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# Angler catch-per-unit-effort in restored and reference sections of the Merced River, California: a preliminary analysis

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The headwaters of the Merced River originate in the western Sierra Nevada, California. The river then flows 217 km westward through Yosemite National Park (YNP) and into the San Joaquin Valley, where it flows into the San Joaquin River south of Modesto, California. Due to its proximity to large population centers and its path through the popular YNP, the Merced River gets extensive recreational pressure from rafters, photographers, swimmers, and fishermen. Recreation, through fishing license sales, equipment sales, and area hotel and camping fees produces high revenue for state and local economies. From 2003–2011, the State of California generated an average of $58,347,000 in sport fishing license sales, with a high of $65,174,000 in 2009 (CDFG 2012). A portion of the revenue generated by fishing is allocated for fish stocking and habitat restoration efforts.

Land use and river management practices such as agriculture, flood control, water supply, and mining have resulted in severe habitat degradation to portions of the Merced River (CDWR 2001). For example, the lower Merced River has shown signs of fragmentation and pooling during periods of low water. River fragmentation and pooling resulted in decreased dissolved oxygen and increased water temperatures (CDWR 2001). Past research has shown that a change in water characteristics can result in assemblage shifts from a coldwater fishery to one that supports large, warmwater-tolerant predators, such as largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*), piscivorous cyprinids such as pikeminnow (*Ptychocheilus grandis*) and hardhead minnows (*Mylopharodon conocephalus*), and other larger predators such as striped bass (*Morone saxatilis*) and white catfish (*Ameiurus catus*) (Brown 2000, CDWR 2001).

The Merced River historically has been an important river for spawning by anadromous salmonids, particularly for Chinook salmon (*Oncorhynchus tshawytscha*) (CDWR 2001). In addition to warming water temperatures and a shift in predator species, suitable spawning habitat was lacking due to a high rate of sedimentation and diminished rates of sediment flushing (USFWS 2001). The lack of cover and suitable spawning habitat has been demonstrated to limit spawning success of native salmonids and result in higher rates of predation on young by avian predators (Grand and Dill 1997), native aquatic predators such as hardhead minnows and pikeminnows (Bettelheim 2001, Peterson and Barfoot 2003), and non-native warmwater predators such as largemouth bass (Rieman et al. 1991).

In order to protect and restore salmonid populations, multiple agencies supported restoration of several sections of the lower Merced River. This included a 2-km section of river upstream from the Highway 59 bridge (37° 28' 14.4" N, 120° 30' 2.3" W) known as the Robinson Reach, a project that began in July of 2001 and was completed in February of 2002 (CDWR 2010). During that project a new channel was constructed and the floodplain was restored to eliminate fragmentation. This helped to create a defined corridor for fish movement while eliminating most of the ponded areas within or near the reach. Gravel and cobble substrate was added to the river to create spawning and rearing habitat. The floodplain and river banks were planted in native riparian species to provide habitat for fish, provide cover from predators, and establish a riparian buffer. However, due to the dry, rocky nature of the floodplain, a majority of the newly planted vegetation died, and the floodplain and riparian area remained quite bare (M. C. Wilberding, personal observation).

We designed a study to examine the fish density in the 2-km restored section of the Merced River (Robinson Reach) and compare it to a non-restored, more natural section of similar length immediately upstream of the Robinson Reach. The upstream reference section flows through hardwood forests and farmland, and included a riffle, run, and pool composition that served as a control for comparison with the restored section.

We designed our investigation to estimate the relative abundance of potential predators of Chinook salmon in each section by conducting an angling catch-per-unit-effort study (CPUE; fish/hr). We used lightweight tackle (light-action rods with 1.8-2.7 kg test line) and small spinners or small Rapala lures (<7.62 cm) thought to mimic age-0 salmonids. Barbless hooks were used in accordance with current fishing regulations. CPUE was analyzed based on (1) fish hooked and lost, and (2) fish landed. To get a better idea of relative abundance, those two categories were pooled into a single category as total hooked, with the assumptions that a hooked, but missed, fish did not bite again, possibly the result of stress or experience.

Angling was conducted from 21 March to 15 April 2012 in the Merced River between the Highway 59 and Snelling Road bridges. This reach was broken into two smaller sections: a 2-km restored section of the Robinson Reach (RR; downstream end 37°28' 23.9" N, 120° 29' 49.2" W) and a 2 km non-restored reference section just upstream of the restored reach (US; downstream end 37° 29' 8.5" N, 120° 28' 52.3" W). Two anglers participated in this study and each angler fished a total of 25 hours in each of the two sections. Angling occurred between 0630 and 1930 and the sections fished both were alternated between outings and anglers. All angling was conducted while wading in the upstream direction. Each angler recorded the date, river section, time fished (start and stop), fish strikes (caught or missed) and time, species, length (mm), and other potentially relevant observations (e.g., weather or water conditions).

To determine if CPUE was similar between anglers we used a Wilcoxon rank-sum test (Hollander and Wolf 1999) in program R (R Core Team 2011). To help ensure samples were independent we made comparisons using the number of fish caught during each hour instead of the cumulative CPUE. We also tested for a significant difference in CPUE between RR and US sections using the Wilcoxon rank-sum test.

CPUE for Angler A (1.40) and B (1.14) did not differ ($W = 372.5$, $P = 0.24$); thus, we pooled data for further analysis. A total of 127 fish were hooked, resulting in an overall CPUE of 1.27 fish/hr. Overall, CPUE was significantly greater ($W = 1785$, $P < 0.001$) in the US reference section (1.84 fish/hr) than it was in the RR restored section (0.70 fish/hr).

