37th Annual

Salmonid Restoration Conference
April 23-26, 2019 in Santa Rosa, CA

Drought, Fire, and Floods—Can Salmon and the Restoration Field Adapt?

Conference Co-sponsors

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Welcome to the 37th Annual Salmonid Restoration Conference

Drought, Fire, and Floods—Can Salmon and the Restoration Field Adapt?

The 37th Annual Salmonid Restoration Conference in Santa Rosa will focus on salmonid recovery in an era of tectonic climate variability. Santa Rosa has experienced cataclysmic drought, catastrophic fire, and floods of Biblical proportions. Those in the watershed and fisheries restoration field are persevering with restoration and recovery efforts in an altered landscape. Many other watersheds that are recovering from historic drought and fires will look to Sonoma County watersheds for guidance, lessons learned, and pioneering attempts to have climate and fire resilience as a guiding principle for watershed restoration.

Dana Stolzman,
SRF Executive Director
and Conference Agenda Coordinator

California has weathered unprecedented climatic conditions and fire catastrophes that have fundamentally altered the way we think about restoration planning and water management. It is our hope that the Annual Salmonid Restoration Conference can shed some light on these pressing issues so we can continue the upstream work of restoring habitat and recovering wild salmon populations. The conference agenda provides a range of tours and workshops to address watershed restoration and recovery efforts.

This year, participants will have the opportunity to visit floodplain and fish passage projects in Lagunitas Creek, tour flow enhancement projects in Dutch Bill watershed, wade in a Stage 0 watershed in Willow Creek, and visit fire-scarred watersheds that are both being actively being restored and are in the process of naturally regenerating. Additionally, participants can learn about an array of PIT tag technology applications in the Russian River watershed or tour integrated floodplain management projects in the Napa River.

Conference workshops will include a Stage 0 design, applications and permitting workshop; assessing ecological risks from streamflow diversions, and the growing impacts of cannabis and instream flows workshop. Additionally, an urban creek workshop will feature innovative, "outside the channel" techniques with an afternoon trolley tour of on-the-ground restoration projects in Santa Rosa.

The conference agenda will explore myriad issues including foodscapes, floodplains, and freshwater-estuarine habitats; monitoring, modeling and strategies to address summertime flows; salmon-habitat relationships, Spring-run Chinook genetic and recovery issues as well as Klamath River basin planning. Concurrent sessions will also focus on planning and strategies for fire resilience.

The Plenary session will focus on the landscape of salmon recovery in a time of climatic extremes and will feature Congressman Jared Huffman, who will speak about legislative efforts to restore working watersheds. Author Langdon Cook of *Upstream* will share from his new book *Fish Tales: A Writer's Journey into the Salmon Connection*. Ellen Hanak of the Public Policy Institute of California will present on managing California's water in a time of drought and climate change. Additionally, scientist Gordon Reeves will present on how climate extremes are affecting salmonid recovery.

The crafting of the SRF Annual Conference is a yearlong interactive process. The production and coordination of the annual conference is a collaborative effort that engages SRF's Board of Directors, our co-sponsors, and our colleagues. We sincerely thank all of the field tour, workshop, and session coordinators who do an outstanding job of creating a dynamic agenda as well as all of the dedicated presenters who are sharing their knowledge and expertise.

SRF greatly appreciates all of our co-sponsors who generously contribute their ideas, time, and resources to the production of the conference. Thanks to all the conference participants who migrate tirelessly to participate in the premier salmon restoration conference in California and for joining us in our efforts to enhance the art and science of restoration and ultimately recover wild salmonid populations.

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Celebrating a Culture of Restoration

Honoring our Watershed Heroes

Every year, the Annual Salmonid Restoration Conference provides an opportunity to honor the contributions that individual practitioners have made to California's fisheries restoration field. Prior to the conference, Salmonid Restoration Federation (SRF) accepts nominations for the awards listed below. Award recipients are honored during the Conference Cabaret and Banquet that is held on the final night of the four-day conference.

Restorationist of the Year

SRF's Restorationist of the Year Award was conceived as a way to honor grassroots salmonid habitat restorationists. It was first presented in 1992 to Bill Eastwood, co-director of the Eel River Salmon Restoration Project, to acknowledge his work to help salmon and for his innovative design modification to the McBain downstream migrant trap.

The award was renamed the Nat Bingham Memorial Restorationist of the Year award following Nat's death in 1998. Nat was a fisherman and a tireless advocate for salmon. Since Nat's death, SRF has honored a restorationist each year at our annual conference with a roast and toast during the Cabaret and Banquet. The honored recipient gets to steward an exceptional brass sculpture, created by noted sculptor Dick Crane, that captures the spirit of salmon, of fish-loving people, and the state of California where these practitioners live and work a life dedicated to the recovery of the species. At the awards ceremony, the previous recipient parts with the sculpture and passes it onto the next honoree.

Lifetime Achievement Award

The Lifetime Achievement Award honors a lifetime of work and contribution to the salmonid restoration field in California.

The Golden Pipe Award

The Golden Pipe is an award for innovators in the salmon restoration field, whether their work be fish passage design, engineered log jams, or championing beavers as restoration partners.

Gordon Becker Memorial River Advocate Award

The restoration community mourns the loss of our cherished colleague and friend, Gordon Becker. He was an adventurer, a scientist, and an effective advocate for healthy rivers and fisheries. Gordon served as an expert witness in the campaign to remove or modify Stanford University's 125-year old Searsville Dam and Stanford's water diversions that harm threatened steelhead trout in San Francisquito Creek. His deep knowledge and enthusiasm for restoring the San Francisquito Creek watershed's native steelhead population helped to propel restoration efforts forward. Gordon shared his expertise freely, as well as his hopes and dreams for a better future for western rivers and watershed management.

The Gordon Becker Memorial River Advocate Award is for Candidates who have been strong river advocates or stewards.

Conference Events

Wednesday, April 24

SRF Annual Membership Meeting 5:30pm
SRF Membership and Supporter Dinner 6:30pm
Screening of ***The Breach*** 8pm

Thursday, April 25

Poster Session and Reception 7 - 10pm

Friday, April 26

Banquet, Awards Ceremony, and Dance!
Doors open at 6:30pm

Casey and the Norway Rats Friday evening at the banquet!

Thank you to our exclusive beer sponsor!

Restoring to Stage Zero, Recent Advances and Applications in Process-Based Habitat Restoration Workshop

Tuesday, April 23

Workshop Coordinators*: Brian Cluer, Ph.D.* and *Michael Pollock, Ph.D., NOAA Fisheries*

Restoring to Stage Zero, Recent Advances and Applications in Process-Based Habitat Restoration

Restoration of whole valley floors to a Stage 0 condition is an ecologically-based goal for alluvial valleys that generally aims to store more water and sediment through restoring the key physical processes that created the alluvial valley. "Undraining" an alluvial valley is approached by either raising the channel bed or re-grading the valley to eradicate the channel, depending on the scale of incision, resources available, ownership, tolerance for disturbance, permit requirements, patience, and other considerations. This course will cover the theory and practice of Stage 0 restoration throughout the life cycle of a project, including: the underlying scientific theory; assessing when whole valley floor restoration is an appropriate goal; introduction to a range of methods of design and construction from progressive channel adjustment to wholesale grading to reset valley surfaces, and emerging monitoring methods aimed at quantifying the ecosystem benefits and costs of different restoration approaches. Permitting approaches in the context of California's regulatory, land ownership and funding frameworks will be extensively discussed, and examples of successfully permitted and implemented valley floor restoration projects from diverse eco-regions will be provided. The workshop will be complimented by an optional field trip the next day to Willow Creek, a valley that was allowed to passively recover to Stage 0 after a careful assessment determined that that was the most cost-effective and ecologically beneficial approach.

Yellow Creek in Tasman Kojam Valley with Mt. Lassen in the background. Photo Credit: Brian Cluer

The Science Basis for Stage 0 Restoration

Brian Cluer, Ph.D., NOAA Fisheries

Alluvial valleys are the result of net deposition. Traditional channel restoration has aimed to balance erosion and deposition, thus it has not restored the fundamental process that created the landscape in the first place. The Stream Evolution Model (SEM) paper of Cluer and Thorne (2013) paper pointed out the relationships between the various alluvial channel configurations and the presence and abundance of habitat and ecosystem functions. The primordial condition represented by a network of vegetated islands occupying a large portion of alluvial valleys was termed Stage 0. Although prevalent over the last 500 million years of geologic history, Stage 0 valleys are relatively rare today. Land development and drainage schemes altered nearly every one of the former Stage 0 settings in the last century, on purpose—to drain rich lands for agricultural production. In the process, the last century of land drainage has created widespread dry valleys with high capacity drainage channels, while collapsing habitat to minimums and making it unreliable for native species. Undisturbed Stage 0 valleys are found today only at high altitudes or high latitudes, where farming is not feasible for climate reasons. We really do live in a unique time and condition not seen over the last 500 million years.

The SEM gave us a way to explain just how much function and habitat was lost during the era of land drainage and channelization. This put into perspective why building habitat or improving habitat only in channels that remain incised is not capable of recovering species or restoring the suite of ecosystem functions. Restoring floodplain stream interaction in alluvial valleys has obtained some traction as an ecologically superior and perhaps necessary approach to salmonid recovery, among several ecosystem reasons. In its way, the SEM gave permission to restoration practitioners to try something different and that is what this workshop is about.

Examples of various completed Stage 0 projects and two main approaches will be presented; valley-reset using grading, and incremental treatment of incision channels. The workshop will include a component on regulatory mechanisms available and impediments to this type of restoration.

Engineering Design Criteria for Process-Based Stream and River Restoration

Damion Ciotti, M.S., *U.S. Fish & Wildlife Service (Presenter),*
and ***Jared McKee, M.S.,*** *U.S. Fish & Wildlife Service*

Restoration of valley floors to a stage zero condition results in substantial increases in aquatic habitat quantity and quality. The restoration of stage-zero habitat is a priority for publicly funded restoration programs aimed at recovery of sensitive species. The aim of this segment of the workshop is to provide participants with design and planning tools developed and applied by the US Fish and Wildlife Service for restoring stage-zero habitat. Stage zero systems form as a result of the recovery of natural fluvial processes and therefore traditional channel and habitat reconstruction approaches are not adequate or feasible for its establishment. Practitioners with a grasp of process based restoration techniques can restore these biodiverse and complex systems over time. This requires that the practitioner address source system problems at a meaningful scale and identify human infrastructure and management constraints to system evolution towards stage zero.

In this segment participants will learn how to delineate a stream evolution corridor (SEC) as a planning tool for characterizing fluvial process space and identifying critical hydrologic, sediment, and landscape dis-connections within river and stream networks. The SEC analysis is also used to communicate with stakeholders and prioritize and evaluate restoration actions and identify those most critical for restoring processes that will rebuild stage zero ecosystems. Participants will also learn the application of design criteria for determining if proposed restoration actions are aimed at restoring natural system processes. Completed and underway Stage 0 restoration sites in California will be presented and serve as examples.

Necessary Geomorphic and Landscape Conditions for Stage 0 Restoration Projects

Conor Shea, Ph.D., P.E., U.S. Fish and Wildlife Service, Arcata, CA

The Cluer and Thorne (2014) Stream Evolution Model (SEM) found that Stage 0 stream systems (dynamically meta-stable network of anabranching channels with vegetated islands) provide the maximum habitats and ecosystems benefits. Consequently, there is great interest among stream restoration practitioners to implement Stage 0 stream systems as part of watershed and stream restoration projects because of the potential to optimize habitat benefits and outcomes (for example, see Powers et al. 2018).

A critical step in stream restoration project development is to assess and characterize the Geomorphic Context of a proposed project. The Geomorphic Context determines what actions are physically and biologically feasible within a proposed restoration project. Geomorphic Context includes geologic controls and hydraulic processes that create and maintain channel form, floodplains, and aquatic and riparian habitat. It also includes land-use practices and actions that impact hydrologic and sediment regimes or constrain channel dynamism. Stream restoration practitioners that propose implementing Stage 0 stream systems should examine a site's Geomorphic Context to determine if a site's geologic controls and processes will support and maintain the creation of a complex anabranching channel network. There is limited guidance available to assist stream restoration practitioners in making this assessment.

This presentation will present guidance on how to identify the necessary geomorphic and landscape conditions that will support a Stage 0 stream system design. The presentation will present the types of sedimentary, geomorphic settings, stream power, and other hydraulic conditions that support and maintain various forms of anabranching channel conditions. It will also discuss sediment movement and the potential for dynamism in anabranching systems. A screening matrix tool will be presented that will assist practitioners to identify feasible Stage 0 design concepts based on an analysis of site conditions.

The Range and Settings of Restored Depositional Valley Types to Stage 0 in the Pacific Northwest

***Paul Burns,** U.S. Forest Service, Siuslaw National Forest (Presenter); and Co-authors:*
***Cari Press** and **Paul Powers,** U.S. Forest Service, Deschutes National Forest; **Johan Hogervorst, Matt Helstab, Nick Grant, Lisa Kurian,** and **Kate Meyer,** U.S. Forest Service, Willamette National Forest; and Restoration Assistance Team, Hydrologists and Fisheries Biologists, U.S. Forest Service, Pacific Northwest Region*

Within the Pacific Northwest Region of the US Forest Service, restoration practitioners have been implementing a process-based, unconfined valley restoration approach referred to as "Stage 0." This methodology diverges from stream restoration approaches that focus on creating a stable channel dimension, pattern, and profile, for establishing a preferred channel geometry. In contrast, Stage 0 methodology is based on the pre-manipulation state (Stage 0) in the Cluer and Thorne Stream Evolution Model (Cluer and Thorne 2013). This methodology uses valley slope, referred to as the geomorphic grade line, as the target elevation of both the low flow shallow groundwater elevation and baseflow wetted area (Powers et al. 2018). The primary goal of Stage 0 design is to maximize floodplain connectivity at all discharge levels, including baseflow, not just at a channel forming discharge. The reset fluvial valley is then able to transition into a complex network of anastomosing flow paths, wetlands, and diverse aquatic habitats.

Studying some of the early meadow restoration projects on the arid, east-side of the Cascade Mountain Range led to the development of the Stage 0 restoration approach. At a traditionally designed meadow restoration project, observations of both failures and areas of high-stream complexity exposed a longitudinal surface that the stream adjusted to, which appeared to be the historic valley floor. Around the same time, projects to repair headcuts in small, second order streams utilizing the method of filling the degraded channel back up to the valley floor, showed rapid succession of wetland features. Restoration specialists deduced that a trend line fit longitudinally through this surface could represent the target elevation for restoration design and called it the Geomorphic Grade Line (GGL) (Powers et al. 2018). They expanded this approach to larger, bedload dominated stream systems on a variety of landscapes ranging from lacustrine valleys in the Oregon Coast Range to moderate gradient valleys in the West Cascades and East Cascades (1-3%). The same general approach was applied across all of these landscapes, which included identifying the historic valley bottom, removing constricting features (berms, roads, etc…), and resetting the valley bottom to eliminate the transport channel and maximize floodplain connectivity. These project types restore fluvial processes and in turn restore ecological benefits that have been largely lost in many alluvial valleys.

Preliminary monitoring of these projects show high shallow alluvial aquifers and a drastic increase in wetted area, side channels, patch heterogeneity, and riparian vegetation. Spring Chinook and Bull Trout were detected immediately after implementation in the west side projects, as well as high juvenile fish densities and macroinvertebrates in some of the east side projects within 1 to 3 years. Monitoring to date indicates that these projects are on the right trajectory and are trending toward Stage 0. Restoring the reach-scale processes that formed the depositional valley in which these projects are located will create habitat for at-risk salmonid populations and other riparian-dependent species and improve ecosystem resiliency.

Geomorphic Grade Line Methodology, a Process-based Approach to Restoring Depositional River Valleys to Stage 0 (Staley Creek Case Study)

Matt Helstab, *U.S. Forest Service, Pacific Northwest Region, and* ***Paul Burns,*** *Siuslaw National Forest, U.S. Forest Service, Willamette National Forest (Co-Presenters); Co-authors:* ***Cari Press*** *and* ***Paul Powers,*** *U.S. Forest Service, Deschutes National Forest; and* ***Johan Hogervorst,*** *Hydrologist, U.S. Forest Service, Willamette National Forest*

The USFS's adoption of Stage 0 (Cluer and Thorne 2013), or process-based restoration approach, began as our attention shifted from the condition in the channel, to the conditions across the entire depositional valley floor. Rather than designing channels that were connected to the floodplain at a bankfull discharge event, we instead, started to fill incised channels to immediately disperse energy laterally across the floodplain. Key to the Stage 0 approach is the concept of stream power per unit width and how this parameter becomes exaggerated in incised channels, often creating a firehose-like effect. Stage 0 restoration projects result in an anastomosing network with an increase in habitat complexity and diversity across the valley floor. The newly formed template allows reestablishment of key processes that restore ecosystem stability and build and sustain properly functioning fluvial systems such as flood attenuation, ground water storage, sediment retention, sorting of substrates, channel movement, and complex cover for stream biota at all discharge stages.

This part of the workshop will give an introduction to the Geomorphic Grade Line (GGL), a relatively simple valley slope design method that was developed as a way to predictably design and implement Stage 0 valley bottom restoration. We will walk through how to design and implement Stage 0 projects using the GGL methodology (Powers et al. 2018).

Complementary Use of Wood Jams, Contour Grading, and Beaver Dam Analogues—Case Examples and Overview of the BDA Design Tool

Rocco Fiori, *Fiori GeoSciences (Presenter) and Co-authors:* ***Doug Shields,*** *Senior Scientific Advisor, cbec eco-engineering;* ***Michael Pollock, Ph.D.,*** *Ecosystems Analyst, NOAA Fisheries;* ***Sarah Beesley,*** *Fisheries Biologist, Yurok Tribe, and* ***Jim Faulkner, Ph.D.,*** *Fisheries, Biologist, Yurok Tribe*

Extending the duration and extent of surface water on the landscape is a primary objective of many aquatic habitat restoration projects. In part 1 of this presentation we will show examples of how this objective is being accomplished in ephemeral tributaries of the Lower Klamath River, where subsurface flow conditions typically occur during the rainless summer months. These projects rely on the complimentary use of channel and floodplain roughness elements (wood jams and willow baffles), contour grading and more recently Beaver Dam Analogues (BDAs). BDAs are channel spanning structures built by humans that mimic or reinforce natural beaver dams, and in many cases are intended to be eventually utilized and enhanced by beaver. BDAs are constructed by driving posts in a row perpendicular to the channel, weaving a mat of willow stems to create a weir supported by the posts and placing a berm of sediment, stone and plant material on the upstream face of the weir. In part 2 of this presentation we will provide an overview of the BDA design tool with discussions on site selection, fish passage, and other design considerations. The BDA design tool is a macro-enable Excel spreadsheet that may be used to perform simple analyses leading to computation of three safety factors. Material quantities and simple cost estimates are also included as output. Key computational modules include hydrologic flow frequency analyses to support selection of design discharge and uniform flow computations to assess preconstruction hydraulics. The design tool also includes spreadsheets to assist the user in inputting geometry of the channel crosssection and the basic BDA geometry. Post-construction hydraulics are based on critical flow over the BDA crest at design discharge. Using these inputs and analyses and estimates of bed material size input by the user, the design tool computes estimates of scour depth downstream from the BDA and then uses Brom's approach for noncohesive sediments to compute the required minimum embedment for the posts. The design tool provides support for users in the form of default input values, tables of wood properties, soil properties and beaver dam dimensions, and a users' manual. The authors aspire to create an improved version of the tool upon receipt of suggestions from users.

Monitoring Stage 0 Restoration —Test Case at Whychus Canyon Preserve, Central Oregon

Mathias Perle, *Upper Deschutes Watershed Council (Presenter), and Co-authors:*
Lauren Mork, *Upper Deschutes Watershed Council and* ***Colin Thorne, Ph.D.,*** *University of Nottingham*

Whychus Creek is the focus of multi-year collaborative restoration efforts intended to support fisheries restoration, improve stream habitat and restore natural stream processes. In 2016 project partners broke ground on the first mile of a six mile restoration project along Whychus Creek at Whychus Canyon Preserve owned by the Deschutes Land Trust.

Project proponents have been committed and focused on restoring key physical, chemical and biological processes employing established principles in process-based stream restoration as well as key principles of ecological restoration in order to establish and support a resilient productive stream ecosystem for the long-terms benefit of fish, wildlife, and water quality. This includes a focus on natural channel floodplain connectivity and processes such as floodplain wide riparian cover, erosion, deposition, and avulsion to create, maintain and support resilient terrestrial and aquatic habitat that can support all life stages of fish and wildlife species over time.

Project monitoring goals include understanding how this restoration implementation technique is performing to inform future phases of Stage 0 restoration. The complexity and typically valley-wide spatial extent of habitats resulting from Stage 0 restoration presents challenges for monitoring geomorphic, fish habitat, and biological outcomes of this restoration approach. Do existing fish habitat metrics (e.g. deep pools per mile, LWD per mile, % fines in riffles), developed for single-thread streams adequately describe the diversity of geomorphic conditions anadromous and native resident fish may use at various life-history stages (e.g. spawning and rearing) in Stage 0 stream systems?

As more large-scale Stage 0 projects are implemented throughout the Pacific Northwest, an imminent need has emerged for a monitoring protocol that can 1) quantify geomorphic conditions across large spatial extents, 2) characterize the biological response to these conditions, and 3) document fish use of and response to specific geomorphic (e.g. geomorphic units, substrate size) hydrologic (e.g. velocities), and biological (e.g. primary productivity, suspended organic material) attributes of Stage 0 systems.

Monitoring results collected and analyzed to date at Whychus Canyon Preserve will be presented. They include abiotic (geomorphology, hydrology, habitat) & biotic metrics (fish, vegetation, wildlife, foodweb) along with stakeholder views.

Restoring to Stage 0—How Do We Get Stage 0 Projects Permitted and Implemented in California?

Carrie Lukacic, *Prunuske Chatham Inc.;* ***Betsy Stapleton,*** *Scott River Watershed Council, and* ***Sarah Beesley,*** *Yurok Tribal Fisheries Program*

Development of the Stage 0 restoration approach is new in California, although the approach is more widely used in the Pacific Northwest. How do hydrologists, geomorphologists, planners, biologists and restoration designers begin to utilize this valuable restoration technique in California where the California Department of Fish and Wildlife, Regional Water Quality Control Boards, Army Corps of Engineers, NOAA Fisheries, and the US Fish and Wildlife Service have yet to develop policy and regulations allowing their implementation? How can we work within the existing regulatory environment to allow for the restoration of natural processes in degraded streams, rivers, or meadow systems and to move these systems towards their pre-disturbance, multi-channel conditions? What regulations might need to change to allow Stage 0 projects to proceed?

During this component of the workshop, brief presentations will explore regulatory policies that support restoration, and how these policies facilitate permitting for and implementation of Stage 0 and Stage 0-like projects such as BDAs. We will review successfully permitted projects, the permitting strategies used, and how to apply the strategies and techniques broadly across the State. Attendees will learn about the regulatory compliance methods used in the Pacific Northwest to identify what techniques can be used locally, and what changes may be necessary for our use in California.

This will be a highly interactive session with participation from permitting specialists, agency staff members and the audience at large. Through structured interactions, a list of specific barriers to Stage 0 project permitting will be developed, along with concrete strategies for addressing them. Students will learn effective strategies to advocate for permitting of innovative restoration projects, and develop networks with others engaged in similar work.

Why Whole Valley Floor Restoration is the Future of "Stream" Restoration

Michael M. Pollock, Ph.D., NOAA Fisheries

I synthesize the evolution of our understanding of how fluvial ecosystems function, emphasizing the growing recognition of the larger spatial and temporal scales at which restoration projects need to be considered in order to be effective. I argue that valley "floors" rather than stream "channels" are the most appropriate economical and ecologically biophysical unit of measure in the context of fluvial ecosystem restoration. Examples of the feedback loops and interactive roles that biological and physical processes play in the development and restoration of stream ecosystems is provided, and tools and design considerations for emphasizing biogenic processes in habitat recovery at appropriate scales is discussed. The magnitude of the restoration needed in order to be effective at achieving societal goals such as the recovery of ESA-listed species and retaining perennial streamflow is at a scale that was hardly imaginable even a few years ago, but the accelerating rate of climate change requires restoration responses commensurate with the scale of the problems we are facing.

Assessing Ecological Risks from Streamflow Diversions by Applying Riffle Crest Thalweg Rating Curves Workshop

Tuesday, April 23

Workshop Coordinators*: William Trush, Ph.D.,* *Co-Director HSU River Institute and* ***Emily Cooper,*** *Stream Scientist, HSU River Institute*

By restricting streamflow diversions to a relatively small percentage change in ambient riffle crest thalweg (RCT) depth, the natural magnitude, duration, frequency, and timing of unregulated streamflows (Q) remain protected. Workshop participants will be shown how to quantitatively link basic concepts in stream hydraulics to stream ecosystem processes, then apply these concepts to practically assess ecological risks from cumulative streamflow diversion during a hydrograph recession. The morning session will review field techniques for measuring riffle crests, show how basic stream channel hydraulics can be estimated from RCT-Q rating curves, then calibrate an RCT-Q rating curve from the realtime USGS gaging website. Real spatial and real temporal variability will then be folded-into this hydraulic RCT framework to demonstrate how stream ecosystem complexity can be quantified at a top-down scale. The afternoon session will synthesize the morning's RCT-Q rating curve analytical/ecological attributes, followed by a step-by-step risk analysis of spawning success of the WY2018 Pacific lamprey run in the South Fork Eel River (bring laptops, or at least a calculator). As time permits, additional instream and riparian ecological processes will be risk-assessed. The final hour will be reserved for discussing top-down versus bottom-up strategies for instream flow diversion policies in California.

Integrating Flood Management, Steelhead, Beaver, and Wildlife Habitat Restoration in the Napa River Watershed Field Tour

Tuesday, April 23

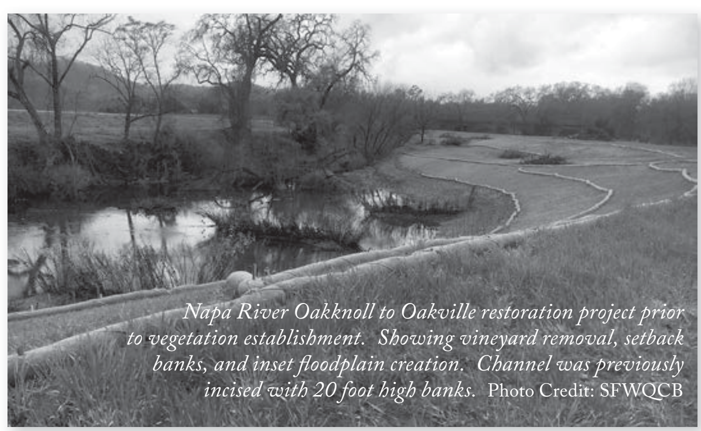
Field Tour Coordinators: *Ann Riley and Leslie Ferguson, San Francisco Regional Water Quality Control Board*

Tour Leaders: *Jorgen Blomberg, ESA; Kate Lundquist and Brock Dolman, Occidental Arts and Ecology Center; Kevin Swift, Swift Water Design; and Marjorie Caisley, California Department of Fish and Wildlife*

This field tour will tour two types of restoration projects: 1) an environmentally sensitive flood management and habitat restoration project located in an urban setting (downtown Napa); and 2) further upstream in agricultural areas, large-scale stream and riparian habitat restoration projects being implemented along the Napa River. The flood control and habitat restoration project along Napa Creek in downtown Napa demonstrates the feasibility of implementing an environmentally sensitive flood management project in a highly urbanized area including the feasibility of using LWD and willow mattress to stabilize banks, removal of infrastructure (parking lots/ bridges and rerouting roads), and creek daylighting to create channel and inset floodplain habitat for steelhead and other wildlife. We also note that following project construction, beavers have colonized the project site, increasing ecologic diversity and providing an opportunity to develop and implement co-existence strategies in Napa creek and nearby downtown Tulocay Creek. The Napa Creek project was approved by the Army Corps of Engineers to provide protection for a 100-year flood, and this project demonstrates that biotechnical and wildlife sensitive flood control projects can be safely constructed in highly urbanized area.

