



2004 Cal-Neva+Humboldt AFS

Concurrent Technical Sessions – Titles and Abstracts

Session Title: To Pulse or Not to Pulse: The Pros and Cons of Pulsed Flows on Habitat and Aquatic Biota

Session Chair: Paciencia S. Young (psyoung@ucdavis.edu)

Date: Friday, April 23, 2004

Time: 1:00-5:00 PM

Titles

The Effects of Managed Flood Release on a Salmonid Spawning Gravel Enhancement Project

Joseph E. Merz, East Bay Municipal Utility District, Division of Fisheries and Wildlife, 1 Winemasters Way Suite K2, Lodi, CA 95240, (209) 365-1093, jmerz@ebmud.com

Co-authors: Joseph M. Wheaton* and Gregory B. Pasternack, Department of Land, Air, and Water Resources, University of California, Davis

*Current Address: School of Geography, University of Southampton, Highfield, Southampton SO17 1BJ, U.K.

Pulse Flows for Alluvial Processes in Bedrock River Ecosystems

William Trush, McBain and Trush, P.O. Box 663, Arcata, CA 95521, (707) 826-7794 ext.12, bill@mcbaintrush.com

Evaluating Pulsed Flow-Based Disturbances of Stream Benthos in Regulated Rivers

Ian Chan, Garcia and Associates (GANDA), P.O. Box 1268, Tahoe City, CA 96145, (530) 363-2008, ichan@garaciandassociates.com

Co-author: Robert Aramayo, Garcia and Associates (GANDA)

Freshwater Mussels and The Potential Impacts Of Pulsed Flows

Jeffrey D. Cook, Spring Rivers Ecological Sciences, P.O. Box 153, Cassel, CA 96016, (530) 335-5446, jeff@springrivers.com

Co-author: Maria J. Ellis, Spring Rivers Ecological Sciences

Some Effects of Spring and Summer Pulse Flows on River-Breeding Foothill Yellow-Legged Frogs (*Rana boylei*) along the North Fork Feather River

Ronald E. Jackman, Garcia and Associates, P.O. Box 776, Fall River Mills, CA 96028, (530) 336-6592, rojack@frontiernet.net

Co-authors: Joseph E. Drennan, Karla R. Marlow, and Kevin D. Wiseman, Garcia and Associates

**Pulsed Flows Effects on Foothill Yellow-Legged Frog Egg Masses,
Filamentous Green Algae, and Fish Stranding in the Pit River**

Maria J. Ellis, Spring Rivers Ecological Sciences, P.O. Box 153, Cassel, CA 96016,
(530) 335-5446, maria@springrivers.com

Co-author: Jeffrey D. Cook, Spring Rivers Ecological Sciences

**Stranding of aquatic organisms during periodic whitewater boating flows on the
North Fork Feather River, California.**

Tim Salamunovich, Thomas R. Payne & Associates, PO Box 4678, Arcata, CA 95518,
(707) 822-5453 x306, trpa@northcoast.com

**Movement of Sacramento Sucker (*Catostomus occidentalis*) and Hitch (*Lavinia
exilicauda*) during a spring, pulse flow below Camanche Dam in the Mokelumne
River, California**

Carson Jeffres, John Muir Institute of the Environment, 183 Kerr Hall, University of
California, Davis, CA 95616, (530)754-5351, cajeffres@ucdavis.edu

Co-authors: Joseph J. Cech Jr, and A. Peter Klimley, University of California, Davis; and
Joseph Merz, East Bay Municipal Utilities District

**Effects of Pulsed Flows on Virtual Fish: What Can We Learn from Individual-
based Models?**

Steve Railsback, Humboldt State University and Lang, Railsback & Associates, 250
California Ave., Arcata, CA 95521, 707-822-0453; LRA@Northcoast.com

**Monitoring the Ecological Effects of Recreation Pulse Flows as a Component of
Dam Relicensing Proceedings in Northern California**

