ADULT PACIFIC LAMPREY PASSAGE AND BEHAVIOR STUDY
(Adult Lamprey Passage Study)

WELLS HYDROELECTRIC PROJECT

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SECOND YEAR
FINAL REPORT
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ABSTRACT

In 2008, Douglas PUD conducted lamprey passage research at Wells Dam using radio-tagged fish collected at Wells and Rocky Reach dams as a voluntary effort to supplement results from the 2007 study. Thirty-eight radio-tagged adult Pacific lamprey were released in the tailrace (n = 18) and fishways (n = 20) of Wells Dam. The goal of the 2008 study was to evaluate adult lamprey behavior and passage performance in the collection gallery and fishway entrances of Wells Dam.

In 2008, up to half of the radio-tagged lamprey displayed uncharacteristic behaviors indicative of death, tag shed, or abandonment of migration. Decreasing water temperatures may have also contributed to the abandonment of migration as lamprey approach Wells Dam near the known overwintering period. Of the remaining fish that appeared active, 15 approached the fishway from the tailrace and five entered (entrance efficiency of 33%). Lamprey activity within the collection gallery indicated that movement was not restricted by flows in this portion of the fishway. At least 11 of 19 (58%) lamprey that volitionally entered or were released in the collection gallery ascended the lower fishway to the trapping area. Fishway modifications to increase trapping efficiency for this study effectively blocked migration for 12 of 14 fish (86%) that encountered the trap (including one fish that ascended the lower fishway twice). The presence of the lamprey trapping structures substantially reduced lower fishway passage efficiency, and substantially reduced recruitment of tagged fish into the upper fishway.

Upper fishway passage times for the four radio-tagged lamprey that ascended the upper fishway were relatively fast (< 4 hours), except for one fish that hesitated during daylight hours. Three of these lamprey (75%) also bypassed the adult counting station undetected, supporting findings in 2007 that a majority (73%, n = 11) of lamprey that ascend Wells Dam are uncounted. No fallbacks of fish that successfully ascended the fishway were observed for the second consecutive year. Overall, results indicate that any potential areas of impediment are restricted to the entrance and the temporary lamprey trapping structure, as upper fishway passage efficiency was 100% for the second consecutive year.

The uncharacteristic behaviors observed with several fish were likely related to handling and tagging effects that are amplified in lamprey collected at Wells Dam because they are considerably thinner than those used in downriver studies. Increasing tag to body mass ratios has been shown to substantially reduce swimming performance in Pacific lamprey. Trapping efforts implemented to achieve the tagging goals of the study also had a significant effect by effectively blocking or impeding a majority (86%) of lamprey during their ascent through the fishways, thus reducing escapement of fish to the upper fishway where passage success has been 100%. These results suggest that future lamprey passage and behavior studies at Wells Dam should use alternative monitoring technology that would reduce or eliminate trapping, tagging, and handling effects.

Passage efficiency from this study is comparable or superior to results from other radio-telemetry studies conducted in the Columbia River during 2008. For example, entrance efficiencies of radio-tagged lamprey at Bonneville Dam ranged from 6% to 32%, compared to 33% at Wells Dam. Fallback at Bonneville was 19% compared to no documented fall back events at Wells

Dam. Median project passage times at Bonneville exceeded 180 hours compared to Wells where lower fishway passage time was 6.1 hours, upper fishway passage time was 5.9 hours, and time spent in or at the trap was 20 hours (32 hours total).

The results from the 2007 and 2008 passage studies at Wells Dam indicate that adult lamprey experience difficulty negotiating water velocities produced by head differentials at the fishway entrances (≤ 3.4 m/s) established as attraction flows for migrating adult salmon. A reduction in head differential to reduce entrance velocities may be warranted to enhance adult lamprey passage at the Project, specifically during nighttime hours to capitalize on the nocturnal behavior of lamprey and avoid interference with salmon.

1.0 INTRODUCTION

1.1 General Description of the Wells Hydroelectric Project

The Wells Hydroelectric Project (Wells Project) is located at river mile (RM) 515.6 on the Columbia River in the State of Washington (Figure 1.1-1). Wells Dam is located approximately 30 river miles downstream from the Chief Joseph Hydroelectric Project, owned and operated by the United States Army Corps of Engineers (COE); and 42 miles upstream from the Rocky Reach Hydroelectric Project owned and operated by Public Utility District No. 1 of Chelan County (Chelan PUD). The nearest town is Pateros, Washington, which is located approximately 8 miles upstream from the Wells Dam.

The Wells Project is the chief generating resource for Public Utility District No. 1 of Douglas County (Douglas PUD). It includes ten generating units with a nameplate rating of 774,300 kW and a peaking capacity of approximately 840,000 kW. The design of the Wells Project is unique in that the generating units, spillways, switchyard, and fish passage facilities were combined into a single structure referred to as the hydrocombine. Fish passage facilities reside on both sides of the hydrocombine, which is 1,130 feet long, 168 feet wide, with a top of dam elevation of 795 feet above mean sea level (msl).

The Wells Reservoir is approximately 30 miles long. The Methow and Okanogan rivers are tributaries of the Columbia River within the Wells Reservoir. The Wells Project boundary extends approximately 1.5 miles up the Methow River and approximately 15.5 miles up the Okanogan River. The surface area of the reservoir is 9,740 acres with a gross storage capacity of 331,200 acre-feet and usable storage of 97,985 acre feet at the normal maximum water surface elevation of 781 feet (Figure 1.1-1).