The second part of the tour showcases 15 miles of habitat restoration occurring further upstream in the Napa Valley in two agricultural reaches along the Napa River: Rutherford and Oakville to Oak Knoll. The goals of these projects are to enhance channel habitat complexity and floodplain connectivity as needed to improve the quality of aquatic and riparian habitat, and reduce sediment delivery associated with channel incision and accelerated rates of bank erosion rates, which also satisfies the requirements of the Napa River sediment TMDL.

Vineyard properties along the River have voluntarily removed vines and relocated flood berms and roads to provide additional room for a more functional river corridor. Restoration techniques include the establishment of inset floodplain and secondary channel features, bank stabilization using biotechnical methods, enhancement of the riparian corridor, instream habitat structures, wetland creation and native plant revegetation. This tour will feature two stops: 1) Rutherford location will demonstrate site evolution where the work occurred over five years ago and vegetation has re-established and geomorphic features have evolved. The second stop will feature a large, newly constructed site featuring approximately six acres of riparian restoration and 7.7 acres of created wetlands, biotechnical-streambank stabilization, instream/floodplain habitat restoration including live wood structures, boulder clusters and grade control riffles. Beaver have been active in both restoration sites. These projects demonstrate that while the River ecosystem will not be restored to its natural state, with the cooperation of local landowners, significant improvements in river geomorphology, riparian, wildlife and aquatic ecology (steelhead, chinook, lamprey, assemblage of native fish, and beaver) can occur.



Napa River Oakknoll to Oakville restoration project prior to vegetation establishment. Showing vineyard removal, setback banks, and inset floodplain creation. Channel was previously incised with 20 foot high banks. Photo Credit: SFWQCB

Living in a Fire Adapted Landscape: Burn Zone Recovery, Natural Regeneration, and Active Restoration in Sonoma County Watersheds

Tuesday, April 23

Field Tour Coordinators*: Karen Gaffney* *and* *Sheri Emerson,* *Conservation Planning Manager, Sonoma County Ag + Open Space*

This full day tour will visit the watersheds and stream systems affected by the 2017 fires in Sonoma County, with an emphasis on targeting recovery actions, long term forest health and resiliency, and the protection and enhancement of stream systems in wildlands, agricultural areas and within the wildland-urban interface. Tour sites will highlight collaborations in Sonoma County to collect and apply science and data to achieve multiple benefits, including sensitive fuel load management, public safety, and resiliency to climate, drought and flood impacts. The tour will visit burned salmonid bearing watersheds including Mark West, Calabazas, and Dry Creek.

Calabazas Creek Open Space Preserve Photo Credit: Sonoma County Ag + Open Space

PIT Antenna Technology: An Array of Applications in the Russian River Watershed Tour

Tuesday, April 23

Field Tour Coordinators: ***Will Boucher,*** *California Sea Grant and* ***Greg Horton,*** *Sonoma Water*

Passive integrated transponder (PIT) antennas have become important tools for informing salmonid habitat and demographic questions. We will provide an overview of advancements in PIT technology that have expanded our capabilities for answering questions that up until now could not readily be addressed with traditional monitoring methods. We will show examples of how we are using PIT antennas for life cycle monitoring, movement, survival, habitat validation, habitat connectivity, and growth in a variety of habitats: Russian River estuary and mainstem, Dry Creek, Green Valley Creek and Porter Creek. Matching PIT antenna and reader configurations to monitoring objectives are important considerations in developing a sound monitoring plan. By strategically siting antenna locations to complement other more traditional sampling approaches, we have developed a robust monitoring program that is less vulnerable to data inconsistencies arising from environmental extremes. At the same time, we can drill-down on critical habitat issues that are impeding population recovery.

Dual PIT antenna array on Porter Creek Photo Credit: California Sea Grant

Growing Impacts: Cannabis and Instream Flows Workshop

Wednesday, April 24 Workshop

Workshop Coordinators*: Elijah Portugal, M.S.,* *Cannabis and Instream Flow Unit, Fisheries Branch, California Department of Fish and Wildlife, and* ***Eli Asarian,* *Riverbend Sciences*

Similar to other forms of agriculture, the commercial production of cannabis has the potential to cause environmental impacts, including physical, chemical, and biological. The cannabis industry has focused production primarily in small headwater tributaries in northern California and Oregon due to the history of illegality, the remote and rugged landscape, culture, and climatic conditions. These areas with a high density of cannabis cultivation are also refugia for threatened and endangered aquatic and terrestrial species. In many cases, decades of aquatic habitat restoration intended to benefit salmonids has occurred in many of these same watersheds. More recently, many entities have made considerable efforts to understand and reduce the negative impacts resulting from the dramatic increase in the scale of the cannabis industry over the past decade. This workshop will explore the impacts of large-scale cannabis agriculture on rivers and streams, with a focus on hydrology, through presentations and discussions with diverse representation from state agency staff, academic researchers, private consultants and NGOs. Specific presentation topics will include: 1) quantifying the recent expansion of cannabis production, 2) hydrological and ecological effects of cannabis production, 3) perspectives on California's system for regulating the environmental impacts of cannabis production, and 4) opportunities and challenges for improving farming practices.

The Green Rush is Real: Quantifying the Rapid Expansion of Cannabis Cultivation in Northern California, 2012-2016

Jennifer Carah *(Presenter), The Nature Conservancy, and Co-authors:* ***Van Butsic, Ph.D.,*** *University of California at Berkeley;* ***Matthias Baumann, Ph.D.,*** *Humboldt Universität zu Berlin;* ***Connor Stephens,*** *University of California at Berkeley; and* ***Jacob Brenner, Ph.D.,*** *Ithaca College*

Agricultural frontiers (think cattle ranching in the Amazon or soybean production in southern African savanna) can form where there is an abundance of occupiable land that becomes cultivated when the income from agriculture greatly overcomes the costs of farming and distribution. Rapid expansion at agricultural frontiers is often associated with minimal regulation and environmental degradation. Using remotely sensed imagery and GIS, we examined how cannabis frontiers have grown in Mendocino and Humboldt counties between 2012 and 2016, while production for medical markets was legal at the state level, but still illegal for recreational purposes or export out of state. We mapped cannabis cultivation sites in a representative sample of watersheds, totaling over 50% of the land area in both counties. Because direct field measurements of environmental disturbance were not possible to obtain at this scale, we instead used remotely sensed proxies of environmental sensitivity. We analyzed four environmental sensitivity proxy variables in relationship to each cultivation site: distance to potential high- quality habitat for coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead trout (*Oncorhynchus mykiss*); distance to paved roads (as a proxy for remoteness); distance to protected public lands; and slope (as a proxy for erosion potential).

From 2012 to 2016 cannabis farms increased in number by 58%, the number of cannabis plants cultivated increased by 183%, and the total area under cultivation increased by 91%. Growth in number of sites (80%), as well as in site size (56% per site) contributed to the observed expansion. When checked against Natural Land Cover data, we found that 88% of areas developed for cannabis cultivation were formerly covered in natural vegetation as late as 2006. Additionally, we did find substantial expansion in areas of overlap with our environmental sensitivity proxy variables. For example, we saw 80-116% increases in cultivation sites near (within 500m) high-quality habitat for threatened and endangered salmonids. Production increased by 40% on steep slopes, sites more than doubled near public lands, and increased by 44% in remote locations far from paved roads. Cannabis farm abandonment during this period was modest, and driven primarily by farm size, not location within sensitive environments. To address policy and institutions for environmental protection, we examined state budget allocations for cannabis regulatory programs. These increased six-fold between 2012 and 2016 but remained very low relative to other regulatory programs.

Trinity Pines in 2016
Photo Credit: CDFW

Cannabis Landscapes in Southern Oregon: Lessons for Legalization

Phoebe Parker-Shames, Ph.D. Candidate*; UC Berkeley Environmental Science, Policy & Management (Presenter), and Co-authors:* ***Van Butsic, Ph.D.,*** *UC Berkeley Environmental Science, Policy & Management;* ***Justin Brashares, Ph.D.,*** *UC Berkeley Environmental Science; Policy & Management; and* ***Mary Power, Ph.D.,*** *UC Berkeley Integrative Biology*

Many states in the Western US are now engaged in a large-scale experiment with the decriminalization of recreational cannabis, but the effects of this policy change on the environment are as yet unknown. To examine the potential landscape impact of cannabis production on fish habitat, we mapped cannabis land use in Humboldt and Mendocino counties in Northern California, and Josephine County in Southern Oregon in 2012/2013 and 2016. After mapping more than one million cannabis plants, we found that outdoor cannabis production is spatially small and clustered, but rapidly increasing, especially in Oregon post-legalization. This creates localized point source disturbances on the landscape. In Oregon, production is concentrated along river corridors, with potential for runoff, while in Northern California, production is on steep slopes with fragile geology that are susceptible to erosion. We analyzed the proximity of cannabis production in both regions to threatened fish habitat, and in relation to fish and water quality surveys in Southern Oregon. The industry, while still small-scale at a regional level, is rapidly increasing post-legalization, especially in Oregon. Its location in remote areas near fish habitat may pose an ecological threat over time with continued growth, if specific mechanisms of impact can be identified and tested (e.g. associated road construction and pesticide use). Careful land stewardship may be required going forward to protect aquatic ecosystems from degradation due to summer water extraction, sediment loading from erosion, and leakage of fertilizers or pesticides to ground and surface waters. As a rapidly expanding industry under new regulatory oversight, cannabis in the northwestern US provides a window into how interactions between policy, land use change, and ecological communities will change across regulatory contexts, landscapes, and scales.

Application of Ecologically-Based Flow Metrics for Northern California Impaired Streams

***Noelle Patterson**, University of California, Davis (Presenter)*
*and **Belize Lane, Ph.D.**, Utah State University*

The Functional Flows Calculator (FFC) [http://eflows.ucdavis.edu] is a new open-source tool based on the functional flows approach for characterizing functional flow components from daily streamflow data. Functional flow components refer to sub-annual aspects of the hydrograph linked to critical ecological functions. Four functional flow components were previously identified for California based on the peer-reviewed literature and expert opinion: dry season low flows, wet season initiation flow event, peak magnitude flows, and spring recession flows. For example, the wet season initiation flow event has been shown to cue salmon migration and the spring recession facilitates riparian recruitment. The FFC calculates 31 functional flow metrics describing key magnitude, timing, frequency, duration, and rate of change characteristics of these functional flow components, such as 'start date of spring recession' and 'duration of dry season.'

The FFC improves upon previous flow metric calculators like IHA or EflowStats in its basis on regional ecological theory, and its reliance on time series analysis techniques for functional flow component identification. The FFC metrics were selected based on broadly relevant relationships between streamflow and river ecology in California, so they can be used to test flow-ecology hypotheses in settings across the state. The signal-processing algorithm used in the FFC is robust to high seasonal and inter-annual variability, so functional flow components can be identified across a wide variety of natural stream classes and water year types. The functional flow metrics were calculated for all 223 USGS reference-condition stream gages in California, with an average period of record of 42 years, and can be calculated for any daily streamflow time series of interest.

We present an application of the FFC and associated calculation and visualization tools to northern California streams affected by cannabis cultivation. The unimpaired ranges of relevant functional flow metrics in northern California streams, such as the magnitude and frequency of peak magnitude flows, reflect inter-annual variability as well as spatial variability across individual streams in the region. These estimated unimpaired metric ranges are then applied to specific streams affected by cannabis cultivation to compare impaired flow conditions to the expected conditions in the absence of diversions. This case study highlights the utility of ecologically-based flow characterization for flow management and restoration.

University of California On-line Grower Survey Characterizes Cannabis Water Use and Cultivation Practices in California

Ted Grantham, Ph.D., *UC Berkeley (Presenter), and Co-authors:* ***Houston Wilson,*** *UC Riverside;* ***Hekia Bodwitch,*** *UC Berkeley;* ***Kent Daane,*** *UC Berkeley;* ***Jennifer Carah,*** *The Nature Conservancy;* ***Christy Getz,*** *UC Berkeley; and* ***Van Butsic,*** *UC Berkeley*

Despite the enormous value, potential environmental impacts, and increasing importance of cannabis in California's agricultural economy, remarkably little is known about how the crop is cultivated. As an initial first step to improve understanding of the social, environmental, and agricultural aspects of cannabis production, researchers at the University of California conducted an on-line survey of cannabis cultivators in the state. The purpose of the survey was to gather information on production practices and basic features of cannabis systems, including cultivation techniques, pest and disease management, water use, labor practices, and grower perceptions of regulations. We received responses from 101 individuals who operate cannabis cultivation sites. Most respondents managed farms in Humboldt and Mendocino County, but responses also included counties in the Sierra Nevada, Central Valley, and Southern California. The majority of cannabis farms included both greenhouse and outdoor cultivation. Most growers reported that groundwater was their primary water source for cannabis irrigation and that groundwater extraction was concentrated in the growing season (June—October). The survey indicated that the use of storage was common, but that for many the expansion of water storage capacity on their farm was cost-prohibitive. Most growers reported using variable amounts of water across the growing season. Outdoor growers applied, on average, about 3 gallons per day/plant (gdp/p) in June, 5 gallons gpd/p in August and September, and 4 gpd/p in October. When standardized by area, outdoor application rates in August and September were similar for greenhouse plants (0.2 gallons/square foot/day). Growers reported the use of chemicals for pest control, but the majority of products were biologically derived and/or approved for use in organic production. Although survey findings cannot be generalized given their unknown representation of California's grower population, they provide valuable baseline information that can guide future research and extension programs, and inform development of effective cannabis cultivation policies.

Water Storage and Cultivation Practices Affect Seasonal Patterns of Water Demand of Cannabis Production in Northern California

Christopher Dillis, *North Coast Regional Water Quality Control Board (Presenter) and Co-authors:* ***Connor McIntee, Bryan McFadin, Lance Le,*** *and* ***Kason Grady,*** *North Coast Regional Water Quality Control Board;* ***Ted Grantham, Ph.D.*** *and* ***Van Butsic,*** *UC Berkeley*

The cultivation of cannabis in Northern California has raised concern for its potential impact on instream flow, however, systematic data on cultivation practices have been difficult to obtain. To date, this lack of data has prevented the ability to account for where farms typically source their water, monthly variation in water demand, or the role of water storage in altering seasonal extraction patterns. This study analyzed water use reporting data from cannabis cultivators in the North Coast who were enrolled for coverage under the North Coast Regional Water Quality Control Board Cannabis Waste Discharge Regulatory Program during the 2017 cultivation year. These self-reported data contained water sources, water storage capacity, and the timing and amount of water both input to storage and applied to plants. We used these data to analyze the distribution of water sources, seasonal extraction patterns, and the role of water storage and sources in affecting these patterns.

We found that while the amount of water applied to plants increased steadily through the growing season (peaking in August), the amount of water reported as actually extracted from the natural system was substantially less than applied water during the summer months. Although water input to storage in the off-season months (November through March) reduced water extraction in the growing season (April through October), farms generally did not have enough storage to completely forbear from surface water extraction during this period. The two most important predictors of storage sufficiency (type of storage infrastructure and type of water source) also had reliable effects on seasonal extraction patterns, further emphasizing the link between water storage and extraction profiles. The differences in extraction patterns are particularly relevant, given that a substantially larger proportion of farms reported well use than previously anticipated. Given these new findings, it will be useful to consider how cultivation practices drive extraction patterns and how these practices may be influenced by participation in the regulated cannabis industry.

Water Quality Impacts of Illegal Marijuana Cultivation on Public Lands, with an Emphasis on Anadromous Fish

***Nathan Cullen** and **Katie Gilman**, Central Valley Regional Water Quality Control Board (Presenters), and Co-authors: **Griffin Perea, Michael Parker, Tricia Bratcher,** and **James Harrington,** California Department of Fish and Wildlife*

Activities associated with illegal cultivation of cannabis on federal and state lands has shown to have deleterious effects to water quality and aquatic ecosystems. Increased erosion from native soil disturbances and loss of vegetation cover, stream diversions, and improper use of chemicals have been documented to have impacts to water quality and cause degradation of physical habitat within streams, although measurable direct effects to water quality are not well understood for anadromous watersheds. To better understand the in-stream impacts from illegal cannabis cultivation sites, The California Department of Fish and Wildlife and the Central Valley Water Board developed a multi-year study within the Deer Creek watershed aimed at identifying and quantifying water quality and ecosystem impacts. Deer Creek, located in Tehama County, was selected due to the high density of illegal cannabis cultivation sites occurring on Federal lands, and due to the presence of spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*), both federally listed. The SWAMP bioassessment protocol was utilized at sites throughout the Deer Creek watershed, in locations both up and downstream from known cultivation sites as well as selected control sites. Sampling was performed in spring and fall over two consecutive years, with analysis on-going. The study seeks to establish if the SWAMP protocol is an adequate means of determining the effects of cannabis cultivation on anadromous fish habitat, or if a modification to the protocol is necessary. The discussion of our results will focus on physical habitat, water quality, and sediment, and will compare the relation of sampling locations and years, and impacts of cultivation sites to water quality and physical aquatic habitat.

Estimation of Cannabis-Related Water Use and Comparison to Measured Instream Flows in Select Trinity County Streams

Bryan McFadin, P.E., *North Coast Regional Water Quality Control Board (Presenter) and Co-authors:* ***Connor McIntee,*** *North Coast Regional Water Quality Board; and* ***Nick Cusick, Callie Grant, Katy Abbott,*** *and* ***Cameron Heyvaert,*** *Americorps Watershed Stewards Project Alumni*

The rapid proliferation of cannabis farming operations in the North Coast of California has led to concerns regarding the impacts of water use associated with cannabis farming. We evaluated the impacts of cannabis growing operations on instream flows in select Trinity River watersheds near the Hayfork, Douglas City and Weaverville communities. We mapped and digitized cannabis operations in the select watersheds and applied water use estimates reported by local cannabis growers in submittals associated with the NCRWQCB's Cannabis Regulatory Program. We also estimated water use associated with surface diversions reported to the State Water Resource Control Board's Division of Water Rights. Both water use estimates were compared to streamflows measured at 33 sites during the low flow season (April—October) throughout the study area. The results suggest that in water scarce areas and areas with high densities of water users, streamflows can be adversely affected by water use, regardless of the nature of the water use.

Impacts of Marijuana Cultivation on Aquatic Resources, with an Emphasis on Anadromous Fish

Patricia Bratcher, *California Department of Fish and Wildlife (Presenter) and Co-authors:*
James Harrington, *California Department of Fish and Wildlife, Aquatic Bioassessment Lab*
and ***Griffin Perea,*** *Regional Water Quality Control Board Region 5*

This study is intended to increase understanding of the effects that cultivation has on the nearby aquatic environment, with an emphasis on anadromous fish and more specifically, spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*), both listed species. The study site is located in Deer Creek watershed, Tehama County. Goals include (1) seeing if there is an effect on anadromous fish from marijuana cultivation practices; (2) developing sampling protocols for use in assessing impacts in the future; and (3) determining the extent of impact from marijuana cultivation versus other land uses or natural perturbations. Study design and preliminary results will be shared.

Cannabis Cultivation Policy and the Continuing Development

***Peter Barnes** (Presenter), and Co-authors: **Daniel Schultz**,*
*and **Sam Cole**, State Water Resources Control Board*

The State Water Resources Control Board (State Water Board) adopted the Cannabis Cultivation Policy (Cannabis Policy) on October 17, 2017 to establish principles and guidelines for cannabis cultivation within a water quality control policy. The Cannabis Policy includes instream flow and gaging requirements that cannabis cultivators must follow to divert surface water. To meet the timeline, scale, and purpose of the Cannabis Policy, the State Water Board, in consultation with California Department of Fish and Wildlife (CDFW) determined that the Tessamann Method was the best methodology to develop the interim instream flow requirements. The Tessmann Method develops instream flow requirements by using percentages of historical mean annual and mean monthly natural streamflow. In general, during the wet season the Tessmann Method compares 40 percent of the mean monthly flow to 40 percent of the mean annual flow and whichever is greater is the flow requirement for that given month. The interim instream flow requirements were calculated at compliance gage locations throughout the state.

For the development of long-term instream flow requirements, the State Water Board, in consultation with CDFW, will evaluate other scientifically robust methods that are more reflective of regional variability and the needs of target species. The State Water Board is actively examining which watersheds are the highest priority within the Cannabis Policy regions and which flow requirements and/or gages need to be updated. As part of this effort the State Water Board is working with UC Davis, UC Berkeley, Southern California Coastal Watershed Research Project, The Nature Conservancy, Trout Unlimited, and US Geological Survey to develop the California Environmental Flows Framework (CEFF) to establish a structured process for developing minimum instream flows. The State Water Board is also working with UC Davis to develop a regional instream flow methodology to develop long-term flow requirements for the diversions of water for cannabis cultivation. As part of this effort, State Water Board staff are currently working on collecting and georeferencing existing watershed or stream specific flow studies and other information that can be used to help inform the development of flow requirements. State Water Board staff plan to compile and geo-reference the existing studies and information collected and make it publicly available. As the scope of this effort is immense, covering the entire state, assistance and participation from entities that conduct stream and biological studies will be an invaluable part of the State Water Board's effort.

Is the Regulatory Process of Water Resources by Cannabis Farmers Working?

Anna Birkas, *Village Ecosystems*

In the North Coast region of California, cannabis cultivation has been a primary economic driver for decades. It has also impacted natural resources, affecting watershed health and instream flows in salmon streams. With Cannabis legalization, state agencies such as CDFW and SWRCB have implemented new policies to regulate cannabis farms.

As a watershed consultant, I have visited hundreds of farms and informed farmers about the policy, process, and environmental cost of compliance. Most of my results are qualitative, while some specific data will be summarized. Many cannabis cultivators have traditionally farmed integrated gardens on rural homesteads by people who consider themselves environmentally sensitive. The issues being addressed on rural homestead properties are often not directly caused by cannabis, but by rural development.

While the policies are well designed to protect watershed health, and their benchmarks should not be degraded, they are not being widely adopted by cultivators. Farmers express that they do not understand the policies, are intimidated by the regulatory process, are not being treated in a fairly compared to other agricultural industries, and cannot afford to enroll. Between the high cost of consultants required to address the technical issues and the extensive reporting requirements, the policies may fail to be applied to most farms. If the policies are not applied to most farms, they will not have a broad reach. Thus, our streams and watersheds will not have the benefit the best resource management strategies.

There is a need for research into the following areas:

- Are the policies being applied to the most appropriate properties?
- Are people engaging in the programs?
- Are the policies affective at preserving economic and cultural heritage?
- Does terminology interpretation increase regulatory burden, is there "Regulatory Creep"?
- Are the policies difficult to understand?
- Are the policies cost prohibitive for small farmers?
- Do policies protect small farmers?
- Is the North Coast at a disadvantage because of the property wide requirement?

Here are some initial ideas to improve engagement:

- Trust building and equal treatment
- Reducing costs, such as the fee for Small Irrigation Use Rights
- Allowing five to ten year timelines
- Providing grants
- Creating a tier status protecting small farmers
- Creating an easy process that farmers can mostly do themselves.

While effective solutions for environmental issues are required, policies must also be widely adopted. If most farmers stop farming there could be adverse economic implications. If they do not enroll, then their properties will not be upgraded. If the most degraded properties are abandoned, then the most devastating watershed issues are not addressed. If a viable economic option for most small farmers is not provided, then larger farms outside the North Coast Region and owned by people that do not have vested interests in their communities and the environment, may dominate the industry. To be successful agencies should look at the success and failure of the social elements of the policies.

Fish-Friendly Cannabis Practices: Scale and Opportunities for Environmental Change

Hollie Hall, Ph.D., Hollie Hall & Associates Watershed Resources ConsultingWater quality and quantity impairments negatively impact the river systems that support fish, animals, and forests of California. These negative impacts are thought to stem from historic and current land management, water diversions, road grading, and agricultural pollution.

The legalization of cannabis cultivation has provided a regulatory forum for the curtailment of negative environmental impacts associated with cannabis farming activities. However, the overall impact changes to cannabis farming practices alone will have on aquatic resources is not yet known. To provide a broader concept of the scale of impact regulation of cannabis farming activities may have a review of the following will be presented:

- The proportion of California's landscape under licensed cannabis cultivation, by cultivation methodology (indoor, mixed light 1, mixed light 2, outdoor);
- The volume and timing of surface water diverted to supply cannabis irrigation under issued water rights by license type and area;
- A comparison of California's land and water use for cannabis production versus other uses; and,
- Specific examples of fish friendly cannabis farmland and water use techniques.

Considerations of the scale of impact that regulation of cannabis farming activities may have is an important component to the ongoing development and implementation of aquatic resources management throughout California. As cannabis legalization promotes a movement tending toward the implementation of regenerative, fish-friendly farming practices the opportunity exists to use compliant farms as role models for the improvement of agricultural and forested lands management.

Coho Salmon: Gauging Cannabis Production Impacts to Summer Rearing Habitat

Corinne Gray, ***California Department of Fish and Wildlife, Bay Delta Region***

Cannabis cultivation in the North Coast region of California is documented in watersheds that currently support or historically supported coho salmon (*Oncorhynchus kisutch*) populations. Cannabis cultivation in these watersheds relies on local sources of water, much of which is hydrologically connected to salmonid summer rearing habitats. The southern geographic extent of coho distribution includes Central California Coast populations where stream flows were impaired by diversions prior to the legalization of cannabis. Cultivation of cannabis can require significant volumes of water for irrigation and can exacerbate poor summer conditions in already impaired watersheds. There are several scientifically based methods currently available to assess the degree that stream flows within a watershed are impaired which do not require extensive field studies or data gathering efforts. We used existing desktop methods to compare current observed flow conditions to established environmental thresholds. Our results for the Russian River watershed demonstrate widespread impairment of summer base flow conditions in juvenile coho salmon rearing habitat.

Thinking Outside the Channel: Innovative Approaches to Urban Stream Restoration Workshop and Field Tour

Wednesday, April 24

Workshop Coordinator*: Tom Hesseldenz,* *Ecological Landscape Architect, Tom Hesseldenz and Associates*

Field Tour Coordinator*: Steve Brady,* *City of Santa Rosa*

The morning workshop will go beyond early versions of urban stream restoration that focused only on instream and streambank improvements to also include accessible floodplain restoration, complete stream channel morphology restoration, flood hazard reduction, water quality improvements, city-wide sub-watershed planning, as well as inclusion of urban wildlife habitat, trails, and other recreational facilities. Presentations will focus on various design methodologies utilized and ways to work with landowners, municipalities, regulators, local residents, and conservation organizations to accomplish large comprehensive urban stream projects.

In the afternoon, participants will ride Rosie the Trolley to visit City of Santa Rosa project sites including Lower Colgan Creek and the Prince Memorial Greenway on Santa Rosa Creek. The Colgan Creek project acquired additional right-of-way to allow for the expansion of the floodplain, increased channel sinuosity, instream habitat features, native riparian planting, and flood resiliency within a previously channelized creek. The Prince Greenway is an urban creek restoration in downtown Santa Rosa that enhanced a grouted rock flood control channel to allow for the installation of habitat features and native plantings within a limited right-of-way. The tour will highlight project development, land acquisition, flood control requirements, funding, challenges, and lessons learned.

"Breakthrough" mural on Railroad Street bridge over Santa Rosa Creek in the Prince Memorial Greenway. Photo Credit: City of Santa Rosa.

Navigating Dynamic Stakeholder, Contractor, and Regulatory Landscape to Improve Urban Streams: A Case Study of the City of Fortuna's Rohner Creek Project

***Steve Allen, P.E.**, and **Brett Vivyan, P.E.**, GHD (Presenters) and **Jeremy Svehla, P.E.**, GHD*

Stream restoration in urban environments poses a wide range of challenges that requires a multi-objective approach to balance stream and floodplain functions, ecosystem services, flood-risk reduction, and stakeholder interests. Common to many urban streams, the historic riparian corridor along Rohner Creek in Fortuna, California, was heavily encroached upon. Urban developments in otherwise flood prone areas occurred, sometimes protected by single purpose engineering systems with limited resiliency. The altered watershed landscape resulted in high-intensity hydrographs, disconnection of the floodplain, channel incision, channel straightening, and significantly increased flood intensities and frequencies. As a result of these changes, most meaningful salmonid and riparian habitats were eliminated.

Making any changes to an urban stream environment is challenging. The patchwork of property ownership placed the burden to permit, manage, and maintain Rohner Creek on individual property owners. Property owners are one type of stakeholder, with regulatory agencies, municipal government, school districts, and interested citizens all being part of the stakeholder group which results in a variety of interests and viewpoints.