Curtis Knight, California Trout, Po Box 650, Mt. Shasta, CA 96067, 530-926-3755,
caknight@jps.net

Abstracts

The Effects of Managed Flood Release On A Salmonid Spawning Gravel Enhancement Project

Joseph E. Merz , East Bay Municipal Utility District, Division of Fisheries and Wildlife, 1 Winemasters Way Suite K2, Lodi, CA 95240, (209) 365-1093, jmerz@ebmud.com

Co-authors: Joseph M. Wheaton* and Gregory B. Pasternack, Department of Land, Air, and Water Resources, University of California, Davis

*Current Address: School of Geography, University of Southampton, Highfield, Southampton SO17 1BJ, U.K.

The addition and placement of spawning gravel is gaining interest as an enhancement tool in regulated anadromous salmonid streams of California. Gravel placement is typically used to improve spawning sediment quantity and quality and enhance spawning parameters, such as channel depth, velocity, substrate permeability and general habitat complexity within specific locations of a regulated, sediment starved channel. However, without appropriate maintenance flows, spawning material can quickly accumulate fines and aquatic vegetation, thereby reducing spawning habitat quality. During a 19-day managed flood flow release (27 May through 13 June 2003), we monitored several physical parameters associated with a fall-run chinook salmon (*Oncorhynchus tshawytscha*) spawning gravel enhancement site in the lower Mokelumne River, California. Topographical surveys showed a 17.4 m³ reduction (2.6%) in placed gravel volume after a peak flow of 56.7 m³ • sec⁻¹. Tracer rocks indicate surface gravels were mobilized as much as 10.6 m. Debris jams, consisting of large woody debris and invasive rooted aquatic vegetation were mobilized. Annual chinook salmon redd surveys suggest a modest increase in spawning activity within a 4 year-old enhancement site following the managed flood flow release.

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Pulse Flows for Alluvial Processes in Bedrock River Ecosystems

William Trush, McBain and Trush, P.O. Box 663, Arcata, CA 95521, (707) 826-7794 ext.12, bill@mcbaintrush.com

Bedrock channels, though principally erosional, exhibit abundant depositional features. Large geomorphically driven hydraulic controls, such as valley width constrictions or expansions and resistant bedrock outcrops, define an overall limit for coarse sediment deposition in each segment of bedrock channel. These geomorphic controls induce coarse depositional features that in turn perform as smaller hydraulic controls inducing finer secondary depositional features. Transverse boulder 'ribs' are prominent self-formed depositional features common in bedrock rivers that function as hydraulic controls for diverse secondary, and even tertiary, depositional features. The occurrence of smaller hydraulic controls within larger hydraulic controls gives rise to a complex, nested depositional channel morphology that provides rich aquatic and riparian habitats. Pulse flows representing flood recurrences from 1.5-yr to > 50-yr are required to make these hydraulic controls work. In rare and relatively short channel segments, bedrock rivers can exhibit alluvial tendencies where one or both banks are being actively shaped (and therefore not rigid). These unique segments are often wide and prone to major backwaters (during high floods when coarse bed material is being actively transported) or are sharply bending (thus promoting abrupt flow separation and coarse sediment deposition). Limited floodplains often develop, serving as magnets for high aquatic and riparian biotic diversity. The geomorphic needs for these novel biological hotspots do not deviate wildly from the pulse flow requirements of more common bedrock reaches in the same river. However, smaller floods with annual maximum recurrences < 5-yr assume a greater role in maintaining channel morphology and perpetuating woody riparian community dynamics. By recognizing nested hydraulic alluvial features and biological hotspots in managing bedrock river ecosystems, the processes forming and perpetuating each depositional layer can be explicitly associated with specific pulse flow magnitudes, durations, frequencies, and timing. Thinking depositionally, and even alluvially, when prescribing diverse pulse flows is critical to the restoration and maintenance of regulated bedrock river ecosystems.