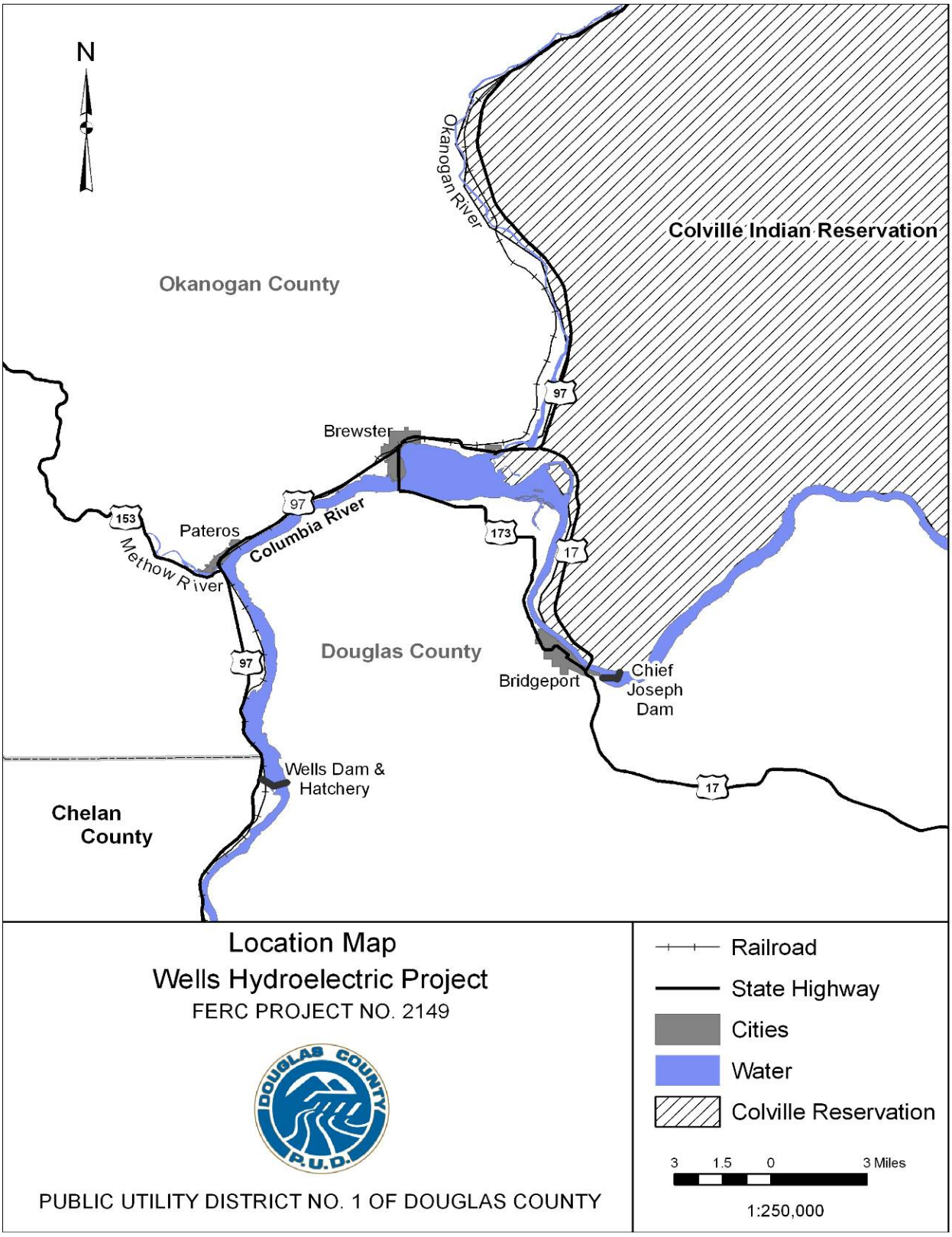

Figure 1.1-1 Location map of the Wells Project

1.2 Relicensing Process

The current Wells Project license will expire on May 31, 2012. Douglas PUD is using the Integrated Licensing Process (ILP) promulgated by the Federal Energy Regulatory Commission (FERC) Order 2002 (18 CFR Part 5). Stakeholders, including representatives from state and federal agencies, tribes, local governments, non-governmental organizations and the general public have participated in the Wells Project ILP, from a very early stage, to identify information needs related to the relicensing of the Wells Project.

In August 2005, Douglas PUD initiated a series of Resource Work Group (RWG) meetings with stakeholders regarding the upcoming relicensing of the Wells Project. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to identify resource issues, and to develop preliminary study plans prior to filing the Notice of Intent (NOI) and Pre-Application Document (PAD). The RWGs were formed to discuss issues related to the Wells Project and its operations, identify information needs, and develop agreed-upon study plans.

The primary goals of the RWGs were to identify resource issues and potential study needs in advance of Douglas PUD filing the NOI and PAD. Through 35 meetings, each RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. An Issue Statement is an agreed-upon definition of a resource issue raised by a stakeholder. An Issue Determination Statement reflects the RWGs' efforts to apply the FERC's seven study criteria to mutually determine the applicability of each individual Issue Statement. Agreed-Upon Study Plans are the finished products of the informal RWG process.

Douglas PUD submitted the NOI and PAD to the FERC on December 1, 2006. The PAD included the RWGs' 12 Agreed-Upon Study Plans. The filing of these documents initiated the relicensing process for the Wells Project under the FERC's regulations governing the ILP.

On May 16, 2007, Douglas PUD submitted a Proposed Study Plan (PSP) Document. The PSP Document consisted of the Applicant's Proposed Study Plans, Responses to Stakeholder Study Requests and a schedule for conducting the Study Plan Meeting. The ILP required Study Plan Meeting was conducted on June 14, 2007. The purpose of the Study Plan Meeting was to provide stakeholders with an opportunity to review and comment on Douglas PUD's PSP Document, to review and answer questions related to stakeholder study requests and to attempt to resolve any outstanding issues with respect to the PSP Document.

On September 14, 2007, Douglas PUD submitted a Revised Study Plan (RSP) Document. The RSP Document consisted of a summary of each of Douglas PUD's RSPs and a response to stakeholder comments on the PSP Document.

On October 11, 2007, the FERC issued its Study Plan Determination based on its review of the RSP Document and comments from stakeholders. The FERC's Study Plan Determination required Douglas PUD to complete 10 of the 12 studies included in its RSP Document. Douglas PUD has opted to complete all 12 studies to better prepare for the 401 Water Quality Certification process conducted by the Washington State Department of Ecology and to fulfill its commitment to the RWGs who collaboratively developed the 12 Agreed-Upon Study Plans with

Douglas PUD. On October 15, 2008, Douglas PUD filed with the FERC the ISR Document that contained final reports for eight of the 12 studies and contained interim progress reports for four of the 12 studies. The ISR Document included results from all ten of the studies required by the FERC in the October 11, 2007 Study Plan Determination. The ISR Document contained final reports for eight of the studies and contained interim progress reports for four of the studies. The ISR Document also included results from two studies voluntarily conducted by Douglas PUD for the reasons stated above. On November 24, 2008, Douglas PUD filed a letter correcting a water temperature figure within the original ISR Document. On December 2, 2008, Douglas PUD filed the final Traditional Cultural Property Study for the Wells Project, which was prepared by the Confederated Tribes of the Colville Reservation under a contract with Douglas PUD.

The deadline for stakeholder comment on the ISR Document was December 15, 2008 pursuant to the approved Process Plan and Schedule for the Wells Project. Comments were filed by the City of Pateros on November 7, 2008 and by the City of Brewster on December 5, 2008.

On January 14, 2009, Douglas PUD filed a letter containing its responses to the comments from the cities on the ISR Document and proposed revisions to the schedule for the Wells ILP. On February 4, 2009, the FERC issued a determination on the requests for modification to the Wells Study Plan and on Douglas PUD's proposed revisions to the schedule. The FERC concluded that there was no need to modify the Wells Study Plan. The FERC also approved Douglas PUD's proposed modifications to the Wells ILP schedule.

This report is the second year of study and final report for the Adult Lamprey Passage Study.

2.0 GOALS AND OBJECTIVES

The goal of the voluntary second season of study was to evaluate the effect of the Wells Project on adult lamprey behavior and passage performance in the collection gallery and fishways entrances of Wells Dam. Other investigations conducted during the 2008 study included gathering information related to fishway passage, timing, and downstream passage events (drop back).

Objectives identified in the 2007 report were as follows:

1. Conduct a literature review of existing adult Pacific lamprey passage studies at Columbia and Snake river dams (see 2007 report);
2. Identify methods for capturing adult Pacific lamprey at Wells Dam (see 2007 report);
3. Document the timing and abundance of radio-tagged lamprey passage through Wells Dam (see 2007 report);
4. Determine whether adult lamprey are bypassing the adult counting windows at Wells Dam (see 2007 report);
5. Where sample size is adequate, estimate passage metrics including fishway passage times and efficiencies, residence time between detection zones, and downstream passage events (drop back); and

6. If warranted, identify potential areas of improvement to existing upstream fish passage facilities for the protection and enhancement of adult lamprey at the Wells Project.

The 2008 study focused on augmenting the sample size needed to meet objectives 5 and 6.

3.0 STUDY AREA

The study area includes Wells Dam, the Wells Dam tailrace, and the Wells Dam forebay (Figure 1.1-1).

4.0 BACKGROUND AND EXISTING INFORMATION

4.1 Life History

Pacific lamprey are present in most tributaries of the Columbia River and in the mainstem Columbia River during their migration. Lamprey have cultural, utilitarian and ecological significance in the basin since Native Americans have historically harvested them for subsistence, ceremonial and medicinal purposes (Close et al., 2002). Little specific information is available on the life history or status of lamprey in the mid-Columbia River watersheds. They are known to occur in the Methow, Wenatchee and Entiat rivers and recently have been captured during juvenile trapping operations in the Okanogan River (BioAnalysts, 2000).

Adult lamprey are parasitic on fish in the Pacific Ocean while ammocoetes (larvae) are filter feeders that inhabit the fine silt deposits in backwaters and quiet eddies of streams (Wydoski and Whitney, 2003). Macrophthalmia is an intermediary life stage, when lamprey migrate to the ocean. Adults spawn in low-gradient stream reaches, generally in the tail areas of pools and in riffles, over gravel substrates (Jackson et al., 1997). Adults die after spawning. After hatching, the ammocoetes burrow into soft substrate for an extended larval period filtering particulate matter from the water column. The ammocoetes undergo a metamorphosis, between 3 and 7 years after hatching, and migrate from their parent streams to the ocean (Close et al., 2002). In the mid-Columbia River macrophthalmia migrate during the spring and early summer (Douglas PUD and LGL, 2008). Adults typically spend 1-4 years in the ocean before returning to freshwater tributaries to spawn.

