Drafting bypass flows and their effects on native fish: linking forest practice rules to fish and game code

Project# EMC-2019-004

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Collaborators: California Department of Fish and Wildlife and National Marine Fisheries Service.

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Project Duration (Years/Months): 2 years and 6 months.

Background and Justification

Timber harvest often requires drafting water directly from local stream sources to reduce erosion and sedimentation effects. Current California Forest Practice Rules (FPRs) require that stream bypass flows be maintained at 2 cubic feet per second (cfs) during drafting in order to maintain downstream aquatic habitat and species. The bypass flow mitigation measure aims to ensure compliance with numerous statutes, codes, and laws including those stipulated by both the federal and California state governments such as Fish and Game Code 1600, Fish and Game Code 5937, the California Endangered Species Act, the Federal Endangered Species Act, and the Clean Water Act. However, the effects of such bypass flows on native fishes have not been monitored nor robustly quantified; therefore, there is potential ambiguity in how managers interpret drafting proposals during permit applications. More objective and science-based decisions could enhance conservation of aquatic resources in California via improved decision making.

Recent pilot data collection efforts suggest that a 2 cfs bypass flow may not be protective of resident fishes during drafting (R. Hawkins, CDFW, personal communication). Pilot data pertaining to the FPRs were collected during 2016 by Robert Hawkins (CDFW) and crew, but these data were not fully analyzed. There were also significant limitations associated with the data set. First, avian predation was high during the experiment and reduced experimental populations by greater than 90%. Second, the study was not replicated, making any final conclusions difficult to fully defend. In collaboration with our partners at CDFW and NMFS, we propose to (i) fully analyze the 2016 pilot study data regarding the effects of the FPRs 2 cfs

bypass flow on fish and (ii) use that information to inform and conduct additional whole ecosystem experiments to ensure robust FPRs during timber harvest.

In accordance with Theme 5 of the EMC strategic plan (i.e., "fish habitat"), we propose a study designed to test the effects of the 2 cfs stream bypass flow on native resident fish during drafting for timber harvest purposes and explicitly tie those results back to the California FPRs. Specifically, we are interested in understanding if there are quantifiable differences in population condition, behavior (motility), and physiology of salmonids over a range of bypass flows, including those required by current FPRs (e.g., 2 cfs). In addition, we will measure a host of environmental variables throughout the study including stream discharge, temperature, and a suite of water quality parameters including dissolved oxygen. Bypass flow effectiveness monitoring will be conducted downstream of the California Department of Fish and Wildlife, Mt. Shasta Fish hatchery. The proposed work is important and timely. California has experienced numerous catastrophic wildfires recently, in part precipitated by the historic drought of 2012-2016. Droughts in California are likely to increase in severity and frequency with the onset of climate change, making bypass flows an important measure to protect salmonids and other fishes.

Objectives and Scope

California FPRs require a minimum 2 cfs bypass flow during water drafting from adjacent streams. The flow is consistent with California Fish and Game Code 1600 and 5937, which stipulate that the protection and conservation of fish is of the utmost public interest and that fish must remain in good condition during such practices. The goal of this research is to examine how water drafting affects the population condition, behavior, and physiology of fish in accordance with California FPRs and to quantify and inform those rules to ensure that fish remain in good condition during such practices. The proposed project will pursue the following objectives:

1) Analyze pilot data and review existing literature
    a. Analyze previously collected pilot data from the California Department of Fish and Wildlife regarding bypass flows on the condition and response of fish and use that data to inform and strengthen the proposed research component of the project (see #2 below).
    b. Review all relevant scientific literature related to water drafting and bypass flow criteria, including those produced by the National Marine Fisheries Service (NMFS) and CDFW (e.g., 2001 and 2002) and produce a scientific review report.
2) Using a robust, replicated study design, examine the condition, behavior, and physiological response of fish to < and > 2 cfs bypass flows.
3) Determine if there are quantifiable differences in population condition, behavior, and physiology of fish under a 2 cfs bypass flow versus other flow treatments.
    a. Determine if the 2 cfs stream bypass flow rule is protective of fish.

Critical Questions and Forest Practice Regulations Addressed

See Section 2.4 of the EMC Strategic Plan (EMC Themes and Critical Monitoring Questions).