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Evaluating Pulsed Flow-Based Disturbances of Stream Benthos in Regulated Rivers

Ian Chan, Garcia and Associates (GANDA), P.O. Box 1268, Tahoe City, CA 96145,
(530) 363-2008, ichan@garaciandassociates.com

Co-author: Robert Aramayo, Garcia and Associates (GANDA)

Regulated rivers may experience manipulated pulsed flows for operational, experimental, or recreational purposes. Understanding the effects of pulsed flows on stream biota, including both the magnitude and timing of manufactured events, is critical for regulatory decision-making in this arena, as the variety of beneficial uses provided for under licensing agreements may pose challenges for aquatic resource management. Studies of pulsed flow effects on benthic macroinvertebrate communities in three regulated rivers in California have documented significant event-related impacts in the context of before-after comparisons. Sampling methodology incorporated in these studies included rapid bioassessment, representative artificial substrate sampling, and drift monitoring techniques. Benthic community measures generally tended to decline following pulsed flow events. Post-flow conditions were also characterized by greater variability overall. Impacts to stream benthos were primarily related to increases in velocity, shear stress, bedload mobilization, and scour that contributed to physical disturbance or removal of benthic macroinvertebrates. Post-event decreases in macroinvertebrate abundance, richness, and diversity exemplified this type of disturbance. However, declines in community measures also reflected changes in the composition of the benthic community driven by catastrophic drift responses. While many catastrophic drift responses resulted from physical disturbance and dislodgement of macroinvertebrates (i.e., passive incorporation into the drift), a significant proportion of catastrophic drift during and after high-flow events resulted from behavioral responses (i.e., active incorporation into the drift). These studies also suggest that the impacts of pulsed flow events are greater during late summer and fall than earlier in the year. Seasonal differences in the susceptibility of benthic organisms to disturbance reflect evolutionary adaptations in the morphology and life history of lotic organisms. In temperate rivers, it is reasonable to expect more flood-adapted assemblages to be present in winter as opposed to summer months, hence the implication that summer pulsed flow events have greater potential for disturbance.

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Freshwater Mussels and the Potential Impacts of Pulsed Flows

Jeffrey D. Cook, Spring Rivers Ecological Sciences, P.O. Box 153, Cassel, CA 96016, (530) 335-5446, jeff@springrivers.com

Co-author: Maria J. Ellis, Spring Rivers Ecological Sciences

Freshwater mussels are considered the most endangered group of animals in North America. Limited information on the basic life history, reproductive biology, ecology, and habitat requirements of mussels hinder conservation efforts. This is especially true for western mussels, because most research has focused on eastern species. Freshwater mussels, which have a unique reproductive strategy to ensure dispersal of juveniles upstream, are highly fecund but have very low natural reproductive success rates. The life history strategies of native western mussels are characteristic of stable habitats and make them very susceptible to ecological disturbances. The primary reasons for extirpation of mussel populations are ecological disturbances, including altered stream flows and other hydrologic changes. Natural high-flow events can have major effects on freshwater mussels. As high flows receded in spring of 1995, numerous mussels were stranded and many died in the Pit 1 Reach of the Pit River. The potential direct impacts of planned pulse flows on mussel abundance and distribution at a mussel bed in the Pit 4 Reach were assessed in 2002. This study demonstrated that mussels were not dislodged or transported from the bed by pulsed flows up to 2,000 cfs in the Pit River. This study did not, however, assess the impact of out-of-season pulsed flows (relative to the natural hydrograph) on mussel reproductive success and juvenile recruitment. Out-of-season flow fluctuations can disrupt reproductive success during sperm release and fertilization, glochidia release and encystment, and juvenile drop-off and attachment. With their low natural reproductive success, pulsed flows during any of these critical periods could result in total loss of a year-class and eventual extirpation of mussel species. Information on the timing of critical reproductive periods would help managers and policy makers in western North America to schedule necessary manufactured flows to minimize potential reproductive interference in native mussels.