Columbia River Basin Pacific lamprey populations have declined in abundance over the last 40 years according to adult counts at dams (Close et al., 2002). Starke and Dalen (1995) reported that adult lamprey counts at Bonneville Dam regularly exceeded 100,000 fish in the 1960s. Counts since 1997 have averaged much lower, at roughly 45,000 fish (range 14,562 to 117,035; DART 2008). Close et al. (2002) attributed several factors accounting for these declines, including juvenile and adult passage at dams, reduction in spawning and rearing habitat, pollution, reduction of ocean food sources, and predation by introduced species.

4.2 Adult Counts

Returning adult Pacific lamprey have been counted at Wells Dam since 1998. Between 1998 and 2007, the number of lamprey passing Wells Dam annually has averaged 350 fish (Table 4.0-1). The relatively small number of adult lamprey observed at Wells Dam can be attributed to the location of the Wells Project (last passable dam on the Columbia River, over 500 miles upstream from the Pacific Ocean) and the estimated 73% of the lamprey that bypass adult fish counting stations in the fish ladders at Wells Dam (LGL and Douglas PUD, 2008). Pacific lamprey counts for Columbia and Snake river dams are presented in Table 4.0-1 and 4.0-2. Although counts at Wells Dam have been identified as underestimated, an average of 0.67% of the total adult lamprey run observed at Bonneville Dam is counted passing Wells Dam (based on the sum of same-year counts at Bonneville and Wells dams 2000-2007).

Table 4.0-1 Pacific lamprey counts at Columbia River mainstem dams (listed in order by river mile), by dam and year, 1997-2008.

Year	Bonneville	The Dalles	John Day	McNary	Priest Rapids	Rock Island	Rocky Reach	Wells
1997	20,891	6,066	9,237	.	.	.	.	.
1998	.	.	.	.	.	.	.	343
1999	.	.	.	.	.	.	.	73
2000	19,002	8,050	5,844	1,281	.	822	767	155
2001	27,947	9,061	4,005	2,539	1,624	1,460	805	262
2002	100,476	23,417	26,821	11,282	4,007	4,878	1,842	342
2003	117,035	28,995	20,922	13,325	4,340	5,000	2,521	1,410
2004	61,780	14,873	11,663	5,888	2,647	2,362	1,043	647
2005	26,667	8,361	8,312	4,158	2,598	2,267	404	214
2006	38,941	6,894	9,600	2,459	4,383	1,326	370	21
2007	19,304	6,083	5,753	3,454	6,593	1,300	696	35
2008	14,562	4,599	6,625	1,530	5,083	880	368	
Total	446,605	116,399	108,782	45,916	31,275	20,295	8,816	3,502
Min	14,562	4,599	4,005	1,281	1,624	822	368	21
Max	117,035	28,995	26,821	13,325	6,593	5,000	2,521	1,410
Average	44,661	11,640	10,878	5,102	3,909	2,255	980	350
SD	36,598	8,264	7,330	4,344	1,583	1,612	738	416

Table 4.0-2 Pacific lamprey counts at Snake River mainstem dams, by dam and year, 1996-2008.

Year	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
1996	737	.	.	490
1997	668	.	.	1,122
1998	.	.	.	.
1999	.	.	.	.
2000	315	94	71	28
2001	203	59	104	27
2002	1,127	284	365	138
2003	1,702	476	660	282
2004	805	194	243	122
2005	461	222	213	42
2006	277	175	125	35
2007	290	138	72	34
2008	264	145	104	61
Total	6,849	1,787	1,957	2,381
Min	203	59	71	27
Max	1,702	476	660	1,122
Average	623	199	217	216
SD	461	124	192	333

Adult lamprey pass Wells Dam from early July until late November with peak passage times between mid-August and late October (Figure 4.0-1). In all years since counting was initiated, Pacific lamprey counts at the east fish ladder were greater than at the west fish ladder. Historically, counting protocols were designed to assess adult salmonids and did not necessarily conform to lamprey migration behavior (Moser and Close 2003). Traditional counting times for salmon did not coincide with lamprey passage activity which occurs primarily at night; the erratic swimming behavior of adult lamprey also makes them inherently difficult to count. Further complicating the comparison of lamprey dam counts, Beamish (1980) noted that lamprey overwinter in freshwater for one year prior to spawning. Consequently, lamprey counted in one year may actually have entered the system in the previous year (Moser and Close, 2003) which confounds annual returns to the Columbia River Basin. While it is unknown to what degree these concerns are reflected in Columbia River lamprey passage data, it is important to consider these factors when examining historic lamprey count data at Wells Dam.

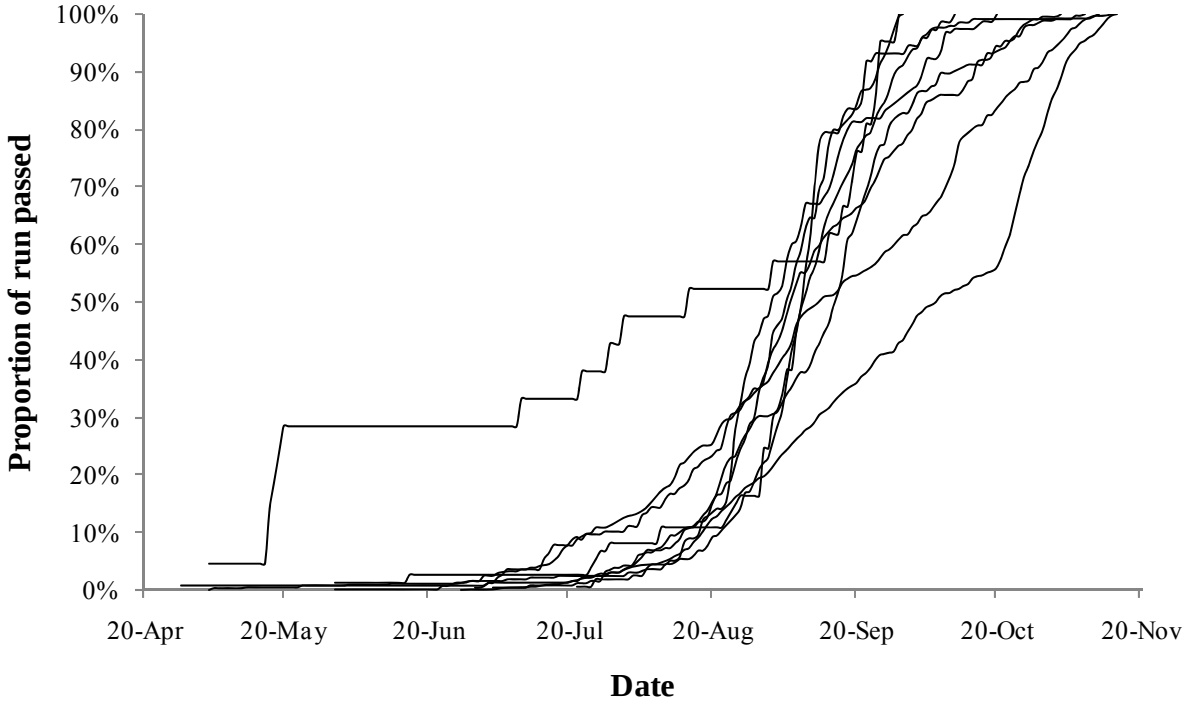

Figure 4.0-1 Run timing of Pacific lamprey at Wells Dam by year, 1998-2006.

Until recently, relatively little information was available on Pacific lamprey in the mid-Columbia River Basin. Two recent reviews of Pacific lamprey (Hillman and Miller 2000; Golder Associates Ltd. 2003) in the mid-Columbia River indicated that little specific information is known regarding population status (Stevenson et. al., 2005). However, with increased interest in the species coupled with a need to collect information for the license application for the Wells Project, Douglas PUD has initiated several studies to investigate Pacific lamprey spawning, juvenile predation and adult passage behaviors.