A top priority Capital Improvement Project in the City's 1982 Storm Drain Master Plan, the City, a disadvantaged community, was able to secure funding in 2012 to develop and implement a comprehensive solution to reduce flood risk while improving habitat and providing a roadmap for long-term management and maintenance. Along the 1-mile project reach, through the heart of town, the City and GHD collaborated extensively with 50 individual property owners to find opportunities for improvements and identify known problem areas that needed attention.

The project was approached with an iterative strategy to both utilize hydraulic modeling to identify problem areas and utilize stakeholder's knowledge of the system to achieve project design objectives. Floodplains were enhanced with side channels, habitat alcoves, and log structures where space allowed. The local high school field was modified for use as an overflow floodplain swale around heavily encroached sections of the channel and to capture local runoff, diverting flow back to Rohner Creek through an inset floodplain. Regulatory agencies were engaged early and often to balance project function and impacts. Extensive floodplain modeling was used to inform project design and communicate flood risk and identify habitat enhancements. Challenges were encountered as contractors with limited in-stream experience implemented the detailed design and property owners saw dramatic changes to their landscape.

This project highlights the successes and challenges associated with funding, stakeholder outreach, floodplain modeling, design, permitting, and construction of a large-scale project to enhance instream and riparian habitats, develop a long-term adaptive management program, and reduce flood risk to below FEMA's 1% Annual Exceedance Probability floodplain designation for 150 parcels.

Ecological Re-Tooling of a Small Town: Comprehensive Urban Stream Restoration in the City of Yreka, California

Thomas F. Hesseldenz, *Ecological Landscape Architect, Tom Hesseldenz and Associates, (Presenter); Co-Authors:* ***John H. Humphrey, Ph.D., P.E.,*** *C.C.M. Hydrologist, Civil Engineer, and Meteorologist, Hydmet Consulting; and* ***David W. LaPlante,*** *Research Geospatial Analyst, Natural Resource Geospatial*

Many urban streams are incised due to increased peak flows and reduced floodplain function resulting from development. Raising or re-routing stream channels to re-access historic floodplains in developed areas is usually not feasible. In areas where development has occurred on alluvial fans, modeling has shown that a much narrower accessible floodplain width than that of the historic floodplain is needed to achieve geomorphic stability. In these cases, the required flood-prone width can be achieved by lowering the grade of adjacent land to the calculated bank-full level of the incised channel, and a new accessible floodplain can be created with relatively low impacts to surrounding development. Modeling has shown that the new floodway created by floodplain lowering and widening can contain up to a 100-year storm event or greater, thereby dramatically reducing flood hazards and associated economic losses. Spoils can often be spread on nearby undeveloped parcels, thereby reducing disposal costs and helping to raise those parcels further above the 100-year flood height.

The new floodplain also provides opportunities for re-routing the stream channel to restore geomorphologically stable channel geometry (width, depth, and sinuosity), and constructing instream features such as pools and logjams for fish habitat. It also provides opportunities for extensive riparian woodland restoration, relocation of storm drain outfalls to the back edge of the floodplain combined with detention basins to capture first-flush storm runoff, and construction of paved and unpaved trails within the new floodplain to create greenways. Additional benefits can be achieved away from primary stream corridors by re-routing runoff from smaller storm events into de-watered ephemeral drainages, and by constructing extensive bioswales and small detention basins where historic drainage channels have been obliterated by development. The cumulative benefits include reduction of peak flows, increased groundwater recharge and base flows, and increased water quality. Restored ephemeral drainages and constructed bioswales and detention basins can be re-vegetated with native riparian species, thereby creating important wildlife habitat and linkages within urbanized areas. These methods are currently being implemented along Yreka and Greenhorn Creeks (salmonid-bearing streams) in Yreka, California, located along Interstate 5 near the Oregon border in the Klamath Basin. Approximately one mile of stream corridor has been restored and a similar amount of bioswales and small detention basins have been constructed to date, and another 1/4 mile of stream corridor restoration is scheduled for restoration in 2019. A comprehensive greenway master plan has also been completed for the entire City and beyond. When the master plan is fully implemented over the next 20 years, approximately 14 miles of stream corridor will be restored, 5 miles of ephemeral drainages will be re-watered, and 5 miles of bioswales and small detention basins will be constructed. Also, up to 14 miles of paved trails and 6 miles of unpaved trails will be constructed within restored stream corridors. The master plan also includes providing fish passage over a small dam on Greenhorn Creek, and retrofitting the City's wastewater treatment facility to reduce impacts to Yreka Creek.

Roughened Channel Chute Construction Techniques, Random Versus Planned Boulder Placements

P. Travis James, P.E., *Michael Love & Associates and* ***Steve Allen, P.E.,*** *GHD (Co-presenters); and Co-author:* ***Greg Garrison, P.E.,*** *GHD*

Penitencia Creek flows through Alum Rock Park, California's oldest urban Park. The Park was founded in 1872 and is located in the foothills east of San Jose. Penitencia Creek supports populations of threatened steelhead trout and is surrounded by unique geology, mineral springs, and abundant wildlife. Even before the Park's founding, European settlers began to alter the Creek's course and today there is almost no part of the channel that has not been manipulated. Park features, over the years, have included two railroads, an aviary, a zoo, a dance pavilion, a tea house, log cabin, a music court, both men and women bath houses, an indoor swimming pool, and a merry-go round. All of which required significant creek and floodplain alterations due to the extremely limited level ground available. Although some features still remain, the Park is now progressing to a more natural setting, focusing on hiking trails, education, and restoration.

At some point within the last century a concrete weir was constructed across Penitencia Creek to create an in-channel pool for Park visitors. Through scour and ongoing channel incision, a 5-foot drop developed downstream of the weir, which created a fish passage barrier. In the summer of 2012, the fish passage barrier was removed by constructing 300 feet of a pool and chute roughened channel. The first storm after construction was between a five and 10-year event and caused damage to the most upstream chute. In 2013, the chute was repaired but the construction technique was altered. During the 2012 construction, chutes were constructed of engineered streambed material (ESM), which is a specifically designed rock gradation, and placed in the chutes randomly. In 2013, the repaired chute used the same ESM gradation but included a rock placement plan to specifically install particular boulders at specific locations within the chute to increase the structural integrity.

To date, several monitoring efforts have been completed at the site. This talk will discuss the channel's overall response overtime with a specific evaluation of the difference in response between the 2012 chute construction technique and the 2013 chute construction technique.

How to Engage Local Communities in Order to Promote Urban Watershed Health & Understanding Around Salmonid Habitat Needs

***Sarah Phillips**, Urban Streams Program Manager, Marin Resource Conservation District*

The Urban Streams Coordination Program should be considered as a model to counties with an abundant number of watersheds interfacing with an urban environment. Since the Marin Resource Conservation District began its Urban Streams Coordination (USC) Program in late 2014, with funding through Marin County, over 2,000 residents in Marin County have been educated. It turns out that having a program dedicated to urban streams really pays off! Throughout the span of the USC Program, residents have come to count on the Program for their watershed needs and curiosities. The USC Program carries out the following activities and this presentation will highlight ideas about how to carry out these activities successfully:

- Consults on proposed projects in order to promote soft engineering approaches, such as laying back the banks and using biotechnical bank stabilization techniques with native plants, as opposed to the traditional retaining walls or riprap installations
- Organizes and leads free hands-on technical trainings for Marin residents to teach them how to implement restoration actions on their own property and why it's critical for watershed health
- Provides free site evaluations for streamside residents that include issue-specific suggestions to guide the residents toward stewardship of their respected watersheds
- Assists in regulatory compliance for residents conducting restoration in order to incentivize residents to carry out larger restoration projects
- Secures free or very low cost native plants to promote riparian revegetation in urban watersheds
- Serves as a communication liaison between local government departments, watershed groups, residents, and regulatory agencies to promote better coordination on any and all restoration efforts and/or watershed issues
- Acts as a facilitator and mediator between multiple residents or regulators and residents to promote positive and productive relationships in order to carry out restoration
- Creates incentives to promote watershed restoration on a parcel by parcel scale
- Secures grants and manages projects that install instream and off-channel habitat features for ESA-listed CCC coho salmon in the Lagunitas Creek watershed on private properties

Partnering with Land Conservation Organizations for Long-Term Protection

Jen Kuszmar, *Sonoma County Ag + Open Space*
and ***Steve Brady,*** *City of Santa Rosa (Co-presenters)*

Salmonid restoration practitioners can achieve longer-term outcomes by also permanently protecting the important habitats being restored by partnering with local land conservation organizations like land trusts and open space districts. In Sonoma County, a publically funded land conservation agency, the Sonoma County Agricultural Preservation and Open Space District (Ag + Open Space), works with public and private landowners, which has resulted in over 76 miles of salmonid bearing streams protected in perpetuity. Through the recordation of conservation easements, critical resources are safeguarded forever. The infusion of funding through the sale of a conservation easement or through acceptance into the Ag + Open Space urban open space grant program allows property owners to invest in restoration activities or to modify practices that result in healthier habitats. In urban environments, conservation easements not only provide critical habitat protection, but also opportunities for people to find respite and to learn about the natural resources surrounding them.

Ag + Open Space has protected over 116,000 acres in Sonoma County since 1990.

Exploring a Stage 0 Valley: Willow Creek—Aggraded, Avulsed, Restored

Wednesday, April 24

Field Tour Coordinators*: Brian Cluer, Ph.D.*, *NOAA Fisheries, and* ***Lauren Hammack,*** *Prunuske Chatham, Inc.*

Willow Creek, a tributary to the Russian River's estuary, has a 2-mile long low gradient alluvial valley that had been managed for drained and irrigated agricultural land for over 100 years. Over the last 30-year period it transformed itself from an incised single-thread channel into a wetland channel complex through channel aggradation and multiple avulsions. This transformation helped inspire Cluer and Thorne's development of the Stream Evolution Model and the concept of Stage 0 channels. In 2011 the fish passage barrier in the lower valley was removed. Coho and steelhead immediately navigated through the multi-threaded wetland channels and returned to the upper watershed to spawn. Coho numbers and migration patterns in the watershed have been monitored by California Sea Grant's Russian River Salmon and Steelhead Monitoring Team since 2011.

Come spend the day learning about and exploring the well-developed Stage 0 channel network of lower Willow Creek. This tour is for those who want to put on their waders and get intimate with the best local example of a Stage 0 stream, a relatively rare channel form in modern time. Come see for yourself the complex array of habitats that salmonids can use, and that may well be necessary for their survival and recovery.

Explore a Stage 0 valley wetland complex. This tour will require waders. Photo Credit: Brian Cluer

Dry Creek Field Tour: Partnerships in Habitat Enhancement and Monitoring for Salmonid Recovery

Wednesday, April 24

Field Tour Coordinators*: Dave Cuneo* and *Gregory Guensch, Sonoma Water*

This all day tour features salmonid habitat enhancement projects and monitoring programs on both private and public lands that demonstrate long-term partnerships that strategically implement conservation practices within the Dry Creek Basin. We will highlight conservation strategies that address issues related to salmonid recovery and that provide long-term solutions for communities and the environment. Tour projects will highlight collaborative efforts guided by the Russian River Biological Opinion, and the Russian River Coho Salmon Captive Broodstock Program, and are implemented collaboratively by both agencies and landowners. Project sites are located on the mainstem of Dry Creek and include engineered log jams, off-channel, and in-channel habitat enhancements.

Dutch Bill Watershed Streamflow Improvement and Coho-Recovery Tour

Wednesday, April 24

Field Tour Coordinators*:*
***Brock Dolman** and **Kate Lundquist,** Occidental Arts and Ecology Center*

Tour Leaders*: **John Green,** Gold Ridge RCD; **Mia van Docto** and **Mary Ann King,** Trout Unlimited; and **Sara Nossaman,** CA Sea Grant*

This full-day field tour will focus on the Dutch Bill Creek Watershed, considered to be one of the most critical watersheds for the recovery of endangered coho salmon and steelhead in the lower Russian River basin. For two decades, multiple stakeholders have utilized a comprehensive suite of strategies to restore this watershed from ridgeline to rivermouth.

The first half of the tour will start in lower Dutch Bill Creek with a discussion about the Russian River Coho Flow Partnership and other partner's restoration efforts. Participants will hear about the Coho Broodstock Program and monitoring efforts, fish passage barrier removals (dams, fishways) instream habitat structures (large wood), sediment control and water quality enhancement techniques (advanced road shaping), and instream flow enhancement projects (water conservation, seasonal storage, irrigation demand reduction, diversion modifications, water right changes, spring reconnecvtion, and augmentation).

The second half of the tour will visit the headwaters of Dutch Bill Creek at the 80-acre Occidental Arts and Ecology Center site. Here, tour participants will see the results of 25 years of upland restoration techniques such as headcut and fuel load mitigation, fish friendly roads, stormwater recharge, graywater, composting toilets, organic food production, wildlife habitat enhancement, community education, and organizing.

The idyllic Occidental Arts and Ecology Center is a research demonstration center in the Dutch Bill watershed in Western Sonoma County that teaches permaculture and watershed restoration practices. Photo Credit: Katherine Harris

Winter Habitat, Floodplains, and Fish Passage in Lagunitas Creek Field Tour

Wednesday, April 24

Field Tour Coordinator*: Greg Andrew,* *Marin Municipal Water District*

Tour Leaders*: Preston Brown,* *SPAWN;* *Erik Young,* *Trout Unlimited;* *and* *Joanna Dixon,* *Marin County Public Works*

This tour will visit four habitat enhancement projects implemented in Lagunitas Creek over the past three years. The enhancement work is designed to improve winter habitat through floodplain restoration in the mainstem of Lagunitas Creek and provide instream enhancement and fish passage in two important salmonid tributaries: Devil Gulch and San Geronimo Creek. Each of the four projects has been a collaboration and each has been spearheaded by a different stakeholder: the Marin Municipal Water District, Salmon Protection and Watershed Network, Trout Unlimited, and Marin County Public Works. All four projects have been grant-funded by the State and, in total, represent a $6.5 million investment for the recovery of coho and steelhead in the Lagunitas Creek watershed.

Log and rock step pools for fish passage improvement in San Geronimo Creek. Photo Credit: Greg Andrew, Marin Municipal Water District

From D.C. to California—Legislative Efforts to Restore Working Watersheds

Congressman Jared Huffman

On April 10, 2019 Congressman Jared Huffman (D-San Rafael) introduced the Northwest California Wilderness, Recreation, and Working Forests Act to guard communities against wildfires, provide local jobs, restore lands impaired by illegal marijuana growing operations, and permanently protect many of northwest California's spectacular wild places and pristine streams. This Act includes several innovative new programs to increase fire resilience, restore forests and fish habitat, stimulate local economies through forest stewardship programs, and enhance recreational opportunities including through trails and visitor centers. Senator Kamala Harris has introduced the Senate version of this important legislation.

Representative Jared Huffman (D-San Rafael) has represented California's second district since 2013. He is currently a member of the Committee on Natural Resources and the House Committee on Transportation and Infrastructure. Prior to his election to Congress, Huffman served six years in the California State Assembly, where he chaired the Water, Parks, and Wildlife Committee, served on the Budget Committee and was co-chair of the Legislative Environmental Caucus. Before his election to public office, Huffman was a Senior Attorney for the Natural Resources Defense Council (NRDC), and a public interest attorney. He also served 12 years in local government as a Director of Marin County's largest special district, the Marin Municipal Water District (MMWD), from 1994 to 2006.

Fish Tales: A Writer's Journey into the Salmon Connection

***Langdon Cook**, author of* **Upstream—Searching for Wild Salmon from River to Table**

To write about Pacific salmon is to examine human identity. Indeed, the salmon is a reminder of our most basic roots in the wild—and a bellwether of our future. Author and journalist Langdon Cook explores this kinship in *Upstream: Searching for Wild Salmon, from River to Table*. It is a book about people as much as it is about fish. Traveling throughout salmon country, he meets the many user groups who depend on and work with salmon every day, from commercial and tribal fishermen to scientists, environmental advocates, and even chefs and fishmongers. In telling their very human stories, he reveals a relationship that's been millennia in the making even as more recent struggles threaten these ties in the Anthropocene Era. As the ultimate wild food in North America, with entire communities that have formed around its lifecycle, the salmon offers Cook a chance to investigate how society values and safeguards such an important linkage to the natural world—and how it responds when those bonds begin to fray. In his keynote presentation, Cook will visit some of the scenes in his book and discuss a few of the characters he writes about in an effort to better understand this age-old connection.

How Climate Extremes Affect Salmonid Recovery

Gordon Reeves, Ph.D., PNW Research Station, Corvallis, OR

Aquatic ecosystems in the Pacific Northwest will be challenged biologically and physically by climate change. Freshwater environments are likely to experience altered thermal and hydrologic regimes, the extent that is likely to vary widely within basins and across this region. Biological effects could be both positive (e.g., more available habitat, extended growing season) and negative (e.g., displacement of recently emerged fry, altered time of smolting). Potentially mitigating or offsetting these effects requires understanding where in the streamscape various effects and processes occur and implementing appropriate actions. It is important that restoration efforts focus on increasing life-history and genetic diversity, and well as population numbers. Monitoring efforts recognize that the interaction of effects in the freshwater and marine environments will have cumulative effects on fish, and that the different species will respond differently and in ways that are novel and unexpected.

Managing California's Water in a Time of Drought and Climate Change

Ellen Hanak, Ph.D., *Water Policy Chair, Public Policy Institute of California (Presenter) and Co-authors:* ***Jeffrey Mount, Ph.D., Ken Baerenklau, Ph.D., Caitrin Chappelle, MPP, Alvar Escriva-Bou, Ph.D., Greg Gartrell, Ph.D., Brian Gray, JD, Jelena Jezdimirovic, Jay Lund, Ph.D., Henry McCann, MA, Josué Medellín-Azuara, Ph.D., David Mitchell, Kurt Schwabe, Ph.D.,*** *and* ***Nathaniel Seavy, Ph.D.,*** *Public Policy Institute of California's Water Policy Center;* ***Van Butsic, Ph.D., Ted Grantham, Ph.D.,*** *and* ***Scott Stephens, Ph.D.,*** *UC Berkeley;* ***Graham Fogg, Ph.D., Thomas Harter, Ph.D., Yufang Jin, Ph.D., Peter Moyle, Ph.D.,*** *and* ***Paul Ullrich, Ph.D.,*** *UC Davis;* ***Sarge Green,*** *California Water Institute, CSU Fresno;* ***David Jassby, Ph.D.,*** *and* ***Daniel Swain, Ph.D.,*** *UCLA;* ***Alan Rhoades, Ph.D.,*** *and* ***Zexuan Xu, Ph.D.,*** *Lawrence Berkeley National Laboratory;* ***Leon Szeptycki, JD*** *and* ***Barton "Buzz" Thompson, JD,*** *Stanford University; and* ***Joshua Viers, Ph.D.,*** *UC Merced*

California's climate is changing. Hotter temperatures, a shrinking snowpack, shorter and more intense wet seasons, rising sea level, and more volatile precipitation—with wetter wet years and drier dry years—are stressing the state's water management system. Recent climate projections indicate that the pace of change will increase. To avoid unwanted social, economic, and environmental consequences, the water system will need to adapt to greater climate extremes and growing water scarcity. While California is making good progress in some areas of drought management, a more focused plan of action is needed. Successful adaptation will require strong leadership at the state and local levels, and cooperation on all fronts. The 2012–16 drought—the hottest in the state's recorded history and one of the driest—offered a window into the future under a warming climate and lessons for managing future droughts. Using these lessons as a starting point, this report offers a road map of essential reforms to prepare for and respond to droughts in California's changing climate.

Key reforms include:

- Plan ahead. Stronger drought planning is critically important for urban water management, groundwater sustainability, safe drinking water in rural communities, and freshwater ecosystems.
- Upgrade the water grid. California needs a comprehensive program to address above- and below-ground storage, conveyance, and operational challenges by mid-century, including repairing facilities that are broken, expanding conveyance and storage capacity, and modernizing and integrating operations.
- Update water allocation rules. California should comprehensively update its water allocation governance. The goals should be to find equitable and efficient ways to allocate limited supplies among competing demands during dry times while promoting efforts to capture and store water during wet times.
- Find the money. Reliable funding is crucial for adapting to climate change. New sources are needed to pay for necessary water-management investments and to fill funding gaps in the state's water system.

The focus of this reform agenda is on drought, because drought more than any other aspect of California's climate reveals the vulnerabilities of water management systems. Importantly, these reforms will improve drought resilience for today's conditions, not just for the future.

Stage 0 Restoration, Design, and Implementation

Session Coordinator*: Brian Cluer, Ph.D.,* *NOAA Fisheries*

Alluvial valleys historically supported well-connected stream/floodplain systems that supported salmonids and other wildlife in robust and resilient ways. Land development and drainage schemes altered nearly every one of the former Stage 0 settings in the last century, collapsing habitat to minimums and making it unreliable to climate cycles. Restoring floodplain-stream interaction in alluvial valleys has gained favor as an ecologically superior, and perhaps necessary, approach to salmonid recovery. This session is an opportunity for practitioners and regulators to discuss the importance of floodplain restoration, how to go about design and implementation, and how to obtain permits to get Stage 0 on the ground.

Stage 0 Restoration at Whychus Canyon Preserve, Central Oregon —Monitoring and Lessons Learned

***Mathias Perle** (Presenter) and **Lauren Mork,** Upper Deschutes Watershed Council; and **Colin Thorne, Ph.D.,** University of Nottingham*

Whychus Creek is the focus of multi-year collaborative restoration efforts intended to support fisheries restoration, improve stream habitat, and restore natural stream processes. In 2016, project partners broke ground on the first mile of a six-mile restoration project along Whychus Creek at Whychus Canyon Preserve, owned by the Deschutes Land Trust.

Project proponents have been committed and focused on restoring key physical, chemical, and biological processes necessary to establish and support a resilient, productive stream ecosystem for the long-terms benefit of fish, wildlife, and water quality. This approach seeks to employ established principles in process-based stream restoration as well as key principles of ecological restoration. This includes a focus on addressing root causes of channel and ecological degradation, and relies on natural channel floodplain connectivity and processes such as floodplain-wide riparian cover, erosion, deposition, and avulsion to create, maintain, and support resilient terrestrial and aquatic habitat that can support all life stages of fish and wildlife species over time. Project design and subsequent implementation at Whychus Canyon Preserve sought to explore the degree to which some of the most ecologically productive stream conditions, described in the Cluer and Thorne Stream Evolution Model as Stage 0, can be achieved through accelerating stream evolution and recovery to achieve the most ecological uplift possible given existing site constraints and opportunities.

Project monitoring goals include understanding how this restoration implementation technique is performing to inform future phases of Stage 0 restoration. Project monitoring, ongoing since 2014, includes evaluating physical and biological metrics such as groundwater, fish habitat, geomorphology, macroinvertebrates, fish usage, and plant community presence/extent. Physical monitoring parameters show an increase in instream habitat quantity and complexity, a water table sufficiently shallow to support riparian plants and numerous channels that have replaced the pre-restoration single-thread, deeply incised channel. Preliminary macroinvertebrate data suggest macroinvertebrate abundance in side channels well above that in unrestored reaches and EPT taxa richness post-restoration equivalent to un-restored reaches. The results of measurements of vegetation, zooplankton, phytoplankton, and periphyton studies performed in August 2018, along with fish density and relative growth rate data to be collected in Fall 2018 will be also be presented. Intensive monitoring effort findings provide vital insights needed to evaluate the benefits and risks of ‘Stage 0” restoration and assess whether improvements in long-term productivity, diversity, and resilience justify the short-term disruption caused when the fluvial system is re-set to its pre-disturbance condition.

A Survey of Forest Service Stage Zero Restoration Projects, and an Introduction to the Geomorphic Grade Line Design Approach

Paul Burns, *Fisheries Biologist, U.S. Forest Service, Siuslaw National Forest (Presenter);* ***Cari Press*** *and* ***Paul Powers,*** *U.S. Forest Service, Deschutes National Forest;* ***Johan Hogervorst, Nick Grant, Matt Helstab, Lisa Kurian,*** *and* ***Kate Meyer,*** *U.S. Forest Service, Willamette National Forest; and* ***James Pettett,*** *Hydrologist, U.S. Forest Service, Siuslaw National Forest*

Throughout the world, a wide range of anthropogenic disturbances have greatly reduced stream health and resilience. In depositional, or response valley types, the primary effect has been the conversion to high capacity transport channels from a likely lower energy, valley-bottom anastomosed channel network.

Within the Pacific Northwest Region of the U.S. Forest Service, restoration practitioners have been implementing a process-based, unconfined valley restoration approach referred to as "Stage 0." This methodology diverges from stream restoration approaches that focus on creating a stable channel dimension, pattern, and profile, for establishing a preferred channel geometry. In contrast, Stage 0 methodology is based on the pre-manipulation state (Stage 0) in the Cluer and Thorne Stream Evolution Model (Cluer and Thorne 2013). This methodology uses valley slope, referred to as the geomorphic grade line, as the target elevation of both the low flow shallow groundwater elevation and baseflow wetted area (Powers et al. 2018). The primary goal of Stage 0 design is to maximize floodplain connectivity at all discharge levels, including baseflow, not just at a channel forming discharge. The reset fluvial valley is then able to transition into a complex network of anastomosing flow paths, wetlands, and diverse aquatic habitats.

Early meadow restoration projects on the arid, east-side of the Cascade Mountain Range led to the development of the Stage 0 restoration approach. At a traditionally designed meadow restoration project, observations of both failures and areas of high stream complexity exposed a longitudinal surface that the stream adjusted to, which appeared to be the historic valley floor. Around the same time, projects to repair headcuts in small, second order streams utilizing the method of filling the degraded channel back up to the valley floor, showed rapid succession of wetland features. Restoration specialists deduced that a trend line fit longitudinally through this surface could represent the target elevation for restoration design and called it the Geomorphic Grade Line (GGL) (Powers et al. 2018). They expanded this approach to larger, bedload dominated stream systems on a variety of landscapes ranging from lacustrine valleys in the Oregon Coast Range to moderate gradient valleys in the West Cascades and East Cascades (1-3%). The same general approach was applied across all of these landscapes, which included identifying the historic valley bottom, removing constricting features (berms, roads, etc…), and resetting the valley bottom to eliminate the transport channel and maximize floodplain connectivity. These project types restore fluvial processes and in turn restore ecological benefits that have been largely lost in many alluvial valleys.

Monitoring to date indicates that these projects are on the right trajectory and are trending toward Stage 0. Restoring the reach-scale processes that formed the depositional valley in which these projects are located create habitat for at-risk salmonid populations and other riparian-dependent species and improve ecosystem resiliency.

Restoration Construction: Bridging Muddy Waters—Lessons Learned from the Pacific Northwest

Matt Koozer, Biohabitats

As the final step of any habitat restoration project, construction can be the most expensive and uncertain. Compared to traditional excavation and construction work, implementing complex salmonid habitat restoration and enhancement project designs is challenging. These projects are often constrained by several factors including in-water work timing restrictions, strict erosion and turbidity control conditions, fish presence, exclusion and salvage, changing or unexpected site conditions, and public perception considerations. This means that productive communications between owners, engineers, and contractors is critical for project success.

In the face of dwindling salmonid populations up and down the West Coast, the field of habitat restoration is adopting a more comprehensive, large-scale approach. Valley-scale projects can easily scale up construction uncertainties due to larger disturbance footprints and increased exposure to weather-related impacts, as well as complex diversion, dewatering, and fish salvage efforts. These concerns are amplified when the contractor is brought into the implementation process late.

Attendees of this presentation will gain a contractor's perspective and recommendations for streamlining restoration construction projects, with an emphasis on time and cost savings. Topics will include beneficial owner/engineer/contractor communications, understanding design intent, pre-construction planning and risk assessment, diversion and dewatering plans, and excavation and wood installation techniques, each of which becomes more critical as project scales increase to Stage 0.

Lessons learned from completed Pacific Northwest river, floodplain, and estuary restoration projects will be used to illustrate unique cost saving means and methods, sequencing, specialized equipment, in-progress adaptive management, and general recommendations for contractor input timing throughout the early design and implementation process. The hope is that bridging the gaps between regulators, owners, engineers, and contractors will inherently result in more cost-effective restoration projects, from concept through construction. These bridges will in turn lead to a greater distribution of restoration funds, a larger restoration footprint, a beneficial public perception of the restoration industry, and an increase in optimism amongst the interdisciplinary restoration practitioners of the contemporary era.

