altered rock) of native people that lived and worked at this site. They also noted additional sensitive landforms where more cultural remains might be buried.

Geoarchaeological coring is one piece of a larger cultural resource survey program in the lower Redwood Creek restoration area. Other activities included a pedestrian survey in which staff searched for significant archaeological features on the surface of the site, rather than below. The survey program frames the Redwood Creek project in the context of a deep past, and reveals more than can possibly be known through documentary evidence such as historic maps and pictures.

Planners are using the ecological history learned from these soil cores to identify past landscapes of Redwood Creek and to further define the watershed's restoration potential. In our forgetful world where most of us can barely keep track of where we last saw our keys, NPS geoarchaeologists are digging into long-forgotten memories of earth's deep past.

Construction staff check grading elevation in 2009. Where to dig and to what level was decided with the help of previous coring data.

Putting Down Sustainable Roots

Seemingly hidden in an expanse of leaning cattails, seedlings peek out of rows of raised beds. A secret garden in the previous pastures of Muir Beach cradles the growth of resilient sedges and rushes that will soon be planted at the restoration site. Future sustainability is the focus as planners make sure that the plants installed in areas altered by the Redwood Creek restoration suit the needs of the ecosystem. During the project many plants will be removed, some due to construction activities and others because they are unwanted or invasive species. As they plan how to replant restored areas, NPS scientists are faced with the challenge of building a sustainable future from the site's past and present states. Soil cores and anthropological evidence such as personal accounts and photographs reveal how Redwood Creek vegetation has changed over the past few hundred years. This vision of the past gives planners an idea of what a healthy ecosystem might look like, although the goal of the restoration is not to recreate any one past point in time.

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Redwood Creek Nursery staff and volunteers grow plants for the project (left). Expansion of the lagoon began in Fall 2009 (center). Plants chosen by park ecologists (right) to revegetate the project site after construction have to be able to withstand harsh winter conditions like sediment movement and floods.

Vegetation managers collaborate with hydrologists and other biologists to identify what species and processes will be affected by the restoration. They then choose plants that will accomplish goals - like meeting the food and shelter needs of imperiled species, and maintaining the creek's natural flow. Planners explored a wide range of plants, from bird-friendly thimble berry to robust native slough sedge. Scientists decided to choose species not entirely representative of past plant assemblages. Instead, these plants were chosen because they are hardy species, native to the area, which can outcompete pushy invasives even in a harsh environment where complete burial by sediment is not uncommon. Ecologists preferentially chose plants with rhizomatous – horizontal and creeping, rather than vertical – root systems for their ability to spread and combat non-native invasion. These plants are chosen for the long-term future of the site. This approach to revegetation will limit the need for constant maintenance like weeding.

Vegetation ecologists divided the site into many parts and mapped the kind of vegetation, or the "plant palette," that will be planted in each area. Some species take up a greater fraction of the palette than others, depending on which plants should be dominant. These plant ratios may be skewed from the ones found in nature. "We don't try to replicate every species found at the reference sites," explained NPS vegetation ecologist Chris Friedel "but use a more narrow plant palette containing plants with certain functions that we want."

Planners are prepared for future environmental changes. "We expect all vegetation communities to gradually migrate up the watershed as sea level rises," explained Friedel noting that "In the shorter-term, it is more important that the plant communities are resilient in the face of…flooding, drought, and changing groundwater levels." The floodplain is subject to annual changes in groundwater elevation and flood frequency. Chosen plants will withstand this wide range of hydrologic conditions.

Near the creek, plants will help stabilize the stream channel and prevent erosion. Fish like endangered coho salmon will benefit from the slower water, shade, and woody debris. River-dwelling invertebrates and migratory songbirds will also enjoy new riparian habitat. In the wetland adjacent to the creek, plants and small areas of cover will provide a home for frogs and waterfowl. In several areas, habitat currently degraded by invasive grasses will be replaced by a more creature-friendly mix of natives.

Scientists produced lists of common and rare plants living in the site, and worked with local tribe members to compile lists of plants with traditional uses (see side bar). They mapped the locations of different plant species using aerial images and fieldwork. Based on this data, ecologists are currently developing a long-term plan that will allow them to track whether revegetation goals, like decreasing invasive species cover, are met.