4.3 Passage Studies

The study of adult Pacific lamprey migration patterns past dams and through reservoirs in the lower Columbia River provided the first data sets on lamprey passage timing, travel times, and passage success at hydroelectric projects (Moser et al., 2002a; Moser et al., 2002b). These studies have shown that less than 50% of the lamprey that encountered a fishway entrance actually passed through the ladder to the forebay (Nass et al. 2005). Similar collection and passage efficiency results were observed at Rocky Reach, Wanapum and Priest Rapids dams during tagging studies conducted at those projects (Nass et al., 2003; Stevenson et al., 2005). Of the 125 radio-tagged lamprey released approximately 7 kilometers downstream of Rocky Reach Dam, 93.6% were detected at the project, and of those fish, 94.0% entered the fishway. Of the fish that entered the Rocky Reach Dam fishway, 55.5% exited the ladder.

During studies at Wanapum and Priest Rapids dams in 2001 and 2002, a total of 51 and 74 lamprey were radio-tagged and released downstream of Priest Rapid Dam, respectively. Over

the two years of study, the proportion of fish that approached the fishway and exited the ladders was 30% and 70% at Priest Rapids and 100% and 51% at Wanapum Dam.

In 2004, Douglas PUD hired LGL Limited to conduct a lamprey radio-telemetry study at Wells Dam in coordination with Chelan PUD which was conducting a similar study at Rocky Reach Dam. A total of 150 lamprey were radio-tagged and released at or below Rocky Reach Dam. The radio-tags used in this study had an expected operational life of 45 days (Nass et al., 2005). The release site was over 50 miles downstream of Wells Dam: the value of the study was limited by the relatively small numbers of tagged fish observed at Wells Dam (n = 18) and the fact that many of the radio-tags detected at Wells Dam were within days of exceeding their expected battery life.

The 2004 study at Wells Dam was implemented through a combination of fixed-station monitoring at Wells Dam and tributary mouths. Collectively, these monitoring sites were used to determine migration and passage characteristics of lamprey entering the Wells Project area. Of the 150 adult lamprey released at or below Rocky Reach Dam in 2004, 18 (12% of 150) were detected in the Wells Dam tailrace, and ten (56% of 18) of these were observed at an entrance to the fishways at Wells Dam. Two of the 10 lamprey approached both fishways to produce 12 total entry events. Three radio-tagged lamprey passed Wells Dam prior to expiration of the tags, resulting in a Fishway Efficiency estimate of 30% (3 of 10) for the study period. A single lamprey was detected upstream of Wells Dam at the mouth of the Methow River (Nass et al., 2005). This estimate probably underestimates actual fishway efficiency, as it is likely that some of the remaining 15 tagged fish detected in the Wells Dam tailrace passed Wells Dam subsequent to battery operational life.

For lamprey that passed the dam, the majority (92%) of Project passage time was spent in the tailrace. Median time required to pass through the fishway was 0.3 days and accounted for 8% of the Project Passage time (Nass et al., 2005).

Although the 2004 study at Wells Dam provided preliminary passage and behavioral information for migrating adult lamprey, the limited observations due to the small sample size (n = 18) is insufficient to address the objectives set forth in Section 2.0 with statistical confidence.

4.4 Aquatic Resource Work Group

As part of the relicensing process for the Wells Project, Douglas PUD established an Aquatic Resource Work Group (Aquatic RWG) which began meeting informally in November, 2005. This voluntary effort was initiated to provide stakeholders with information about the Wells Project, to collaboratively identify potential resource issues related to Project operations and relevant to relicensing, and to develop preliminary study plans to be included in the Wells Pre-Application Document (PAD) (DCPUD, 2006).

Through a series of meetings, the Aquatic RWG cooperatively developed a list of Issue Statements, Issue Determination Statements and Agreed-Upon Study Plans. Based upon these meeting and discussions, the Aquatic RWG proposed to include a radio-telemetry study to assess lamprey behavior as it relates to passage, timing, drop back and upstream migration. The need

for this study was agreed to by all of the members of the Aquatic RWG, including Douglas PUD. This study will help to inform future relicensing decisions and will fill data gaps that have been identified by the Aquatic RWG.

The Issue Statement and Issue Determination Statement listed below were included in the PAD (section number included) filed with the FERC on December 1, 2006:

4.4.1 Issue Statement (PAD Section 6.2.1.3)

The Wells Project may affect adult Pacific lamprey behavior related to ladder passage, timing, drop back and upstream migration.

4.4.2 Issue Determination Statement (PAD Section 6.2.1.3)

Work group members have determined that this issue has a tie to the Project as it relates to lamprey migration through Wells Dam. Preliminary passage information has been collected at Wells Dam (LGL and Douglas, 2008); however, the sample size of the study was limited and additional information is needed. A radio-telemetry study would be feasible to address passage, timing, drop back and upstream migration. The results of an adult lamprey passage study would also be useful during the development of Protection, Mitigation and Enhancement (PME) measures.

The resource work group agreed that a radio-telemetry study to assess lamprey behavior as it relates to passage, timing, drop back and upstream migration should be conducted at Wells Dam during the two-year ILP study period.

4.5 Project Nexus

The Wells Project may affect adult Pacific lamprey behavior related to ladder passage, timing, drop back and upstream migration. Potential problems facing successful passage of adult Pacific lamprey at dams may be related to their unique method of movement and specific areas within fishways: specifically, adult Pacific lamprey at other projects have experienced difficulty passing over diffusion gratings and through areas of high velocity, bright light and through orifices with squared, un-rounded edges. Typically, lamprey move through an adult fishway in a repeated series of motions consisting of attaching to the ladder floor with their mouths, surging forward, and re-attaching. The physiological response of adult Pacific lamprey to exhaustive exercise may be immediate, sometimes severe, but short-lived (Mesa el al., 2003). This may suggest that lamprey have difficulty negotiating fishways with high current velocities.

The proposed lamprey radio-telemetry study will assist in providing the information needed as identified by the Aquatic RWG and will inform the development of future license requirements.

5.0 METHODOLOGY

The study methodology used in 2007 for Objectives 1 through 4 (see 2.0 for description) is described in the first annual report *Adult Pacific Lamprey Passage and Behavior Study (Adult Lamprey Passage Study): Wells Hydroelectric Project, FERC No. 2149* (LGL and DCPUD, 2008). In both 2007 and 2008, radio-telemetry techniques were used to address Objective 5 (estimation of lamprey residence times and fishway passage times; and documentation of downstream passage events). Lamprey were captured, handled, tagged and released, and were subsequently tracked using radio-receivers. The specific methods used in 2007 are outlined in LGL and DCPUD (2008). Methods employed in 2008 are described in detail below.

5.1 Capture, Tagging, and Release of Lamprey

5.1.1 Trapping

Four lamprey traps were deployed at Wells Dam to capture adult lamprey for tagging. Lamprey traps were designed by Douglas PUD and LGL in the spring of 2007 and then modified in the spring of 2008 to increase trapping efficiency. Each aluminum holding box (0.6×0.4×0.6 m) was deployed along the fishway wall on the upstream side of an overflow weir. The traps passively captured fish that traveled over the weir through an overflow slot adjacent to the fishway's outer wall. The trap's funnel served to guide lamprey from the wall and weir sill into a chute and then into a holding box. Traps were affixed to the fishway wall by tracks that allowed operators to raise the unit out of the water for fish removal and cleaning (Figure 5.1-1). Two traps were located between Pools #39 and #40 in each fishway. The traps were numbered in ascending order, from the westernmost (Trap 1) to the easternmost (Trap 4) trap.