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Some Effects of Spring and Summer Pulse Flows on River-Breeding Foothill Yellow-Legged Frogs (*Rana boylei*) along the North Fork Feather River

Ronald E. Jackman, Garcia and Associates, P.O. Box 776, Fall River Mills, CA 96028, (530) 336-6592, rojack@frontiernet.net

Co-authors: Joseph E. Drennan, Karla R. Marlow, and Kevin D. Wiseman, Garcia and Associates

We monitored the effects of spring channel maintenance pulse flows and summer whitewater recreation flows on breeding activity and reproductive success of foothill yellow-legged frogs (*Rana boylei*) on the Cresta Reach of the North Fork Feather River from June to October in 2002 and 2003 for the Pacific Gas and Electric Company. Over 50 percent of known *R. boylei* egg masses (N = 8) were negatively affected (i.e., lost, scoured) during the 1 June 2002 pulse flow (1,600 cfs). This finding caused managers to cancel all pulse flow events within three weeks of any egg mass occurrence in 2003. Some 2002 egg masses were detached prior to the pulse flow leaving them immediately vulnerable. Underwater video monitoring in 2003 showed predatory activity of introduced signal crayfish (*Pacifastacus leniusculus*) likely contributing to egg mass detachment. Hatching egg masses and small tadpole groups were also exposed to the 2002 pulse flow. At one site, we documented a steep drop in small tadpole numbers from the pre-flow to the post-flow monitoring period. To test whether this reflected natural attrition of recently-hatched tadpoles, we counted tadpole numbers during a one-week period of base flows in 2003. An average loss of 25 tadpoles per day was calculated by regression; however, tadpole numbers at many sites dropped from hundreds initially to dozens or only a few during the survey period. Causes of observed tadpole attrition at oviposition/hatch sites included predation (crayfish, garter snake, fish), dispersal, and hiding. Effects of summer recreation flows on large-sized tadpoles counted pre-flow and post-flow by visual encounter surveys were inconclusive; however, some stranding mortality was documented. Numbers of juvenile and adult frogs appeared unaffected by pulse and recreation flows. Finally, we report on changes to depth, wetted perimeter, and flow velocities at frog breeding sites measured during high flow releases.

Oral

Pulsed Flows Effects on Foothill Yellow-Legged Frog Egg Masses,
Filamentous Green Algae, and Fish Stranding in the Pit River
Maria J. Ellis, Spring Rivers Ecological Sciences, P.O. Box 153, Cassel, CA 96016,
(530) 335-5446, maria@springrivers.com
Co-author: Jeffrey D. Cook, Spring Rivers Ecological Sciences

The potential effects of pulsed flows on foothill yellow-legged frog egg masses, attached filamentous green algae, and fish stranding were assessed during a series of high-flow test releases conducted during May and August 2002 for Pacific Gas and Electric Company's Pit 3, 4, and 5 Hydroelectric Project. Foothill yellow-legged frogs in the vicinity of Deep Creek in the Pit River laid their egg masses on substrate such that they were either sheltered from flow or experienced below ambient flow velocity. Although adept at selecting oviposition sites where velocities were relatively unaffected by increasing discharges, approximately half of the egg masses were either scoured or likely to be scoured by the five days of high flow releases. Velocity measurements and field observations suggest that changes in flow direction as well as increased velocities resulted in scouring. It also appeared that the duration of flow events had a potentially larger impact than overall magnitude. The impact of high flows on attached filamentous green algae coverage was assessed at three one-meter-square plots before, during, and after the August test flows. Based on qualitative observations, algal coverage decreased by more than two orders of magnitude during unscheduled spills that occurred before the start of the study. This decrease was the result of the break-off of long algal strands. Although algae rebounded sufficiently to evaluate the effects of the test flows, algal strands never attained the length and coverage observed prior to the spills. Short-lived, high-magnitude flows likely have a similar potential to break off algal strands as longer-duration flows of equal magnitude, but longer duration flows have a greater potential to scour algal holdfasts off substrate by mobile bedload. Algal recovery following longer duration flows would likely be slower than following short-lived flow peaks of equal magnitude. The potential for fish stranding in the Pit River was assessed immediately following the highest flow releases in August. A combined total of 54 fish were found stranded in a total of 587 square meters of ponded water at six stranding locations. With the very limited number of potential stranding locations, the low numbers of stranded fish observed, and the low frequency of high flow events during summer, fish stranding appeared to be a relatively minor concern in the Pit River project reaches.

