**Abstract-** Large, temperate rivers (LTR) throughout the northern hemisphere have undergone dramatic and long-term anthropogenic changes. Such impacts have altered the hydrologic, sediment, temperature and flow regime of these systems and have had negative impacts on their native flora and fauna. Numerous projects have been undertaken to counteract these impacts in the past three decades. Unfortunately, a strong tendency has emerged to focus river conservation, restoration and monitoring on charismatic or economically important fauna without thorough consideration of watershed attributes and processes of the watershed that control biodiversity and production. Furthermore, uncertainty as to how well restoration projects actually work demonstrates the critical need for research to evaluate how habitat manipulations directly influence aquatic resources. Confounding our understanding of how to restore riverine function is the fact that most LTR have been under some state of impairment long before any attempt was made to study them, making evaluation even more difficult.

In this study, I examined the effects of chinook salmon (*Oncorhynchus tschawytscha*) and steelhead (*O. mykiss*) spawning habitat enhancement on specific parameters associated with the spawning environment in the Mokelumne River, a regulated stream in California's Central Valley. Specifically, I assessed:

1. effectiveness of a project to enhance spawning habitat for chinook salmon;
2. benefits of gravel enhancement to the development and survival of native chinook salmon and steelhead embryos;
3. effects of gravel enhancement on the benthic macroinvertebrate community associated with these spawning habitat enhancement sites and;
4. prospects of estimating an appropriate bed sediment budget for these projects.

Results from specific assessments are as follows:

Physical measurements taken before and after gravel placements show that spawning gravel enhancement sites significantly increased channel water velocities, intergravel permeability and dissolved oxygen, reduced channel depths and equilibrated intergravel and ambient river temperatures. These positive benefits remained throughout a 30-month monitoring period. Adult chinook salmon began spawning at previously unused sites within 2 months after gravel placement and continued to use sites for the length of the study period. Topographical channel surveys provided a useful tool for monitoring bed material transport and layering redd locations on contour maps.

Spawning bed enhancement increased survival of chinook salmon embryos in a regulated California stream with a gravel deficit. Eyed chinook salmon eggs planted in enhancement gravels had higher survival to swim-up stage than did eggs planted in unenhanced spawning gravels, although no significant difference in growth was observed. Intergravel temperatures and substrate size within spawning sites were highly correlated with distance downstream from the lowest non-passable dam. Strong correlations were also observed between intergravel turbidity and total suspended and total volatile solids. Four multiple regression models built with a combination of physical parameter measurements performed well in predicting survival and length of chinook salmon and steelhead embryos under various conditions. Survival models accounted for 87% of the variation around the mean for chinook salmon and over 82% for steelhead. Growth models accounted for 95% of the variation around the mean for chinook salmon and 89% for steelhead. These findings suggest that spawning bed enhancement can improve survival of salmonid embryos in degraded habitat.

Additionally, measuring a suite of physical parameters before and after spawning bed manipulation can accurately predict benefits to target management species. Gravel enhancement can be an effective means for improving salmon spawning habitat in rivers with low gravel recruitment because of upstream dams.

In spawning enhancement projects, benthic organisms colonized new gravels quickly, equaling densities and biomass of unenhanced spawning sites within 4 weeks. Macroinvertebrate species richness equaled that of unenhanced sites within 4 weeks and diversity within 2 weeks. Standing crop, as indicated by densities and dry biomass, was significantly higher in enhancement sites after 12 weeks and remained so over the following 10 weeks. Although mobile collector/browsers initially dominated new gravels, sedentary collectors were the most common feeding category after 4 weeks, similar to unenhanced sites. These data suggest that cleaned gravels from adjacent floodplain materials, used to enhance salmonid spawning sites, are quickly incorporated into the stream ecosystem, benefiting benthic macroinvertebrate densities and dry biomass.

Finally, short-term bed elevation and feature adjustments were monitored over 36 months at three Chinook salmon (*Oncorhynchus tschawytscha*) spawning bed enhancement sites in the regulated lower Mokelumne River, California. Our data show that spawning bed sites containing 794 – 1323 $m^3$ of enhancement gravel lost from 3-20% of remaining gravel volume annually during controlled flows of 8 – 70 $m^3$ $sec^{-1}$ and 2.6 – 4.6% of placed material during short-duration (19 days) flow releases of 57 $m^3$ $sec^{-1}$. The oldest site lost ~50% of placed material over the four-year monitoring period. Of the mechanisms monitored, gravel deflation was the greatest contributor to volumetric

reductions, followed by surface scour. Salmon spawning, scour around placed features and over-steepened slopes also contributed to volumetric reductions. As sites matured, reductions were less pronounced. Sites entrained as much large woody debris as was lost over the study and large woody debris settled on constructed gravel berms for periods of <12 months to >4 years. While complexity is an extremely important aspect of ecological function, production of highly diverse and complex habitat features appears to come at a cost. Placement of features such as gravel berms, boulders and large woody debris, to attract spawning Chinook salmon, increased gravel cut within enhancement sites. Furthermore, increased spawning activity can reduce the longevity of enhancement sites.