Attaining Stage 0 Ecologic Benefits with the Complementary Use of Contour Grading, Simple Roughness Elements, Wood Jams, Beaver Dam Analogues, and Time

***Rocco Fiori**, Fiori GeoSciences (Presenter), and Co-authors: **Sarah Beesley, Scott Silloway, Andrew Antonetti,** and **Jim Faulkner,** Yurok Tribe*

Our restoration team has been working to restore stream and valley habitats in the 3rd to 5th order tributaries of the Lower Klamath River since 1996. The depositional reaches of many of these streams have an ephemeral flow regime, with subsurface flow conditions occurring during prolonged rainless periods typical of summer, but can also happen during mid-winter months. The dominant geomorphic conditions operating within these valley floors can be described as either: 1) excessive sedimentation with rapid floodplain turnover rates that tends to bury or replace productive Holocene floodplain soils with Anthropocene gravels, or 2) transport conduits with low sediment and wood retention capacity, and poor floodplain connectivity. Past logging and in-stream wood removal activities are part of the disturbance history of these systems.

A key aspect to our restoration approach has been the ability to work with these systems over time to incrementally achieve Stage 0 ecological benefits. We have developed a treatment palette that includes the complementary use of contour grading, channel and floodplain roughness elements, wood jams, and more recently beaver dam analogues. All features are constructed with native materials, i.e. local alluvium, logs, slash, and plant materials only, no metal or imported rock is used. In systems with a braided channel network and degraded riparian function our treatment palette has been used to successfully route, sort, and preferentially retain spawning gravels within the channel and deposit fine sediments on higher surfaces to produce a more resilient valley floor that has multiple channel anabranches and forest islands. We have learned that wood jams can be constructed to be either semi-permeable or permeable and this difference can be used to achieve desirable outcomes. For example, where a flow obstruction is needed to force a split in the flow path, semi-permeable jams are used. Yet where sediment intrusion could rapidly fill a side channel, permeable log jams are placed at the inlet that allows water to pass but maintains sediment routing in the primary channel. For the permeable jams to function as a sediment control structure our design relies on restraining members (i.e. vertical posts, batter piles, and inclined key members) for stability instead of alluvial ballast. In entrenched systems increased floodplain connectivity and habitat complexity has been achieved with the use of constructed alcoves, wood jams, and channel spanning obstructions, i.e. wood jams and beaver dam analogues.

An overview of techniques and lessons learned from our suite of low-cost, process-based restoration projects will be presented. Topics will include design considerations and physical and biological performance outcomes.

Process Based Design Criteria for the Scoping and Design of Stage 0 Restoration Projects

Jared McKee, M.S., *U.S. Fish and Wildlife (Presenter),*
and Co-author: ***Damion Ciotti, M.S.,*** *U.S. Fish and Wildlife*

The U.S. Fish and Wildlife Service (Service) Habitat Restoration Division has developed broadly applicable design criteria based on published ecological standards and process based principles for fluvial restoration. These criteria are aimed at advancing process based ecological restoration design and steering stakeholders towards restoration actions that operate at meaningful ecosystem process scales, are adaptive, increase space for fluvial action, and restore sediment and stream (dis)connectivity.

Completed and underway Stage 0 restoration sites will be presented and serve as examples of the design criteria in use. The primary restoration project example will be one mile of stream and a 60-acre floodplain in the Sierra Foothills. The goals of the project involved shifting a degraded stream from an incised single thread channel to a Stage 0 reach with active depositional processes instream and across the floodplain. The project does not involve stream channel reconstruction beyond the use of BDAs and hand-placed wood jams to meet stream and floodplain form objectives.

In three years, approximately 30 acres of stream/floodplain/potential Stage 0 habitat evolved from a single thread channel dominated by oak and grassland to a permanently flooded Stage 0 condition with highly complex stream and wetland morphology. Instream restoration investments by the Service for the project are relatively low (less than $10,000) and include hand-placed wood jams and beaver dam analogues (BDA).

The project provides the Service validation of the newly developed design criteria as well as an ideal demonstration of maximum stream restoration with minimum intervention. This approach will enable the Service Program to invest restoration resources at a greater spatial scale. It is also an opportunity to experiment with stage zero restoration under the confines of an active cattle grazing operation. Specific methods, lessons, results, and mistakes will be discussed.

Restoring to Stage 0, Recent Advances and Applications in Process-Based Habitat Restoration

Carrie Lukacic, *Prunuske Chatham Inc. (Presenter) and Co-authors:* ***Betsy Stapleton,*** *Scott River Watershed Council and* ***Sarah Beesley,*** *Yurok Tribal Fisheries Program*

Development of the Stage 0 restoration approach is new in California, although the approach is more widely used in the Pacific Northwest. How do hydrologists, geomorphologists, planners, biologists, and restoration designers begin to utilize this valuable restoration technique in California where the California Department of Fish and Wildlife, Regional Water Quality Control Boards, Army Corps of Engineers, NOAA Fisheries, and the U.S. Fish and Wildlife Service have yet to develop policy and regulations allowing their implementation? How can we work within the existing regulatory environment to allow for the restoration of natural processes in degraded streams, rivers, or meadow systems and to move these systems towards their pre-disturbance, multi-channel conditions? What regulations might need to change to allow Stage 0 projects to proceed?

During the workshop, brief presentations will explore regulatory policies that support restoration and how these policies facilitate permitting for, and implementation of, Stage 0 and Stage 0-like projects such as BDAs. We will review successfully permitted projects, the permitting strategies used, and how to apply the strategies and techniques broadly across the State. Attendees will learn about the regulatory compliance methods used in the Pacific Northwest to identify what techniques can be used locally, and what changes may be necessary for our use in California.

This will be a highly interactive session, with participation from permitting specialists, agency staff members, and the audience at large. Through structured interactions, a list of specific barriers to Stage 0 project permitting will be developed, along with concrete strategies for addressing them. Attendees will learn effective strategies to advocate for permitting of innovative restoration projects, and develop networks with others engaged in similar work.

Salmonid Foodscapes in River Networks —Synthesizing the Phenology of Habitat Suitability and Food Availability Across a River Network

Session Coordinator*: Gabriel Rossi,* UC Berkeley

River networks are shaped by well-described geomorphic and hydrologic dynamics. But for mobile aquatic organisms like juvenile salmon, a river network is also a dynamic foodscape in which seasonal pulses of productivity coincide with hydraulically-mediated habitat connectivity, to present a shifting mosaic of feeding and growth opportunities. The salmonid foodscape describes relationships between (1) the physical suitability of habitat for foraging and (2) food availability in those habitats for foragers, in habitats along a river network. The movement patterns of juvenile salmonids through linked riverine habitats, from headwater streams to mainstem rivers, to floodplains and estuaries may be driven by gradients of access, suitability, and productivity within each habitat type. Therefore, to understand how a population of juvenile salmon can grow—it is necessary to consider the spatial distribution and phenology of foraging habitats throughout the whole river network.

This conference session will draw on presenters with unique experience in different aspects of the Foodscape—including primary production and secondary production, instream flow, physical habitat across the riverscape (headwaters to estuary), and salmon life history diversity and behavior. To date, the management of salmon has mostly focused on site-specific physical habitat needs… without linking food availability (drift flux, benthic productivity, and terrestrial-aquatic linkages) to physical habitat across the river network. Presentations in this section will collectively sketch out the salmonid foodscape to inform effective management and recovery of salmon and river health.

A Foodscape Approach to Salmonid Ecology and Management

***Gabriel Rossi** (Presenter), and Co-authors: **Mary E. Power, Ph.D., Stephanie Carlson, Ph.D.,** and **Theodore Grantham, Ph.D.,** UC Berkeley*

River networks are shaped by well-described geomorphic and hydrologic dynamics. But for mobile aquatic organisms like juvenile salmon, a river network is also a dynamic foodscape in which seasonal pulses of productivity coincide with hydraulically-mediated habitat connectivity, to present a shifting mosaic of feeding and growth opportunities. The salmonid foodscape describes relationships between (1) the physical suitability of habitat for foraging and (2) food availability in those habitats for foragers, which both vary in space and time throughout the river network. The movement patterns of juvenile salmonids from headwater streams to mainstem rivers, to floodplains and estuaries may be driven by gradients of access, suitability, and productivity of linked riverine habitats. Therefore, to understand the value of different life history strategies that juvenile salmon can exploit it is necessary to consider the spatial distribution and phenology of prey in foraging habitats throughout the whole river network.

Aristotle noted that "Those who wish to succeed must ask the right preliminary questions." Yet, in the effort to recover salmon populations we have too rarely asked how juvenile life histories depend on the spatial and temporal distribution of their food or how human alteration of river ecosystems has changed this foodscape. In this presentation, we describe a foodscape model to help tackle questions about the ecology and management of salmon. We will introduce a set of generalized variables to assess the favorability of foraging habitat across the river network. Using data from the Eel and Russian rivers we will show how a foodscape approach may lead to different hypotheses and different management prescriptions than an approach based solely on physical habitat and flow. Consideration of salmon food resources may also expand the methods that investigators use to evaluate the quality of salmon habitat. By adopting a perspective that includes food web dynamics—restoration practitioners, water managers, and fisheries biologists can expand their toolkit for facilitating the recovery of salmon populations and degraded river ecosystems.

Algae and Cyanobacteria in "Salmonid Foodscapes" Along River Networks

Mary E. Power, Ph.D., *UC Berkeley (Presenter), and Co-authors:* ***Jacques C. Finlay, Ph.D.,*** *University of Minnesota;* ***Keith Bouma-Gregson, Ph.D.,*** *UC Berkeley;* ***Laurel Genzoli,*** *University of Wyoming;* ***Gabe Rossi*** *and* ***Phil Georgakakos,*** *UC Berkeley;* ***Paula C. Furey, Ph.D.,*** *St. Catherine University;* ***Rex L. Lowe, Ph.D.,*** *U. Wisconsin, Madison; and* ***Raphael Kudela, Ph.D.,*** *UC Santa Cruz*

Consumers in salmon-bearing food webs of the Eel, and similar rivers, along the California North Coast are fueled in large part by attached algae. Most Eel River consumers derive most of their carbon directly or indirectly, via prey, from algae where river channels drain > 10 km2. Some aquatic invertebrates (e.g., the scraping larval caddisfly *Glossosoma*) appear to be built of algae even in much smaller, darker headwaters. Whether these algal-based food webs support good growth of salmonids and other predators depends on the amount, type, and fate of river algal production during a given summer low-flow season. Amount, type, and fate of algae, in turn, depend on winter and summer hydrology, as well as land and water use and stewardship. Diatoms are the most nutritious algae in river food webs. Epilithic diatoms cover sunlit stony substrates during stable flow periods, while epiphytic diatoms cover host plants, particularly the green macro-algae (*Cladophora*), which proliferates during early summer if winter floods the preceding winter have scoured away large grazers. One or more winter scours often precede a food web in which diatoms flourish on rocks and plant hosts, and support salmonids and other predators. If, however, extremely low summer base flows allow sunlit channels to become warm and stagnant, cyanobacteria can proliferate and overgrow *Cladophora-diatom* assemblages. Several genera of these cyanobacteria in North Coast rivers have proven to be neurotoxic to dogs. Much remains to be learned about the natural history of potentially toxic riverine cyanobacteria: how they overwinter; where, when, and why they proliferate during their summer growth season; and how they and their toxins move through riverine habitats and food webs. We also need to investigate the importance of algal and cyanobacterial exports from rivers for coastal estuarine and lagoon ecosystems along the North Coast. Earlier studies at the mouth of the Eel suggest that riverine green algae and diatoms may be important but cryptic food sources for estuarine consumers, while studies off Monterrey Bay have shown that river-produced microcystins can kill sea otters offshore. More Eyes on the Eel and similar watershed programs are needed to track ecological responses to hydrologic and land use changes affecting salmon via algae throughout river networks, including in newly restored coastal habitats along the California North Coast.

Linking Spatial Patterns of Stream Metabolism, Ecosystem Processes, and Juvenile Salmonids in a River Network

Matthew Kaylor, *Oregon State University, Department of Fisheries and Wildlife (Presenter) and Co-authors:* ***Seth White,*** *Columbia River Inter-Tribal Fish Commission;* ***Dana Warren,*** *Oregon State University—Department of Forests, Ecosystems, and Society;* ***Ted Sedell,*** *Oregon Department of Fish and Wildlife—La Grande Fish Research; and* ***W. Carl Saunders,*** *Utah State University—Department of Watershed Sciences*

Researchers continue to struggle to understand the processes that drive spatial patterns in river networks and managers lack tools necessary to account for these patterns in planning management actions at watershed scales. In this study, we collected data on physical habitat, nutrient concentrations, biofilm standing stocks, stream metabolism (gross primary production [GPP] and ecosystem respiration [ER]), and ESA-listed juvenile salmonid density from approximately 50 sites across two sub-basins of NE Oregon. Our goals were to 1) leverage emerging statistical approaches to evaluate network patterns in these metrics, and 2) determine network-scale linkages among these metrics, thus providing inference of processes driving observed patterns. We then use results from this study to guide an experimental study focused on increasing juvenile salmonid productivity—salmon carcass additions.

Spatial patterns of nutrient concentrations suggested high ecosystem demand for nutrients with co-limitation by N and P in one basin and limitation by N in the other. Nutrient limitation predictions were further supported by experimental results using nutrient diffusing substrates across both sub-basins. The physical parameters solar exposure and stream bankfull width, rather than nutrient concentrations, were the most supported predictors of GPP, despite clear nutrient limitation of biofilms. Spatial statistical network (SSN) models explained 54-57% and 36-39% of the total variation in network-scale GPP and ER, respectively. Juvenile salmonids were concentrated in cool, oligotrophic headwaters where nutrient concentrations, biofilm standing stocks, and rates of GPP were low relative to the broader stream network. In the carcass addition study, we targeted three stream sections where juvenile salmonid abundance was high but oligotrophic conditions were likely resulting in food limitation. These sections were situated along a thermal gradient that also resulted in shifting fish communities with downstream distance. Carcass additions increased growth rates of juvenile salmonids in all three pairs. Although a biofilm chlorophyll a increased after carcass addition in two of three pairs—indicating a bottom-up responses—stable isotope and diet analysis revealed salmonid growth responses were fueled by direct consumption of eggs. Non-salmonids did not consume eggs and stable isotope responses indicate enrichment that likely occurred through bottom-up pathways.

Floodplains in the Foodscape: Physical Process to Productivity

Carson Jeffres, Ph.D., *Center for Watershed Sciences, UC Davis (Presenter) and Co-authors:* ***Jacob Montgomery,*** *California Trout;* ***Eric Holmes,*** *UC Davis; and* ***Jacob Katz,*** *California Trout*

Floodplains are ephemerally flooded habitats that function neither solely as lentic or lotic habitats, but have processes of each that result in exceptionally productive food webs. The seasonal flood pulse in California generally coincides with outmigration of juvenile salmonids from upstream rearing habitats and can provide significant food resources for rapid growth rates prior to entering downstream estuary and marine environments. During flood events, riverine waters slowly flow across the landscape and allow for increased water substrate interaction, facilitating decomposition of terrestrial material. As terrestrial material decomposes, it fuels a heterotrophic food web that results in prolific zooplankton production. In addition to the heterotrophic pathway, the slowed water drops sediment and clears, thus resulting in autotrophic production through phytoplankton and algae. With parallel productive pathways of carbon sourcing, there is ample carbon to support prolific production of large bodied zooplankton which provide food resources for juvenile salmonids. The ephemeral nature of floodplain habitats allows for large bodied cladocerans such as Daphnia pulex to flourish. Under a permanently wetted environment such as lakes, permanent residents would graze the large bodied zooplankton and ultimately select for smaller bodied zooplankton. But the ephemeral nature of floodplains does not allow for permanent top-down grazing pressure and allows for the seasonal resource pulse that juvenile salmonids are able to utilize. Floodplains, as all habitats for juvenile salmon, are critical to maintaining salmon populations. Understanding how floodplains fit into the salmon foodscape in a river network can help guide management of imperiled salmon populations.

"Counting Calories" Juvenile Steelhead Feeding Ecology in an Intermittently Closed Estuary—Russian River

***Erin Seghesio**, NOAA Fisheries (Presenter)*
*and Co-author: **Charles Simenstad,** University of Washington*

Estuaries are increasingly being valued as potential rearing habitat for juvenile *Oncorhynchus mykiss* (steelhead). Previous research (2008) by Hayes and Bond has found that steelhead rearing in an intermittently closed small estuary had greater growing opportunities and thus were more successful in their recruitment back to the adult population. As part of this study, the Russian River estuary was sampled to determine over time and range, the distribution, composition, and relative abundances of potential steelhead prey items and diet before and during a freshwater lagoon conversion. The formation of a freshwater lagoon when the estuary entrance is closed increases the water level from an average of 1 meter to a managed 2.3 meters. The flooded lagoon provides juvenile steelhead and other salmonids the opportunity to feed in peripheral habitats, and potentially allows for new or expanded prey resources and increased consumption and growth rates. But during the conversion to a freshwater lagoon, the water quality decreases dramatically with temperatures increasing and dissolved oxygen decreasing.

Analyses of the diet composition of steelhead sampled indicate that epibenthic crustaceans and aquatic insects were the dominant prey. The highest density of common prey taxa was found in benthic core samples, but the greatest diversity was in the epibenthic samples. Bioenergentic modeling was used to evaluate if growth would be affected by an extended closure. The modeling results showed that smaller steelhead are able to grow at a faster rate under the same circumstances. Steelhead can continue to grow under temperatures associated with a freshwater lagoon conversion by either; consuming higher caloric prey, increasing consumption rate, or finding refuge. Although, steelhead are feeding primarily on lower calorie epibenthic organisms, higher quality prey organisms do exist. The highest density of common prey taxa was found in benthic core samples, but these species were not able to colonize the shoreline during the short closures. The amount of time it takes for the water quality to improve during the conversion to a freshwater lagoon and then the length of the closure will determine if steelhead will benefit from the increase in habitat.

Incorporating Foodwebs into Salmon Habitat Monitoring in the Columbia River Basin

Seth White, Ph.D., *Columbia River Inter-Tribal Fish Commission (Presenter) and Co-authors:* ***Matthew Kaylor,*** *Oregon State University;* ***Casey Justice, M.S.,*** *and* ***Lauren Burns, B.S.,*** *Columbia River Inter-Tribal Fish Commission;* ***Edwin Sedell, M.S.,*** *Oregon Department of Fish and Wildlife;* ***Dana Warren, Ph.D.,*** *Oregon State University; and* ***Sean Sullivan, M.S.,*** *Rhithron Associates, Inc.*

Salmon habitat monitoring programs have a long tradition of evaluating status and trends of physical stream conditions such as geomorphology, substrate composition, riparian condition, wood recruitment, water temperature, and streamflow. With the exception of fish monitoring, biological factors such as food webs and other ecosystem processes are often ignored or relegated to research studies, which tend to occur on shorter time frames than routine monitoring and therefore are less able to track long-term trends over large spatial scales. Some programs additionally collect benthic macroinvertebrates (BMIs), but limit metrics to those representing water quality such as indices of biotic integrity, observed/expected taxa scores, or percent sensitive or tolerant taxa. In this presentation, we describe a salmon habitat monitoring program in the Grande Ronde River, a major tributary of the Columbia River, that explicitly incorporates foodwebs and other ecosystem processes to arrive at a 'foodscape' perspective of stream networks inhabited by salmonids. In addition to physical habitat monitoring described above, the program includes collection and analysis of drifting invertebrates as a measure of food availability; refined analysis of BMI data arriving at propensity to drift and ecological network indices; network-scale assessments of nutrients, gross primary production (GPP), and ecosystem respiration (ER); and experimental additions of salmon carcasses and evaluation of food web responses along a longitudinal gradient of water temperature and fish assemblage composition. Findings to date illustrate that (1) life history traits of BMIs predict their propensity to drift and become available as food for foraging salmonids in the water column; (2) metrics of ecological network properties for BMIs are useful for describing habitat quality; (3) river network scale patterns of GPP and ER can be predicted from landscape characteristics; and (4) salmon carcass additions elicited a bottom-up food web response, but also a direct consumption response of juvenile salmonids foraging on carcass material. Furthermore, many of these food web and ecosystem-level properties are sensitive to environmental factors related to climate change—namely water temperature and streamflow—which make them useful for parameterizing bioclimatic models. Inclusion of these foodweb components to a salmon habitat monitoring program additionally addresses existing objectives of federal, state, and tribal salmon recovery plans. Moving forward, our program aims to establish empirical linkages among physical habitat metrics, climate-related factors, and food web-related factors described here for better predicting the cumulative impacts of climate change and land management on resilience of salmonids and other aquatic life.

Innovations in the Science and Management of Dry Season Water Supply for Salmonid Recovery in California

Session Coordinator*: Tim Bailey, Institute for Sustainable Forestry*

Projected future low flow conditions represent an existential threat to the viability of aquatic ecosystems throughout California. The competition for scarce water resources during the long dry season is one of the fundamental challenges for salmonid populations throughout the State. Finding solutions that respond to these water supply challenges is going to require both sophisticated hydrologic models and the broad adoption of beneficial cultural practices for watershed management. This is a venue to share advances in our growing understanding watershed eco-hydrology. The session will profile recent progress developing hydrologic models at hillslope and watershed scales, surface flows and ground water interactions, and adaptive watershed management strategies that are being deployed to respond to the escalating climate emergency.

The Salmonid and The Subsurface: The Importance of Rock Type for Understanding and Sustaining Northern California Aquatic Ecosystems

David Dralle, *Department of Earth and Planetary Science, UC Berkeley (Presenter) and Co-authors:* ***W. Jesse Hahm,*** *Department of Earth and Planetary Science, UC Berkeley;* ***Daniella Rempe,*** *Jackson School of Geosciences, University of Texas Austin;* ***Mary Power, Ph.D.,*** *Department of Integrative Biology, UC Berkeley;* ***Stephanie Carlson, Ph.D.,*** *Department of Environmental Science, Policy, and Management, UC Berkeley; and* ***Bill Dietrich, Ph.D.,*** *Department of Earth and Planetary Science, UC Berkeley*

In upland landscapes, rock uplift, weathering, and surface erosion create a structured critical zone, defined as the hydrologically active near surface layer that extends from the vegetation canopy down to underlying fresh bedrock. How does the structure of the critical zone (CZ)—especially below shallow soils and into saprolite and weathered rock—control water storage and release to North Coast forests and streams? Here, we address this question with a synthesis of observational and modeling results from two intensively studied catchments and hillslopes in the Eel River watershed.

A thin CZ and low water storage capacity in the Central Belt mélange (a geologic formation that underlies half the Eel River watershed) results in an oak savanna ecosystem and seasonally ephemeral streams (in spite of ~2 m / y of precipitation). In contrast, deeper weathering profiles in the fractured mudstones of the neighboring Coastal Belt seasonally store large volumes of water, sustaining robust summer baseflows and dense evergreen forests. Our findings reveal bottom-up, lithologic controls on weathering profiles, subsurface water storage capacity, and summer baseflow drainage from the critical zone. Results highlight how, in addition to plant physiology and climate, the subsurface is a key regulator of ecosystem productivity, stream temperature, water availability, and forest response to drought.

Predicting the Spatial and Temporal Distribution Of Wetted Habitats in Intermittent Streams and its Implications for Long-Term Drought Impacts

Hana Moidu, Ph.D. Candidate, *UC Berkeley (Presenter) and Co-authors:* ***Ross Vander Vorste, Ph.D.,*** *UC Berkeley;* ***Mariska Obedzinski, Ph.D.*** *and* ***Sarah Nossaman Pierce,*** *CA Sea Grant;* ***Ted Grantham, Ph.D.*** *and* ***Stephanie Carlson, Ph.D.,*** *UC Berkeley*

In California, where intermittent streams make up much of the river network, insufficient summer streamflow is often the bottleneck for imperiled species survival, including that of salmon at the southern end of their range. During dry periods, these organisms depend on persistent wetted reaches and isolated pools as their only refuge, from which they may recolonize surrounding habitats upon rewetting. Despite the importance of intermittent streams for oversummer survival, little is known about the physical controls on the drying dynamics in these systems, nor the processes that sustain viable habitat refugia throughout the dry season. This study aims to improve the understanding of spatio-temporal controls on habitat suitability of endangered Coho salmon (*Onchorynchus kisutch*) and threatened steelhead trout (*O. mykiss*) in the intermittent tributaries of the Russian River watershed. Using summer wetted habitat condition data collected by the Russian River Salmon and Steelhead Monitoring Program from 2012-2018 in combination with antecedent climatic data and landscape-level variables, we are proposing a model to simulate the degree and distribution of stream drying at the reach scale at multiple sites. This research helps to advance understanding of the use and importance of intermittent stream habitats for endangered salmon at the southern extent of their range, and can be used to inform management and guide conservation action.

Lessons from Low Flow Monitoring and the Impacts of Drought on Streamflow Conditions in Small Coastal Watersheds

Mia van Docto, Conservation Hydrologist, Trout Unlimited

Insufficient summer streamflow has been recognized as a limiting factor to the recovery of coho salmon populations in coastal streams. Trout Unlimited's Conservation Hydrology team (formerly CEMAR's Conservation Hydrology department) has been studying low flow conditions and human water demand in five tributary watersheds of the Russian River (as a member of the Russian River Coho Water Resources Partnership), as well as in 15 other tributary watersheds in coastal California. One of the main challenges of working in these watersheds is the micro late-summer streamflows and the annual variability of rainfall which make it difficult to accurately assess the impact of human water demands and the benefits of streamflow enhancement projects on low flow conditions.

This presentation will discuss the insights we've learned through our nine years of streamflow monitoring as well as how the modeling tools we employ can help resource managers prioritize areas for streamflow enhancement projects. We will discuss the impacts of direction diversions on coastal streams, the effects of water releases on streamflow conditions, the tools we use to estimate human water demand, and the cumulative impact of the recent drought on streamflow conditions. Using priority tributary watersheds in the Russian River, as well as examples from other watersheds outside of the Russian River, as example case studies, we will discuss how we have employed these approaches in our work and the lessons we learned.

Quantifying Ecological Risk from Diversion Rates During the Hydrograph Recession in the South Fork Eel River

***Emily J. Cooper** (Presenter),*
and Co-author: ***William Trush, Ph.D.**, Humboldt State University, River Institute*

Ecological responses and evolutionary adaptations to the natural hydrograph recession in coastal California streams are at-risk due to altered water availability from streamflow diversions. This research connects stream hydraulics to ecological processes by relating streamflow (Q) to the Riffle Crest Thalweg (RCT) as a hydraulic control and realizing the RCT as a principal facilitator of biological activity. Using the RCT-Q relationship, we identified flows and dates in WY2018 that corresponded to aquatic and riparian species' life stages and habitat use relative to the RCT in pool-riffle hydraulic units. By knowing life stage timing and observing ecological features or biological occurrences as evidence of life stage-specific habitat use, we identified flows necessary for Pacific lamprey redd egg incubation (*Lampetra tridentata*) and salmonid smolt outmigration (*Oncorhynchus spp*). We then assessed risk to subsequent life stage success (expressed as n days of habitat inundation) during streamflow recession rates subjected to incremental diversion rates.

Following a storm that peaked at 25,000 cfs on 7 April 2018, estimated Pacific lamprey redd construction ranged from 8 April 2018 to 8 June 2018 and between 10,000—200 cfs. All lamprey redds assessed at high or extreme risk were constructed during flows exceeding 800 cfs, corresponding to dates before 1 May 2018. The Moderate—No Risk redds were constructed between 1000 and 200 cfs, representing flows controlled by bedform hydraulics. We assessed how risk thresholds for lamprey redd inundation and smolt outmigration conditions responded to higher recession rates from iterative streamflow diversions compared to the response of risk thresholds to the flood recession. As expected, with increasing diversion rates, the number of days habitat was inundated decreased, and risk increased. While the level of ecological risk varied among species and hydraulic units with different RCT-Q rating curves, a change in recession streamflow with a diversion rate ≤ 5% of the RCT depth protected life stage success.