The primary EMC critical questions that will be addressed include:

a) Theme 3 (Road and WPLZ Sediment) as related to the following critical questions:

   Are the FPRs and associated regulations effective in *(d) maintaining or improving fish passage through watercourse crossing structures?*

b) Theme 5 (Fish Habitat) as related to the following critical questions:

   Are the FPRs and associated regulations effective in (*b) maintaining and restoring the distribution of foraging, rearing, and spawning habitat for anadromous salmonids?*

Study linkages to Theme 3(d) and Theme 5(b): fish motility *(*movement) is one of the primary response variables we will examine to better understand the effects of drafting water at < and > 2 cfs flows and, thus, is directly related to fish passage and Theme 3(d). While the study proposes to look at the effects of FPRs related to drafting of water during timber harvest on fish and fish habitat, we believe that our study design will also help assess fish passage since movement is one of the primary response variables. In addition, drafted water may also be used for watercourse crossing construction (CDFW 2015), which is also directly related to Theme 3(d) as noted above. For Theme 5(b), we are specifically examining if current FPRs and the associated regulations maintain fish habitat, primarily through foraging and rearing (see Research Methods).

The proposed project addresses the following Forest Practice Regulations: California Forest Practice Rules 923.7, 943.7, 963.7: "Maintenance and Monitoring of Logging Roads and Landings". Specifically, *(E) Bypass flows for Class I Watercourses shall be provided in volume sufficient to avoid dewatering the Watercourse and maintain aquatic life downstream, and shall conform to the following standard:*

1. *Bypass flows in the source Stream during drafting shall be at least 2 cubic feet per second*
2. *Diversion rates shall not exceed 10 percent of the surface flow*
3. *Pool volume reduction shall not exceed 10 percent.*

In addition, the proposed project addresses California Fish and Game Code 5937, California Fish and Game Code 1600, the California Endangered Species Act, the Federal Endangered Species Act, and the Federal Clean Water Act.

Research Methods

Experimental Design and Response Variables

Using a series of replicated stream reaches, we propose to manipulate flows below the Mt. Shasta Fish Hatchery in collaboration with the CDFW to understand the effects of water withdrawal during drafting on salmonid condition, behavior, and physiology. Juvenile salmonids (*O. mykiss*) will be obtained from the Mt. Shasta Fish Hatchery (California Department of Fish and Wildlife, Mt. Shasta, California, USA). Fish will be transported to the study area in insulated and oxygenated 114 L plastic containers. Prior to experimentation, individual fish will be weighed (wet mass ± 0.1 g), measured for fork length (FL; ± 1.0 mm) and distinctively marked

using a Passive Integrated Transponder (PIT) tag. Individual fish will be randomly separated and assigned into the different flow treatment groups (see below). Efforts will made to ensure that relative densities of fish in each treatment are reflective of naturally occurring densities in the wild. Inlets and outlets of each stream reach will be blocked with netting to minimize emigration and immigration between reaches. Directly measured response variables will include (i) behavior/motility (i.e., magnitude and direction of movement), (ii) population condition – defined as somatic growth rate and population mortality rate, and (iii) changes in physiology during the experiment (i.e., cortisol levels indicative of stress and immunological response and the potential for pathogenic infections under different bypass flows).

During the experiment, individual fish will be exposed to a range of flows including a control flow (natural conditions), 1 cfs, 2 cfs and 4 cfs (treatments) to understand the range of biological response. At each reach, water drafting will occur four times/day, five days a week from May through mid-July with four thousand gallons of water drafted at a rate of 350 gallons /minute as stipulated by NMFS (2001). Drafting rates will not divert more than 10 percent of current streamflow (NMFS 2001), as ensured by an installed staff gauge. Water flows will be reduced using a hatchery flow control structure as the spring/summer season progresses from May through July to simulate naturally declining flows of a small Class 1 northern California stream (CDFW 2006). The propose study uses a modified BACI design to ultimately assess the effects of bypass flows on the aforementioned response variables.

Behavior

The primary response variable to assess changes in behavior associated with water drafting and reduction of flows to 2 cfs is motility and habitat usage within experimental reaches. Prior to experimentation, individual fish will be anesthetized and distinctively marked with a 12.5 × 2.1 mm, 134.2 kHz full-duplex passive integrated transponder (PIT) tag (Biomark Inc., Boise, Idaho, USA). PIT tag marking will be conducted strictly following the methods of CBWA (1999). PIT tag detection systems will be used to quantify and ultimately determine change in movement (magnitude and direction) over each experimental reach as associated with water drafting and bypass flow criteria. Behavior response variables will be compared across treatments and the control.

