EXPERIMENTS WITH JUVENILE CHINOOK SALMON PASSED THROUGH HIGH-VOLUME, FISH-FRIENDLY PUMPS AT RED BLUFF RESEARCH PUMPING PLANT, SACRAMENTO RIVER, CALIFORNIA

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Introduction

Four runs of chinook salmon (*Oncorhynchus tshawytscha* Walbaum) provide the Sacramento River drainage in northern California with the distinction of having adult and juvenile salmon in its water throughout the year (Fisher 1994). Construction of a high dam (184 m) at Shasta, California in 1938-1944 eliminated access to spawning grounds in cold mountain streams at high elevations in the drainage. In 1964, a low-head dam was completed on the Sacramento River downstream of Shasta near Red Bluff, California. The dam at Red Bluff was built, maintained and operated by the U.S. Bureau of Reclamation. Its purpose was to divert water (85 m^3/s) to irrigate semi-arid portions of the Central Valley of California.

Fisheries resources in the Sacramento River and its tributaries were affected in a variety of ways when operations at Red Bluff Diversion Dam began.

Impediments for populations of anadromous salmon and steelhead captured the majority of attention. The dam delayed timely passage for adult salmonids on migration runs to upstream spawning grounds. This was due in part to relatively low attraction flows from fish ladders that were put in place when the dam was constructed. Out-migrating juvenile salmonids that were disoriented by turbulence while passing under gates of the dam were fed upon by predators that congregated in the dam's tailwaters. Louvers with bypasses for juveniles were put in place across the channel that carried diverted water and fish into the forebay of the irrigation canal. That system proved unsatisfactory. During 1980-1995, fish ladders at the dam were improved. Modern drum-screens were put in place with bypass conduits that carried diverted fish back to the Sacramento River. In spite of these improvements, salmon runs in the river continued to decline.

As a result of interactions between State and Federal fish regulatory agencies, the gates of Red Bluff Diversion Dam were raised on various experimental schedules during spring and summer of years between 1986 and 1993. In 1993, the National Marine Fisheries Service directed the Bureau of Reclamation to raise gates on the Red Bluff Diversion Dam on September 15 of each year, and to leave them out of the water until the following May 15. This mode of operation allowed for deliveries of water for irrigation during high demand in summer, allowed protected winter-run adult chinook salmon unimpeded passage to upstream spawning grounds, and provided open passage for the majority of winter-run juveniles during their annual out-migration from spawning grounds. The Bureau of Reclamation, as part of its continuing commitment to improve fish-passage at Red Bluff, agreed to construct a Research Pumping Plant at the diversion dam. This pumping plant, in combination with other pumping alternatives available at Red Bluff, would meet water delivery requirements for irrigation during the dam-out period from September to May when demands for irrigation water are relatively low.

Methods

Construction of the Red Bluff Research Pumping Plant was completed in 1995. Two Archimedes lifts (11.58 m long, 3.05 m diameter) and an internal helical pump (0.91 m inlet and outlet) were installed in the plant. Unlike Archimedes lifts that had been successfully employed worldwide in industrial applications for lifting water and slurries of various solids, the lifts at Red Bluff had revolving barrels, three fixed flights, rotating seals at intakes, fluctuating

internal water-surface elevations (about 1 m), and operated at a relatively high rotational speed 26.5 rev/min. The lifts delivered water at 2.4-2.5 m^3/s. The internal helical pump installed at Red Bluff was the largest of its kind ever built. During work for this paper the pump was run at 350-375 rev/min and delivered water in the range of 2.3-2.8 m^3/s. The predecessor of the internal helical pump at Red Bluff was developed several decades ago to meet the need of the fishmeal industry of Peru for rapid off-loading and delivery of ocean harvest to processing plants (Stahle and Jackson 1982).

The purpose of work for this paper was to compare the two types of pumps in regard to safe passage for juvenile chinook salmon. Juveniles used were hatchery-reared. Two experiments were conducted. Both experiments consisted of repetitious trials in which samples of chinook were passed concurrently through two operating pumps. In one experiment, the Archimedes lifts were compared by passing samples of chinook through each of the two lifts. The two types of pumps in the plant were compared in a second experiment in which one of two Archimedes lifts was selected randomly, and it and the internal helical pump were operated simultaneously during fish-passage trials. *Treatment* samples were released in pump intakes, and *control* samples were released at pump outfalls. Fish from all samples were recovered in holding tanks located on downstream fish-bypass channels. A pump-passage effect (treatment effect) was indicated where the difference between treatment and control samples was statistically significant (P=#0.05).

Results and Conclusions

In the experiment to compare the Archimedes lifts, no pump-passage effect on mortality was detected for either lift. Mean mortality for all treatment and all control samples used with both lifts was low; 1.2%-1.8%. In the experiment to compare the Archimedes lifts and internal helical pump, no pump-passage effect on mortality was detected for the lifts. A significant pump-passage effect on mortality was detected for the internal helical pump (P=0.0006). The estimated pump-passage effect for the helical pump was low (2.6%). Pump-passage effects were not detected in either of the two experiments for %-frequency of surviving fish that were descaled, or for %-fish with other kinds of sub-lethal injuries. The extent of descaling and kinds of other injuries on 99% of surviving fish were not debilitating. We concluded that the Archimedes lifts and internal helical pump at Red Bluff are indeed "fish-friendly", and can be used successfully for deliveries of irrigation water. This technology is being

considered for application at other water diversion sites in California to protect fisheries resources.

References

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