Stranding of aquatic organisms during periodic whitewater boating flows on the North Fork Feather River, California.

Tim Salamunovich, Thomas R. Payne & Associates, PO Box 4678, Arcata, CA 95518, (707) 822-5453 x306, trpa@northcoast.com

As part of the Rock Creek-Cresta Settlement Agreement, Pacific Gas and Electric Company agreed to provide monthly whitewater recreation flows in two reaches of the North Fork Feather River (NFFR) during the period of June through October. Two years of surveys (2002 and 2003) conducted at several areas of the river during down-ramping have generated estimates for the densities of stranded fish, amphibian tadpoles, and benthic macroinvertebrates resulting from these managed recreation flows. Survey techniques have allowed identification of spatial and temporal patterns of stranding for resource managers. Two years of studies have revealed that the whitewater releases in the relatively high-gradient areas of the NFFR canyon have resulted in very low stranding densities of aquatic organisms. Our surveys suggest that the periodic managed flows have resulted in low stranding densities and that existing down-ramping rates appear adequate for protecting the aquatic resources of the NFFR. During the 2002 field season, auxiliary evaluations were conducted to address the potential for overnight predation and scavenging of trout fry that might be missed if surveys require more than a single day to complete. These tests suggested that there was an overnight loss of about 27 percent of the fry to small invertebrate scavengers that live in the cobble bar such as ants, slugs, and yellow jackets. The complete consumption of trout fry to scavengers were identical whether test fish were concealed beneath cobbles or left fully exposed. During the 2003, some simple evaluations were conducted to estimate recovery rates for stranded organisms during a survey. Stranding bar sites were seeded with known quantities of small fish lures and beads (used to simulate small macroinvertebrate items). Survey crews salvaged an average of 80.5 percent of the small fish lures (range 68 to 92 percent recovery) and 58.8 percent of the beads (range 41 to 79 percent recovery).

Presentation format preference: [ORAL \(only\)](#)

Movement of Sacramento Sucker (*Catostomus occidentalis*) and Hitch (*Lavinia exilicauda*) during a spring, pulse flow below Camanche Dam in the Mokelumne River, California

Carson Jeffres, John Muir Institute of the Environment, 183 Kerr Hall, University of California, Davis, CA 95616, (530)754-5351, cajeffres@ucdavis.edu

Co-authors: Joseph J. Cech Jr, and A. Peter Klimley, University of California, Davis; and Joseph Merz, East Bay Municipal Utilities District