Population Condition

The condition of salmonid populations during the experimental period will be assessed in terms of somatic growth (e.g., absolute growth in mass ($g \cdot day^{-1}$)) and population mortality as assessed by a mark recapture framework (see Lusardi et al. 2019, Pine et al. 2007), with experimental reaches serving as replicate experimental units. Individual salmonids will be weighed and measured immediately before and after the experiment. Earlier data collection efforts found that avian predation during the pilot phase was extremely high and reduced experimental populations by approximately 90%. Avian mist nets or cordage will be used to prevent avian predation throughout the experiment. Population condition response variables will be compared across treatments and the control.

Physiology

Salmonids may be subjected to physiological stresses associated with bypass flow treatments that may inevitably increase mortality. Changes in bypass flows between treatments may also change pathogen presence and immunological response of salmonids to pathogenic infections which may also reduce survivability. Considering this, qPCR DNA pathogen detection will be utilized to quantify parasite prevalence, while signs of infection will be assessed by mRNA expression of an immunological response, such as transcriptomic expression of the TRL1 and TNFα genes or Immunoglobulin M (Hoffmaster et al. 1988; Bartholomew et al. 1997; Li et al. 2010; Atkinson & Bartholomew 2014; Hallet et al. 2012; Bjork et al. 2014). Further, we propose to also assess lethal and sublethal physiological stress, including examination for clinical signs of infection and parasite prevalence within gill, liver and head kidney tissue, but also general stress response of stress-related proteins associated with water quality and flows with liver tissue, and blood plasma to assess cortisol levels (Marine & Cech 1998; Veal et al. 2002; Sardella et al. 2004; Todgham et al. 2005; Sardella & Kueltz 2009). Physiological measures as noted here will be compared across treatments and the control.

Environmental Variables

A host of additional environmental variables will be measured during the experiment to assess effects on salmonids including discharge, temperature, water quality (including dissolved oxygen) and changes in food web dynamics. Flow and temperature will be continuously monitored using Onset pressure transducers (stage) and temperature gauges at each replicated reach. A staff gauge will be installed and discharge will be measured periodically to establish a stage discharge relationship in each reach. Benthic macroinvertebrates will be sampled and identified to the lowest practical order to understand the effects of bypass flows on community dynamics and changes in prey resource availability for foraging salmonids. Sampling will follow standard operating procedures for the collection of benthic macroinvertebrate samples following the Surface Water Ambient Monitoring Program Bioassessment Procedures for wadeable streams (SWAMP 2007). Stream macroinvertebrates will be collected using a 500 μ mesh D-frame net, preserved in ethanol and returned to the laboratory for processing and identification. Trends in quantifiable metrics throughout the experimental period will be assessed to determine biological response of stream conditions and food availability for salmonids.

Scientific Uncertainty and Geographic Application

The spatial scale of our study is at the site scale and there may be certain ecosystem properties that are specific to our study reach that may not extrapolate to all watersheds. However, there are inherent tradeoffs between the spatial scale of study and the practicality of conducting a manipulative experiment to inform policy. Ecological manipulative studies, as proposed here, are the most effective experimental studies enabling researchers to make strong connections between environmental variables of choice (i.e., bypass flows) and the response of test organisms (i.e., salmonids). We believe that the results of the proposed study will greatly inform current bypass flow guidelines associated with the FPRs and will be broadly applicable to Class I streams

throughout California. Additionally, we anticipate that the results of the study (including the review of the pilot data and existing literature) will be the best available science to inform bypass flow policy under the current FPRs. Ultimately, we assume this will greatly inform relevant policy and managers tasked with difficult resource management decisions.

Collaborations and Project Feasibility

The project is highly feasible and strongly supported by our partners. Our primary collaborators on the projects are: University of California, Davis, California Department of Fish and Wildlife, and the National Marine Fisheries Service.

Project Deliverables

1) Analyze pilot data, summarize, and report findings (Year 1; see detailed project timeline)
2) Technical literature review (scientific report) of existing bypass flow requirements to keep fish in good condition, including NMFS water drafting specifications (NMFS 2001) and the joint CDFW and NMFS guidelines on maintaining instream flows to protect fisheries (CDFW and NMFS 2000) (Year 1; see detailed project timeline).
3) Experimental bypass flow study, data collection, and lab analysis (Year 2 and Year 3; see detailed project timeline)
4) Data analysis, write up of results, provide scientific report to EMC and submit to peer reviewed journal for publication (Year 2 and Year 3; see detailed project timeline)
5) Presentation of results and recommendations to EMC (Year 3; see detailed project timeline)

