Relating flow, habitat, temperature, food ration, and drift of macroinvertebrates to size of sub-yearling and yearling steelhead.

Pre-proposal prepared by N Hemphill

Why is this study important to managers?

Benthic Macroinvertebrates are an important component of the Trinity River ecosystem and are expected to change in response to our management actions. By quantifying the flow-habitat relationship for major Benthic Macroinvertebrate (BMI) species, BMI habitat can be managed to promote food availability for juvenile salmonids as well as the ecological health of the Trinity River. Using a bioenergetics approach and information from the flow-BMI habitat relationship, the effect of flow on ration and juvenile growth can be modeled. This approach helps managers to better understand the implications of flow on potential growth of juvenile salmonids. Ultimately the success from juvenile emergence to smolt is dependent on juvenile growth as well as on ecosystem capacity. The flow-ration relationship can indicate how to balance physical modification to improve habitat capacity with the necessary food availability to supply the existing or constructed habitat.

Introduction

One of the influences of dams on natural ecosystems is to remove disturbance and variation in flow. Dams reduce the frequency, magnitude and duration of floods and reduce the effects of drought. Aquatic organisms in particular macroinvertebrates are adapted to a highly variable flow regime (Lytle and Poff 2004). Macroinvertebrates are an important ecosystem component (Cardinale and Palmer 2002, Vannote et al. 1980); as secondary producers they play an important role in food webs, transfer energy and biomass between primary producers and fish, and, bridging between primary producers and fish. Habitat changes caused by dams may be the primary impact on macroinvertebrates (Lessard and Hayes 2003). Macroinvertebrates influence many ecosystem functions and processes such as nutrient spiraling, decomposition, and primary productivity (Wallace and Webster 1996). Differences over time in river conditions can alter linkages among invertebrates and ecosystem functioning (Cardinale and Palmer 2002). Due their short life cycle, importance in the ecosystem and sensitivity to changing habitat macroinvertebrates are thought to be an ideal trophic level to study to assess changes in ecosystems.

Functional groups (grazers, shredders, gatherers, filterers and predators) of macroinvertebrates influence different ecosystem processes. Therefore the relative proportions of these groups and overall diversity of macroinvertebrates are important properties of the river ecosystem. Dams influence the relative proportions of these functional groups. Macro-invertebrate drift was sampled below two dams; and included a high diversity of Trichoptera, Diptera, Ephemeroptera, and Plecoptera (Tonkin et al. 2009). The proportion of Ephemeroptera, Plecoptera and Trichoptera (EPT) was 3–4 times higher in the unregulated section of the river, but overall densities were similar along the river (Tonkin et al. 2009). Management actions such as gravel augmentation may influence invertebrate functional groups. On the Mokelumne River invertebrate standing crop, density and functional group changed within weeks after gravel augmentation; peaking 12 weeks later (Merz and Chan 2005). However, low species diversity was observed, 3 species comprised over 61% of the organisms (Merz and Chan 2005). Percent EPT (Ephemeroptera, Plecoptera, and Trichoptera) was negatively correlated with substrate compaction and % boulder in the substrate composition (Tiemann et al. 2005). Robinson and Jolidon (2005) examined organic matter processing in the context of microbial activity and invertebrates and concluded that in alpine rivers that environmental conditions significantly affected ecosystem functioning. Species within functional groups are not always ecological equivalents thus influencing how biodiversity changes may affect ecosystem function (Vaughn 2010).

Stream ecologists agree that chironomids, Ephemeroptera, Trichoptera and stoneflies are a good group to evaluate the health of the ecosystem. Rapid assessments are based on EPT the three good indicators of invertebrate community health. I would add in chironomids as they are an important component of young fish diets. These four taxomonic groups encompass a wide range of functional group: grazers, filterers, gatherers, predators and shredders.

Background

On the Trinity River, the dipterans simuliidae and chironomidae dominated Chinook and steelhead diets in the past (Appendix C 1980). Coho salmon consumed chironomids cladocera, mayflies, black flies and worms. Very few Trichoptera were consumed by this species. In the

American River, Chinook salmon and steelhead fed primarily on chironomids, baetids, and hydropsychids (Merz and Vanicek 1996). In the lower Mokelumne River, California, juvenile chinook salmon fed on zooplankton, chironomid, hydroptilid, and hydropsychid pupae (Merz 2002a and b).

During the period 1970-1980 (Appendix C 1980) the Trinity River, deep swift runs and pools did not support many invertebrates; the highest diversity and numbers were found in shallow (<10 inches deep) riffles composed of small rocks of two to four inches and velocities from 1-2 fps. In 1980, the riffles near the hatchery were dominated by black fly larvae, with 3,636 per sample at the hatchery declining to 80 per surber sample at Lewiston Bridge. Coho appeared to select more mayflies than the other two salmonids. Exclusive of simuliids, the average number of invertebrates was 80 per square foot up near Lewiston Dam. In the reach between Indian Creek and the confluence of the North Fork the number dropped to 45 invertebrates per square foot.

