Pulsed Flow Program

ABSTRACTS

First Pulsed Flow Program Workshop

Putah Creek Lodge
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For more information on the UCD-CEC Pulsed Flow Program, visit our website at
http://animalscience2.ucdavis.edu/pulsedflow/index.htm

ABSTRACTS

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Evaluating the Impacts of Manufactured Recreation Streamflows on the Macroinvertebrate Community of a Regulated River

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Benthic macroinvertebrate data from reaches of the North Fork Feather River (Plumas County, CA) that were affected and unaffected by monthly pulsed recreation streamflow releases in 2004 were compared using a before-after-control-impact (BACI) design. Macroinvertebrate populations in the treated and control reaches were sampled concurrently using representative artificial substrates (rock basket samplers) and standard kick-sampling techniques. Macroinvertebrate data were compiled into two multi-metric indices: the widely applied Benthic Index of Biotic Integrity (B-IBI), and the recently developed hydropower multi-metric index (Hydro-MMI) designed to be sensitive to the effects of hydropower operations. Analysis of variance (ANOVA) was used to test for a pulsed-flow effect using these multi-metric indices. No significant difference in B-IBI was detectable; however, the control-to-treated difference in Hydro-MMI was significantly different from pre- to post-flow ($p < 0.10$). Among basket-sample data, seasonal trends between these two reaches were generally similar; however, kick-sample data suggest a seasonal pattern of increasing richness and abundance in the control reach that was not observed in the treated reach.

Comparisons of the basket- and kick-sampling techniques demonstrated that basket samplers selected for a subset of the benthic community dominated by filter-feeding organisms such as net-spinning caddisflies. These organisms appeared able to quickly colonize and capitalize on free interstitial spaces provided in basket samplers. Therefore, kick samples provided a better representation of the overall benthic community. Differences in the composition of the two sample types suggest that seasonal trends among basket-sample data primarily followed natural seasonal patterns for the filter-feeder-dominated community that developed in basket samplers, which may have been less sensitive overall to flow-related changes than the larger benthic community by virtue of more specific microhabitat preferences and adaptations.

We recommend that future evaluations of pulsed recreation streamflows be based on direct bottom sampling methods such as kick sampling, instead of artificial substrate sampling. Kick samples appeared to detect pulsed-flow-related disturbances better than basket samples, particularly across longer (i.e., seasonal) time scales. The Hydro-MMI was more useful than the B-IBI, or individual metrics, for both discriminating baseline control-to-treated differences and detecting pulsed-flow-related disturbances. We therefore recommend that benthic macroinvertebrate data from future studies of pulsed-flow effects be compiled and evaluated using the Hydro-MMI. We thank the Public Interest Energy Research Program of the California Energy Commission, the State Water Resources Control Board, and the UCD Pulsed Flow Program, as well as Pacific Gas and Electric Company, for their financial support of this project.

Laboratory Investigations of Stream Fish Longitudinal and Lateral Displacement from Simulated Pulse Flows

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Pulsed water flows are common in many California rivers, due to demands for hydroelectric power and whitewater-associated recreation. However, impacts of pulsed flows on native fishes are mostly unknown. Using laboratory flumes, we tested three species' movements and behavior during simulated pulsed (ramped) flows. Longitudinal displacement was tested at the UC Davis J. Amorocho Hydraulics Laboratory using a 16.5 x 0.6-m flume (14°C), in which individual fish, 4 to 7-cm-long fish (n = 11 - 12 per species) was exposed to pulsed velocities from 0.10 (low) to 0.31 (medium) to 0.46 (high) m s^{-1} and back to medium and low velocities, for 20 min each (100-min total pulse). Neither rainbow trout, hardhead, nor Sacramento sucker showed significant mean longitudinal displacements from their central starting point during any of the velocity phases of the pulse. All species selected velocities significantly < mean water velocity in the flume during each of the velocity phases, primarily by using river-rock substrate for hydraulic cover, except for trout, which swam at 0.10 m s^{-1}, during the low velocity phase at the end of the pulse. Of the three species, suckers used the substrate for cover the least, apparently using their body shape to maintain position on smooth-bottom areas, during the medium and high velocity phases of the pulse. Throughout the experiments, the suckers swam the least and the trout swam the most.