Detailed Project Timeline

The duration of the project will be 2 1/2 years starting in the summer of 2020 and extending until December 2022 (Table 1). During year 1 of the project, we propose to fully analyze the recent pilot data collected by CDFW. Despite significant limitations in the data associated with the experimental design, numerous samples exist (physiological, growth data, etc.) that have not been analyzed. We suggest this information will be essential in informing the planned research component of the proposal that will directly tie FPRs and associated bypass flows requirements to population condition, behavior, and physiological metrics measured during the experimental phase of the proposed project. During Year 1, we will also produce a scientific review paper of all bypass flow literature as it relates to fish passage and condition including a review of NMFS (2001) and CDFW and NMFS (2002). During Year 2 of the project, we will prepare for the experiment, calibrate and set up instrumentation, conduct field work, and execute the experiment. During year 3, we will analyze the collected samples (e.g., physiological samples), analyze the data, write the final scientific report, and submit the report to the EMC and to a scientific journal for publication. In addition, results, findings, and recommendations will be presented to the EMC. For a complete detailed project timeline, please see Table 1.

Table 1. Detailed timeline of the project.

	Academic Period									
Activity	Su 20	F 20	W 21	Sp 21	Su 21	F 21	W 22	Sp 22	Sum 22	F 22
Objective 1 – Pilot Data and Literature Review										
Analyze pilot data and report findings										
Review existing literature										
Scientific literature review paper										
Objective 2 – Experiment and Data Collection										
Site selection and preparation										
Instrumentation										
Field work and data collection										
Objective 3 – Analysis and Writing										
Sample analysis, data analysis, writing										
Final report and findings										
Presentation to EMC										
Submit to peer review Journal										

Requested Funding

We request $239,313 in EMC funding for this project. We have secured $58,153 in matching funds and in-kind contributions for the project. We have attached a detailed budget table (xls) with the proposal and have followed the example budget template as provide by EMC.

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Table 2. Detailed Project Budget

Category	Description	Year 1	Year 2	Year 3	Total
Personnel	Principal Investigator ($40.72/hr)	$ -	$ 13,883.00	$ 4,767.00	$ 18,650.00
	Laboratory and field technician ($29.33/hr)	$ -	$ 9,998.00	$ 5,149.00	$ 15,147.00
	Graduate student ($27.88/hr)	$ 38,765.00	$ 39,928.00	$ 9,792.00	$ 88,485.00
Fringe Benefits	Principal Investigator (average benefit rate: 41%)	$ -	$ 5,636.00	$ 1,993.00	$ 7,629.00
	Laboratory and field technician (average benefit rate: 41%)	$ -	$ 4,059.00	$ 2,152.00	$ 6,211.00
	Graduate student (average benefit rate: 2.1%)	$ 775.00	$ 838.00	$ 215.00	$ 1,828.00
Other	Graduate Student fees	$ 16,263.00	$ 17,890.00	$ -	$ 34,153.00
	Gael liability insurance (1.5% total salary)	$ 581.50	$ 957.15	$ 295.62	$ 1,834.23
Operating Expenses	Physiology sampling equipment and analysis	$ -	$ 8,500.00	$ -	$ 8,500.00
	Passive Integrated Transponder arrays and tags	$ -	$ 15,000.00	$ -	$ 15,000.00
	Level loggers and thermisters (water levels and temperature	$ -	$ 2,500.00	$ -	$ 2,500.00
	Invertebrate sampling supplies and analysis	$ -	$ 500.00	$ -	$ 500.00
	Lodging/rent	$ -	$ 3,500.00	$ -	$ 3,500.00
Travel	Vehicle rental	$ -	$ 1,160.00	$ -	$ 1,160.00
	Food (CalHR per diem rates)	$ -	$ 3,000.00	$ -	$ 3,000.00
Indirect Costs	indirect cost rate of 15%	$ 8,458.00	$ 19,103.00	$ 3,655.00	$ 31,216.00
Matching or In-Kind Contributions	Time on project from co-PI Fangue	$ 11,535.00	$ 14,159.00	$ 6,224.00	*$ 31,918.00*
	Time on project from co-PI Rypel	$ 10,175.00	$ 10,570.00	$ 5,490.00	*$ 26,235.00*
Total Costs with in-kind contributions		$ 86,552.50	$ 171,181.15	$ 39,732.62	*$ 297,466.27*
EMC Funding Request		**$ 64,842.50**	**$ 146,452.15**	**$ 28,018.62**	**$ 239,313.27**