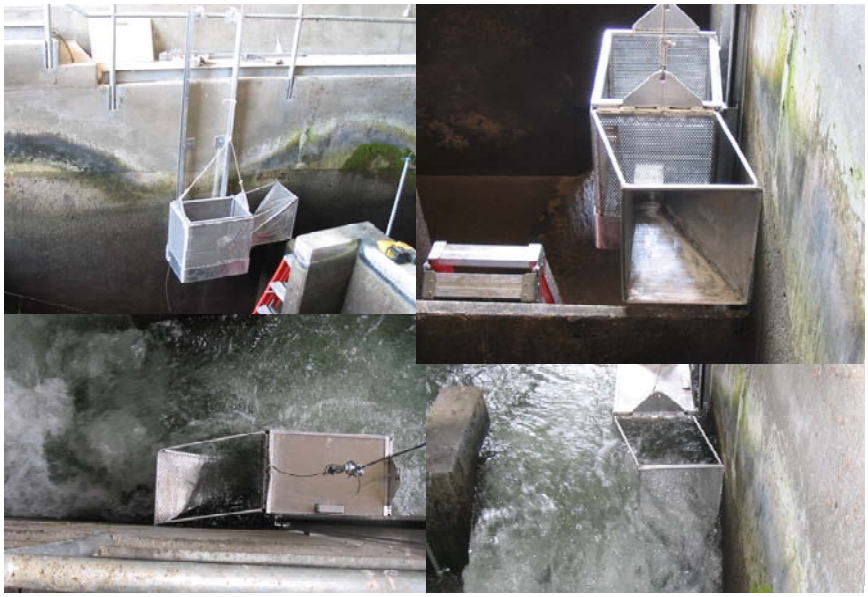

Figure 5.1-1 Douglas PUD adult lamprey trap. Views (clockwise from top left) from the side (at installation), front (at installation), front (active), and top (active) in the east fishway of Wells Dam.

Expected trap efficiencies were based on the following assumptions: 1) only a small portion of lamprey will utilize the weir orifice to pass between fishway pools; 2) lamprey will be attracted to the reduced flow and ease of travel along the fishway wall; 3) trap escapement will be negligible; and 4) lamprey will not drop back upon encountering the trap. These assumptions were based on flow measurements, documented swimming capabilities of adult lamprey (see literature cited), and observed lamprey behavior at fishways of other hydroelectric projects (Chris Peery, University of Idaho, personal communication).

Results from the 2007 study indicated that trapping efficiency was lower than expected (less than 25%, LGL and DCPUD, 2008). Since passage over the middle of the weir or around the trap seemed unlikely, lamprey were presumed to have passed through the orifices at greater proportions than initially anticipated. In an attempt to improve trapping efficiency and reach proposed sample size in 2008, the Aquatic Resource Work Group agreed to the installation of a perforated plate on the floor of the weir orifice. This would effectively eliminate orifice passage (by preventing burst and attach swimming), forcing lamprey to resort to passing into the trap. Video of lamprey behavior at federal projects document similar actions at blocked orifices (Chris Peery, University of Idaho, personal communication).

Trapping was initiated following the first observed lamprey at the Wells Dam fish counting stations, and continued over a ten week period (2 August to 15 October, 2008). In 2008, traps were fished daily. Except when extraneous circumstances prevented it, all traps were checked twice each day: once in the morning (6:00-10:00 hrs) and once in the evening (15:00-17:00 hrs). All fish were identified, enumerated, and bycatch was released into the fishway upstream of the trapping location. Lamprey were immediately transferred by covered buckets into insulated holding tanks to await the next tagging session (taggers worked three days per week). Holding tanks (113L Igloo MaxCold 120 coolers, 1.0×0.5×0.5 m) and were hooked-up to circulating flow-through river water. Tanks were maintained at ± 2°C fishway temperature, and dissolved oxygen was kept within 9-12 mg/L). The maximum capacity for each tank was set at eight lamprey (roughly 30 grams of fish per liter of water), and maximum holding time prior to tagging was set at 36 hours (M. Moser, NOAA, personal communication; Molly Haddock, WDFW, personal communication).

Additional lamprey were obtained from concurrent trapping efforts at Rocky Reach Dam (42 miles downstream). The supplementation was in response to the low numbers of lamprey observed at Wells Dam and to meet the proposed sample size target of the study (40 lamprey tagged each year). Lamprey captured at Rocky Reach Dam were moved to holding tanks by Chelan or Douglas PUD employees. LGL biologists visited Rocky Reach Dam on 5 occasions in 2008 (13 and 15 August; 2, 5 and 6 September) to transport fish to Wells Dam for tagging. Fish were transported by truck in a 113 L cooler filled with river water. An air tank and air stones were used to maintain proper oxygen levels. The 42-mile trip generally took an hour and lamprey were tagged as soon as possible (20-60 minutes after arrival at Wells Dam), always adhering to the 36 hour maximum holding time criterion.

5.1.2 Tagging and Release

Model NTC-4-2L Nano Tags (Lotek® Newmarket, Ontario) with an 87 day battery life were used for all lamprey. The tags were set up in 5.0 second burst rates on a frequency of 148.320 or 148.780 MHz. Tag dimensions were 18.3 mm (length) by 8.3 mm (diameter), with a dry weight of 2.1 grams – less than 0.8% of total body weight for all lamprey. Tags were sequenced, activated, and tested prior to each surgery.

Surgical tagging methods were based on techniques described by Moser et al. (2002a), Close et al. (2003), and Stevenson et al. (2005), in combination with LGL Limited guidelines for surgical tag implantation. The tagging area was prepared with a tub containing a heavy sedation mixture and two surgery buckets, one containing a light sedation mixture and the other river water. Tricaine methane sulfonate (MS 222) was used as an anesthetic in 2008, with the heavy and light sedation mixtures prepared at 70 mg/L and 49 mg/L, respectively. A few drops of Stress Coat (Aquarium Pharmaceuticals, Inc. Chalfont, PA) were added to all containers and the surgery trough to minimize effects of handling. The surgery trough was made of sectioned PVC tubing, angled to allow pooling near the head and gills of the lamprey. Tubing from the surgery buckets to the trough allowed controlled flow of either the light sedation mixture or water over the gills of the lamprey (Figure 5.3-2). Surgery tools were placed alongside the surgery trough and the radio-tag was activated and tested.

Lamprey were tagged by surgically inserting a transmitter into the peritoneal cavity. The surgery began by first transferring an individual lamprey to the heavy sedation tub. Fish would generally lose equilibrium after a few minutes and were usually adequately anesthetized within eight minutes. The lamprey was then removed from the solution, weighed to the nearest gram, measured length (to the nearest 0.5 cm) and girth (to the nearest mm), and placed into the surgery trough. The spout from the light sedation bucket was opened to maintain flow of anesthetic during the procedure. A 1.5-2.0 cm incision was made approximately 1 cm above the ventral midline with the posterior end of the cut ending in line with the anterior insertion of the first dorsal fin. A catheter was inserted into the peritoneal cavity, and pushed through the side of the fish, approximately 3 cm posterior to the incision (Figure 5.3-3). The radio-tag antenna was threaded through the catheter and the tag was inserted into the peritoneal cavity. In 2008, a PIT tag was also inserted into the peritoneal cavity. Following tag insertion, an internal antibiotic (Liquimycin) was pipetted into the peritoneal cavity, and 2-3 sutures were used to close the incision. A 19 mm suture needle was used, with 3-0 absorbable surgical suture thread. A light coat of antibiotic ointment (Polysporin) was applied to the closed incision and the fish was subsequently moved to the recovery tank.

Figure 5.1-2 Lamprey tagging trough, surgery buckets, scale, and platform.

Figure 5.1-3 Radio-tag and data form (left) and incision and catheter prior to tag insertion during the surgery process.

Fish were typically released upon recovery (approximately one hour post-surgery), but in some cases releases were delayed beyond the recovery time. Mean time to release was 1.5 h in the recovery tank, and ranged from 0.7-2.7 h. To release a radio-tagged lamprey, it was placed into a 19 L bucket with 8-10 L of water, and the covered bucket was lowered by rope into the water, the lid was removed, and the lamprey was allowed volitional release from the container. Radio-tagged lamprey were released into the tailrace (into the east or west alcove) or into the fishway (into the east or west collection gallery). One fish was released into the west fishway, mid-ladder. Releases typically took less than 10 minutes.

5.2 Radio-Tracking

5.2.1 Fixed Station Receiver Arrays

The movement and passage of radio-tagged lamprey at Wells Dam were documented by combining detection data collected using both underwater and aerial antenna stationary arrays (Figure 5.2-1). The arrays were designed to detect movements of radio-tagged lamprey from the Columbia River into the fishway entrances and through the exits at Wells Dam, and were also designed to detect downstream passage movements. Aerial antennas were used in the tailrace and at remote stations on tributary mouths. Underwater antennas were used in the fishways. A total of 12 Lotek telemetry receivers, composing multiple arrays (8 at Wells Dam, 1 at the 'Gateway' site in the Columbia River downstream of the Wells Dam tailrace, 1 at the Methow River mouth, 1 at the Okanogan River mouth, and 1 for mobile tracking) were used during the study.