The three species' lateral displacement was tested using a 2.0 x 1.2-m flume (14°C) that incorporated a 16-cm-wide channel on one side and a 102-cm-wide sloped gravel bank area, including pools, which was inundated with the pulse, at CABA. Individual fish, 5 to 10-cm-long fish (n = 6-7 per species per acclimation time) was introduced for either long (16-17 h) or short (2 h) acclimation times to the flume. During the experiment, water depth was increased from 19-21 cm to 54 cm, and back to 19-21 cm during the 140-min pulse. While none of the trout were stranded during the pulse, 1 of 6 suckers (after short acclimation) and 2 of 7 hardhead (after short acclimation) were stranded during the pulse. No fish were stranded after long acclimations. While trout were observed to inhabit the bank pools during experiments after the long acclimation periods, hardhead and suckers were observed to inhabit the bank pools during experiments after the short acclimations. Although all three species were observed to make occasional movements throughout the water column during the pulse, they mostly stayed near the bottom, especially in the channel. Research was supported by the Public Interest Energy Research Program of the California Energy Commission and the Division of Water Rights of the State Water Resources Control Board through the CABA Pulsed Flow Program of the University of California, Davis.

Identifying Climatic and Water Flow Triggers Associated with the Onset of Breeding Activities in a Foothill Yellow-Legged Frog (*Rana Boylii*) Population on the North Fork Feather River, California

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We investigated the association of climate and water flow with breeding activities of the foothill yellow-legged frog (*Rana boylii*) in six tributaries of the North Fork Feather River and their associated breeding sites on the mainstem river. The study area included three tributaries on the Poe Reach and three tributaries on the Cresta Reach. During the 2004 breeding season, we conducted visual encounter surveys for foothill yellow-legged frogs from April 13 to June 11. We captured, sexed, weighed, measured and photographed all adult frogs observed, and noted their reproductive condition and precise location using GPS and flagging. Photographs included unique markings on chins and flanks that were used to differentiate individuals. During 2005, we conducted visual encounter surveys and radio telemetry from February 14 to June 15. We radiotagged 30 female and 6 male frogs to increase our sample size of frogs and facilitate determination of frog movements. Concurrent with frog surveys, we collected data on environmental conditions including water temperature, air temperature and flow level to determine how these variables were associated with frog movements and breeding activity. In general, frogs initiated breeding when mainstem flows approached base level and water temperatures began to increase. Precipitation, air temperature, and tributary conditions did not appear to be associated with initiation of breeding; however, at the time of this writing only the 2004 data has been analyzed. For the pulsed flow program workshop, we will present the preliminary results of the two-year study.

Acknowledgements:
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Reproductive Timing of Freshwater Mussels and the Potential Impacts of Pulsed Flows on Reproductive Success

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Between April and November 2004, the reproductive cycles of native freshwater mussel species, *Anodonta californiensis*, *Anodonta wahlamatensis*, *Gonidea angulata*, and *Margaritifera falcata*, were investigated in the Pit River of northeastern California, in order to determine if and when pulsed flow events associated with hydroelectric facilities operations could adversely affect mussel reproduction. Spawning, glochidial release, and juvenile excystment from host fish are vulnerable periods in mussel reproduction that could be affected by pulsed flow events. Beginning in February 2005, data were also collected in two of the Pit River's more thermally stable, spring-fed tributaries, Fall River and Hat Creek, in order to determine potential differences in reproductive timing associated with temperature and flow regime.

Results to date indicate that periods of spawning and glochidial release in the Pit River occur throughout most of the year for *Anodonta* species, but only during the spring and early summer for *Gonidea angulata*. Gravid *G. angulata* were first observed at sites in the Pit River in March and April after water temperatures exceeded 10 °C and were no longer observed in August when water temperatures peaked at 22 °C. Similar reproductive patterns were observed for *Anodonta* spp. and *G. angulata* in the Fall River between March and June 2005. Gravid *Margaritifera falcata* were only found at one location in the Pit River between April and June, but no gravid females were found at other locations in the Pit River during this time or in Hat Creek between February and June 2005. Nearly all species of fish, including members of Cyprinidae, Catastomidae, Embiotocidae, Centrarchidae, Cottidae, and Salmonidae, collected in the Pit River between March and June 2005 were infected with both *Anodonta* spp. and *G. angulata* glochidia. *Anodonta* spp. were typically encysted on the fins and *G. angulata* were on the gills. Newly excysted juveniles of both genera were collected in stream drift throughout this period. Although encysted *M. falcata* were not found this spring (i.e., 2005), infected salmonids will likely be collected during the summer.