Of the 127 fish hooked, 92 were salmonids (*Oncorhynchus spp.*), with a CPUE of 0.92 fish/hr; 32 were non-salmonid piscivorous fish with a CPUE of 0.32 fish/hr. Due to their similar morphologies rainbow trout, cutthroat trout, and hybrids were grouped as *Oncorhynchus* spp. Fish species caught in order of decreasing occurrence were: *Oncorhynchus* spp., pikeminnow ($n = 21$), hardhead minnow ($n = 5$), largemouth bass ($n = 3$), spotted bass ($n = 3$), and unidentified fish that were lost ($n = 3$). Of the 92 salmonids, 68 (73.9%) were in the US reference section (1.36 fish/hr) compared with 24 (26.1%) in the RR restored section (0.48 fish/hr). Of the non-salmonid fish hooked, 23 (71.9%) were in the US (0.46 fish/hr) and 9 (21.1%) were in the RR (0.18 fish/hr).

This preliminary study was conducted to assess the results of large-scale restoration and reconstruction efforts on the Robinson Reach. Those restoration efforts were in large part to provide a defined corridor for movements and suitable spawning and rearing habitat for Chinook salmon. Our study was conducted to estimate relative abundance of piscivorous fish, which may prey on juvenile Chinook.

Greater CPUE in the US reference section than in the restored RR section (1.84 and 0.70 fish/hr, respectively) could be due to the abundant streamside vegetative cover, instream woody debris, and riffle, run, pool make-up of the US reference section, which contained far more streamside cover than did the RR section (~2-5%; personal observations). The lack of cover in the RR section likely provided limited habitat and protection for fish, created a potential for warming stream temperatures (Beschta 1997), and increased vulnerability of fish to terrestrial predators (Harvey and Stewart 1991). Instream habitat complexity and cover are essential for viable salmonid populations, and often yield increased salmonid abundance and average fish size (Boussu 1954). Additionally, salmonid populations and production typically are higher in streams that contain woody debris in comparison with sections where woody debris has been removed or is absent (Dolloff 1986). Riparian vegetation and large, instream woody debris are essential habitat components, and the limited amount of this habitat available in the RR section is likely a limiting factor for salmonid populations.

In addition to the lower CPUE in the RR section, the paucity of cover likely presented a problem for both adult and juvenile fish. Vegetative cover (both in water and overhanging) is very important, not only for carbon input, but also for maintaining cooler water temperatures and providing cover for young fish, while simultaneously providing access to food (plankton and aquatic invertebrates) for those juveniles. Indeed, Jones et al. (1999) reported a decline in fish abundance in southern Appalachian streams lacking forested riparian buffers. Murphy et al. (1986) also reported that vegetative buffer strips on streams provided woody debris and habitat, resulting in increased primary production and abundance of parr and fry salmonids.

We observed rafts of common mergansers (*Mergus merganser*) swimming and feeding on juvenile fish in the RR section on multiple occasions, whereas we did not observe those piscivorous birds in the US reference section. The presence of those predators could have an adverse effect on survival of juvenile salmonids as well as increasing mortality rates during times of out-migration. Collis et al. (2002) reported that juvenile salmonids accounted for up to 74% of the diet of avian predators (California gulls [*Larus californicus*] and ringbilled gulls [*Larus delawarensis*]) feeding in a freshwater environment. Wood (1987a) reported that juvenile salmonids formed a large portion of the diets of common mergansers in freshwater environments. Wood (1987b) also demonstrated that daily consumption of fish by merganser ducklings was up to 80% of their body weight, and that mergansers were capable of consuming up to 65% of the wild smolt production in freshwater ecosystems. These studies suggest that avian predation can have a substantial negative influence on juvenile salmonid survival rates and recruitment. Juvenile salmonids present in the RR section are probably more susceptible to avian predation than juvenile salmonids in the US section, likely a result of the near absence of riparian vegetation and limited instream cover in the RR section.

In addition to the lack of cover in the RR section, another area of potential concern was a connected warmwater backwater area (37° 28' 29.7" N, 120° 29' 25.8" W), an area that provided habitat for predators with the ability to move from the warmwater refuge into the river to prey on juvenile salmonids. A large proportion of the non-salmonid piscivorous fish hooked in this study were at the confluence of the mouth of the backwater and the Merced River. Additionally, in the floodplain across from the confluence there was a second warmwater pond (37° 28' 40.7" N, 120° 29' 35.1" W) that could become connected when flows inundate the flood plain. This raises the potential for recurring introductions of large warmwater predators that likely inhabit that pond.

The results of this study and the observations made while spending a substantial amount of time on the river indicate that the restored RR section of the Merced River had a lower CPUE of salmonids, higher presence of avian predators, a near absence of riparian cover and suitable aquatic habitat, and greater connectivity to a warmwater areas in comparison to the US reference section. Based on these preliminary results and observations, we suggest that riparian re-vegetation efforts be conducted and that instream woody debris be increased so that the RR section more closely resembles the US reference section. Such habitat improvements could reduce predation from both fishes and birds, and also establish a more suitable hydrologic environment, specifically reducing water temperatures. We also suggest that connectivity of warmwater areas to the RR section be managed to minimize the potential influence of non-native warmwater predators on juvenile salmonids, and that additional studies continue to monitor abundance, reproduction, and recruitment of salmonids, thereby allowing researchers to further evaluate the effectiveness of reconstruction and rehabilitation efforts, and inform adaptive management decisions.

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