Benefits of Agricultural Water Conservation Strategies to Improve Summer Low Flows, Navarro River Watershed, California

Christopher Woltemade, Ph.D., *Shippensburg University (Presenter), and Co-authors:*
Linda Macelwee, *and* ***Patty Madigan,*** *Mendocino County Resource Conservation District;*
and ***Erica Lundquist,*** *Mendocino County Natural Resources Conservation Service*

The Navarro River watershed drains 816 km2 of the northern California Pacific coast ranges and supports native populations of coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). Low summer discharge and warm water temperatures have been identified as factors driving declines in the range and abundance of salmonids. Naturally low summer discharges (<3 cfs; < 0.1 cms) are exacerbated by water withdrawals for irrigation and other uses. Summer discharge has been especially low during recent drought years (e.g. 2013-2015).

Agriculture includes over 3,000 acres (1,200 ha) of vineyards and orchards in the Anderson Valley, providing important sources of employment and income. Irrigation consumes over 2,000 acre-feet (2.5 x 106 m3) of water annually and has potential for substantial increase. Water is sourced mainly by stream diversions during high winter flows (to fill storage ponds) and, to a lesser extent, direct diversions during lower summer flows and groundwater use. Several recent efforts have increased water conservation in the watershed with the goal of maintaining or increasing summer stream discharges.

A monthly hydrologic water budget was developed to simulate water fluxes between atmosphere, soil, groundwater, and streams over the period of discharge records (1951-present). The model was applied to a range of water conservation scenarios to determine the benefits of reduced summer withdrawals to enhance discharge volumes on key tributaries and the main stem Navarro River. Results were assessed for selected climate and discharge conditions representative of years with moderately wet, near average, moderately dry, and severe drought conditions. Water conservation scenarios included a range of investments from modest projects, such as a 10 acre-foot increase in off-stream storage of irrigation water, to ambitious, widespread adoption of conservation strategies, such as reducing summer irrigation withdrawals to zero via greater winter diversions to off-stream storage. Flow benefits are relatively modest in terms of absolute flow rates but represent substantial percentage increases in summer flows. Summer flows during moderate and severe drought years could be increased by over 100% of historic values. Benefits to increased summer discharge are shown to vary considerably across the various tributary streams.

Roll Your Own Data Logger: Use the Mayfly Solar Powered Computer Board to Automate Collection of Low Flow Physical Stream Conditions

Neil Hancock, ***Independent Software Engineer***

Want to be able to monitor physical stream parameters, with the graphs available in real-time, to detect and respond to anthropogenically induced physical events? The Stroud Water Research Center's (SWRC) *enviroDIY.org* initiative provides the tools.

The SWRC and enviroDIY community have created an Arduino Mayfly solar powered computer board with 5V and 12V (requires add on "wing" board") interfaces to scientific and industrial sensors.

This session will be an interactive tutorial on compiling a Modular Sensors data logger for interfacing to 20+ instruments for monitoring physical parameters and graphing them on the data.enviroDIY.org data portal.

Data, Planning, and Actions for Watershed Resiliency: Fires, Floods, and Climate Change

Session Coordinator*: Karen Gaffney, Sonoma County Ag + Open Space*

In the last five years, California has experienced some of the largest and most damaging fires in history, with substantial impacts to human communities, forests, stream ecosystems, and local economies. This session will explore opportunities to enhance watershed resiliency to fires, floods and extreme events exacerbated by climate change. Presenters will discuss data, analysis, and planning efforts to achieve multi-benefit outcomes on the ground. The session will cover landscape scale analysis of forest quality, hydrologic and geomorphic processes, fuel loading, and carbon sequestration, and will outline how these data are used to target interventions that reduce impacts to human health and safety while protecting and enhancing sensitive ecosystems and supporting local jobs and revenue.

Mapping Riparian Areas for Long-Term Riparian Corridor Conservation & Resiliency to Extreme Events

Karen Gaffney *and* ***Allison Schichtel,*** *Sonoma County Ag + Open Space (Co-presenters) and Co-authors:* ***Mark Tukman*** *and* ***Dylan Loudon,*** *Tukman Geospatial;* ***Joan Florsheim, Ph.D.,*** *UC Santa Barbara;* ***Matt O'Connor*** *and* ***Jeremy Kobor,*** *O'Connor Environmental*

The Sonoma County Agricultural Preservation and Open Space District (Ag + Open Space) is a voter-approved special district that protects the diverse agricultural, natural resource, and scenic open space lands of Sonoma County for future generations, primarily through conservation easements. Ag + Open Space has invested significant public funds to protect watersheds and stream corridors that are important for supporting biological diversity and will continue to do so in the future. Ag + Open Space employs a data-driven approach to land conservation, and is invested in the enhancement of countywide data and analysis tools to support this work. Data such as LiDAR and fine-scale vegetation mapping inform the prioritization of areas for protection, conservation easement design, and long-term stewardship of protected lands. Most recently, Ag + Open Space worked with Tukman Geospatial to develop a map of riparian areas, including channel and floodplain boundaries, for streams with an upstream catchment area of 2,500 acres or greater in Sonoma County. These data were developed through a semi-automated process using a model in Ecognition, which is informed by and calibrated using LiDAR data and digital elevation models, historic flood information, available hydrologic models, and field observations. To refine this remote sensing and modeling work, Ag + Open Space is working with fluvial geomorphologist, Dr. Joan Florsheim, to develop field protocols to enhance riparian model outputs and inform localized riparian protections. Ag + Open Space utilizes these riparian data along with other hydrologic, vegetation and habitat, land use/land cover, landscape permeability, and climate resiliency data to develop priority areas for riparian protection, to support policy and funding initiatives, and to achieve conservation outcomes on the ground. In the wake of the 2017 fires in Sonoma County, these data and have become even more important in considering long term resiliency to extreme events, including fires, floods, landslides, droughts, and other effects of climate change.

Effects of the Thomas Fire on *Oncorhynchus mykiss* and Stream Communities of the Los Padres National Forest

Kristie Klose, Ph.D., *Forest Fisheries Biologist, Los Padres National Forest (Presenter) and Co-authors:* ***Scott D. Cooper, Ph.D.,*** *Research Professor, UC Santa Barbara;* ***Jason White, M.S.,*** *South Coast Habitat Restoration—Earth Island Institute; and* ***Erika Eliason, Ph.D.,*** *Assistant Professor, UC Santa Barbara*

Wildfire is thought to have many negative impacts on stream salmonid populations, yet data on the effects of wildfire and ensuing debris flows on salmonid populations in California is limited. The Thomas Fire burned 114,000 hectares in Ventura and Santa Barbara Counties between Dec. 4, 2017 and Jan. 12, 2018. We sampled physical, chemical, and biological variables and censused steelhead trout in 9 trout streams inside and 5 control trout streams outside the Thomas Fire footprint in Los Padres National Forest (LPNF) in the summer of 2018. Trout remained at average densities > 1/m2 in control streams, but were greatly reduced or extirpated by fire or debris flows in streams in burned basins, where stream to bankfull width and pool-riffle ratios, riparian canopy cover, and leaf litter mass declined, and current velocity and temperature increased. In burned basins, trout persisted at 3 sites characterized by intact riparian cover and deep pools, but were extirpated at six sites, nearly all of which received extensive debris flows that filled in pools and destroyed riparian vegetation. Although it is not known how rapidly trout populations will recover from wildfire and debris flows, LPNF surveys conducted in 2016-07 showed that 7 of 9 streams unaffected by fires contained trout, but that trout were absent in all streams draining basins that had burned within the last ten years; however, this pattern was confounded by the lengthy drought (2012-2018) affecting all of our study streams. We suspect that trout recovery in streams where they were extirpated will depend on adequate, perennial flows, the re-establishment of deep pools, the recovery of riparian vegetation, and trout access to burned sites (no barriers).

Report from a Russian River Field Station in the Heart of the 2017 Wildfire Zone: Pepperwood's Integrated Approach to Evaluating and Advancing Watershed Resilience

Tosha Comendant, Ph.D., *Conservation Science Manager and* ***Lisa Micheli, Ph.D.,*** *President, Dwight Center for Conservation Science at Pepperwood (Co-presenters) and Co-author:* ***Michelle Halbur,*** *Preserve Ecologist, Dwight Center for Conservation Science at Pepperwood Preserve*

Pepperwood serves as an integrated climate-ecosystem field station for California's Coast Ranges and as a facilitator of productive exchanges across scientific disciplines and between scientists and land and water managers at our Dwight Center for Conservation Science. Prior to the 2017 Northern Californian Complex fires, which burned over 90% of the 3200-acre field station located in the headwaters of the lower Russian River, we had been collecting weather, hydrology, and biological data via a Sentinel Site monitoring framework for nearly a decade. Pepperwood hosts the Terrestrial Biodiversity Climate Change Collaborative (TBC3.org) and other science affiliates to advance research addressing questions of watershed hydrology, vegetation ecology and management, and wildlife conservation. We also convene planning and implementation projects including the Mayacamas to Berryessa Landscape Connectivity Network and Climate Ready North Bay, to develop landscape-scale strategies for adaptive management of our conservation and working lands.

In the face of a potentially even more fire-prone future, the time is now to take a multi-disciplinary approach to collect the data our community needs to understand the local drivers of fire, to monitor landscape recovery, and to support resilient forest management and rebuilding strategies moving forward. In addition to coordinating assessments of recent fire impacts, we are helping to translate that growing information base to identify management needs and prioritize actions with public and private partners based on feasibility, urgency, efficiency, and principles of climate-smart adaptive management. This presentation will provide a high-level overview of pre- and post-fire data collection focused on monitoring watershed and ecosystem indicators, and describe how this data is informing resilience strategies at scales ranging from the parcel, to watersheds, to the region as a whole.

Spatial Analysis and Forest Canopy Damage Modeling —The 2017 North Bay Fires

Mark Tukman *(Presenter) and Co-Author:* ***Dylan Loudon,*** *Tukman Geospatial*

The 2017 North Bay fires burned tens of thousands of acres of Sonoma County's natural and man-made landscapes. We examine and report on the effects of the fire on the county's forests, providing insights about how damage to the forest canopy was distributed across vegetation types and how riparian areas fared during the fires. This presentation is rich with spatial data, maps, and animations that examine the fire's effects on vegetation and the response of vegetation communities post-fire.

After the Planning Ends: Advancing Objectives of the Fire and Flow Strategic Planning

Stacie Fejtek Smith, D.Env., *NOAA Restoration Center*

The Fire and Flow Forum Strategic Plan (*http://schabitatrestoration.org/projects/fire-and-flow*) was developed through a nine-month stakeholder strategic planning process that was started in response to the December, 2017 Thomas Fire and January, 2018 debris flows that ravaged extensive portions of endangered southern steelhead habitat. Driven by persistent Santa Ana winds and exacerbated by severe lack of rainfall, the Thomas fire alone burned 281,893 acres in Santa Barbara and Ventura counties. It resulted in an estimated $2.2 billion in damages and was one the largest wildfires in California history at the time. In less than a year, multiple fires have exceeded the destruction caused by the Thomas Fire and subsequent debris flows. In November, 2018, the Woolsey fire burned an additional 97,000 acres in Los Angeles and Ventura counties, while the Northern California Camp Fire simultaneously became the deadliest fire in Californian history.

The purpose of the Fire and Flow Forum Strategic Plan is to guide watershed recovery and resiliency building in southern California. The Thomas Fire and the Montecito Debris Flows mobilized a diverse expert stakeholder group, including local/state/federal government, nonprofits, academics, private and public sectors, to develop a regionally cohesive and prioritized strategic plan. The strategic plan and the process used to create it can serve as a guide for stakeholder collaboration to meet the needs of wide-ranging interests throughout California facing similar threats. The Fire and Flow Forum Strategic Plan developed five priority focus areas that covers 17 goals and 100 SMART (Specific, Measurable, Attainable, Relevant, and Timely) objectives needed to achieve their shared mission and vision. The 5 focus areas include; 1. Restoration and Infrastructure, 2. Community Science and Outreach, 3. Research and Monitoring 4. Future Management, Preparedness, Resiliency, and 5. Coordination & Prioritization.

Fisheries Restoration in the Era of Megafires: How Can Fish Habitat Restoration Account for the Fire Next Time?

Will Harling, *Director, Mid Klamath Watershed Council*

The Klamath Mountains in far northern California have experienced regular megafires (over 100,000 acres in size) regularly since 1977. Lessons learned about how large-scale, high-severity fires affect salmon habitat, and how fish habitat restoration projects can better anticipate and accommodate for the eventuality of wildfire across our fire prone state, will be shared. Specifically, methods employed by the Western Klamath Restoration Partnership, a diverse group of local, tribal, state, and federal partners, to address both instream and upslope restoration simultaneously in 70 anadromous tributaries to the Klamath River, will be described. Tools for understanding both fire risk and opportunities for restoring fire process at the landscape scale from the Wildland Urban Interface (WUI) to the wildlands, in an effort to both protect and enhance alluvial process and function, will be unpacked. The goal of this presentation is to equip fisheries biologists and watershed restorationists with the tools to address both fire risk and opportunity on their landscapes.

Floodplains and Functions: From Concept to Creation

Friday Morning Concurrent Sessions

Session Coordinators*: Eric Ginney,* *Environmental Science Associates and* ***Lauren Hammack,*** *Prunuske Chatham, Inc.*

Floodplains exist throughout the landscape and the salmonid populations we are seeking to maintain and recover engage these floodplains across a continuum of time and space. Floodplains near estuaries offer different restoration opportunities than those in headwater meadows, bounded alluvial valleys, or bedrock canyons. The science, design criteria, and restoration for some of these landscapes is more mature than in others. This session will present key concepts from the perspectives of fisheries biologists, fluvial geomorphologists, and others, and bring perspectives from the worlds of both science and practical application. Restoration practitioners will present projects and describe how designs were developed that seek to meet the key processes and habitats illustrated by other presenters focusing on the science and what it suggests.

Getting Food Delivered: The Influence of Flows and Floodplains on Coho Salmon Survival and Growth

Eric Ettlinger, ***Aquatic Ecologist, Marin Municipal Water District***

Coho salmon survival and growth is impacted by stream flows at every stage of their freshwater life cycle. High stream flows negatively impact survival by scouring redds, displacing fry, and requiring large expenditures of energy avoid entrainment. On the positive side, elevated stream flows deliver benthic and terrestrial invertebrates to the water column, where they become available as food. Flashy coastal streams experience floodplain inundation only briefly, so foraging out of the stream channel is very risky. Instead, coho likely feed on invertebrates delivered to them from the floodplain. Logging, dam construction, bank stabilization, and urbanization have resulted in channel incision, increased stream velocities, diminished instream shelter, and reduced connectivity between streams and floodplains. In these environments salmonids are forced to expend more energy while receiving fewer inputs of terrestrial invertebrates from floodplains.

The relationships between stream flows and water temperature on coho growth and survival were investigated for Lagunitas Creek, a regulated and incised stream in Marin County, California. Numerous stream flow variables were investigated including minimum and maximum discharges, storm frequency, and flow durations of various magnitudes. Mathematical models were developed to describe coho survival during incubation, emergence, and overwintering. Factors impacting growth were also investigated for late-summer juveniles and smolts.

Water temperature does not appear to significantly influence coho growth or survival. Flows above 2,400 cubic feet per second (cfs) have impacted incubation survival in five of the last 22 years, likely through streambed scouring. Spring flows in excess of 160 cfs appear to reduce the survival of newly-emerged fry, but summer survival appears to be high. Overwinter survival is negatively correlated with the number of moderate flow events peaking at between 60 and 500 cfs. These discharges presumably require coho to expend significant amounts of energy but do not provide adequate inputs of terrestrial invertebrates. Habitat enhancements that can mitigate these flow impacts will be discussed.

Floodplain Geomorphology of Green Valley Creek —Legacy Effects of Settlement and Management

Matthew O'Connor, Ph.D., CEG, O'Connor Environmental, Inc.

Green Valley Creek (GVC) is a tributary of the lower Russian River in western Sonoma County. It is designated as a Core Area in the Federal CCC Coho Salmon Recovery Plan and is actively used by coho and steelhead. Juvenile coho from the Russian River Coho Salmon Broodstock Program are released into the watershed annually, and fish monitoring data indicate good growth rates for juveniles along with returns of adults to spawn. GVC is the subject of substantial habitat restoration efforts by the Russian River Coho Water Resources Partnership and others.

Coho spawning and rearing habitat is found primarily in upper GVC west of the town of Graton. Upper GVC begins at the confluence of Atascadero Creek. The present geomorphic configuration of GVC is akin to an alluvial fan where it encounters the Atascadero/GVC floodplain. Alluvial fan processes are complicated by several factors, including:

- historic channel and floodplain management affecting riparian vegetation and channel conveyance,
- watershed erosion, stream channel incision, and sedimentation,
- a road and bridge that constrain the stream channel, and
- increasingly frequent and severe flooding of the road and an adjacent vineyard.

Analysis of the causes of flooding and evaluation of flood mitigation approaches for the Gold Ridge Resource Conservation District (RCD) beginning in 2013 revealed significant historic change in floodplain conditions and suggested that human impacts on geomorphic processes operating over at least the past 80 years, likely since European settlement, have had significant effects on floodplain conditions and the associated aquatic environment. Conceptual plans for flood mitigation were developed and considered by stakeholders leading to a general consensus strategy for a long-term channel restoration plan to "reset" and maintain GVC conditions that balance aquatic habitat and flood-mitigation objectives.

Recent investigation of the Atascadero Creek wetlands located immediately upstream of the GVC confluence has revealed that sedimentation from GVC has raised the elevation of Atascadero Creek, causing its impoundment and the development of a perennial wetland. Aquatic habitat in this wetland may provide seasonal habitat for juvenile coho, but stagnant water and emergent vegetation create significant seasonal and transient anoxic water quality conditions. Planning for coho habitat enhancement/restoration in the Atascadero marsh/floodplain area is underway.

The GVC/Atascadero Creek confluence and floodplain are geomorphically active and are critical elements of the aquatic ecosystem that have been significantly impacted by human management. It is a "reconciled ecosystem" that has significant habitat value but requires ongoing human intervention to maintain its beneficial habitat qualities while mitigating harmful consequences in the human environment.

Planning for Recovery—Filling the Rearing Habitat Deficit on the Lower American River, California

Chris Hammersmark, Ph.D., P.E., *cbec, inc. eco engineering (Presenter), and Co-authors:* ***Matt Weber,*** *cbec, inc. eco engineering;* ***Joe Merz, Ph.D.,*** *Cramer Fish Sciences; and* ***Lilly Allen,*** *Sacramento Water Forum*

Central Valley salmonid stocks continue to decline despite considerable multi-faceted efforts to reduce stressors and provide appropriate conditions for the fresh water aspects of salmon and steelhead life cycles. While a previous focus of salmonid recovery efforts in the lower American River has been on gravel augmentation efforts to improve habitat conditions for spawning, in recent years the focus has been shifting to include the augmentation of rearing habitat through both flow manipulation and habitat enhancement efforts. But how much rearing habitat is really needed and where should it be located? This presentation will provide an overview of science-based planning efforts to quantitatively identify and prioritize potential rearing habitat enhancement projects. The overall spatial need for rearing habitat is estimated with the Emigrating Salmonid Habitat Estimator (ESHE) Model using the AFRP doubling goal for Chinook salmon on the lower American River. The amount of existing habitat is estimated through the application of a detailed two-dimensional hydrodynamic model combined with habitat suitability indices to estimate habitat suitability throughout the river corridor. The difference between these two (habitat required minus habitat available) is the rearing habitat deficit which varies both spatially and temporally (throughout a given year and between years). A high-resolution digital elevation model of the river corridor and results of the hydrodynamic model are used in combination to calculate the height of existing floodplain areas above typical spring flows in order to identify and develop conceptual designs for potential floodplain enhancement (lowering) sites. The height above river analysis is also used to quantify the volume of material that would need to be excavated to provide frequently inundated off-channel habitat at each site as an initial proxy for project cost. The identified sites are compared to the estimated rearing habitat deficit combined with other factors (existing land use, access, etc.) to prioritize potential projects that will be advanced to more detailed design development in future phases of the effort.

Creating Floodplain Habitat in Incised Streams in the North Bay Region, California

Jason Q. White (Presenter),
and Co-author: Jorgen A. Blomberg, Environmental Science Associates

Changes in the landscape over the past centuries have caused severe incision that disconnects streams from their historic floodplains, resulting in a loss of critical salmonid habitat and ecosystem functions. Historically, during winter storms, stream channels would exceed their capacity from excess runoff and would frequently spill out onto floodplain areas for extended periods of time. This connectivity of water between channel and floodplain provided access for native rearing salmonids to fertile habitat to 'fatten up', and to take refuge for survival. As the landscape changed through various human activities, stream processes were affected, causing streams to evolve from multi-channel streams with wetland-floodplain complexes to deeply incised and disconnected channels. This loss of floodplain connectivity has caused a loss of habitat critical to supporting stable salmonid populations.

Environmental Science Associates (ESA) has been working with a range of clients, resource agencies, and landowners to recreate and re-establish these lost floodplain habitats within a number of incised North Bay salmon-bearing streams. Salmonids have varying needs depending on the species, life stage, and season. ESA applies a design approach that reshapes the landscape to create floodplain surfaces that achieve specific timing and duration of flow connectivity based the targeted species, life stage, and season. The design approach is founded on the latest salmonid research and analytical tools, to assess and optimize habitat performance.

ESA has used this approach to create highly functional and connected floodplain habitat in three degraded systems critical to salmonid recovery in the North Bay Region of the San Francisco Bay Area: the Napa River from Oakville to Oak Knoll, Dry Creek near Healdsburg, and Lagunitas Creek within the Golden Gate National Recreation Area. The goal of the Napa River project is to create winter rearing habitat for steelhead and Chinook. To achieve this goal, the incised stream corridor was expanded with large inset benches and transitional ecotone slopes. Floodplain elevations were set to a level that allowed for sufficient inundation duration for establishing primary productivity during winter, which is needed to support rearing salmonids. In contrast, the goal of the Dry Creek project is to create summer rearing habitat for coho and steelhead. To this end, ESA designed perennial flowing multi-thread channels on the floodplain within the incised stream corridor that provide specific beneficial conditions for salmonids rearing over summer months. The goal of the Lagunitas Creek project is to create both summer and winter rearing habitat for coho. These goals are achieved by removing fill material placed at the turn of the twentieth century within the inset floodplain. Given the need for both summer and winter rearing habitat, the Lagunitas Creek project used a combination of the methods used for the Dry Creek and Napa River projects: ecotone slopes, benches, and seasonal and perennial secondary channels. The created floodplain habitats in all three projects were enhanced with large wood structures and biotechnical features. This presentation will discuss the research, analysis, design, and construction that went into creating floodplain habitat in these three important North Bay systems.

Planning, Implementation, and Monitoring of Off-Channel Habitat Enhancement and Floodplain Reconnection in the Dry Creek Habitat Enhancement Project, Russian River Basin

***Neil Lassettre** (Presenter), and Co-authors: **Gregg Horton, David Manning, Andrea Pecharich, Mark Goin, Celeste Melosh,** and **Eric McDermott,** Sonoma Water*

The Dry Creek Habitat Enhancement Project is being carried out as part of the Reasonable and Prudent Alternative of the Russian River Biological Opinion (Biological Opinion). The goal of the project is to restore 6 miles of juvenile coho and steelhead habitat along 14 miles of Dry Creek, a tributary to the Russian River. The programmatic Biological Opinion outlines habitat goals (characteristics, area to be created, types of habitat) to be achieved over 15 years from 2008 to 2023. The project relies on enhancing habitat through floodplain reconnection and creation of off-channel habitat.

Opportunities for enhancement arose from a pre-project evaluation of habitat condition that determined the feasibility of potential approaches and led to conceptual designs for the length of Dry Creek by reach and functional segment. Consulting teams further developed conceptual designs into draft and final plans based upon site condition and input from project partners (Sonoma Water, NMFS, CDFW, ACOE). The final plans show differences in design approach but remain consistent in the conceptual approach to enhance off-channel habitat and reconnect floodplains.

Monitoring and evaluation of the project is guided by the Dry Creek Adaptive Management Plan (AMP), which details performance metrics, monitoring types (implementation, effectiveness, validation), scales (spatial, temporal), and rating criteria. Effectiveness monitoring focuses on the physical response of Dry Creek to enhancement measures, while validation monitoring focuses on the biological response. Due to the expected lag time in biological response, physical response is a major driver determining short-term project success or failure. Still, long-term success of the project will ultimately be determined by the biological response.

The primary effectiveness metrics focus on optimal ranges of depth, velocity, and cover at baseflow (110-175 cfs). Sonoma Water is using several methods to evaluate project performance against these metrics, including using traditional survey and flow measurement tools (total stations and flow meters) to collect topographic and hydraulic data, and topography using structure from motion from aerial photographs taken by a small unmanned aerial system. The data are integrated within a GIS to visualize, characterize, and quantify juvenile coho and steelhead habitat area by performance metric (singly and combined) to detect habitat change through time, and to detect physical change of in-channel and floodplain areas (scour and fill) using geomorphic change detection.

The primary biological response (validation) metrics focus on juvenile salmonid habitat utilization in summer and winter, juvenile abundance within enhanced sites, and how that abundance compares to non-enhanced reaches. Stationary PIT (Passive Integrated Transponder) antenna arrays, backpack electrofishing, and snorkel surveys are used to detect habitat utilization and mark-recapture surveys are used to estimate abundance. Monitoring of non-enhanced reaches also provides important context for separating biological responses to habitat enhancement as opposed to responses resulting from changes in broader watershed-scale influences and/or variability in marine survival.

The results of the monitoring program have led to changes in elements of project design, and proved useful in evaluating and re-designing projects after large 2016-2017 storms.

Floodplains Across Time and Space: One Size Does Not Fit All (Especially on the Yuba River)

Eric Ginney (Presenter), Justin Gragg, Michael Strom, M.S., Scott Stoller, P.E., and Ann Borgonovo, P.E., Environmental Science Associates

The preceding speakers in this session have outlined the ecological importance and diversity of floodplains and have offered thoughts on how designs were developed to meet the key processes and habitats necessary to support recovery and sustainability of salmonid populations. While there are significant similarities across the landscapes in terms of the importance of (for example) food web contributions and the physical space of floodplains contributing lower-velocity rearing habitat, other factors such as the magnitude and duration of inundation and the importance of hydraulic forces in driving geomorphic processes that create and maintain spawning habitat vary across the landscape and these locations offer different restoration opportunities.

This presentation provides a summary of key physical and ecological processes and how they vary across time (by examining hydrology) and space (by examining landscape position). It offers thoughts on how the practice of salmonid habitat restoration can establish a common language and approach to assessment, planning, and design by examining floodplains through a common lens of processes, the priority of which changes across the landscape in a way that can be generally agreed upon as being vital to the factors creating and maintaining critical habitats. In conclusion, it provides an example of how the priority of one design criteria (flood-stage hydraulics) changes based on landscape position; specifically, how spawning habitat function and sustainability can be driven by floodplain morphology and the resultant flood-stage hydraulics, as demonstrated at the recently-completed Yuba River Canyon Restoration Project site located in the transition from a canyon to a less-constricted valley reach. The presentation also highlights the unique site and the design and construction challenges of the Yuba River Canyon Restoration Project.

Summertime Blues: Salmonid Survival and Ecosystem Response at the Base of the Hydrograph

Friday Morning Concurrent Sessions

**Session Coordinators*: Sarah Nossaman Pierce* and *Mariska Obedzinski,* *CA Sea Grant, Russian River Salmon and Steelhead Monitoring Program*

Flow impairment has been recognized as a bottleneck to salmon recovery in many of California's coastal stream systems, but we still have much to learn about the specific variables that drive juvenile salmonid condition and survival in intermittent streams, where average daily flow can persist in just tenths to hundredths of a cubic foot per second over the dry summer months. This session will focus on current scientific research investigating environmental and biological responses to changes in streamflow at the low end of the hydrograph. Collectively, this work contributes to a better understanding of the effects of flow impairment on salmonids and the habitat on which they depend, in order to support effective management of our limited water resources.

