Summary Project Completion Report

Assessment of Habitat Complexity and Ecological Functions provided by Gravel Bars resulting from Gravel Augmentation and Channel Rehabilitation in the Trinity River

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It has been hypothesized that creation of in-channel gravel features is a way to provide simplified river channels below dams with topographic, hydrologic and thermo-chemical diversity. This study attempts to explore whether or to what extent restored gravel features contribute to increased habitat complexity based on fluvial process and mechanical design, and if so, how the increased complexity might subsequently increase material exchange and biodiversity, so as to provide a comprehensive picture of the ecological function of restored gravel bars and assess their role in the ecological recovery of regulated channels.

Field-based hydro-geomorphological observation of differently formed gravel features was conducted at four restoration sites on the Trinity River in Northern California. At the primary location, the Lowden Ranch rehabilitation site (RM104.4-105.3), four constructed gravel features were selected: a point bar that was mechanically constructed by direct gravel placement; another point bar and a medial bar that were deposited by flows downstream from a high-flow gravel injection; and an island created by side channel excavation. Examining this diversity of construction methods offered an opportunity to contrast mechanical versus dynamic gravel bar construction. Three additional naturally-deposited gravel bar features located in three other rehabilitation project sites were also studied in order to compare them with the gravel bar features in the Lowden Ranch site. These were a medial bar in the Steelbridge Day Use site (RM99), a point bar in the Indian Creek site (RM95) and another point bar in the Upper Junction City site (RM80). All field work was performed under base flow conditions of 320 and 450 cfs, between the summer of 2012 and the summer of 2013.

Methods consisted of field-based observation of the morphology, organic matter quality and thermal diversity of the gravel bars, as well as measurements of habitat complexity and determination of hyporheic flowpaths. Measurements of surface water elevation, inshore length, and hydraulic gradient, as well as basic water quality parameters such as temperature, dissolved oxygen, electrical conductivity, pH, and hydraulic gradient were taken at each gravel feature. The ecological function of the gravel features was assessed using a number of parameters including particulate organic matter (POM) composition and retention, water temperature modulation, hyporheic exchange and macroinvertebrate response.

Morphology, Inshore Length and Hydraulic Gradient

Hydraulic gradient (HG) and inshore length (IL) were measured at all bars. Hydraulic gradient, the slope of the surface water elevation ($m\ m^{-1}$) in open channel flow, was determined by measuring water surface elevation along the bar perimeter. The inshore length was measured at head and tail ends and each secondary channel, such as side channel and alcoves. The shallow water zone, defined as the area between the water's edge and the 50 cm isobaths, was also measured. All parameters were found to vary depending upon the method of gravel bar formation. Overall, the dynamically constructed gravel features had higher hydraulic gradients both longitudinally and laterally than the mechanically constructed bars. Fluvially deposited bars were found to have wider shallow water zones, higher hydraulic gradients and greater permeability than mechanically constructed features. The deposited (dynamically constructed) medial and point bars had the highest inshore length values in head and tail. The naturally occurring bars at the other three sites were found to be more similar to the dynamically constructed bars in the Lowden Ranch site than to the mechanically constructed ones, but to have unique individual morphoplogies.

Organic Matter Quality

Particulate organic matter composition, concentration and retention were evaluated. Suspended and benthic POM were sampled along with source origin POM (including plankton, terrestrial plants and instream algae). To investigate POM composition, suspended particulate organic matter (S-POM) was sampled at all four field sites using a drift net sampler and analyzed for stable carbon-nitrogen isotopes and C/N ratios. S-POM concentration was calculated as the ratio of S-POM mass to water volume. S-POM retention of the in-channel gravel features was quantified as the difference in S-POM concentrations between the upstream end and downstream end of each feature.