Preliminary data indicate that the timing and duration of reproductive events differ between mussel genera, however, all three genera exhibit some degree of reproductive activity during spring and early summer. Given that most rivers typically experience natural high flows in the spring and early summer, potential negative effects of manufactured pulsed flow events during this time would likely be minimal. During later summer months, however, out-of-season high flows could disrupt spawning and glochidial release and/or push host fishes into habitats unsuitable for survival of excysting juveniles of all genera.

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Radio-telemetry Studies Assessing Pulsed Flow Impacts on the Distribution of Fishes in the American River

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We examined the effect of pulsed flows on the spatial distribution of trout in two reaches of the American River, where water is released for the purpose of whitewater rafting and the generation of electricity. These water releases from dams represent a significant departure from the natural hydrograph, temporarily increasing water volume and flow speed within the river. Firstly, we tracked three radio-tagged rainbow trout during pulsed flows, occurring daily over a fifteen-day period during August 2004, in a wide reach of the South Fork below Chili Bar Dam. The maximum discharge rates ranged from 40.0- 90.0 m^3s^{-1}, with the discharge increasing from 5.0-50.0 m^3s^{-1} from 06:00-09:00 hrs, remaining >40.0 m^3s^{-1} from 09:00-16:00 hrs, and decreasing from 40.0- 5.0 m^3s^{-1} from 16:00-19:00 hrs on 9 August 2004. Vast areas of cobble, exposed between flows, were submerged by rapidly flowing water during the daily water discharges. Two individuals were either removed from the river (by predators) or traveled downstream out of the range of our detection, whereas one stayed within 100 m of the release site over the seven-day period. As a result of our inability to capture trout in the river, we will tag and track hatchery-raised rainbow trout during pulsed flows in the river during August 2005. Secondly, we located seven radio-tagged trout before, during, and after a single pulsed flow in the narrow reach of Silver Creek downstream of Camino Dam. Water discharges from Camino Dam into Silver Creek were negligible, varying from 0.3-2.1 m^3s^{-1} from 1 October 2003 to 30 September 2004, with the exception of 15 September 2004. The rate of discharge on this day rose from 0.5 m^3s^{-1} at 06:00 hrs to 18.5 m^3s^{-1} at 09:45 hrs, stayed constant until 14:45 hrs, and then dropped to 1.8 m^3s^{-1} by 17:30 hrs and 0.5 m^3s^{-1} by 20:15 hrs. One rainbow (T1) and six brown trout (T2-7) were tracked in Silver Creek. The minimum distance moved between tracking events was 0 m; maximum distance was 120 m. T 4 was not detected after being tagged and released. We detected little movement either up or down stream between the pre-pulse and pulse (i.e., in response to the pulsed discharge of water) compared with the movements between the release after tagging and the pre-pulse and between the pulse and post-pulse for the one rainbow trout (T 1) and two brown trout (T2 and T3). Two rainbow trout (T 5 and T 6) appeared to move downstream during the pulse; and one rainbow trout (T 7) appeared to move upstream. The distances between the three conditions can be normalized by dividing each distance, by the number of days between subsequent position determinations. When the distances are normalized per day, there are no significant differences apparent between the distances moved between: 1) release after tagging and the pre-pulse (Wilcoxon Test, $p = 0.125$), the pre-pulse and pulse ($p = 0.063$), and pulse to post-pulse ($p = 0.563$). We conclude that there were no differences between the movement of the trout, standardized for daily movement, during the pulsed flow and before and after the flow. The one day pulsed flow on Silver Creek did not appear to alter fish daily movement patterns. We would like to acknowledge the support given for these studies by thee Public Interest Energy Research Program of the California Energy Commission and the Division of Water Rights of the State Water Resources Control Board through the Pulsed Flow Program of the Center for Aquatic Biology and Aquaculture at the University of California, Davis.

