Migration Passage Patterns of Pacific Lamprey at Bonneville Dam, 1996-1998

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ABSTRACT

For three years, we have evaluated migration passage patterns of surgically-implanted radio-tagged adult Pacific lamprey in the lower Columbia River to gain insight into factors affecting their survival. Fish traveled quickly from the release site to Bonneville Dam. Although more than 85% were detected at collection channel entrances, less than 40% successfully passed above the dam. We discuss potential problem areas that may decrease Pacific lamprey passage success.

INTRODUCTION

Populations of Pacific lamprey (*Lampetra tridentata*), like those of other northwest anadromous fish species, have significantly declined in abundance in recent years (Close et al. 1995). In the Columbia and Snake River basins, Pacific lamprey were once present in all waters where salmon and steelhead were found (Simpson and Wallace 1978). Currently, the distribution of Pacific lamprey is limited to the waters below Chief Joseph Dam on the Columbia River and below Hells Canyon Dam on the Snake River (Close et al. 1995). Both of these dams lack adult fishways for passage. Kan (1975) suggested that access to available habitat rather than distance from the ocean is the critical factor in the distribution of lamprey. Adult migration patterns past dams and reservoirs in the Columbia River basin affect or limit Pacific lamprey survival.

In this study, we used radio telemetry to monitor Pacific lamprey movements to look at ways in which dams may affect their access to spawning habitat. Objectives of the study were to determine return time of tagged lamprey from downstream monitors to Bonneville Dam, fishway travel time, total time at dam, passage routes, and behavior at Bonneville Dam.

METHODS

Trapping and Tagging

Pacific lamprey were collected from the fishway entrance at the Fisheries Engineering Research Laboratory at Bonneville Dam. A total of 85, 147, and 205 adult fish were tagged in 1996, 1997, and 1998, respectively. Fish selected for tagging had a total body weight of at least 450 g, and tagging occurred when the temperature did not exceed 20.5° C. Prior to tagging, fish were anesthetized with a 0.06-g/L anesthetic solution of tricaine methanesulfonate (MS222), examined for injuries and sexual maturity (if possible), measured, and weighed. After examination and tagging, fish were placed in a recovery tank with aerated fresh water and allowed to regain equilibrium.

Tags were manufactured by Lotek Engineering Inc. of Newmarket, Ontario, Canada. The tags were sealed in an epoxy capsule, 4.3-cm long by 0.9-cm diameter. Each had a tag life of 7 months, weighed 7.0 g in air, and had a 20-cm long external antenna attached to one end. The water weight of the tag did not exceed 1-1.25% of the fish dry weight, as recommended by Winter et al. (1978).

Radio transmitters were surgically implanted in Pacific lamprey as fish condition and survival is higher compared to external attachment (Bjornn et al. 1996). Surgical techniques were similar to those described by Hart and Summerfelt (1975), Reinert and Cundall (1982), Ross (1982), and Mellas and Haynes (1985). Surgical tools and transmitters were sanitized in a solution of benzalkonium chloride. The tag was implanted into the body cavity through a 4- to 5-cm incision in the mid-ventral body wall. A cannula was used to thread the antenna of the radio tag subcutaneously to an exit site anterior to the cloaca. Incisions were closed with 5 to 6 stitches, using a 19-mm, FS-1 quarter-round cutting needle and absorbable polydioxanone monofilament. Baciguent and Betadine were applied to the suture area and antenna exit to prevent infection.

Lamprey were released below Bonneville Dam on the north shore at Skamania Landing, Washington at river kilometer (RKm) 225.7, and on the south shore at Dodson, Oregon, (RKm 225.6) in 1996 and 1997. The 1998 release site was closer to Bonneville Dam, at Hamilton Island boat launch on the north shore and Tanner Creek on the south shore (both RKm 231.5).

Antenna and Receiver Locations

The number of antennas installed at Bonneville Dam (RKm 235.1) increased as the study progressed, beginning with 93 in 1996 and finally 106 in 1998. Nine-element air antennas were placed at two downstream fixed sites, one on the south shore near Tanner Creek and one on the north shore near Hamilton Island

boat launch; additional air antennas were placed below the dam at the navigation lock entrance, and on each side of the forebay above the spillway (Figure 1). Air antennas were utilized to cover a distance up to 0.4 km on level ground but were limited to detecting tags in the upper 9.1 m of the water column. Underwater antennas were placed at entrances to, and inside the collection channels and fish ladders of both Powerhouse I and Powerhouse II, at the spillway entrances, and at fish ladder exits. Underwater antennas detected radio-tagged fish within a range of approximately 9 m in all directions.