Impacts of Low Summer Streamflow on Salmonids Rearing in Russian River Tributaries

Mariska Obedzinski, *California Sea Grant (Presenter), and Co-authors:* ***Andrew Bartshire, Andrew McClary, Sarah Nossaman Pierce,*** *and* ***Nick Bauer,*** *California Sea Grant; and* ***Gregg Horton*** *and* ***Aaron Johnson,*** *Sonoma Water*

Insufficient streamflow has been recognized as a limiting factor for survival of endangered coho salmon and threatened steelhead populations in the Russian River; however, quantifying the impacts of low flow on fish is difficult. As is typical of many small California coastal streams, summer surface flows in Russian River tributaries drop to levels that are so low they are difficult to accurately measure and, in many cases, streams become intermittent or completely dry, especially during drought years. Furthermore, streamflow is often not a direct indicator of instream habitat availability on a streamwide scale. As an alternative to measuring flow, we conducted wet/dry mapping to document the wetted habitat conditions that rearing juveniles experience during the driest time of the year. Spatial data was collected in late summer to document where Russian River tributaries were wet, intermittent or dry. Wetted habitat data was then related to redd distribution data from the previous winter and juvenile snorkeling count data collected earlier in the summer season. Survey reaches were selected from the California Coastal Monitoring Program's Russian River sample frame using a random, spatially balanced approach. Results from four years of data collection on 20 streams indicate that adults frequently spawn in stream reaches that become dry the following summer, and that in many streams juveniles are observed in stream reaches that become dry later in the season. These data underscore the need to improve streamflow in coastal California streams in order to achieve long-term recovery of salmonid populations.

Effects of Extreme Drought on Juvenile Coho Salmon Survival in the Russian River

Ross Vander Vorste, Ph.D., *UC Berkeley (Presenter), and Co-authors:* ***Stephanie Carlson, Ph.D., Ted Grantham, Ph.D.,*** *Department of Environmental Science, Policy, and Management, UC Berkeley;* ***Mariska Obedzinski*** *and* ***Sarah Nossaman Pierce,*** *California Sea Grant*

In the last decade, extreme droughts affected regions worldwide, including an unprecedented multi-year drought in California. For species on the brink of extinction, quantifying environmental factors that influence survival of populations during droughts has become a pressing issue in species conservation. We used a mixed model approach to identify factors that influenced juvenile coho salmon survival in stream pools across eight stream reaches within the Russian River, California between 2011-2017. Antecedent precipitation, pool depth, and dissolved oxygen positively affected survival. Whereas, % of watershed area in croplands, duration of stream pool disconnection, and coho salmon density negatively affected survival. Despite harsh conditions during drought, survival was maintained in several reaches. Our results inform predictions on future salmon survival in an area where extreme droughts will become exacerbated and help identify priority reaches for protection and enhancement.

The Effects of Flow Augmentation on Invertebrate Drift, Salmonid Foraging Behavior and Inter-Pool Movement in a Mediterranean Stream

Weston Slaughter *and* ***Keane Flynn*** *(Co-presenters), and Co-authors:* ***Gabriel Rossi, Ph.D. Candidate,*** *and* ***Ted Grantham, Ph.D.,*** *UC Berkeley*

Expanding offstream water storage capacity in ponds and tanks for streamflow augmentation in the dry season is a promising approach for mitigating flow-related impacts to juvenile salmon and steelhead in California. In the summer of 2017 we began a study quantifying the effects of flow augmentation on the connectivity, quantity, and quality of juvenile salmon habitat during the low-flow season on Porter Creek, a tributary to the Russian River in Sonoma County, CA. In the summer of 2018, we expanded this study to explore the relationship between flow augmentation, benthic invertebrate drift, and fish foraging behavior in a paired-reach Before-After-Control-Impact (BACI) design. We also investigated the impact of flow enhancement on pool-to-pool fish movement using PIT tag technology.

Porter Creek (20 km2) is an intermittent stream which provides over-summering habitat for juvenile steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*). In 2014, a vineyard landowner on Porter Creek entered into a voluntary drought agreement to release water stored in an off-stream reservoir, through a telemetered pipe system, and into the stream channel in order to maintain suitable habitat conditions for rearing juvenile salmon and passage for out-migrating smolts. From June to September of 2017 and 2018, water from the enhancement system was released in controlled 1 to 2 week pulses, at rates between 50 to 400 gallons per minute. At selected augmentation treatments we surveyed benthic macroinvertebrate (BMI) drift, physical habitat characteristics, and collected in-stream video for a quantitative analysis of salmonid foraging behavior, in paired riffle-pool units above and below the augmentation point. Movement from a subset of PIT tagged fish was continually monitored by sequential antenna arrays between a series of four pools below the augmentation point between June and August. Finally, fish growth and pool densities were measured on a monthly interval by electrofishing and recording changes in fish growth and abundance.

Here we present preliminary results from our analysis of the effects of flow augmentation on BMI drift, in-pool foraging behavior, and inter-pool movement. The Porter Creek augmentation experiment provides a unique opportunity to evaluate the effect of flow alteration in a controlled setting. Quantifying the biological impact of flow alterations (diversion or augmentation) is a perennial management challenge. Studies like this can be used to inform future augmentation management and develop more accurate flow-ecology relationships to facilitate recovery of imperiled salmon and steelhead populations.

Flows That Support Coho Smolt Outmigration: Hydraulic Controls on Downstream Movement in the Russian River Watershed, CA

Brian Kastl, M.S., *UC Berkeley (Presenter) and Co-authors:* ***Mariska Obedzinski,*** *CA Sea Grant;* ***Stephanie Carlson, Ph.D.,*** *UC Berkeley;* ***Sarah Nossaman Pierce,*** *CA Sea Grant; and* ***Ted Grantham, Ph.D.,*** *UC Berkeley*

Migratory salmon populations are declining in coastal watersheds worldwide, including endangered coho salmon (Onchorynchus kisutch) of California's Russian River. One potential life cycle bottleneck is juvenile outmigration, when the movement of smolts from tributary streams to the ocean may be limited by low streamflow in spring and early summer. However, little is known about the flow and hydraulic conditions that smolts require to successfully outmigrate. This study investigates how variation in hydrologic and geomorphic characteristics, including streamflow dynamics and channel form, influence outmigration timing of coho salmon in Russian River tributaries. We measured water depths at 12 riffle crest thalweg sites, spread over 0.5—2 km-long reaches, at each of five streams throughout the March—June 2018 outmigration season. We simultaneously took discharge measurements to develop a rating curve in each stream, relating flow to riffle crest depths. Next, we converted continuous stage gage data to continuous riffle crest thalweg depth estimates, which we analyzed in relation to observed smolt movement past PIT-tag antennae. Findings indicate that outmigration is concentrated during periods of shallow riffle crest thalweg depths of 4—20 cm and during peak discharge events. A longer duration of suitable outmigration depths among streams is associated with outmigration that extends up to three weeks later in spring. Rating curves suggest that the discharge required to reach commonly used minimum outmigration depth requirements varies by a factor of eight among streams. The results of our study will improve the understanding of physical controls on smolt outmigration and can guide instream flow recommendations for coho salmon in California's coastal streams.

Beyond Flow Regimes: Dissolved Oxygen Controls on Juvenile Salmonid Health and Persistence

Cleo Woelfle-Erskine, Ph.D., *University of Washington (Presenter) and Co-authors:*
Stephanie Carlson, Ph.D., Ted Grantham, Ph.D.,
and ***Pablo Rodriguez Lozano, Ph.D.,*** *UC Berkeley*

Juvenile salmonids are highly mobile and seek out flow and temperature microhabitats to feed, rest, and regulate metabolism. Some of the most productive habitats for growth include side channels, off-channel ponds, isolated pools in intermittent streams, and beaver ponds, yet these also commonly experience low dissolved oxygen (DO) levels. Published sub-lethal and lethal DO thresholds are commonly used to evaluate habitat suitability. However, observational data from diverse coastal streams indicate that coho salmon and steelhead trout may survive and thrive in habitats where localized DO levels fall below these standards for days or even weeks. We hypothesize that the apparent tolerance of juvenile salmonids to DO minima are an artifact of measurement methods, in which DO is measured at point locations in discrete events, and which fail to capture variation in DO resulting from stream metabolism dynamics (photosynthesis and respiration), inputs of surface, ground, and hyporheic water, mixing, and re-aeration (diffusion across the air-water interface); we present results from multi-tracer studies that discriminate among source water to pools and identify processes driving hypoxia in intermittent streams (Larsen and Woelfle-Erskine 2018). New technologies hold promise for measuring spatial and temporal variation in DO conditions, tracking microhabitat use by salmonids, and understanding the physical mechanisms that create DO refugia for fish. Improved quantification of DO regimes complements emerging conceptual models of stream thermal-scapes (Steel et al. 2017) and foodscapes (SRF session), will help to advance understanding of DO controls on fish health and survival, and will support development of new field protocols.

Dynamics That Influence Dissolved Oxygen Concentrations in Salmonid Rearing Pools and Possible Implications for Management

***Sarah Nossaman Pierce,** California Sea Grant and **Bryan McFadin,** North Coast Regional Water Quality Control Board (Co-presenters), and Co-authors: **Mariska Obedzinski, Andy McClary, Elizabeth Ruiz, Chris O'Keefe,** and **Andrew Bartshire,** California Sea Grant; and **Lance Le,** North Coast Regional Water Quality Control Board*

Salmon and steelhead rearing in coastal California's intermittent streams often face habitat limitations during the dry summer months, including dissolved oxygen (DO) impairment, which can become a significant threat to fish as streamflow recedes. Recent studies in tributaries to Salmon Creek and the Russian River have documented a positive relationship between DO and oversummer survival of juvenile coho; however, little is known about the physical and hydraulic mechanisms that influence DO concentrations when flow approaches, or falls to, zero. While specific DO objectives have been established for California's North Coast, there is no practical method for tracking or predicting DO impairment across multiple streams. We are seeking to identify readily-measurable parameters that indicate whether DO concentrations are likely to fall below salmonid habitat suitability criteria under low flow conditions in different stream systems and, ideally, to define threshold values for those parameters.

In collaboration with partners at the North Coast Regional Water Quality Control Board and CA Department of Fish and Wildlife, CA Sea Grant designed a pilot study to address this question. We collected continuous DO data and biweekly measurements of various physical and water quantity parameters at 12 riffle-pool complexes in different hydrologic reaches of three tributaries to the Russian River over two summer seasons. We then evaluated the effect of each parameter on DO concentrations in relation to water quality standards. Additional watershed-scale covariates were also incorporated. We used a variety of modeling techniques to determine which variables best explained whether water quality conditions at each study site met minimum daily DO objectives. While further study is warranted, preliminary results yielded useful considerations for the scientific and resource management communities.

The Freshwater-Estuarine Transition Zone Part 1: Salmon Life Histories and Habitat Use

Friday Morning Concurrent Sessions

Session Coordinators*: Jay Stallman* and *Abel Brumo, Stillwater Sciences*

This session will focus on the freshwater-estuarine transition zone in coastal watersheds on the North American Pacific margin. The session will feature a diverse range of topics, including (1) hydrogeomorphic processes that create and maintain salmon habitat in riverine, floodplain, and estuarine habitats spanning the coastal plain; (2) salmon life histories and habitat use in these reaches; and (3) exemplary habitat restoration planning, implementation, and monitoring work that draws on or has contributed significantly to an understanding of physical and ecological processes in this transition zone.

Critical Connections: Freshwater-Estuary Habitat for Salmon and Marine Fishes

Rebecca Flitcroft, Ph.D., *USDA Forest Service, PNW Research Station (Presenter) and Co-authors:* ***Mary Santelmann,*** *Department of Ocean and Atmospheric Sciences;* ***Ivan Arismendi,*** *Department of Fisheries and Wildlife; and* ***Nicole Feiten*** *and* ***Aubrey Myers,*** *Water Resources Graduate Program, Oregon State University*

Linkages between freshwater, estuary, and marine environments is an emerging and critical topic of applied research. Estuaries bridge environments for anadromous fishes such as salmon, and, where habitat is available, provide a critical opportunity to express phenotypic variability that contributes to population-scale resilience. Further, estuaries are a critical rearing area for marine species. Tide-gates and other modifications to river flow made by land development may hamper connectivity between environments, limiting movement and constraining benefits of estuary habitats. Research exploring linkages between freshwater, estuary, and marine environments is still incipient: the literature is dominated by studies of freshwaters, with few articles focusing on habitat needs in estuary and marine systems. Pan-environment studies are rare, pointing to a gap in our understanding of complex habitat relationships that might be significant in the development of long-term conservation and restoration plans for Pacific salmon, particularly in light of the potential impact of climate change.

Juvenile Coho Salmon Life History Variants in Humboldt Bay Tributaries

Grace Ghrist, M.S. Candidate *and* ***Maddie Halloran, M.S. Candidate,*** *Humboldt State University (Co-presenters) and Co-author:* ***Darren Ward, Ph.D.,*** *Humboldt State University*

The decline of coho salmon (*Oncorhynchus kisutch*) in California is the result of various anthropogenic effects across the landscape, affecting all stages of their anadromous life history. As salmon habitat becomes more fragmented through human actions, the need to better understand the importance of connections between different habitats and watersheds only grows. Monitoring a subset of the remaining populations is essential to evaluate the success of management plans and develop new restoration projects. Coho salmon life-cycle monitoring programs in California generally estimate juvenile production and demographic rates using only juveniles that remain in their natal streams before outmigrating as smolts. If individuals leave their natal watershed to rear in the estuary or to enter neighboring streams, they are not counted in traditional outmigrant monitoring efforts, and smolt abundance estimates might not accurately reflect current conditions. Coho salmon in the Humboldt Bay watershed display alternative life histories that involve rearing in the estuary and moving through estuaries to adjacent watersheds, but it is unclear to what extent these individuals contribute to population growth or whether they lead to demographic connections between streams.

In the Humboldt Bay watershed, we PIT tagged juvenile coho salmon in the fall and detected their movements through tributaries and estuaries over their first winter, through smolt migration, and when they returned to spawn as adults. Using two separate multistate models, we modeled juvenile movement and survival within and between different watersheds, in order to better define the appropriate scale for this monitoring and restoration. Our models allowed us to incorporate multiple life history strategies which can be used to report unbiased survival estimates of juvenile coho salmon with different life histories.

A Novel Approach to Estimate Winter Movement and Survival of Juvenile Coho Salmon

***Nicholas Van Vleet,** Humboldt State University (Presenter), and Co-author: **Mark Henderson,** USGS California Cooperative Fish and Wildlife Research Unit*

Life history diversity of juvenile coho salmon (*Oncorhynchus kisutch*) has not been documented until relatively recently, and can have important implications for population production. Recent studies have identified multiple patterns of downstream movement into estuaries, including spring fry migrants, fall and winter parr migrants, and spring smolt migrants. The most typical pattern is spring smolt migrants, and coho salmon juveniles that migrate into estuaries as fry or parr, typically referred to as nomads, can make significant contributions to adult returns. Previous research has estimated winter movement and survival rates with mark-recapture models that utilize passivate integrated transponder (PIT) tag technology. Both movement and survival have been typically estimated in two separate Cormack-Jolly-Seber (CJS) models. Typically, these models ignore temporal variations in survival (i.e., detection date is irrelevant) in order to estimate movement and survival rates at particular locations within the study area over a period of time. In contrast to CJS models, multi-state models use mark-recapture data to estimate survival and movement within the same model framework. The multi-state model can also be used to separately estimate survival rates in space and time by having time-varying occasions paired with discrete spatial states that animals can transition between. This project uses a multi-state model to provide estimates of early emigration rates for fall/winter migrant juvenile coho salmon, as well as survival rates for spring smolt migrants. Preliminary simulation trials have been conducted to validate model structure, explore potential parameter biases, and test the effects of violations of model assumptions. Based on the results from these simulations, I developed models to examine the effect of various individual and environmental covariates (e.g., streamflow, temperature, gradient, fork length at fall tagging) on survival and migration probabilities.

Barred from the Ocean: Consequences of a Unique Estuary Phenomenon on Juvenile Growth and Population Recruitment of Chinook Salmon in Redwood Creek

***Emily Katherine Chen** (Presenter) and Co-author: **Mark James Henderson, Ph.D.,** Humboldt State University and U.S. Geological Survey, California Cooperative Fish and Wildlife Research Unit*

Estuaries are commonly touted as important habitats to juvenile salmonids, yet the broad range of characteristics of estuaries results in varying effects on salmonid recruitment. In bar-built estuaries, periods of low flow result in sand-bar formation at the mouth of rivers, closing access to the ocean. Remaining outmigrants become trapped and are unable to exit into the ocean, regardless of estuary conditions. How might this phenomenon affect the efficacy of these estuaries as juvenile rearing habitat?

We evaluated the prevalence, survival, and growth of Chinook salmon (*Oncorhynchus tshawytscha*) estuarine juveniles and compared them to ocean rearing juveniles. We marked and recaptured juvenile outmigrants in the estuary to assess estuary conditions. Scales and otoliths from spawner carcasses were evaluated to determine their juvenile life history. To assess the contribution of different life histories to population recruitment, we integrated these and additional life cycle monitoring data into a stage-structured life cycle model in the Bayesian framework. The results of our study provide insight into the efficacy of bar-built estuaries, an estuary type that may become more prevalent with the rise in frequency of drought conditions in the state.

Influence of Environmental Variability on Juvenile Steelhead Abundance, Growth, and Movement in a Seasonally Closed California Estuary

Rosealea M. Bond, *UC Cruz and NMFS Southwest Fisheries Science Center (Presenter), and Co-authors:* ***Ann-Marie K. Osterback, Cynthia Kern, Alexander Hay,*** *and* ***Jeff Perez,*** *UC Santa Cruz and NMFS Southwest Fisheries Science Center;* ***Joseph D. Kiernan,*** *NMFS Southwest Fisheries Science Center*

Estuaries serve a critical function in the early life history of anadromous Pacific salmon by providing a physiological transition zone, connectivity between diverse habitats, and enhanced growth opportunities prior to ocean entry. In California, many estuaries become seasonal lagoons during the dry season when sandbars disconnect streams from the ocean. Recent research conducted in the Scott Creek watershed (Santa Cruz County) demonstrated that juvenile steelhead (*anadromous Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) were able to persist and grow throughout the duration of lagoon closure, despite protracted periods of high water temperature (>20) and low dissolved oxygen concentration. Oversummer persistence of salmonids was presumably facilitated by abundant prey resources in the lagoon and the retreat of individuals to less stressful (i.e., cooler) riverine habitat in the lower watershed. Although abiotic conditions in the Scott Creek lagoon have been well-documented, conditions immediately upstream of the estuary remain poorly understood.

To better understand how juvenile salmonids responded to dynamic abiotic conditions in the seasonal lagoon and adjacent freshwater habitat, we conducted an intensive study in the lower 1.75 km of Scott Creek during the 2018 dry season (June-November). We deployed a distributed temperature sensing instrument and fiber-optic cable (total cable length of 1.6 km, nodes every 0.25 m, measurements every 10 min) to continually characterize the thermal regime of the lagoon and lower mainstem creek. Monthly water chemistry profiles were used to track the longitudinal position of the freshwater-estuarine interface and document areas of thermal stratification. We concurrently conducted monthly mark-recapture sampling in the Scott Creek lagoon to quantify juvenile steelhead abundance, growth, and movement during the study period. A series of stationary PIT tag antenna arrays—operated in the lower lagoon (River kilometer (rkm) 0.59), upper lagoon (rkm 1.03), and mainstem creek (rkms 1.32 and 1.70)—provided insight into relationships between fish movement patterns and environmental conditions in each area.

Following sandbar closure on 03 July, lagoon water temperature increased from 17 °C to over 22 °C by mid-August. In contrast, riverine water temperature immediately upstream of the freshwater-estuarine transition zone was consistently more than 4 °C cooler during this period and likely served as important thermal refuge habitat for steelhead. By mid-September lagoon water temperature had cooled and thermal conditions were similar in the lagoon and lower mainstem creek. We found juvenile steelhead were abundant in the Scott Creek lagoon and exhibited positive growth during all months of the study. Fish movement was bi-directional between the lagoon and mainstem creek and the frequency of movement events was associated with changes in water temperature. This study demonstrates the dynamic nature of coastal lagoons and underscores that connectivity between lagoon and riverine habitats is critical for the oversummer persistence of juvenile salmonids.

Prioritizing Actions to Accommodate Multiple Salmonid Rearing Strategies in Lower Elk River, Humboldt Bay, CA

Darren Mierau, *CalTrout (Presenter) and Co-authors:* ***Jay Stallman,*** *Stillwater Sciences;*
Bonnie Pryor *and* ***Jeff Anderson,*** *Northern Hydrology and Engineering*

In heavily degraded watersheds, decisions about where to invest resources to best achieve salmonid population recovery are often challenging due to uncertainty in historical ecology and desired future conditions, incomplete technical information, and lack of reliable decision support models to weigh alternative approaches. In Elk River, the largest tributary to Humboldt Bay, excessive channel aggradation with fine sediment coupled with chronic high suspended sediment concentrations resulting from timber harvest affect all salmonid life stages. In addition to sediment impairment, land use changes have transformed the lower 8.5 miles of the Elk River valley from a mosaic of different vegetation types and connected secondary flow pathways to monotypic agricultural lands and rural residential developments with roadways, dikes, drainage channels, and tidegates disrupting floodplain and tidal connectivity. Past management of these areas has retained some of the historical channel and floodplain functions, which provides substantial restoration opportunities with fewer constraints than in more urbanized areas. Several alternative juvenile rearing strategies existed within the historical valley mosaic, and some of these tactics persist within the currently degraded habitat conditions.

We previously reported during development of the Elk River Recovery Assessment (Pryor et al., SRF 2015) that effective restoration in these situations requires (1) documenting existing conditions; (2) defining desired conditions; (3) identifying site specific opportunities and constraints; (4) predicting the system trajectory with existing sediment loads; and (5) predicting the system trajectory with reduced sediment loads. After subsequently completing empirical studies and modeling with these objectives in mind, we have a much-improved understanding of current fluvial processes, salmonid habitat impairments, and the expected results of large-scale recovery actions throughout the 18-mile project area. Potential treatments likely required to achieve measurable salmonid population responses in lower Elk River and associated tidal reaches include:

- Controlling sediment sources from the upper watershed through timberland management;
- Trapping sediment to prevent fine sediment from being transported downstream to aggraded mainstem channel reaches;
- Mechanically removing sediment stored in mainstem channel reaches to restore flood conveyance, improve sediment transport continuity, and increase the potential to scour pools and sort bed material;
- Extensively reconstructing instream habitat;
- Expanding and improving the riparian corridor;
- Selectively lowering natural levees to maintain floodplain connectivity and directed flood-flow pathways; and
- Restoring tidal marshes and slough channels with full or muted tidal inundation.

Restoring hydrogeomorphic processes and salmonid population abundance to Elk River will require considerable investment in sediment remediation and habitat rehabilitation driven by strategic decision-making. We look forward to further developing a shared vision of a restored Elk River valley and estuary through the Elk River Watershed Stewardship Program.

Let the River Run: Insights into Understanding the Klamath Basin

Friday Morning Concurrent Sessions

Session Coordinators*: Michael Belchik, Yurok Tribe, and Cynthia Le Doux-Bloom, Ph.D., Humboldt State University, Department of Fisheries Biology*

The session will feature a range of insightful topics related to the Klamath River and key Tributaries, including: (1) Klamath Dam Removal Overview; (2) Baseline Klamath River Physical Data Analyses Pre-Dam Removal; (3) Genetics of spring Chinook and relevance to reintroduction efforts post-dam removal; (4) Reintroduction Potential for Coho Salmon after Dam Removal; (5) Genetics of Pacific Lamprey and use of Modern Genetics Techniques and Traditional Environmental Knowledge; and (6) Potential Comprehensive Restoration Strategies in the Scott River.

Presenters include tribal and agency scientists, academics conducting studies in the Klamath Basin, and the Executive Director of the Klamath River Renewal Corporation.

Overview of the Klamath River Renewal Project

Mark Bransom, *CEO, Klamath River Renewal Corporation*

The Klamath River Renewal Corporation (KRRC) is an independent nonprofit organization formed in 2016 as part of the amended Klamath Hydroelectric Settlement Agreement (KHSA). Signatories of the amended KHSA, including the States of California and Oregon, local governments, Tribal nations, dam owner PacifiCorp, irrigators, and several conservation and fishing groups, appointed KRRC to take ownership of four PacifiCorp dams — JC Boyle, Copco No. 1 & 2, and Iron Gate — and then remove these dams, restore formerly inundated lands, and implement required mitigation measures in compliance with all applicable federal, state, and local regulations.

KRRC is undertaking baseline monitoring and field studies and will be responsible for monitoring and adaptive management after dam removal. KRRC and PacifiCorp's joint application for license transfer and KRRC's application for license surrender will be evaluated by FERC and are subject to environmental review under the National Environmental Quality Act (NEPA), the California Environmental Quality Act (CEQA), and other environmental permitting processes. Early construction will begin as soon as 2020, setting the course for dam removal in 2021. Sediment release will take place between January and March to minimize impacts to aquatic species. The prior NEPA analysis (2012) found that impacts from dam removal on lower river salmonids (particularly sediment impacts) would be short-term and last approximately one to two years. Oregon Department of Environmental Quality (ODEQ)'s issuance of its final Section 401 Water Quality Certification in September of 2018 confirms that the removal of J.C. Boyle Dam will, in the long term, provide substantial water quality improvements to the Klamath and will help combat fish disease and toxic algae blooms.

Populations are expected to recover from sediment impacts by year five, after which significant benefits to migratory fish are expected. Specifically, fall-run Chinook populations could increase by up to 80%. These issues will be more closely studied in the forthcoming FERC, NEPA, and CEQA analyses. Anticipated KRRC project benefits include: 1): anadromous fish passage to and from at least 420 miles of historical habitat above Iron Gate Dam (when combined with fish passage at Keno Dam), 2) anadromous fish access to low gradient historical habitat of critical importance to spawning and rearing under Copco 1 and Iron Gate Reservoirs, 3) natural recruitment of spawning gravel and river processes within and below the Hydroelectric Reach, 4) elimination of much of the elevated late summer/fall water temperatures in and below the Hydroelectric Reach by removing the largest reservoirs, 5) improved dissolved oxygen and pH conditions , 6) elimination of much of the algal toxins produced in the Hydroelectric Reach and transported downstream, and 7) reduced concentrations of myxospores associated with carcasses accumulating below hatchery facilities, thus reducing disease. This presentation will provide an update on regulatory processes, technical developments, schedule, and other elements of the dam removal and restoration program

Analyses of Ancient and Contemporary Klamath Basin Spring Chinook Provide Insights for the Future

Tasha Q. Thompson, UC Davis, Animal Science Department

The Klamath historically hosted hundreds of thousands of adult spring Chinook, but only a small fraction of those numbers remain. Here, we review both the historical and contemporary distributions of spring Chinook in the Klamath to provide insights for conservation of remaining populations and restoration in the upper basin after Klamath dam removal. First, we examine archaeological samples from sites above the Klamath dams. Identification of spring Chinook among the samples agrees with historical documentation and suggests the presence of spring Chinook in the upper basin dates back at least thousands of years. Next, we consider the contemporary distribution of spring Chinook in the basin, with insights from an analysis of samples from carcass surveys. Finally, we discuss the implications of our results for the future of spring Chinook conservation and restoration in the Klamath.

Pre-Dam Removal Topographic Base-Line Data Collection on the Klamath River—Collaboration in Action

David (DJ) Bandrowski, P.E., *Yurok Tribe (Presenter)*
and Co-authors: ***Tony Jackson,*** *PLS – USACE; and* ***Jenny Curtis,*** *USGS*

Four dams on the Klamath River are planned for removal in 2021 to restore volitional fish passage and salmonid habitat across more than 400 miles of river in the upper Klamath basin. During dam removal a substantial portion of the accumulated sediment will be released to the river downstream in a relatively short period of time. The release of reservoir sediment has the potential to impact downstream reaches in a variety of ways across a range of temporal and spatial scales. Sediment erosion, transport, and deposition provide the underlying physical framework for the responses of aquatic and riparian ecosystems to dam removal. Thus, pre-dam removal baseline survey of river bed bathymetry and near shore terrestrial topography are necessary to understand potential responses and impacts to flood hydraulics, geomorphic evolution, and sediment transport dynamics. System-wide topographic surveys will underpin a quantitative understanding of both the short and long term river response to dam removal. This data collection effort will also serve as the foundational dataset to be used in the future to quantify and compare physical change and sediment transport processes over time.