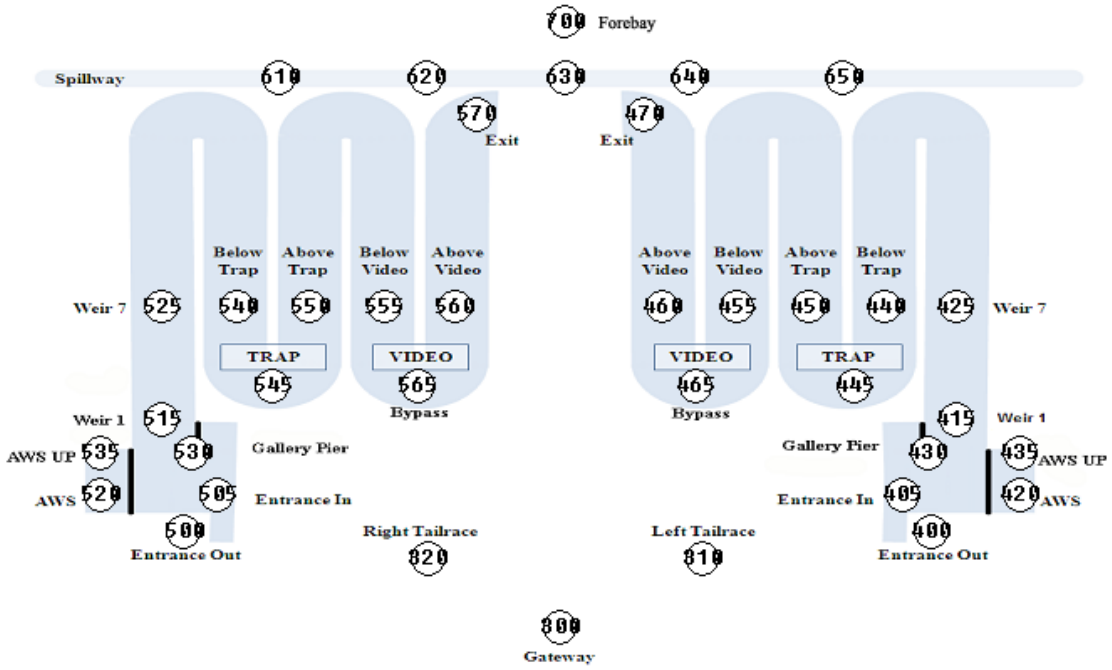

Figure 5.2-1 Fixed-station receiver detection zones used to detect radio-tagged lamprey at Wells Dam by station number, 2008.

5.2.2 Mobile Tracking

Mobile tracking was conducted by foot and by boat. Foot surveys were conducted within the fishways, using a single aerial antenna. Boat tracks were performed by running transect lines (oriented upstream and downstream) in a 2 km reach of the river downstream of Wells Dam. A post was mounted in the boat to secure twin three-element aerial antennas, which were pointed in opposite directions (usually at each bank). Once a tag was detected, a short-range underwater

antenna (stripped coaxial cable) was used to accurately locate the tag position. During boat-tracking, the tailrace was partitioned into local area zones (see Figure 5.2-2). Signals of unknown origin, and those obtained prior to developing the detailed zones were classified as 'unknown'.

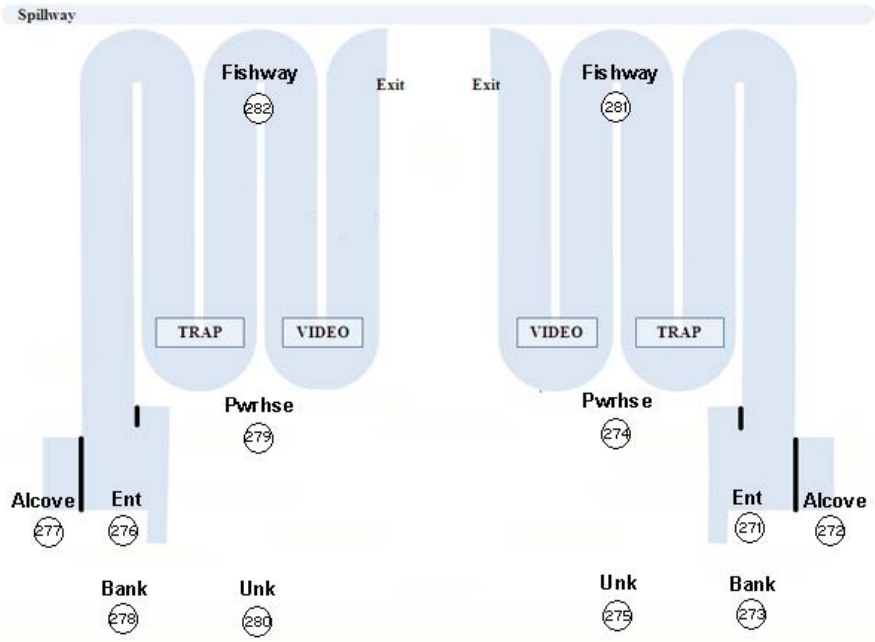

Figure 5.2-2 Mobile-tracking zones used for radio-tracking lamprey at Wells Dam by station number, 2008.

5.3 Data Processing and Analysis

The data collected were managed and analyzed using Telemetry Manager, a program developed in Visual FoxPro by LGL Limited. Individual antennas were grouped into "zones" that define pivotal areas of interest, such as individual fishway entrances and exits.

5.3.1 Detections and Movements

The number of fish detected at each zone was summarized using the Telemetry Manager database. Each time a fish was detected in a zone, the duration of the detection event (the amount of time the fish spent in the zone) was calculated. The operational database was also used to map movements of fish among zones. For every combination of among-zone movements, the number of times a fish performed that movement was calculated, as was the amount of time it took to get from one zone to the next.

5.3.2 Passage Times and Ascent Rates

Passage times were calculated from benchmark dates and times corresponding to the first and last detection of a given radio-tagged lamprey at specific locations. At Wells Dam, the benchmark times for lamprey that passed the Project were:

1. first detection in the tailrace,
2. first detection at the fishway entrance (outside antenna),
3. last detection at the fishway entrance (inside antenna),
4. first detection at the 'Above Trap' zone,
5. first detection at the 'Below Video' zone,
6. first detection at the 'Above Video' zone,
7. first detection at the 'Video Bypass' zone,
8. last detection at the 'Video Bypass' zone,
9. first detection at the fishway exit, and
10. last detection at the fishway exit.

From these benchmark times, passage times were calculated for each radio-tagged lamprey for the following passage segments:

Segment	Time	Name
A)	1 to 2	Tailrace Passage time
B)	2 to 3	Entrance Passage time
C)	3 to 10	Fishway Passage time
D)	1 to 10	Project Passage time

Passage times were also calculated for segments of each fishway:

Segment	Time	Name
E)	3 to 4	Lower Fishway Passage time
F)	4 to 10	Upper Fishway Passage time

In addition, the upper fishway was further segmented, and passage times were calculated for the following:

Segment	Time	Name
G)	4 to 5	Above Trap to Below Video
H)	5 to 6	Below Video to Above Video
I)	6 to 9	Above Video to Exit
J)	9 to 10	Residence time in Exit zone

For fish that used the video bypass, the following passage times were calculated:

K)	5 to 7	Below Video to Video Bypass
L)	7 to 8	Residence time in Video Bypass zone
M)	7 to 9	Video Bypass zone to Exit

The residence and passage times for each radio-tagged lamprey were determined by working backwards through a sequence of detections. The fishway of ultimate passage and the respective passage time were determined by identifying a sequence of detections in the ascent of a fishway, starting with detections in a fishway exit zone.

5.3.3 Definition of Downstream Passage Events and Drop Back

A downstream passage event was defined as a tag that is detected at a fishway exit and subsequently detected in the tailrace or a fishway entrance without any detections at antennas monitoring the inside fishway zones. Drop back is defined as those tags in a fishway detection zone that are subsequently detected in zones directly downstream within the fishway.