Aseasonal Pulsed Flow Effects on the Foothill Yellow-Legged Frog (*Rana Boylii*): Approach and Preliminary Analysis of Recent Studies

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The foothill yellow-legged frog (*Rana boylii*) is one of a few California amphibians whose complete life cycle is associated with stream environments. Its life stages occur along a mobility continuum from immobile (eggs) to highly mobile (adults) such that adaptations which improve survival rate vary in relation to ontogeny. To avoid disturbance, the timing of this complex life history and set of habitat preferences is synchronized with the seasonality of runoff during the predictable cycle of wet winters and dry summers occurring across its. Over the last half century, the foothill yellow-legged frog has declined dramatically. Dams and reservoirs, including their associated pulsed flows, have been cited as likely factors in decline. Because of its declining status, this species has increasingly become a focal species in water management planning, especially in FERC re-licensing of hydroelectric dams. Due to the dispersed nature and different agency involvement in the licensing efforts, a comprehensive assessment of pulsed flow effects on foothill yellow-legged frogs has yet to be conducted.

We are conducting a two-phased project conducted over two years to address the above described research and water management needs. Phase I involves a review of published and unpublished literature, collation and analysis of data from recent studies, and identification of knowledge gaps. Phase II then directly applies the information gathered in Phase I to refine the focus of experiments regarding relative vulnerabilities of various life stages to discharge fluctuation and to develop hydrodynamic models of frog habitat.

Here we focus primarily with Phase I progress. To date we have identified recent studies from seven different regulated river systems, mostly unpublished. The studies have examined both effects of pulsed flows on eggs, tadpoles, frogs, and their habitats, and in some cases their resources (e.g. detachment and export of periphyton due to a pulse). We have compiled a list of variables and identified those that are consistent across these studies. These variables will be used in both a meta-analysis and summarized individually as appropriate. We have also taken advantage of this spring's atypical rainfall events to observe the effects of natural pulse flows on eggs and recently hatched larvae in an unregulated river to provide another basis for comparison. In addition, we have conducted some re-analyses of data in the studies to clarify relationships between frog breeding population size and available breeding habitat area. This is important because a common thread among existing studies is the implicit, yet untested, assumption that FYLF are limited by breeding habitat area in regulated rivers. Over the next few months, we will finalize Phase I analyses. For Phase II, we are field-rearing tadpoles in flow-through enclosures. The larvae are from a robust coastal population and will be used in artificial stream channel manipulations of velocity and substrate size in August. We are also collecting baseline data for hydrodynamic models.

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Fish Response to a One-Day Whitewater Kayaking Flow Pulse Release in Silver Creek, a Tributary of the South Fork American River

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We studied the response of fish to a 1-day pulse flow release for whitewater kayaking from Camino Dam on Silver Creek, a tributary of the South Fork American River. On 15 September 2004 flows in the Camino Reach of Silver Creek were increased from a base flow of 17 cfs to a peak of 653 cfs by midday, then decreased back to base levels. A representative 300 m study reach was chosen, beginning about 500 m downstream of the dam. This reach was chosen because a preliminary snorkel survey indicated that there were very few young-of-the year fish in the first 500 m downstream of the dam. The reach was subdivided into three 100 m sections. During the week before the pulse we captured a sub-sample of fish by minnow trapping and angling. Fish were anesthetized with carbon dioxide, given visible elastomer implant (VIE) marks on both the adipose and caudal fins, with a unique color for each section of the study area, and returned to the location from which they were captured. The marking was intended to allow us to detect whether a fish in a given section had been displaced upstream or downstream during the pulse. The day before and the day after the pulse release we counted fish in the three sections by snorkeling. Flow data were obtained courtesy of the Sacramento Municipal Utility District, which operates Camino Dam. We monitored water temperature and dissolved oxygen at the upstream end of the sample reach before, during, and after the pulse. Water samples collected before, during and after the pulse will be analyzed for nutrients, conductivity, and turbidity. Pool length, maximum depth, and maximum width were measured when the flow was at 17 cfs. Water temperatures before and after the pulse were about 10.7 ^{o}C. Values observed on the day of the pulse ranged between 10.2 and 10.9 ^{o}C. Dissolved oxygen was approximately 11 mg/L during the pulse, and 9.64 mg/L the following day. The three sections of the study reach contained between three and seven pools each. Two species of fish were observed: rainbow trout (*Oncorhynchus mykiss*), and non-native brown trout (*Salmo trutta*). Fish were categorized as young-of-the-year (total length less than 10 cm), juvenile (10-18 cm), or adult (greater than 18 cm). Both species were observed in all three sections both before and after the pulse. Young-of-the-year fish were observed in all sections both before and after the pulse, as were juveniles and adults. Preliminary analyses suggest that fish were not displaced downstream by the pulse, but may have taken cover behind the rocks and crevices which were prevalent in the reach.