Stable carbon and nitrogen isotope analysis of suspended and benthic POM showed that the three potential POM sources (terrestrial leaf, epilithic algae and reservoir plankton) collected in the wetted channel exhibited an obvious isotopic distinction in $\delta^{13}C$-$\delta^{15}N$ combination. Among S-POM samples, most of the $\delta^{13}C$ values decreased and C/N ratios increased, especially in the case of the medial bar at Lowden Ranch, indicating that algal contribution to S-POM was reduced and terrestrial leaf contribution was increased as a result of the retention process. Thus, the qualitative change in S-POM composition was due to the S-POM retentiveness of the gravel features. In contrast to the stable S-POM in the source composition, benthic-POM (B-POM) showed a spatial variation in the $\delta^{13}C$ and C/N ratios, providing a variety of energy sources for secondary production with benthic communities in the vicinity of the gravel bars. Among the four gravel features at Lowden Ranch, the point bar downstream from the high-flow gravel injection showed the greatest B-POM diversity in the $\delta^{13}C$ and $\delta^{15}N$ biplot. The isotopic results for the B-POM samples indicate that this bar provides the greatest variety of organic matter quality to the river ecosystem and can thus support the most diverse functional macroinvertebrate and fish feeding groups.

All of the gravel features retained suspended POM and accumulated various types of benthic POM along the perimeters, resulting in greater food availability and benthic macroinvertebrate biodiversity. S-POM concentrations flowing into the downstream end of three of the four features in the Lowden Ranch site (with the exception of the island) were significantly lower than those at the upstream ends. This is evidence that in-channel gravel features have S-POM retention capacity. S-POM retention efficiency, the S-POM concentration reduction per meter, showed the highest value for the medial bar. The different ranges of S-POM concentration among the four features suggest that S-POM retention efficiency can be influenced by the gravel bar’s creation mechanism as well as its topologic shape. The fact that the higher retention efficiency occurred at features that were fluvially deposited, rather than the mechanically constructed, suggests that fluvial deposition processes contribute to increasing retention.

Water Temperature Modulation

Water temperature was monitored using thermometer data loggers (with 0.02°C resolution) installed along the peripheries of the gravel features including at bar-head, bar-tail, mainstem side, and in the secondary channels (side channel, split channel and alcove). The loggers were deployed at mid-depth, and temperature readings were taken every 10 minutes continuously between July and August 2012. Diurnal water temperature fluctuations observed at the deployed loggers showed a notable thermal heterogeneity due to hyporheic flow, especially in bar-tails and alcoves. Water temperature data along the wetted margins of the four gravel bars showed distinct thermal regimes. The medial bar at Lowden Ranch showed a notable thermal difference between head and tail, with the temperature in the tail being cooler than at the head during the daytime and warmer at night. Temperatures in the alcoves at the downstream ends of bars were approximately 6 hours out of phase with the bar heads and showed a diurnal range approximately half as large as most other locations.

Hyporheic Exchange

Hyporheic flow pathways through the four gravel features at the Lowden Ranch site were estimated by interpolation of the surface water elevation along the gravel features. These hyporheic flow pathways were then verified by dye injection. Hyporheic flowpaths were positively identified across the medial and point bars, but not the island. Water quality components at the downwelling and upwelling points were measured, including pH, electricity conductivity (EC), dissolved oxygen (DO) and total dissolved solid (TDS). Hyporheic exchange across the gravel bars (with the exception of the island) tended to decrease pH and dissolved oxygen. As noted above, hyporheic exchange also moderates water temperature fluctuations and produces a phase lag in the diurnal temperature regime.

Macroinvertebrate Response

Benthic macroinvertebrates were sampled at all four field sites and analyzed for stable carbon-nitrogen isotopes and C/N ratios, and identified down to family level. Western Pearlshell Mussel distribution in the vicinity of the bars was also mapped. In all four gravel features at Lowden Ranch, the side channel at the island, the secondary channel around the medial bar, and alcoves at the other bar features showed a higher diversity of benthic macroinvertebrate families than the main channel. The largest mussel habitat in the Lowden reach was located in the tail area of the medial bar.

Conclusions

Restoring gravel bars provides simplified regulated reaches with hydraulic diversity in velocity and depth, thermal diversity via hyporheic flow, food source diversity through S-POM retention and B-POM distribution (depending on trophic source types), and bed substratum diversity via upwelling hyporheic flow. The integrated hydro-thermal-food diversity within a gravel bar enhances habitat complexity, which supports a high biodiversity of benthic macroinvertebrates in response to a wide range of functional feeding group and life form types, as well as salmonids.

These findings suggest that gravel bar restoration can play an important role in river rehabilitation. They increase hyporheic exchange and POM retention by creating hydraulic controls that increase hydraulic gradients at baseflow and by improving substrate permeability and macroinvertebrate production through the placement of coarse-sediments that contain a small proportion of fines.