5.3.4 Definition of Approach, Entrance, and Passage Efficiencies

For the purpose of analysis, a fishway was 'approached', if a lamprey was detected at the fishway entrance (by the antennas outside the entrance), or anywhere inside the fishway. A fishway was 'entered' if a lamprey was detected by the antenna on the inside of the fishway entrance, or anywhere inside the fishway. 'Entrance Efficiency' was defined as the proportion of fish that approached a fishway that subsequently entered it. 'Fishway passage' occurred when a lamprey that entered a fishway successfully exited into the forebay. Any fish that was detected at the fishway exit zone was considered to have successfully passed the dam. 'Passage Efficiency' was defined as the proportion of fish that entered a fishway that successfully reached the exit.

5.3.5 Video Bypass and Trapping Efficiency

Video bypass rates were calculated from the radio-tagged lamprey tracking histories. All lamprey that passed though the vicinity of the counting area were detected by the radio-telemetry equipment. They were detected either: 1) at the video counting detection zone; 2) in the video bypass detection zone; or 3) in both. No radio-tagged fish passed through the area undetected (i.e., no fish were detected farther upstream without being detected at one of these two zones). The total number of radio-tagged lamprey that passed through the area was known, and the video bypass rate was calculated as the proportion of the total that bypassed the counting station.

Trapping efficiency was assessed by dividing the number of fish caught in the traps by the number known to have encountered them. The number known to have encountered the traps included the number that was trapped, the number of radio-tagged fish that passed without being recaptured, and the number of 'untagged' fish that passed without being captured. The number of untagged fish that passed without being captured was estimated from the video-counting data: The timestamp assigned by the video-counting staff to each lamprey passing the count window was compared to the radio-detection data to determine how many of the observed fish were tagged and how many were untagged. Then, the number of untagged fish at the count window was divided by the video-bypass rate to calculate the total number of untagged lamprey in the upper fishway.

6.0 RESULTS

The study conducted in 2007 sufficiently addressed questions related to Objectives 1 through 4. The results from the 2007 report are detailed in the first annual report *Adult Pacific Lamprey Passage and Behavior Study (Adult Lamprey Passage Study): Wells Hydroelectric Project, FERC No. 2149* (LGL and DCPUD, 2008). The 2008 radio-tracking study was performed to address remaining questions related to entrance efficiency and collection gallery behavior (see LGL and DCPUD, 2008). The results from the second year of study are detailed in the results below.

6.1 Capture, Tagging, and Release of Lamprey

6.1.1 Trapping

Each adult lamprey trap was checked twice daily over the 75 day trapping period. In total, 206 fish were caught representing six identified species (see Table 6.1-1), including 22 jack Chinook salmon (*Oncorhynchus tshawytscha*), 38 Chinook smolts, 51 chub/suckers (peamouth *Mylocheilus caurinus,* chiselmouth (*Acrocheilus alutaceus*), and suckers (Catostomids)), 24 Pacific lamprey, 1 rainbow trout/steelhead smolt (*O. mykiss*), 54 northern pikeminnow (*Ptychocheilus oregonensis*), and 15 sockeye salmon (*O. nerka*). Roughly half (51%) of the catch was composed of chubs, suckers, and northern pikeminnow. Catches were highest in the third week of trapping (week ending 22 August, Table 6.1-1), largely due to a surge in northern pikeminnow catch. In 2008, 88% of the lamprey were removed during the morning trap checks (i.e., fish were captured overnight and early morning), and the majority of the Chinook (82%) and sockeye (100%) were removed during the afternoon trap checks.

Table 6.1-1 Total fish captured by species and week of trapping at Wells Dam, 2008.

	Week of trapping (end date)											
Fish taxa	8/8	8/15	8/22	8/29	9/5	9/12	9/19	9/26	10/3	10/10	10/17	Total
Chinook - jack		3	1	3	4	1	1	3	3	3		22
Chinook - smolt	2	1		7	9	10	3	3	3			38
Chub/Sucker	8	5	11	1	2	10	10	3		1		51
Pacific lamprey	1	3	6	6	2	5	1					24
Rainbow/steelhead					1							1
N. pikeminnow	3	1	32	1		3	5	3	4	1	1	54
Sockeye		6	7	1	1							15
Species unrecorded					1							1
Total	14	19	57	19	20	29	20	12	10	5	1	206

From 6 August to 17 September, a total of 24 lamprey were caught at Wells Dam (Table 6.1-1), including 13 in the east ladder, and 11 in the west ladder. All lamprey were in excellent condition at the time of capture except two: one individual with a damaged eye, and one individual with an open wound behind the dorsal fin. Eight of the collected individuals were recaptured radio-tagged lamprey from this study, with one fish recaptured twice. Recaptures were released into the fishway mid-ladder (7 fish) or into the collection gallery (1 fish). In one case, a recaptured lamprey was re-anesthetized to replace some missing sutures. Otherwise,

adequate healing from the surgery had occurred. Of the remaining 16 lamprey, 15 were radio-tagged.

From 12 August to 5 September, 25 lamprey were collected at Rocky Reach Dam and transported to Wells Dam. Twenty-three of these were of adequate size and tagged. Despite the additional handling and collection location, there were no obvious differences in tracking history that would suggest that Rocky Reach Dam lamprey behaved differently from those captured at Wells Dam. The mean length, weight and girth of lamprey from the two dams differed by 1.3% or less (length: $t_{38} = 0.79$, $P = 0.43$; weight: $t_{34} = 0.16$, $P = 0.87$; girth: $t_{37} = 0.29$, $P = 0.77$).

6.1.2 Tagging and Release

In 2008, thirty-eight lamprey were radio-tagged between 6 August and 19 September (Appendix A). These fish averaged 63.9 cm in total length (58-72 cm), and 0.38 kg in weight (0.30-0.56 kg). The girth of these fish averaged 10.1 cm, ranging from 9.1 to 12.0 cm. Sex was only determined for one female fish when oocytes were noticed during surgery. Total surgery time averaged 10.7 minutes (8-16 min), including an average 4.8 minutes (3-7 min) of heavy sedation and 5.9 minutes (4-11 min) of light sedation/surgery. Fish were held in the recovery tote for an average of 90.2 min (40-161 min). Fish generally showed immediate signs of recovery and appeared to be in vigorous condition prior to release.

Eighteen fish were released into the Wells Dam tailrace, and 20 fish were released into the fishway. Of the 18 tailrace fish, 9 were released into the east alcove (7 trapped in east ladder, 2 at Rocky Reach Dam), and 9 into the West Alcove (7 trapped in west ladder, 2 at Rocky Reach Dam). Of the remaining fish, 9 were released into the east collection gallery (all trapped at Rocky Reach Dam), 10 into the west collection gallery (1 trapped in west ladder, 9 at Rocky Reach Dam), and 1 into the West Fishway mid-ladder (trapped at Rocky Reach Dam).

6.2 Radio-tracking

Fixed stations were operated from the first week of August through the first week of November. Stations were downloaded at least weekly throughout the study period. A single receiver in the lower west fishway malfunctioned and was offline during the period 13 through 20 August, which could have resulted in missed detections at the fishway entrance. Otherwise, all stations were functional throughout the study.

Six boat-based mobile tracking events were performed in the Wells Dam tailrace (5 and 18 September; 2, 8 and 23 October; 12 November). Foot-based mobile tracking events around the dam were performed on 15 occasions over the duration of the study period (18, 20, 22, and 25 August; 1, 8, 12, 19, 22, 24, 26, and 29 September; 3, 6, and 8 October). Thirty-five detections of twenty-seven individual radio-tagged lamprey occurred during mobile tracking efforts (24 during boat-based tracks, and 11 during foot-based tracks). Two lamprey detected during mobile tracking were never detected by fixed station receivers.

6.2.1 Detections

All 38 radio-tagged lamprey were detected at some point subsequent to their release. The 38 radio-tagged lamprey were detected a total of 583 separate times at fixed and mobile stations. The duration of each detection ranged from a few hits over a couple seconds to as many as 24,168 hits over a 67.8-hour period (Fish 1 remained inactive outside the entrance of the left fishway from 25 to 28 August). The earliest fixed station detection occurred on 6 August (at 11 PM outside the entrance of the left fishway) and the last occurred 4 November (at 4 AM in the right side of the tailrace). The period of detections coincides approximately with the migratory activity of lamprey in the immediate area (lamprey observations at the fish counting window ranged from 11 July to 5 October).