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Regulating Pulse Flows and the Snowmelt Hydrograph in Bedrock/Boulder-Dominated Sierra Nevada Rivers

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The prominent component of annual hydrographs missing from many regulated Sierra rivers is a peak runoff event generated by late spring - early summer snowmelt. While snowmelt runoff floods are highly dependable annual events that accomplish most 'routine' physical work - scouring depositional features, transporting fine/coarse sediment, and building floodplains - the snowmelt runoff hydrograph is also biologically fundamental to sustaining river ecosystems. Our project, to quantify the snowmelt hydrograph's many ecological roles for bedrock/boulder dominated Sierra rivers, is sponsored by the Public Interest Energy Research Program of the California Energy Commission and the Division of Water Rights of the State Water Resources Control Board and coordinated through the Pulsed Flow Program of the Center for Aquatic Biology and Aquaculture of the University of California, Davis. Studies of two similar tributaries to the Tuolumne River are underway to investigate these ecological roles: the unregulated Clavey River and regulated Cherry Creek. The Clavey River snowmelt runoff peaked at 6,850 cfs on May 16, 2005, representing a 4.7-yr flood recurrence. The Cherry Creek snowmelt runoff peaked at 3,390 cfs on May 21, 2005, representing a 14-yr flood recurrence. Preliminarily, this peak was insufficient to drown-out most secondary hydraulic controls (primarily exerted by boulder ribs) on the Clavey River. These controls shielded established riparian vegetation, even most saplings, from significant scour. Many depositional features still remain underwater (through June 17, 2005) and have not yet been assessed for scour/deposition. On Cherry Creek, many secondary hydraulic controls in the canyon reach were drowned-out. Overall, the peak flow on Cherry Creek promoted channel confinement by depositing silt and coarse bed material onto former floodplains now encroached by mature trees, whereas gross geomorphic changes to the Clavey River were not observed (pending potential channel bed changes still submerged). Three cycles of habitat mapping for fish, amphibians, and macroinvertebrates have been accomplished for developing habitat-flow relationships throughout the snowmelt recession limb. Exposed bar features and point bars on Cherry Creek, now immobilized by mature trees, provide more emergent fry and spawning habitat for rainbow trout, as well as amphibian and macroinvertebrate habitat, during peak flows than the Clavey River. As snowmelt flows recede, however, the Clavey River should provide extensive habitat (more than in Cherry Creek) that coincides with the life history timing of the native fish and amphibians. Habitat mapping on both rivers will continue as snowmelt flows recede.

Background Perspective and Flow Regime Effects on California Native Fish Assemblages: Case Studies

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Our project was a literature review of previous studies on selected river systems with the initial goal of consolidating information on native fish species and associated streamflow conditions. Our main intent was to examine the results of surveys in several unpublished reports and to summarize them in a form that would be more accessible to other researchers but we also drew from more recent journal publications if such studies were available.

The information that we reviewed varied widely in extent and quality among the different rivers. The most extensive studies were the surveys for the lower Pit River and North Fork Mokelumne River. Those two studies contained data on fish species abundance and distribution and on streamflows for an array of locations in their respective watersheds--hence, providing potential data for a more detailed future examination of fish-streamflow relationships.

We did not discern any consistent, meaningful relationships that pervaded the range of studies that we examined in the time-frame of our project. However, the search for a general pattern was subordinated by our primary goal of broadly summarizing the results of the studies in terms of fish and streamflow data. It is possible that further evaluation that focuses on one or two of the data-rich studies may yet identify a pattern between streamflow regimes and fish population robustness. In a broad sense, we were able to achieve the goal of providing descriptive summaries of streamflows and fish population information for each of the selected rivers but we were unable to form a detailed analytical understanding based on that information.

A secondary aspect that emerged in our project was a simplified conceptual framework for approaching the question of how streamflow regimes affect fish species assemblages. We suggest examples of some parameters to utilize and questions to ask in regard to describing streamflow changes and their effects on fish. We also provide examples of working hypotheses that may aid our understanding--on a broad temporal and spatial scale--of how streamflow regimes and fish assemblage composition are related.

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