Plants that fulfill these myriad requirements were propagated at the Redwood Creek Native Plant Nursery at Muir Woods. As much as possible, skilled nursery staff and volunteers carefully collected the seeds within the watershed, taking into account factors like genetic diversity. Nursery staff used local research and past experience to grow the plants. By performing experiments on each species, nursery staff figured out the best way to make their seeds germinate. When the site and plants are ready, staff and volunteers will plant each species in its planned location. By considering all aspects of the ecosystem, including non-native and human-induced factors, NPS is taking steps towards sustainably maintaining the site's natural and cultural resources for future generations.

Volunteers work with park staff to maintain on-site propagation beds of wetland species such as sedges and rushes which will be planted in the restored areas.

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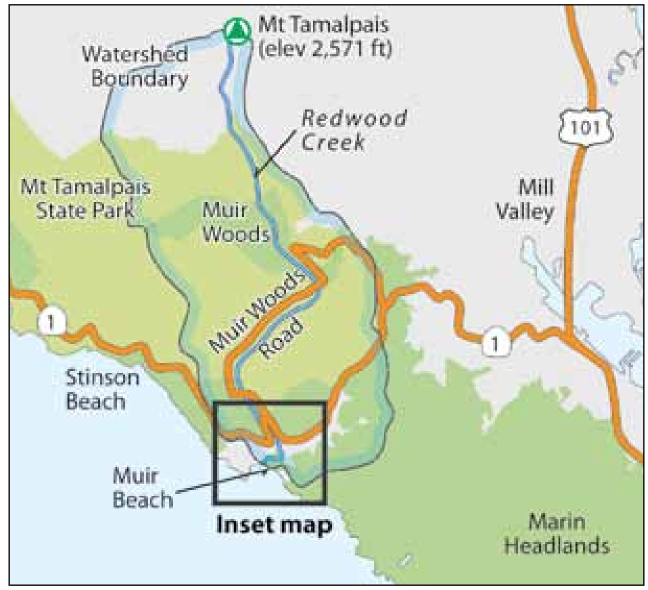
Redwood Creek Restoration at Muir Beach

Over the past decade NPS has been planning an extensive ecological restoration project in lower Redwood Creek. Redwood Creek is the heart of a watershed that begins at the top of Mt. Tamalpais, extends through the renowned redwood forests of Muir Woods National Monument, and drains into the Pacific Ocean at Muir Beach near the famously beautiful coastal Highway 1. Among other goals, the project will increase habitat for endangered coho salmon and threatened steelhead trout, maintain habitat for threatened California red-legged frogs, decrease flooding on nearby roads, and create a self-sustaining ecosystem that requires minimal future human maintenance. Read more at http://www.nps.gov/goga/naturescience/muir-beach.htm.



Map of the project site, off Highway 1 to the north of San Francisco.

My Science Communication Internship

By Elaine Albertson

It's lucky that I didn't know what to expect when I arrived in the Marin Headlands as a summer intern because, had I made them, my assumptions surely would have been wrong. Through an e-mail from my major department's list I learned of the opportunity to be a science communications intern for the Golden Gate National Recreation Area (GGNRA). At the time I had a slight idea of what the park was, no idea that I had actually been there before several times, and an excellent idea of how much more interesting a summer job in a national park would be than any of my alternatives. I decided to apply. And I was thrilled when they offered me the job.

In June I moved in late on a Sunday night. By Tuesday I was in the field slogging through knee-deep Point Reyes mud (not too bad, usually it's thigh-deep) counting fish. Though I was a science communications intern, the orderliness of my job title didn't hold me back from the chance to dig into the heart of NPS science. Much of GGNRA science happens in the field, and in preparation for communicating it I got to experience it first hand. I climbed over barnacles to peer into tide pools at six in the morning; I crawled through gnarled willows to monitor vegetation; I donned waders countless times to submerge the lower half of my body in chilly coastal waters. And in the other half of my time I got to write about it. I learned in leaps and bounds, talking to scientists, reading paper after paper. My view of the "real world," the realm of office jobs and cell phone signals, would be forever jarred by my knowledge of the park lands I studied and tended, patrolled and monitored, described and explored during my surprisingly perfect summer job.

Elaine Albertson is a junior at Stanford University.

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Internships

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