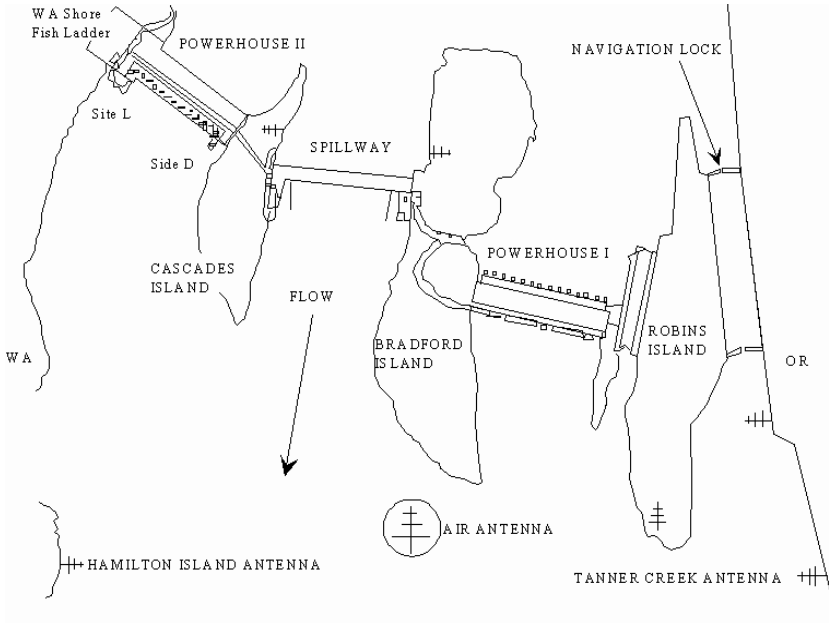

Figure 1. Bonneville Dam study area.

These antennas were connected to 26 receivers manufactured by Lotek Engineering. Each receiver was programmable and could detect radio transmitters on 25 different frequencies and up to 150 individual codes per frequency. Two types of receivers were utilized. The SRX-400 scanned each frequency for 6-second intervals and stored up to 128 KB of data in 7 or 8 data banks (these receivers were used at single-antenna sites, such as downstream sites below the dam). The SRX-500 digital spectrum processor (DSP) was used in tandem with the SRX-400 to obtain multiple detections at a fixed site. The DSP was also used with the ASP-8 multiple-antenna switching unit to obtain simultaneous monitoring of up to eight different antennas.

RESULTS

Of the Pacific lamprey released below Bonneville Dam in 1996, 1997, and 1998, 82.4%, 86.4%, and 89.3%, respectively, were detected outside collection channels at the dam, and 61.2%, 66.0%, and 77.1%, respectively, were detected inside the collection channels (Table 1). The annual successful passage rates at the dam were 18.8%, 32.0%, and 36.1%, respectively. Of the fish that were detected inside collection channels, 30.8%, 48.5%, and 46.8% were subsequently detected at the top of the fish ladders or navigation lock during the respective 3 years.

Table 1. Detections of radio-tagged Pacific lamprey at Bonneville Dam.

Year	Lamprey Released Downstream	Detected Outside Collection Channel	Detected Inside Collection Channel	Migrated Past Bonneville Dam
1996	85	70	52	16
1997	147	127	97	47
1998	205	183	158	74

The median travel time from last detection on a downstream monitor to first detection at Bonneville Dam (approximately 2.8 km) ranged from 0.58 days in 1996 to 0.48 days in 1997. After the release site was moved approximately 6 km closer to Bonneville Dam in 1998, the median travel time for the same distance decreased to 0.10 days (3-year minimum 0.004 days, 3-year maximum 14.039 days).

Upon first arrival at the dam, the largest percentage of lamprey were detected outside the collection channel at the large shore entrances on either side of Powerhouse II: site D (23% to 26%) and site L (10% to 16%) (Figure 2a). The largest percentage of entrances into the collection channel occurred at site D (27% to 42%) and site L (9% to 22%) (Figure 2b); the largest percentage of exits out of the collection channel occurred at site D (30% to 49%) and site L (6% to 14%) (Figure 2c).

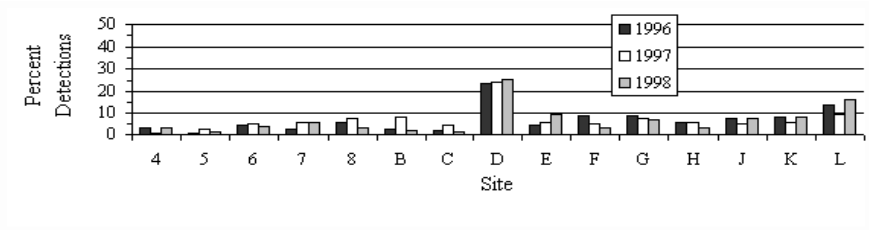

Figure 2a. Arrival sites for Pacific lamprey at Bonneville Dam.

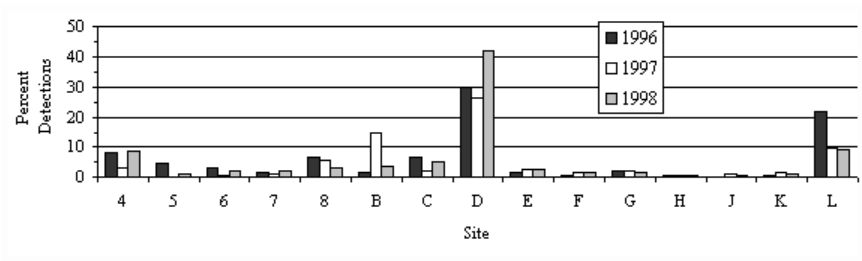

Figure 2b. Entrance sites for Pacific lamprey at Bonneville Dam.