During the summer of 2018 a multi-agency team collected this topographic data across the Klamath basin from the estuary to Iron Gate Dam. Phase I of the project was an Aerial Imagery and LiDAR (topo-bathy) survey flown in June of 2018 by Quantum Spatial Inc. (QSI) with funding support from USGS, NOAA, KRRC, and others. Phase II was a bathymetric boat-based hydrographic multi-beam sonar survey through a collaboration between the Yurok Tribe, Hewlett Foundation, and U.S. Army Corps of Engineers – Engineering Research and Development Center (ERDC). Currently the multiagency team is in the process of completing Phase III which is the post-processing of the entire data set into a fully integrated mosaic that will produce a seamless topographic Digital Terrain Model (DTM) of the entire Klamath River. Phase IV will be the development of a 2D-Hydrodynamic Model of the river's existing flow conditions that will be implemented by the Bureau of Reclamation – Technical Service Center (TSC) – Sedimentation and River Hydraulics (SRH) Group. The final goal of the project is to have a foundational data set that management and the scientific community will utilize to better understand the effects of dam removal, measure geomorphic evolution, and help monitor the biological response of a newly free-flowing Klamath River.

Recolonization Potential for Coho Salmon in California Tributaries to the Klamath River Above Iron Gate Dam

Max Ramos, M.S. Candidate, *Humboldt State University (Presenter), and* ***Darren Ward, Ph.D.,*** *Humboldt State University*

Four major dams on the Klamath River are slated for removal in 2021, restoring access to hundreds of miles of potential habitat for anadromous fishes. The coho salmon (*Oncorhynchus kisutch*) in the Klamath River are classified under the Southern Oregon/Northern California Coast evolutionarily significant unit as a threatened species. We are using physical habitat and biological features of three major tributaries to the Klamath River above the dams to assess available habitat and its fundamental capacity to support coho salmon post dam removal. The intrinsic potential (IP) modeling approach developed by the National Oceanic and Atmospheric Association (NOAA) and the habitat limiting factors model (HLFM) developed by Oregon Department of Fish and Wildlife (ODFW) will be utilized to assess habitat. In addition, we are developing an occupancy model using a Bayesian approach and data from reference sites below the dam and from other watersheds to estimate the potential distribution and abundance of juvenile coho salmon at the sites. Results from this analysis can be used to make management decisions for habitat restoration efforts and future coho salmon population goals.

Evidence for the Genetic Basis and Inheritance of Ocean and River-Maturing Ecotypes of Pacific Lamprey (*Entosphenus tridentatus*) in the Klamath Basin

Keith Parker, M.S., *Yurok Tribe Fisheries Department (Presenter),*
and Co-authors: ***Andrew Kinziger, Ph.D.*** *Humboldt State University;*
Jon Hess, Ph.D.*, and* ***Shawn Narum, Ph.D.,*** *Columbia River Inter-Tribal Fish Commission*

The Klamath Basin supports the highest diversity of lamprey species (n=5) of any single watershed in the world, with the anadromous Pacific lamprey suggested to have been the river's biomass-dominant fish species historically. Pacific lamprey are important contributors of marine-derived nutrients and organic matter to the food web of oligotrophic streams which are far inland from the Pacific Ocean, a primary food source for pinnipeds, and likely a trophic level buffer to some species of migrating salmon as pinnipeds preferentially consume Pacific lamprey.

Culturally, Pacific lamprey are a tribal trust fish species protected under tribal treaty and other rights, continue to provide direct subsistence when other high lipid foods (e.g., salmon) which are unavailable to Native American Tribes of the Basin, while providing the high caloric values (2x-4x kcal/g of salmonids) for indigenous people coinciding with the coldest season of the year. The Klamath River Tribes possess traditional ecological knowledge (TEK) of Pacific lamprey including run-timing, harvest methods, and indirect subsistence provided by the hunting of estuarine marine mammals which historically followed the freshwater migration of thousands of adult Pacific lamprey. Currently, Pacific lamprey harvest in the Klamath Basin has reduced substantially due to declines in abundance, impacting Klamath River tribes with adverse health, social, economic, and spiritual effects.

Surveys of genetic variation have improved our understanding of the relationship between fitness-related phenotypes and their underlying genetic basis. We investigated the association of genetic variation with ecotypic differentiation in Pacific lamprey as they initiated their anadromous migration by intercepting 219 individuals over 12 months in the Klamath River, utilizing Native American traditional methods of catch (eel hook). Each individual was genotyped (GT-seq method) at 308 neutral and adaptive single nucleotide polymorphism (SNP) loci and recorded morphological traits, including egg mass as an indicator of female sexual maturity. The onset for freshwater migration for an ocean-maturing ecotype (mature eggs) identified was predominantly the winter, whereas a river-maturing ecotype (immature eggs) entered during all seasons and a genetic basis of the ecotype diversity was revealed. Genotype-phenotype association mapping identified sixteen SNPs significantly associated to egg mass forming two groups of linked loci and ten other SNPs significantly associated to total length. A duplicate dominant epistasis inheritance model best supported the ocean- and river-maturing ecotypes, accurately predicting ecotype in 83% of the samples. The adaptive genetic variation revealed is useful for conservation planning as it indicates that the river-maturing ecotype carries standing genetic variation capable of producing both ecotypes (e.g., both heterozygous and homozygous individuals), while the ocean-maturing ecotype is almost exclusively homozygous.

A restoration application of these molecular findings is that when assessing stream restoration projects, the river-maturing ecotypes could perhaps be prioritized as they contain the genetic diversity capable of producing both ecotypes (i.e., heterozygosity), whereas the ocean-maturing ecotypes do not. Additionally, healthy populations of Pacific lamprey could be used as an indicator of ecosystem health, effective restoration implementation, and recovery of flow-watershed relationships.

Developing a Comprehensive Restoration Plan for the Scott River—Klamath Basin

Erich Yokel*, Scott River Watershed Council (Presenter), and Co-authors:*
Charnna Gilmore *and* ***Betsy Stapleton****, Scott River Watershed Council*

The Scott River, a major tributary to the Klamath River, is a highly productive, low gradient river system that currently supports one of the largest populations of wild Southern Oregon/Northern California Coast (SONCC) coho salmon. These wild coho are an important resource for repopulating the upper Klamath Basin after dam removal.

In the Scott River, as is the case with most ecologically valuable alluvial valleys, legacy effects have significantly altered the stream and riparian condition and human infrastructure dominates the landscape. Finding restoration opportunities in this setting is a complex task involving both scientific and social considerations. The Scott River Watershed Council (SRWC) has completed a two-year planning effort to identify the highest value restoration opportunities for coho salmon in the Scott Watershed.

The SRWC utilized a LiDAR DEM and the River Bathymetry Toolkit (RBT) in ArcGIS to identify and prioritize potential sites for floodplain and off channel habitat restoration in the Scott River Watershed. The RBT was used to generate inundation models for the Scott River and thirty-one tributaries (154 miles). The inundation models were utilized to identify areas with floodplain connectivity and/or potential off channel habitat features (e.g. abandoned historic channels). Fifty discrete sites were identified and evaluated for future project planning and implementation.

In addition to the identification and prioritization of the discrete sites, an analysis was performed to identify unconfined stream reaches with high quality riparian canopy that are connected during the base flow period. Classified layers were created and combined to identify stream reaches with suitable physical characteristics to support coho salmon; generating a reach level prioritization for future protection, enhancement, and restoration programs.

In conjunction with the GIS mapping techniques, on-the ground evaluations and community outreach efforts were used to create a guide for Scott Watershed restoration that balances ecological and human considerations.

This session will share the technical and social process undertaken, as well as the results of the effort. The authors believe the study's methodology can be applied to the basins above the four Klamath dams that will be removed to identify streams with restoration potential and existing habitat for anadromous salmonids.

New Approaches to Investigate Salmon-Habitat Relationships in Hydrologically Altered River Basins

Friday Afternoon Concurrent Sessions

Session Coordinator*: Eli Asarian,* *Riverbend Sciences*

This session will feature a range of novel approaches for investigating salmon-habitat relationships. Featured watersheds include the Eel, Noyo, Trinity, Klamath, San Joaquin, Sacramento, Stanislaus, and Tuolumne Rivers. Approaches include new genetic technologies, modeling software, and metrics.

Every Fish That Dies Gets Eaten

JD Wikert, *U.S. Fish and Wildlife Service*

Outmigrating juvenile salmonids in the San Joaquin Basin experience low survival. One suite of possible management actions includes efforts at reducing impacts from predators on these juvenile fish. Several studies have been undertaken on the Stanislaus River in an effort to understand factors influencing mortality in juvenile salmonids. Both flow and habitat have been identified as significant factors influencing mortality during rearing and migration of juvenile salmonids. A better understanding of relationship between flow, habitat, and predation will greatly assist in effectively managing limited resources to support self-sustaining populations of salmon and steelhead. Multiple factors influencing mortality will need to be addressed to achieve any lasting improvement in survival of juvenile salmonids. Come to the presentation for more detail on this important topic.

A New Metric for Measuring Downstream Effects of Dams on Floodplain Inundation on Floodplain Inundation

Alison G. Willy, *U.S. Fish and Wildlife Service (Presenter) and Co-authors:* ***Stephanie D. Millsap, Lauren R. Sullivan,*** *and* ***Mark Gard,*** *U.S. Fish and Wildlife Service*

It has been well established that dams can alter the natural hydrographs of rivers, often by diminishing the magnitude, timing, duration, and frequency of hydrograph components. The importance of floodplain habitats as rearing habitat for juvenile salmonids has also been well documented. Traditional methods of quantifying flow changes do not address changes to inundation in floodplain habitats. The USFWS has developed a cumulative acre-day metric that integrates floodplain inundation over time and space. When a cumulative acre-day analysis was conducted for the Stanislaus River and the Tuolumne River, a positive relationship was shown between cumulative acre-days inundated and juvenile salmon survivorship for each river. A cumulative acre-day analysis can also be used to compare how alternative flow proposals affect floodplain inundation. This metric has been used to both quantify the loss of juvenile salmonid rearing habitat in the Yuba, Tuolumne, and Sacramento Rivers and also quantify the acres of floodplain restoration necessary to mitigate for inundation reductions.

Predicting Salmonid Spawning Habitat Using Geospatially Constructed Stream Morphology Derived from High-Resolution LiDAR-Derived DEMs and Field Survey Data in the Indian Creek Watershed, Mendicino County, CA

Justin P. Bissell, *GIS Manager, Pacific Watershed Associates*

Development of GIS tools and methods to accurately model stream geomorphology is of key importance to state and private agencies seeking to provide for human safety, economic development, and management of natural resources. In service to this, a new GIS toolset (Numerically Interpolated Flow Track Inferencing - NIFTI) was developed to predict stream geomorphology using a high-resolution Digital Elevation Model (DEM) and field data. The NIFTI toolset, developed with ESRI ArcMap, R-ArcGIS Bridge, ArcHydro, Spatial Analyst, and R-Studio, takes inputs of high-resolution DEM data, an estimate of threshold contributing area for stream inception, and calibration points of known or estimated bankfull widths. Outputs include bankfull width predictions, stream channel centerlines, and bankfull corridors for the entirety of the modeled hydrologic network for the extent of the DEM. Given inputs of stream depths in selected locations, NIFTI can also develop depth predictions; additionally, inputs of stream widths at flood stage can yield watershed-scale flood stage stream width predictions. The toolset can be used by any discipline with an interest in stream hydrology, including water resources, stream/river geomorphology, and flood hazards. The NIFTI GIS toolset was originally developed to geospatially model endangered salmonid species habitat in the Indian Creek Watershed (tributary to the South Fork Eel River) and thus to assist in grant funding and intelligent decision-making for resource use. Outputs from the NIFTI toolset were successfully used in conjunction with other DEM-derived data and field surveyed presence location data of salmonid spawning habitat in MaxEnt to derive watershed-wide spawning habitat probability surfaces specific to the stream system. All geospatial outputs from the project—NIFTI-generated stream morphology predictions (bankfull widths, stream corridor morphology, and stream centerlines)—were field-verified by the author, Pacific Watershed Associates staff, and California Department of Fish and Wildlife staff. Limitations and uncertainty of the NIFTI toolset include that the accuracy of outputs from the NIFTI toolset become questionable when the stream widths being modeled are less than the resolution of the DEM input, or when there is a high degree of anthropogenic disturbance on the landscape. Though the toolset and geostatistical models used for prediction were developed for a high degree of flexibility while retaining accuracy, there may be unforeseen effects in using the NIFTI toolset in other environments, and it is always recommended that field verification of results be performed.

Using Genetics to Investigate the Ecology and Distribution of Summer Steelhead in the Eel River Basin

Samantha Kannry, *UC Davis, Ecology Graduate Group*

The Eel River is home to some of the southernmost extant populations of summer-run steelhead. Summer dive surveys of the two Eel River populations have resulted in population estimates that average 800 adult fish in the Middle Fork Eel River and 150 adult fish in the Van Duzen River, both quite low for long term persistence. The summer-run life history is an important example of an adaptive variation that has the potential to increase resilience of a species, considering cumulative anthropogenic ecosystem alterations. We collected tissue samples distributed throughout the basins, of primarily juveniles, with a focus above and below migration barriers. The migration barriers included several partial and complete barriers in the form of steep boulder roughs and waterfalls in the Van Duzen and Middle Fork Eel Rivers. We also collected samples from the Upper Eel River to look for the presence of summer-run alleles in what is now a solely resident population since the construction of Scott Dam in 1922. We will utilize recently developed markers at the GREB1L locus to determine the migration type (summer-run or winter-run) of individuals. We will also analyze population structure using Rapture sequencing data to provide insight into the adult spawning and juvenile rearing distributions, as well as the ecological factors that have allowed premature migrants to persist in these locations despite having been extirpated from many other rivers in California. This research will help to better inform future conservation and management of this species.

Modeling Flows in Northwest California Watersheds with VELMA-2.0

Melissa Collin *and* ***Sean Fleming,*** *Humboldt State University (Co-presenters)*
and Co-authors: ***James Graham Ph.D.,*** *Humboldt State University,* ***Jonathan Halama Ph.D.,*** *Willamette University,* ***Bob McKane Ph.D.,*** *and* ***Paul Pettus,*** *Environmental Protection Agency*

The watersheds of Northern California are dynamic and continually changing environments that provide ecological benefits to the wildlife and living communities (CA's Primary Watershed, 2017). Many of these watersheds have high temporal variability in flow rate, precipitation, temperature, and other factors (Abdelnour, et al, 2011). What we do not know is the degree in which these variables are changing daily, monthly, and annually, and their effects on the surrounding areas. Our research looks to utilize the watershed modeling software VELMA 2.0 (Visualizing Ecosystem Land Management Assessments) developed by the EPA (Environmental Protection Agency) to study Northern California watersheds. The objective of this research is to create a lens through which to accurately model water flow rates throughout California, with the focus of the study being the interpretation of Nash-Sutcliffe statistical scores (Nash & Sutcliffe, 1970). The Noyo, Eel, Trinity, and Russian River watersheds were the watersheds selected for this research. Their selection was based off of data accessibility, their close proximity to one another, and also being some of the largest watersheds of Northern California.

Of our four selected watersheds, we were able to successfully run three, the Noyo, Trinity, and Eel. Of the three watersheds we modeled, the Noyo watershed resulted in the highest output average of the Nash-Sutcliffe statistical accuracy, with an average of 0.78 and a peak of 0.94 in the year 2010. The Eel had an average Nash-Sutcliffe statistical accuracy of 0.31, with the peak coefficient being 0.54 in 1998. The Trinity had the lowest Nash-Sutcliffe statistical accuracy, with an average of -3.44 and a peak of 0.28 in the year 1997. The Russian River watershed simulation experience an unexpected error and has not yet been successfully run.

The Noyo watershed was the most accurate due to multiple factors. The Noyo has by far the smallest drainage area, only spreading across 106 sq. miles, while comparatively the Eel River watershed has a drainage area of 3,113 sq. miles and the Trinity's drainage area is 2,936 sq. miles. The Noyo River is also the least changed by humans, with no dams or major diversions, unlike the Eel and Trinity.

To increase overall accuracy of both the Eel and Trinity Rivers, adding additional pour points/gauge stations could help improve scores and analysis. VELMA could be run using a gauge station located before a large water diversion, such as the Trinity Dam located outside of Weaverville in the Trinity watershed. Running the simulation with different pour points could potentially improve the simulation by looking at flow rate located before a drastic change in flow. Breaking the larger watersheds into smaller subsets could also increase potential accuracy.

The software VELMA-2.0 was able to model impacts that varying flow rates, chemical contamination, temperature, land cover, and precipitation have on the ecology of a bioregion. This application could be used to produce accurate simulated flow rates that can assist in future watershed analysis.

Rates of Whole River Primary Production Influence Water Quality and Basal Food Web Resources in the Klamath River

Laurel Genzoli, *University of Montana (Presenter), and Co-authors:*
Robert O. Hall, *Flathead Lake Biological Station, University of Montana,*
and ***Eli Asarian,*** *Riverbend Sciences;* ***Jacob Kann,*** *Aquatic Ecosystem Sciences*

The growth and decay of algae and aquatic plants influence salmon habitat, but quantifying these processes in rivers is challenging. River metabolism, which includes estimates of gross primary production (GPP) and ecosystem respiration (ER), can be used to better understand salmon-habitat relationships in rivers by describing basal food resources and because these processes influence dissolved oxygen concentrations and pH levels, both of which are important water quality considerations for salmon.

Although long-term studies of patterns and controls on GPP and ER in rivers are limited, affordability of in-stream oxygen sensors and developments in statistical methods are making daily measurements of ecosystem metabolism more accessible. We calculated daily ecosystem metabolism at three reaches on the Klamath River from 2007–2017 during the May–November water quality monitoring season using monitoring data collected by the Karuk and Yurok tribes. Daily GPP on the Klamath River reached rates among the highest values reported for rivers (> 20g O2 m-2 d-1). There was a strong relationship between GPP and ER, which, coupled with positive values of net ecosystem production (NEP), suggest that the Lower Klamath River derives most of its energy from in-situ primary production during the monitoring period. Lower NEP at downstream sites indicate an increasing dependence on transported algae or terrestrial derived materials at these sites that are a greater distance from dams and reflect a larger watershed area. GPP was low during spring run-off, because discharge likely controls within year variation in GPP, while variation in GPP during summer base-flow may be driven by nutrients and internal dynamics, such as primary producer assemblages. Higher maximum daily pH values and lower minimum daily dissolved oxygen values, indicating poor water quality conditions, were associated with higher rates of GPP. Daily estimates of GPP and ER allow for assessing the controls on these ecosystem processes, bringing us closer to identifying the range of conditions that lead to salmon-supporting riverine food webs and water quality.

The Freshwater-Estuarine Transition Zone Part 2: Habitat Restoration Planning, Design, and Implementation

Friday Afternoon Concurrent Sessions

Session Coordinators***: Jay Stallman , PG,*** *and* ***Abel Brumo,*** *Stillwater Sciences*

This session will focus on the freshwater-estuarine transition zone in coastal watersheds on the North American Pacific margin. The session will feature a diverse range of topics, including (1) hydro-geomorphic processes that create and maintain salmon habitat in riverine, floodplain, and estuarine habitats spanning the coastal plain; (2) salmon life histories and habitat use in these reaches; and (3) exemplary habitat restoration planning, implementation, and monitoring work that draws on or has contributed significantly to an understanding of physical and ecological processes in this transition zone.

Using Coho Salmon Monitoring in the Smith River to Advance Restoration Planning

Marisa Parish Hanson, Smith River Alliance

The historic floodplains and surrounding landscapes of many coastal streams contain the elements needed for human settlement, development, and cultivation of agricultural resources. Like many coastal plains and estuaries, the Smith River coastal plain has undergone extensive road development, diking and draining using levees, tide gates, and riprap to accommodate human settlement and land use practices. These alterations have resulted in degraded quality and quantity of available salmonid habitat in the estuary and coastal streams. Low gradient freshwater estuarine habitats such as sloughs, backwaters, off channel ponds, and emergent tidal wetlands are especially productive areas for rearing juvenile salmonids throughout the Pacific Northwest and in California, including in the Smith River Plain. Estuaries and other riverine habitats along the coastal plain represent a small fraction of area in a given watershed, but their role in salmonid productivity can be substantial given all anadromous fish use the estuary prior to ocean entry.

Beginning in 2011, the Smith River Alliance (SRA) and California Department of Fish and Wildlife established the most intensive basin-wide salmonid monitoring effort to date in the Smith River. We monitored abundance, spatial structure, and productivity of multiple life stages of salmonids, particularly ESA threatened coho salmon. These efforts led to more focused spatial and temporal monitoring of salmonid habitat use and availability in the estuary and coastal plain beginning in 2014. The Smith River Alliance used results from these concurrent studies to work with the Del Norte Resource Conservation District and landowners for a restoration planning effort across the Smith River coastal plain.

Our planning process used biological data as well as landowner feedback to implement a holistic conservation planning approach of evaluating ecological as well as economic and social factors. Land ownership, opinions, and land management goals may change over time, while the biological impacts and benefits of a project are static. Therefore, a biological score and total project score were calculated to allow for all projects to be evaluated on their biological merit alone, as well as with social and economic factors. Our goal was to identify and prioritize restoration opportunities along anadromous streams. Restoration objectives focused on restoring stream function, improving long-term ecosystem health, increasing water quality, supporting recovery of salmonids, and protecting biological integrity and biodiversity across the Smith River Plain.

The recently completed plan provides a foundation of scientific knowledge and input from resource professionals and landowners, with consistent and subjective evaluation of 137 restoration opportunities across the Smith River Plain. SRA is now using this plan to advance high priority restoration actions with willing landowners. Our actions aim to reach a balance of improving stream health while considering landowner management needs in the Smith River Plain.

Design of Tide Gates to Maintain Estuarine Function in Muted Tidal Systems

Rachel Shea, P.E., Engineering Geomorphologist, Michael Love & Associates, Inc.

The juxtaposition of managed low-lying areas and tidal systems often necessitate the use of tide gates. Tide gates are typically one-way culverts with gates that remain closed on incoming tides to prevent tidal waters from inundating low-lying land and streams that were historically tidal but are now freshwater riverine systems. On outgoing tides or during high flow events, the gates open and allow stream flows to drain into the tidal system. Traditional tide gates effectively preclude an estuarine environment upstream of the gate and block native aquatic species from movement into riverine systems.

In recent years, a new generation of tide gates have been designed and installed with the intent of improving the connection between tidewater and freshwater systems. These new tide gates allow a limited amount of tidal inflow, called a muted tide, into the riverine system to create a longitudinal transition from the marine to freshwater environment while preventing upstream tidal flooding.

The new generation of tide gates mute the incoming tides with the use of a float system that holds the gate open on an incoming tide until the upstream stage reaches a predetermined threshold, then closes the gate. They often have a small adjustable opening on the main gate to allow aquatic organism passage and a small amount of tidal inflow once the main gate closes. These gates also use side-hinged doors that allow exchange of the full water column, produce slower water velocities to accommodate fish passage, and improve outflow.

Tidal muting and tide gate design and operation can have significant effects on the development of a functioning estuarine system upstream of the tide gate. Design of muted tidal systems involves extensive hydraulic analyses to evaluate passage of aquatic species, prevent upstream tidal flooding, and create the desired estuarine conditions, including salt marsh vegetation zonation and mixing zones.

This presentation will illustrate the types of analysis and considerations employed with this new generation of tide gates. Two constructed tide gates designed to provide aquatic organism passage and to promote development of the full range of tidal marsh species will be used as case examples to highlight the design process.

Martin Slough Enhancement Project: Landscape Scale Restoration in Humboldt Bay

***Bob Pagliuco**, NOAA Restoration Center (Presenter) and Co-authors: **Craig Benson**, Humboldt State University; **Don Allan**, Redwood Community Action Agency; **Karlee Jewell**, Northcoast Regional Land Trust; **Morguine Sefcik**, Redwood Community Action Agency*

Juvenile coho salmon seek slow velocity areas as rivers rise during storm events, and studies have shown a significant increase in the growth and survival of juvenile coho salmon who occupy off-channel habitats near the estuary for refuge or rearing opportunities. Additionally, off-channel features also provide lentic habitat that many wildlife species rely upon for crucial reproductive or migratory life history purposes. These habitats have become limited in Humboldt Bay, CA due to a number of factors, including channelization and loss of wetlands. Martin Slough is an important tributary adjacent to the Elk River estuary that provides crucial non-natal rearing habitat for one of the largest coho producing tributaries of Humboldt Bay.

The Martin Slough Enhancement Project is a multi-phased landscape-scale project that will increase the resiliency of the coastal ecosystem by restoring a muted tidal inundation supporting restored tidal wetlands, improve fish access through a tide gate, decrease the vulnerability of the coastal community by reducing flood impacts, use spoils from Martin Slough for tidal marsh restoration in the White Slough Unit of the Humboldt Bay National Wildlife Refuge, and increase the diversity and amount of fresh and saltwater wetland/estuarine habitat, off-channel habitat, and riparian vegetation in this important tributary. The project will support the recovery of steelhead, Chinook, coho and other protected marine resources such as tidewater goby while striving to achieve a healthy balance between agriculture, recreation, and habitat. The Redwood Community Action Agency has been leading this project for the past 18 years and has partnered with the landowners (Northcoast Regional Land Trust and the City of Eureka) to restore this habitat on a working landscape that supports cattle grazing and a municipal golf course.

The Martin Slough Enhancement Project was awarded DWR, NOAA, USFWS, SCC, California Natural Resources Agency, and Ocean Protection Council as project funders funding in 2017 to complete phases 2-4 of this project. This presentation will provide details on the planning, design, implementation, and monitoring results of the landscape-scale restoration project on Martin Slough, highlight partnerships, and focus on lessons learned.

Recreating Extended-Duration Flooded Wetlands and Habitat Complexity in the Lower Ten Mile and Garcia Rivers

Lauren Hammack, *Prunuske Chatham, Inc. (Presenter) and Co-authors:*
David Wright, *The Nature Conservancy and* ***Mike Jensen,*** *Prunuske Chatham, Inc.*

Within the Central California Coast coho range, many alluvial floodplains in the stream-estuary transition zone have undergone extensive aggradation as a result of intensive land use practices dating back to early European settlement. A full one to two meters of aggradation is not uncommon. This aggradation has disconnected channels from their floodplains and reduced overall habitat complexity. Additionally, many Central Coast streams and rivers now overtop their floodplains during peak flow events that exceed the five-year recurrence interval storm.

Recovery of Central California Coast coho populations will require restoring access to floodplain habitat in the stream-estuary transition zone. In acknowledgement of this, The Nature Conservancy has secured conservation easements in the lower reaches of the Ten Mile River and Garcia River to protect and enhance critical coho habitat.

Multi-year hydrogeomorphic and salmonid utilization studies were conducted to document existing habitat conditions and use in the approximately two-mile-long project reaches. Habitat enhancement concept designs and construction plans were then developed with input from multiagency technical advisory committees.

The habitat enhancement designs for these entrenched alluvial valley reaches include a variety of approaches to increase floodplain connectivity and complexity for juvenile salmonid rearing. Recreating extensive, frequently inundated floodplain features requires moving large volumes of sediment, either through mechanical means or by inducing geomorphic-scale erosion and deposition processes.

In 2018, the first phase of projects was constructed on the South Fork Ten Mile River, consisting of four engineered log jams and a 1.2-acre seasonally flooded wetland. A Before After Control Impact (BACI) monitoring program has been initiated to evaluate project effectiveness and to inform the design and implementation of future projects.

A Vision for Freshwater-Estuarine Transition Zone Restoration in San Francisco Bay

Scott Dusterhoff, *San Francisco Estuary Institute (Presenter) and Co-authors:*
Katie McKnight, *and* ***Robin Grossinger,*** *San Francisco Estuary Institute*

The freshwater-estuarine transition zone provides critical rearing habitat for salmonids that occupy watersheds along the Pacific Coast of the United States. Within San Francisco Bay, there were once dozens of creeks that drained watersheds and emptied into tidal channel networks, providing rearing habitat for coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead trout (*Oncorhynchus mykiss*). Over the past 200 years, most of these freshwater-estuarine transition zones where creeks meet the Bay have been modified for flood management and land reclamation, contributing to the widespread loss of salmonid habitat throughout the region. The current rethinking of land management along the Bay edge to benefit people and wildlife is providing opportunities to rehabilitate impacted Freshwater-Estuarine Transition Zones and bring back lost habitat for salmonids and other native species.