Our recent management actions have changed the type of disturbances, the type of substrate and the interactions between substrate and disturbance. These disturbances and changes in substrate influence invertebrate community structure and secondary productivity. As we anticipate change in the bed form, the reduction of fines and the increase in transport and deposition of coarse material we would predict corresponding change in the benthic macroinvertebrate community structure and function.

Importance to the Trinity River Restoration Program

A productive and diverse benthic macroinvertebrate (BMI) community is important for maintaining stream ecosystem integrity under a regulated flow regime (Jowett 2007). The 1980 (Appendix C 1980) study predicted that the density of invertebrates should significantly increase as the substrate was cleansed of fines. Fine bed material storage has decreased through much of the TRRP domain (Gaeuman and Krause 2011). We would predict a corresponding increase in the density, biomass and species composition of invertebrates associated with this change. In addition where we have changed a reach to include more inundated gravel bars we would predict that we would see higher numbers of invertebrates and a higher diversity.

If we look at the IAP (2009) we predicted that as channel complexity increases that fish growth rates, survival, and condition would correlate positively to increases in invertebrate production, species diversity and abundance. Salmonids, especially steelhead derive most prey from drift of benthic macroinvertebrates (Elliot 1970). In addition, terrestrial insects that fall into the drift can be a seasonally important food source that can provide a significant percentage of a trout's annual energy intake (Saunders and Fausch 2007). A strong correlation between daytime invertebrate drift density and the relative growth rate of cutthroat trout was found in an Oregon stream (Wilzbach et al. 1986).

Habitat for many of the most important aquatic macroinvertebrate prey occurs in riffle areas, which are sensitive to flow management. During base flow conditions, releases from Lewiston Dam offer substantial control over flows as far downstream as the North Fork Trinity. Potentially, macroinvertebrate habitat throughout the Program area can be managed to optimize food availability (terrestrial and aquatic macroinvertebrate production) with respect to requirements of early life stage salmon and steelhead. Riparian vegetation hanging over the river or grasses and shrubs on the floodplain during high flows are sources of terrestrial insects. If we were interested in how floodplains function to provide terrestrial insects to young fish using the floodplains during high flow we could design surveys of terrestrial insects immediately before spring increases in flow.

Prioritization of assessments

What aspect of this important component of the ecosystem would be the most cost effective and reasonable to assess?

Improving knowledge and predictions of ecological responses to flows can be achieved by coupling physical system models to ecological responses and (2) clarifying empirical relationships between flow and the desired ecological responses through monitoring of experimental flow releases (Shafroth et al.2010). One of the first assessments in the Integrated Assessment Plan (IAP) proposed for macroinvertebrates was to estimate of the area of suitable habitat for benthic production at different flows. Aerial photographs showing locations of riffles and a well documented discharge-to-depth relationship in the riffles could provide insight into the effects of flow management on productive invertebrate habitat. In addition, 2-d hydrologic modeling could supply at a smaller spatial scale than the 41 miles detailed depth and velocity profiles at different flows over riffle areas. We currently have the aerial photography, HEC-RAS, and 2- d hydraulic modeling to support this assessment. It should also be feasible to use existing hydraulic modeling to estimate the area of suitable habitat for benthic production, velocities and depths. In addition output from HEC-RAS could be used to predict inundation levels on a larger scale.

A second assessment step would provide linkages between invertebrate drift out of riffles and salmonid growth. Models have been used to predict effects of water velocity on prey capture rates and gross energy intake rates by juvenile coho salmon and steelhead (Piccolo et al. 2008). Values for costs of swimming, energy composition of food in the drift, energetic costs of obtaining food can be obtained from the literature (e.g Trudel et al. 2005). Diet relative to prey availability (Johnson and Ringler 1980), and relation to growth rate (Rosenfeld and Taylor 2009) can also be estimated from the literature. Temperature has an influence on consumption rates and growth of fish as well as on macroinvertebrate communities (Lessard and Hayes 2003). Coupling aerial photography (available), temperature (available), hydraulic modeling (available), and bioenergetics modeling (parameters to be based on literature values) could provide predictions on the linkages between salmonids, temperature, ration (access to food resources), flow and growth rates, and size in the upper Trinity River. We propose to start with steelhead juveniles as much data is available in the literature, it is a species that lives year round in the Trinity River, and smolt size has been tied to marine survival (e.g. Lum 2003).

Once consumption is estimated from a bioenergetics model (e.g. Hayes et al. 2007,Railsback and Rose, 1999, Beauchamp et al.1989) predictions of growth can be compared to change in size class over time. Details on the modeling will be provided in the full proposal. However the models would benefit limited sampling of drift, size distribution over time, and benthic invertebrates, velocities and depth of riffles. Limited growth rates (or a surrogate of size distribution over time) and invertebrate sampling key locations would allow insight into which combination of physical processes, prey availability and flows might be producing the highest juvenile steelhead growth and thus size.

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