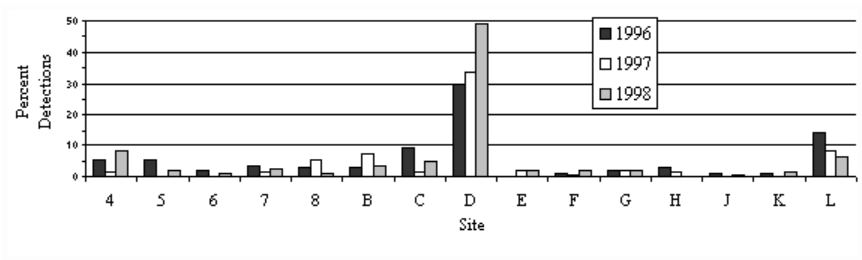

Figure 2c. Exit sites for Pacific lamprey at Bonneville Dam.

The median fishway passage time from the last collection channel entrance to the last record at the top of a ladder was 1.1 days in 1996 and 1997, and 1.0 day in 1998 (3-year minimum 0.102 days, 3-year maximum 12.733 days). Several areas where lamprey turned around in the fish ladders were identified (Figure 3). Net direction was calculated by subtracting downstream movement from upstream movement at fish ladder sites. The total time at Bonneville Dam from first arrival outside the collection channel to last record at the top of a ladder was 4.5 days in 1996, 4.8 days in 1997, and 5.4 days in 1998 (minimum 0.026 days, maximum 37.226 days). Lamprey that migrated over Bonneville Dam did not appear to have a preference for either fish ladder (P = 0.6079).

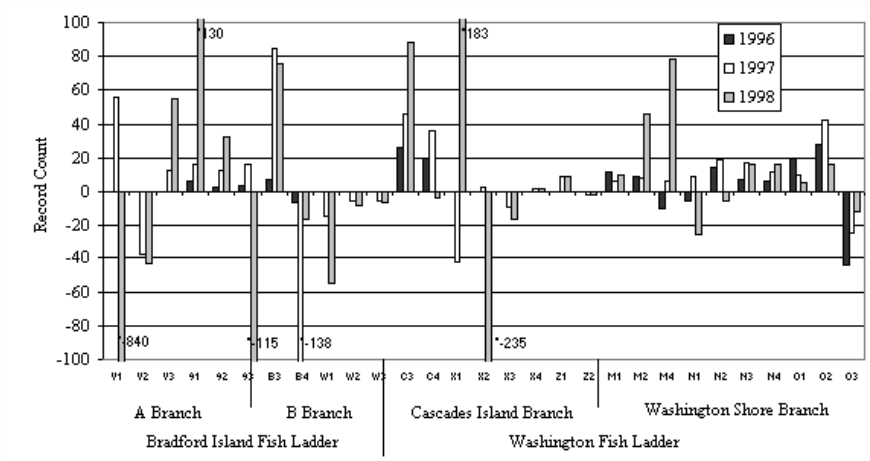

Figure 3. Net direction of movement in fish ladders.

DISCUSSION

Radio transmitters were successfully implanted in Pacific lamprey and their migrational behavior was monitored below, at, and above Bonneville Dam. Although fish that successfully passed the dam did so in approximately 5 days, less than 50% of the fish that entered the collection channels from the tailrace migrated past the dam. Water velocity both at entrance sites and in fishway transition areas may inhibit successful dam migration.

We noticed lamprey appeared to have the most difficulty in transition areas, where the tailwater elevation changes and water velocities increase. Auxiliary water enters the ladder in different locations depending on the tailwater elevation, which varies depending on the river flow. Net downstream movement at sites V1, V2, B4, and W1 in the Bradford Island fish ladder, C4, X1, X2, and X3 in the Cascades Island fish ladder, and M4, N1, and N2 in the Washington Shore fish ladder is a likely result of such transition area conditions. The Bradford Island and Washington Shore fish ladders have slotted leads that narrow the ladder downstream from the Visitor's Center window. Significant downstream movement was observed in 1998 at site 93, and all 3 years at site O3, both of which are located directly downstream from the windows. Lamprey may back down the ladder at these narrowings instead of continuing upstream migration. Furthermore, some lamprey move through the slots into the auxiliary water channel. Lamprey have been found stranded in these auxiliary water channels during dewatering at Bonneville Dam (Starke and Dalen 1995). Slotted leads in the crowding weirs below counting windows could be modified to eliminate the passage of lamprey into the auxiliary water channel.

Future studies will continue to evaluate lamprey behavior at Bonneville Dam and analyze migrational behavior at upstream tributaries and dams. In addition, flow velocity and other hydraulic conditions in existing fish ladders will be studied and potential for redesign will be analyzed. As identified from arrival site and collection channel entrance and exit use in the vicinity of site D and site L, lamprey may prefer slower water velocities.

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