Radiotelemetry was used to determine the locations and daily movements of Sacramento sucker *Catostomus occidentalis* (size range 278-495mm TL, n=6) and hitch *Lavinia exilicauda* (range 168-223mm TL, n=6), associated with spring, pulse flows in the Mokelumne River. River flows (Camanche Dam releases) increased from 12.5 m³ s⁻¹ to 56.7 m³ s⁻¹ over four days then was decreased to 14.1 m³ s⁻¹ over a 10 day period. The increase in flows apparently initiated movement in the four suckers that were able to be tracked for the entire study. Two of the suckers showed distinct downstream movements and two suckers showed upstream movements, with major movements exhibited during the high river flows. Individual sucker's maximum movements ranged from 80 m to 12.55 km (mean: 3,657 m) from the release location. In contrast, hitch showed very little movement from the backwater habitat in which they were collected and released. They exhibited movements in the backwater areas, but there was no clear relationship between the flow increases and hitch movements. On one occasion, a hitch moved into a side channel of the river, but it had returned to the backwater area when it was located, subsequently. Because tagged hitch numbers decreased throughout the study, we hypothesized that they were being removed through predation. On several occasions, osprey were seen with fish, of the size used in our study, in their talons. Unfortunately, it was not possible to locate the transmitters near a local osprey nest, located on an electrical power pole, due to the associated electrical interference. In summary, Mokelumne River flow increases were associated with medium to large-scale movements in Sacramento suckers, in both upstream and downstream directions, but had little, apparent effects on hitch. Research funded by the California Agricultural Experiment Station (grant no. 3455-H to JJC), East Bay Municipal Utilities District,

Presentation format: **oral or either**

Effects of Pulsed Flows on Virtual Fish: What Can We Learn from Individual-based Models?

Steve Railsback, Humboldt State University and Lang, Railsback & Associates, 250 California Ave., Arcata, CA 95521, 707-822-0453; LRA@Northcoast.com

Effects of pulsed flows are relatively easy to understand at the level of individual fish: stranding kills fish, moving in response to flow changes can reduce feeding and increase swimming, and changes in the production or timing of invertebrate drift can affect feeding. But what are the population-level consequences of these individual-level processes? And how do these processes depend on site-specific habitat and biological conditions? These questions are practically impossible to answer using empirical research alone. However, individual-based models (IBMs) address these kinds of questions by simulating the behavior and physiology of the individual animals making up a virtual population. *inSTREAM* is an IBM designed to predict effects of instream flow, temperature, and turbidity on stream trout populations (see: www.humboldt.edu/~ecomodel). One version of *inSTREAM* is designed for research on effects of pulsed flows. The model simulates how the movement, feeding, growth, and mortality of individual trout are affected by flow at an hourly (or shorter) time step; and what the long-term, population-level consequences are. This model can address such questions as: (1) For fish feeding and growth, is it better for flows to vary rapidly or slowly? (2) If feeding is disrupted when fish move, is there an important effect on growth? (3) Does the magnitude, or only the frequency, of flow pulses affect fish growth? (4) If flow pulses change the timing of peak invertebrate drift, what are the effects on growth and survival? Are these effects different if fish can anticipate regular flow pulses? (5) Does stranding mortality of juveniles affect adult populations? Building and applying *inSTREAM* has identified key field research objectives that could improve our predictive understanding of how flow pulses affect fish populations.

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Monitoring the Ecological Effects of Recreation Pulse Flows as a Component of Dam Relicensing Proceedings in Northern California

Curtis Knight, California Trout, Po Box 650, Mt. Shasta, CA 96067, 530-926-3755, caknight@jps.net

Numerous Federal Energy Regulatory Commission (FERC) dam relicensing proceedings are currently underway on California's rivers and streams. These proceedings present a unique opportunity to improve the flow regime below hydropower diversions in an attempt to mimic pre project flow regimes, increase fish habitat, improve spawning gravels, revitalize vegetation recruitment and improve water quality among other such benefits. While the focus of these recommended flows is typically ecological enhancement, flows for recreational purposes (ie white water rafting) are often recommended, with some controversy, with the stipulation that these flows do no ecological harm. This has set the stage for developing adaptive management programs that identify variables to measure and establish monitoring protocols. One such monitoring program is underway on the Feather River and another is being developed on the Pit River among others. California Trout has participated in these proceedings and has worked to establish monitoring programs that identify easily measurable variables, establish thresholds of significance and develop, *a priori* predictions and recommended actions based on monitoring results. This presentation will discuss results of monitoring programs to determine the effects of recreational pulse flows on rivers impacted by hydropower projects and how these results are being used to inform management decisions.

Oral