This talk presents a vision for restoring the freshwater-estuarine transition zone along a portion of the South San Francisco Bay shoreline. The vision focuses on breaching a levee protecting a historical commercial salt pond slated for restoration (Pond A8) and allowing Calabazas and San Tomas Aquino creeks to drain directly into the pond. The breach will establish the hydrogeomorphic processes necessary to evacuate excess sediment out of the lower reaches of the creeks, and build and maintain brackish marsh habitat within the Freshwater-Estuarine Transition Zone that will be resilient under a rising sea level. The collaborative, science-based process for developing the vison will be discussed, as will similar multi-benefit visions that have been developed elsewhere in San Francisco Bay.

Butano Marsh Channel Reconnection and Resilience Project

***Jai Singh**, cbec eco engineering and **Jim Robins**, Alnus Ecological (Co-presenters) and Co-authors: **Kellyx Nelson**, San Mateo RCD and **Chris Hammersmark, Ph.D., P.E.**, cbec eco engineering*

This multi-objective project addresses critical fish passage, water quality, and flood risk challenges affecting Butano Creek, Pescadero Marsh and the surrounding community of Pescadero in unincorporated San Mateo County. Anthropogenic disturbances to the watershed have significantly increased sediment delivery to Butano Creek and the Pescadero Marsh. Along large portions of the project reach, the creek channel no longer exists due to sediment accumulation that has filled the channel to the top of its banks and subsequent establishment of vegetation on top of the accumulated sediment. The resulting condition is nearly impassable for anadromous fish and other native fish species. These issues are of particular concern for populations of endangered Central California Coast coho salmon (*Oncorhynchus kisutch*) and threatened Central California Coast steelhead (*Oncorhynchus mykiss*). Compounding these challenges are the regular development of high levels of anoxia in Butano Marsh which cause devastating annual fish fills in Pescadero Lagoon during natural breaching events in late fall and early winter. The loss of Butano Creek's conveyance capacity also causes chronic flooding of Pescadero Creek Road, disconnecting the town from its main access route and emergency services following even moderate rain events.

While the issues of fish passage, water quality and flooding have been the source of controversy and enmity across stakeholder groups for decades, the past five years have seen a tectonic shift in collaboration and cooperation amongst key stakeholders. While this shift can be attributed to myriad factors, several key mechanisms appear most significant. These include: (1) funding for and development of an RCD-led effort to identify solutions to flooding along Pescadero Creek Road at Butano Creek; (2) scientific research on the mechanisms, drivers, and impact of anoxia on aquatic resources; and (3) a realization that the loss of a defined creek channel through Upper Butano Marsh was a common variable contributing to water quality degradation, lack of escape habitat and fresh water inflows during episodes of poor water quality, and chronic flooding of the road. Moreover, with significant flooding in the winter of 2017 and documentation of a massive anoxia-driven fish kill in 2016, the planning paradigm shifted from a focus on the risks associated with action to the risks associated with inaction. This shift resulted in a unique opportunity for collaboration among disparate interests in developing an actionable plan to address these long-standing problems.

The upcoming project will excavate accumulated sediment from the Butano Creek stream channel to reestablish fish passage between the estuary and the watershed and to reduce flooding of Pescadero Creek Road during low magnitude, frequently occurring flood events. This sediment will be beneficially reused to selectively aggrade Butano Marsh, filling in relic ditches, borrow pits, and other man-made low spots that generate anoxic conditions and allow anoxic water to rapidly drain from the marsh into the lagoon following breaches. These actions will restore salmonid access to the watershed's spawning habitat, provide refuge during times of poor water quality in the marsh, and ameliorate the conditions that create anoxic water and drive fish kills.

Strategies for Improving Streamflow

Session Coordinators*: Sarah Nossaman Pierce, CA Sea Grant, and Matt Clifford, JD, Trout Unlimited*

Insufficient oversummer streamflow is a significant limiting factor to salmonid recovery in many of coastal California's intermittent streams, including several of the highest priority coho salmon streams in the Russian River watershed. The long-term impacts of drought, anthropogenic water use, and landscape-scale changes, as well as local groundwater dynamics and environmental factors, must be considered when developing effective strategies for flow improvements. This session will focus on practical and innovative approaches to enhancing summer streamflow. Possible topics include (but are not limited to) collaborative and watershed-scale efforts that address this complex issue, strategies for setting and achieving flow targets, challenges and techniques associated with effective project implementation, guidance on navigating the permit process and water rights laws, and efforts to include groundwater dynamics and other environmental factors in project development.

Planning and Implementing Streamflow Improvement Projects in the Russian River Watershed with the Coho Partnership

Jessica Pollitz, P.E., *Engineer, Sonoma Resource Conservation District (Presenter) and Co-author:* ***John Green,*** *Lead Scientist / Project Manager, Gold Ridge Resource Conservation District*

The Russian River Coho Water Resources Partnership (Partnership) has been planning and implementing instream flow improvement projects in the Russian River watershed for 9 years. Sonoma and Gold Ridge Resource Conservation Districts, both members of the Partnership, have been working with rural and agricultural landowners to implement on the ground projects in high priority coho salmon streams to improve summer flows in the streams while increasing water supply security using a range of strategies. Working with the Partnership on science-based approaches to identifying restorable flow-impaired stream reaches and quantifying critical instream flow thresholds for coho in these reaches, both RCDs have had success using that information to identify, plan, and implement a variety of water management projects, demonstrating that it is possible to provide for both human water needs while not impairing habitat for threatened and endangered salmonids. These projects include implementation of water conservation measures to reduce water demand; installation of irrigation efficiency measures; development of alternative water sources, including rainwater catchment; provision of water storage so that water can be diverted during times of high flow for use during the dry season; and adjustments to the timing and rate of diversion. The variety of project types range in cost, simplicity, and impact from small to watershed-scale.

Just Add Water: An Overview of Small-scale Flow Releases and Monitoring Tools to Support Salmonid Recovery in the Lower Russian River Basin

Elizabeth Ruiz *(Presenter) and Co-authors:* ***Sarah Nossaman Pierce, Mariska Obedzinski, Andrew Bartshire, Andy McClary,*** *and* ***Chris O'Keefe,*** *CA Sea Grant, Russian River Salmon and Steelhead Monitoring Program*

In lower Russian River tributaries, insufficient summer streamflow is a bottleneck to salmonid recovery. Typically, tributaries within the watershed become intermittent in early- to mid-summer, and in drought years as early as late spring. Since the peak of the drought in 2015, small-scale flow releases have been used to augment instream flow to improve wetted habitat and water quality conditions for juvenile salmonids during the dry summer months. Flow releases can yield highly beneficial effects when timed appropriately. However, determining the release timing, duration, and quantity that will most benefit fish is challenging given the unpredictable nature of stream drying and the limited amount of water generally available from release sources. Despite the recognized value and relatively low cost of flow releases, there are no clear standard procedures in place to guide their timing or monitor their effectiveness.

At CA Sea Grant, we use a variety of tools and survey methods to help inform the appropriate timing and duration of flow releases for the benefit of fish, and to evaluate the effectiveness of those releases. Routine surveys mapping wetted habitat and riffle crest depth, discharge measurements, intermittency and water quality loggers, time-lapse cameras, and life-cycle monitoring are all regularly utilized to guide these efforts. These techniques are also used to identify connectivity thresholds (flow levels below which pools become disconnected from surface flow) and document seasonal and interannual trends in water quality and wetted habitat availability.

This discussion will include an overview of flow releases implemented in recent years on Green Valley and Dutch Bill creeks in Sonoma County, CA and the applications of innovative monitoring tools employed by CA Sea Grant to inform appropriate release timing and document the associated impacts.

Addressing Land Use Impacts to Restore Dry Season Flows

Tasha McKee, *Water Program Director, Sanctuary Forest Inc. (Presenter) and Co-authors:* ***Sam Flanagan,*** *Geologist, Bureau of Land Management and* **Joel Monschke P.E.**, *Engineer/ Geomorphologist, Stillwater Sciences*

Sanctuary Forest is working with collaborating agencies and partners to address land use impacts that increase winter runoff and result in decreased groundwater storage capacity and lower summer streamflows. This presentation will focus on two streamflow enhancement pilot projects located in Baker Creek in the Mattole Headwaters of Northern California. The two projects represent two strategies: 1) addressing channel incision resulting from logging and instream wood removal / impacts and 2) addressing reduced upslope infiltration and groundwater storage caused by logging impacts and loss of wetlands. We will discuss preliminary outcomes and how we are applying lessons learned to Lost River, an adjacent tributary in the Mattole headwaters

The Baker Creek Instream Project aimed to restore an 1800-foot reach of incised stream with the objectives of reconnected floodplains, increased summer and winter juvenile pool habitat, increased groundwater storage, and improved summer flows. The project was implemented between 2012 and 2017, and includes ~20 instream log weirs. Restoration work was initially focused on raising the channel bed to improve floodplain and groundwater connectivity, in addition to improving instream habitat complexity. The Baker Creek Upslope Project was designed to increase infiltration such that upslope groundwater levels are higher in the spring and decline more slowly through the summer, thereby contributing to summer streamflows. Additional objectives include restoration of the wetland ecosystem, expansion of the wetland vegetation through planting, and elevation of the groundwater level. The methodology consists primarily of building earthen ponds and is based on scientific studies and groundwater rainwater harvesting techniques from the Mattole and other parts of the world, including the work of international consultant Sepp Holzer, Austria and Tarun Bharat Sangh (TBS), Rajasthan, India. In the summers of 2017 and 2018, three off-channel ponds with total surface water storage capacity of ~3.2 million gallons were constructed adjacent to the instream reach.

Lessons Learned from Agricultural Water Storage Projects in Coastal San Mateo County

Joe Issel, *Natural Resource Specialist (Presenter), and* ***Jarrad Fisher,*** *Senior Project Manager, San Mateo Resource Conservation District*

San Mateo Resource Conservation District's program, "Water For Farms, Fish, and People" has implemented water conservation and storage projects to improve water security, water use efficiency, and instream flows. The program is supported by key partners, which include Trout Unlimited, USDA Natural Resources Conservation Service and County of San Mateo. Water conservation projects include upgrading sprinklers, replacing, redesigning water distribution systems, and replacing pumps and control systems. Water storage projects include constructing and replacing/repairing tanks and ponds. To date the RCD and partners have completed over 30 projects, resulting in over 31 million gallons (~95 acre feet) of water storage and 51 million gallons (~157 acre feet) of water conservation per year, primarily in the San Gregorio and Pescadero watersheds. This presentation will discuss overall program history and goals, accomplishments and methods for quantifying benefits, program funding mechanisms and discussion of costs, project planning and design methods, permitting, construction, monitoring, and maintenance.

Water Right Permitting for Small-scale Streamflow Enhancement Projects in Coastal California—Practical Considerations

***Matt Clifford, JD** (Presenter) and Co-author:*
***Mary Ann King,** Director, California Water Project, Trout Unlimited*

Recent years have seen an increasing number of projects to change water management at existing water diversions in coastal California watersheds, with the goal of increasing summer baseflows to improve rearing conditions for steelhead and coho salmon. These projects most commonly take the form of switching the timing of existing diversion from summer to winter using off-stream storage. But they can involve other measures as well, such as moving points of diversion, reducing instantaneous rates of diversion, conjunctive management of ground and surface water, and releases from existing reservoirs. Most such projects require either the acquisition of a new water right from the State Water Resources Control Board, or approval of changes to an existing water right, or both. In addition, the water diversion associated with these projects is typically subject to regulation by the California Department of Fish and Wildlife under section 1602 of the Fish and Game Code. This presentation will address the scope and application of these legal requirements in the context of small-scale streamflow enhancement projects, as well as some common strategies for permitting, with case examples from several coastal California watersheds.

Challenges in Evaluating the Effectiveness of Streamflow Enhancement Efforts

John Green, *Lead Scientist/Project Manager, Gold Ridge Resource Conservation District*

Over the past decade there has been a variety of efforts to improve streamflow in salmonid habitat streams by addressing anthropogenic water demand and water extraction. Typically, streamflow enhancement projects have included the construction of water storage, where water is collected from a variety of sources and stored during the wet winter months for use during the summer/fall dry season. These efforts are often coupled with water conservation measures, and have achieved their most obvious successes in locations where the diversions are substantial in comparison with streamflow. In many coastal salmon streams, however, both flows and water diversions are very small, and in many cases water is diverted indirectly via shallow alluvial wells. These situations raise challenges in how to measure the impacts of both the diversions and efforts to address them. The relationships between streamflow and groundwater tend to be poorly understood and are likely highly variable spatially, and the benefits of a single project may be dwarfed by variations in flow, both from year to year and within a single season. This raises the question of whether it is possible to accurately predict or measure the benefits of a project or group of projects. To make informed judgements about project effectiveness, it may be necessary to re-examine the conceptual models supporting our understanding of human impacts to streamflow.

Possibility of a Renaissance for Spring-Run Chinook: Fact or Fiction?

Session Coordinators*: Cynthia Le Doux-Bloom, Ph.D.,* *Humboldt State University, Department of Fisheries Biology, and* ***Michael Belchik,* *Yurok Tribe*

In July 2018, the California Fish and Game Commission received a petition to list Upper-Trinity River spring-run Chinook salmon (*Oncorhynchus tshawytscha*) as endangered under the California Endangered Species Act.

Nearly two decades earlier, the Central Valley Spring-Run ESU was originally proposed as endangered, but instead listed as a threatened species after NMFS concluded that this ESU was likely to become endangered in the foreseeable future. The complete extirpation of the spring-run from the San Joaquin River, and the loss of historical spawning habitat above the dams in the Sacramento and Klamath River basins have resulted in greatly reduced distributions of spring-run Chinook salmon in Northern California. Is the possibility of a renaissance for the spring-run Chinook fact or fiction?

The session will feature a range of insightful topics, including (1). Spawning Migration Timing, (2). Juvenile Life-History, (3). Physiological Responses, (4). Re-Introduction Planning and Implementation, and (5). Genetics.

Ocean Fisheries and Central Valley Spring Run Chinook Salmon

Will Satterthwaite, Ph.D., *NOAA Fisheries (Presenter) and Co-authors:* ***Flora Cordoleani****, UC Santa Cruz;* ***Michael O'Farrell,*** *NOAA Fisheries;* ***Brett Kormos,*** *California Department of Fish and Wildlife; and* ***Michael Mohr,*** *NOAA Fisheries*

Ocean salmon fisheries off the California and Oregon coast are primarily supported by fall run Chinook from the Sacramento-San Joaquin and Klamath-Trinity basins, but due to the mixed-stock nature of these fisheries, spring run Chinook are impacted as well. Central Valley spring Chinook (CVSC) are designated threatened by state and federal authorities. However, harvest of CVSC is not actively managed, on the assumption that measures in place to protect endangered Sacramento winter Chinook (primarily time/area restrictions and minimum size limits) are sufficiently protective of CVSC as well. The validity of this assumption depends, among other things, on similarities in the stocks' ocean spatial distribution, size-at-age, and maturation schedules. Ocean fishery recoveries of coded-wire tags and genetically-identified CVSC suggest that CVSC have a more northerly distribution than winter Chinook, while escapement data and cohort reconstructions suggest later maturation. Thus, ocean fishery regulations crafted to protect winter Chinook alone may not be highly effective for CVSC. However, regulations to constrain impacts on Klamath and California Coastal Chinook may also serve to reduce CVSC impacts. Should more active management of CVSC be desired, current options are limited. The most promising approach is likely one based on estimating age-specific exploitation rates using cohort reconstructions applied to tagged Feather River Hatchery fish. At minimum, exploitation rates could be monitored and compared to proxy thresholds. If reference harvest rates were established, harvest models could be developed to predict impact rates as a function of fishing regulations similar to fall Chinook fisheries. Abundance forecasts would require improved juvenile production data (e.g., from genetic sampling of juvenile emigrants), since sibling-based forecasts similar to those commonly used for fall Chinook would not be available in time for preseason fishery planning. The representativeness of exploitation rate estimates derived from hatchery proxies for natural-origin fish is uncertain, but existing data do not demonstrate obvious differences in ocean distribution or size-at-age between Feather River hatchery-origin and Butte Creek natural-origin fish. Substantial new investments in tagging and/or sampling would be needed to directly estimate impacts on natural-origin CVSC. Establishing CVSC-specific harvest targets or limits requires improved understanding of production throughout the CVSC lifecycle, e.g., through juvenile production estimates and long-term information on spawner age structure.

Effects of Wildfire on Salmon: A Spring Chinook Story

***Rebecca Flitcroft,** USDA Forest Service, PNW Research Station, Corvallis, OR*

Pacific Northwest salmonids are adapted to natural disturbance regimes that create dynamic habitat patterns over space and through time. However, human land use, particularly long-term fire suppression, has altered the intensity and frequency of wildfire in forested upland and riparian areas. Emerging research points to unexpected resilience mechanisms present in native fish populations. Recent modeling work has indicated that some life stages of Spring Chinook salmon in the Wenatchee River watershed may benefit from allowing wildfire to occur. In some applications, wildfire may be a useful habitat restoration tool. However, this story is complicated by the needs of local communities, and conflicting consequences of wildfire on vulnerable aquatic and terrestrial species. Discussions of the effectiveness of wildfire to result in species specific habitat restoration outcomes may be enhanced by considering individual life stages, habitat enhancement and fire predictions throughout river networks, and the broader impact of wildfire on other threatened or endangered species.

An Engineer's Perspective on Spring-Run Fish Passage Improvements and Reintroduction Efforts

Jon Mann, P.E., Senior Hydraulic Engineer, California Department of Fish and Wildlife

Recent fish passage improvement projects for spring-run Chinook salmon have been implemented and others are in planning and design phases. Additionally, fish passage investigations to facilitate reintroduction of salmon, including spring-run Chinook, to historic habitats are being conducted. The perspective of a fish passage engineer will be provided concentrating on projects and studies in the Central Valley. Current status of those projects' fish passage effectiveness and the challenges of reintroduction studies will be highlighted.

The Evolutionary History of Spring Chinook

***Michael R. Miller, Ph.D.**, UC Davis, Animal Science Department*

Recent research revealed that variation at a single genetic locus (GREB1L) distinguishes spring Chinook from fall Chinook. Here, we consider how this finding can be used to inform conservation and restoration actions. First, we review the evidence suggesting spring-run alleles (at GREB1L) are integral to the existence of spring Chinook. Next, using both theoretical models from the Rogue River and empirical evidence from the Klamath River, we explore whether fall-run populations can be expected to act as reservoirs of spring-run alleles in the event that spring Chinook are extirpated. Finally, we discuss practical applications for using the genetic basis of spring migration to directly inform conservation and restoration tactics.

The Persistence of Spring-run Alleles and Implications for Conservation

Tasha Thompson, UC Davis, Animal Science Department

Spring Chinook face many disadvantages relative to fall Chinook. By entering freshwater months before they spawn, spring Chinook give up feeding and growth time in the ocean, spend large amounts of time confined and exposed in freshwater habitats, and undergo the energy-intensive process of sexual maturation while fasting. Yet, despite these disadvantages, spring Chinook historically thrived in many coastal rivers. This historical abundance indicates the benefits of the spring-run life history outweighed the costs. Here, we explore the historical evolutionary advantages of the spring-run life history, consider how anthropogenic activities are impacting these advantages and driving declines, and discuss how an evolutionary perspective can be useful in spring Chinook conservation and restoration efforts. Finally, we discuss spring Chinook in the context of climate change, and why the spring-run life history may become increasingly important to the species.

The Genomic Basis of Ecotypic Differentiation in Chinook Salmon in California

J. Carlos Garza, Ph.D., *NOAA Southwest Fisheries Science Center and UC Santa Cruz (Presenter) and Co-authors:* ***Neil Thompson, Anthony Clemento, Devon Pearse,*** *and* ***Eric Anderson,*** *NOAA Southwest Fisheries Science Center and UC Santa Cruz*

The origins of ecotypic differentiation in salmonid fishes have long intrigued biologists, fishermen, managers, and fish-oriented human communities. Among the species with such distinct ecotypes, spring-run and fall-run Chinook salmon populations are among the best known, because of their large size and their temporal differences in migration timing that have historically made fish available for harvest over a much longer period of time than just one of the ecotypic 'runs' alone.

We describe here an in-depth evaluation of the genomic basis of ecotypic differentiation in Chinook salmon in California, using data from a combination of whole genome sequences, amplicon sequencing of target gene variants, and life history variation.

We use the whole genome sequence data to provide a detailed picture of the genomic region previously shown to be associated with 'run' class designation in Chinook salmon across several basins and elucidate the evolutionary processes that have led to variation in this region. We also show how specific genetic variants that are entirely associated with class membership are currently distributed throughout California. Combining these results with data on timing of migration and reproduction allows us to dissect the spring-run phenotype in the Klamath River and define the heritable basis of this important ecotypic differentiation. In addition, these results inform efforts to repopulate the upper Klamath River basin with Chinook salmon when, starting in two years, the process of dam removal/ river restoration begins.

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Poster Session Presenters

RETU Grassroots in Action
Presented by Charlie Schneider
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Stream Flows for Steelhead: Methods to Identify Instream Flow Needs in the Ventura River Watershed
Presented by Danielle Ingrassia
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Russian River Watershed-Wide Programs for Water Quality
Presented by Adriane Garayalde
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The Eel River's Final Frontier: Are Sacramento Pikeminnow Setting Roots in the North Fork?
Presented by Zane Ruddy
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California Water Action Plan—Updates on Modeling and Data Collection
Presented by Valerie Zimmer
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Benthic Macroinvertebrate Drift and Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) Diets in Response to a Flow Release on the Trinity River downstream of Lewiston Dam
Presented by Thomas Starkey-Owens
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Weeding through the Impacts of Legal Cannabis: CDFW and Cannabis Cultivation
Presented by Ange Baker
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Effects of Rain-on-Snow Events on Suspended Sediment Loading in the Truckee River Basin, California: Implications for Aquatic Habitat and Water Quality Under Climate Change
Presented by Brian Hastings
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Porter Creek: A Case Study in Flow Augmentation and Interagency Cooperation
Presented by Weston Slaughter
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WSP Information and Recruitment
Presented by Greg Poulton
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Salmon Habitat Restoration Priorities SHaRP South Fork Eel River
Presented by Allan Renger
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Assessment of the Relative Risk of Surface Water Diversions on Juvenile Salmonids and Lampreys in the Lower Mokelumne River
Presented by Robyn Bilski
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Northern California/Nevada Council, Fly Fishers International
Presented by Mark Rockwell
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Design and Implementation of Width Expansions to Address Incision on the Napa River / Design and Implementation of Secondary Channels in Dry Creek, Sonoma County, California
Presented by Jason Quitiquit White
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2018 Carr Fire—Stream and Fisheries Impacts on Clear Creek, Redding CA
Presented by Sam Provins
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Dry Creek Habitat Enhancement Site Utilization by Juvenile Steelhead
Presented by Monica Tonty
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Using Environmental DNA to Assess the Timing and Movement of Juvenile Coho Salmon
Presented by Emerson Kanawi
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Beaver Restoration in California
Presented by Kate Lundquist
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Estimating Predator Fish Density and Distribution in the Sacramento—San Joaquin Delta Using DIDSON Acoustic Cameras
Presented by Christopher Loomis
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Comparing Equations for Salmonid Redd Identification on a Central California Coastal Creek
Presented by Lindsay Hansen
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Wood in World Rivers
Presented by Elektra Mathews-Novelli
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Pacific Lamprey in Freshwater Creek, a Missing Ecological Link
Presented by Ali Singh
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Thermal Acclimation and Heat Hardening's Effect on Thermal Tolerance in Chinook Salmon Populations from California and Oregon
Presented by Heather Bell
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Large Wood Restoration Effectiveness for Salmonids in Pudding Creek, CA: A Before-After-Control-Impact Experiment
Presented by Natalie Okun
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Analyzing California Reference Streamflow with the Seasonally-Based Functional Flows Calculator
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Habitat Enhancement Projects: Installing LWS
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Applied Science to Inform Cannabis Regulatory Efforts
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Bullock Bend In-Stream Habitat Restoration
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Floodplain Food Delivered to Your Delta Doorstep: From the Fish's Perspective
Presented by Mollie Ogaz
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Juvenile Salmon Growth in Natal Rivers vs. Delta: Should I Stay or Should I Go?
Presented by Laura Coleman
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Using Pacific Lamprey as a Surrogate Species to Assess Juvenile Salmonid and Watershed Health
Presented by Cynthia Le Doux-Bloom
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Characterization of Thermal Regimes of Side Channels, Alcoves, and Ponds on the Willamette River, OR
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TMDLs on Salmonid Streams
Presented by Jackie Van Der Hout
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Dissolved Oxygen and Temperature in Lagunitas Creek and Walker Creek
Presented by Emma Goodwin
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Post-Fire Erosion Prevention and Sediment Control Planning and Priotitized Treatment Strategies: How to Improve Water Quality, Reduce Turbidity, and Prevent Channel Incision in Areas Devastated by Wildfire
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Monitoring Central Valley Spring-run Chinook Salmon in the San Joaquin River
Presented by Hilary Glenn
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A Spatial Mapping Tool to Access Natural Flows for All Streams in California
Presented by Julie Zimmerman
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Linking Sand Transport and Accumulation to Predict Salmonid Egg Survival
Presented by Matthew Meyers
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The Effect of the Thomas Fire on Stream Habitat in Upper North Fork Matilija Creek
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Growing Plants for Habitat Restoration
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Upstream Fish Passage at Beaver Dam Analogues Placed in McGarvey Creek
Presented by Jimmy Faukner
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Thinking Outside the Box: A Study on Culvert Design and Brook Trout Habitat in the Upper Gunpowder River Watershed in Maryland
Presented by Katie Bartling
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Do Non-Native Prey Protect Salmonids from Avian Piscivores?
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Dry Creek Habitat Enhancement Effectiveness Monitoring
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Salmon Restoration Federation Cardno Restoration Project Highlight Reel
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Information on RR Confluence & RR Watershed Association
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FISHPass, a Decision Support Tool to Select Fish Passage Barriers for Remediation, Newly Developed and Revised
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Large Wood Helicopter Loading Project—Promoting Natural Processes for Spring Run Chinook
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Working with Beaver and Multiple Restoration Techniques towards Stage Zero Streams
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Ecohydraulic Modeling of Coho Habitat in Lower Russian River Tributaries
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Dam Operations and Fish Habitat: Piave River Case Study
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Fall Run Chinook Salmon: Return to Putah Creek
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Evaluating the Effect of Diversions for Cannabis Cultivation on Salmonid Passage
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Does Annual Discharge Affect Chinook Salmon Production on the Shasta River?
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Remote Sensing and Vegetative Classification in Restoration-Targeted Watersheds
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Citizen Science Reliability, Repeatability and Resiliency – An Analysis of Water Quality Data Collected from Malibu Lagoon State Beach
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"Wilding" Salmon Using Agricultural Floodplain Ecosystems
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Stream Restoration on Usal Redwood Forest
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Adult Salmonid SONAR Monitoring Programs on the Lower Mainstem Eel River and South Fork Eel River
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In Summer Heat, Salmon Need Flowing Water
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Deep in the Weeds: Sampling Juvenile Chinook in Inundated, Densely Vegetated Riparian Areas
Presented by Jack Eschenroeder
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An Adventure in Unanchored Large Wood Habitat Restoration Design: Monitoring Results and the 5-Year Mark and Beyond
Presented by Cheryl Hayhurst
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Manzana Creek Watershed Anthropogenic Sediment Reduction Assessment, Aquatic Protection and Road Restoration Planning Project
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Post-Fire Response: Strategies for Emergency Culvert Replacement on Rural Roads
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How Channel and Floodplain Alteration Affect Groundwater and Riparian Forests
Presented by Jeff TenPas
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Time for a Change: Legislative Reform of Fishery Restoration
Presented by Richard McMurtry
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Streambank Stablilization and Restoration Practices
Presented by Jason Miller
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Salmonid Restoration Federation's Mission Statement

Salmonid Restoration Federation was formed in 1986 to help stream restoration practitioners advance the art and science of restoration. Salmonid Restoration Federation promotes restoration, stewardship, and recovery of California native salmon, steelhead, and trout populations through education, collaboration, and advocacy.

SRF Goals & Objectives

1. **To provide affordable technical education and best management practices trainings to the watershed restoration community.**
2. **Conduct outreach to constituents, landowners, and decision-makers to inform the public about the plight of endangered salmon and the need to preserve and restore habitat to recover salmonid populations.**
3. **Advocate for continued restoration funds, protection of habitat, enhanced instream flows, and recovery of imperiled salmonids.**

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