6.3 Lamprey Movement and Passage Behavior

6.3.1 Movements

The 38 tagged lamprey made a total of 284 directional movements between detection zones subsequent to the first detection after release, averaging 7.5 moves per fish (range 0-39; Tables 6.3-1 to 6.3-3). The most frequent moves were between left and right tailrace arrays (Table 6.3-1), between the left inside entrance and the left collection gallery pier, and between the left Pier 1 and the upstream AWS (Table 6.3-2). Movements in the tailrace ranged from 3.3 minutes between the left tailrace and the left outside entrance, to 8.9 days between left tailrace and the zone outside the right fishway entrance (Table 6.3-1). Movements within the fishways ranged from 4 seconds in the left fishway between the inside entrance and the collection gallery pier zones, to 2.2 days in the left fishway between the 'below trap' and 'above trap' zones (Table 6.3-2).

Table 6.3-1 Duration of lamprey movements (h:mm:ss) within the tailrace at Wells Dam, by frequency of occurrence, 2008.

Direction	From (detection zone) → to (detection zone)	Count	Min	Max	Average
Up	Gateway → E. Tailrace	4	17:57:02	44:05:25	33:09:06
	Gateway → W. Entrance Out	1	119:34:47	119:34:47	119:34:47
	E. Tailrace → E. Entrance Out	3	03:19	16:11:52	5:27:23
	E. Tailrace → W. Entrance Out	1	214:52:18	214:52:18	214:52:18
	W. Tailrace → W. Entrance Out	1	45:14:22	45:14:22	45:14:22
Down	W. Entrance Out → W. Tailrace	1	11:32	11:32	11:32
	W. Entrance Out → E. Tailrace	3	2:41:43	194:07:17	66:54:35
	E. Entrance Out → W. Tailrace	1	21:40	21:40	21:40
	E. Entrance Out → E. Tailrace	3	55:11	25:44:26	9:44:08
	W. Tailrace → Gateway	3	1:38:41	1:46:31	1:41:35
	E. Tailrace → Gateway	2	2:14:13	2:16:27	2:15:20
Across	E. Tailrace → W. Tailrace	28	10:42	44:06:41	6:12:37
	W. Tailrace → E. Tailrace	23	05:04	49:53:03	11:30:05
	E. Entrance Out → W. Entrance Out	1	140:28:43	140:28:43	140:28:43

Table 6.3-2 Duration of lamprey movements (h:mm:ss) within the fishways at Wells Dam, by frequency of occurrence, 2008.

Direction	From (detection zone) → to (detection zone)	Count	Min	Max	Average
Up	E. Entrance In → E. Gallery	14	00:04	11:21	01:31
	E. Weir 1 → E. Weir 7	9	00:15	07:55	02:29
	E. Weir 1 → E. Gallery	2	00:25	01:55	01:10
	E. Weir 1 → E. AWS up	10	00:20	07:40	02:40
	E. AWS down → E. AWS up	2	58:51	1:20:41	1:09:46
	E. Weir 7 → E. Below Trap	8	1:39:23	4:24:55	2:37:45
	E. Gallery → E. AWS up	3	04:40	17:54	09:33
	E. Below Trap → E. Above Trap	3	27:19	52:53:53	17:58:09
	E. Above Trap → E. Below Video	2	1:55:32	13:53:35	7:54:33
	E. Above Trap → E. Above Video	1	1:32:02	1:32:02	1:32:02
	E. Below Video → E. Video Bypass	2	05:30	06:05	05:48
	E. Above Video → E. Fishway Exit	2	16:39	1:26:25	51:32
	E. Video Bypass → E. Fishway Exit	1	49:09	49:09	49:09
	W. Entrance In → W. Gallery	4	00:20	10:50:51	2:44:34
	W. Weir 1 → W. Weir 7	2	01:07	05:35	03:21
	W. Weir 1 → W. Gallery	2	00:29	01:30	01:00
	W. Weir 1 → W. AWS up	3	03:02	25:45	13:31
	W. Weir 7 → W. Gallery	1	01:00	01:00	01:00
	W. Weir 7 → W. Below Trap	2	3:31:25	5:19:23	4:25:24
	W. Below Trap → W. Above Trap	1	11:53:14	11:53:14	11:53:14
	W. Above Trap → W. Below Video	1	2:45:15	2:45:15	2:45:15
	W. Below Video → W. Video Bypass	1	02:10	02:10	02:10
	W. Video Bypass → W. Fishway Exit	1	29:29	29:29	29:29
Down	E. Video Bypass → E. Above Video	1	02:45	02:45	02:45
	E. Below Trap → E. AWS up	2	12:56:04	20:18:03	16:37:03
	E. Below Trap → E. Gallery	1	1:49:51	1:49:51	1:49:51
	E. Below Trap → E. Weir 7	1	23:23	23:23	23:23
	E. AWS up → E. Gallery	4	00:20	21:07	07:14
	E. AWS up → E. AWS down	1	1:21:57	1:21:57	1:21:57
	E. AWS up → E. Weir 1	12	00:10	18:09	03:19
	E. Gallery → E. AWS down	2	10:14	16:42	13:28
	E. Gallery → E. Weir 1	6	00:25	03:16	01:08
	E. Gallery → E. Entrance In	16	00:04	02:45	00:23
	E. Weir 7 → E. Weir 1	2	02:35	05:00	03:48
	E. AWS down → E. Entrance In	1	01:30	01:30	01:30
	W. Below Trap → W. Weir 7	2	10:47	13:37	12:12
	W. AWS up → W. Weir 1	3	02:00	04:00	02:54
	W. Gallery → W. Weir 1	4	00:30	03:19	01:30
	W. Gallery → W. Entrance In	4	00:05	3:53:43	58:51
	W. Weir 7 → W. Weir 1	2	01:50	03:40	02:45
	W. Weir 1 → W. Entrance In	1	05:50	05:50	05:50

Table 6.3-3 Duration of lamprey movements (h:mm:ss) between the tailrace and fishways at Wells Dam, by frequency of occurrence, 2008.

Direction	From (detection zone) → to (detection zone)	Count	Min	Max	Average
Down	E. Gallery → E. Entrance Out	1	00:10	00:10	00:10
	E. Entrance In → E. Entrance Out	6	00:05	23:46:57	3:58:06
	E. Entrance In → W. Tailrace	1	365:00:31	365:00:31	365:00:31
	E. Entrance In → E. Tailrace	1	00:03	00:03	00:03
	W. Entrance In → W. Entrance Out	6	00:04	07:31	02:51
Up	E. Tailrace → E. Entrance In	1	01:54	01:54	01:54
	E. Entrance Out → E. Entrance In	4	00:05	03:27	00:55
	W. Entrance Out → W. Entrance In	4	01:55	24:33	09:04
	W. Entrance Out → E. AWS up	1	99:18:43	99:18:43	99:18:43

6.3.2 Fishway Passage Metrics

Entrance and Passage Efficiency

Tailrace releases

Of the 18 lamprey released into the tailrace, five were stationary throughout the study period, and were presumably mortalities or shed tags. An additional lamprey was only detected twice, and yielded insufficient data for characterization of movements. The remaining 12 lamprey were examined for entrance and passage efficiency.

Over the study period, 11 of the 12 (91.7%) 'active' tailrace-released lamprey approached a fishway entrance. Several of the lamprey made multiple approaches (maximum for one fish was 3), and a total of 17 separate approaches occurred at the west (n = 6) and east (n =11) fishways. The fishway entrance that was approached was significantly associated with the tailrace side on which the lamprey was released ($\chi^2 = 6.8$, df = 1, Fisher's exact test $P = 0.018$). Specifically, the eastern releases approached the east fishway 9 times, and the west fishway once; whereas the western releases approached the east fishway 2 times, and the west fishway 5 times (note that lamprey trapped at Wells Dam were released on the same side of the tailrace as the ladder in which they were caught, thus it was impossible to separate the effects of capture location from those of release location when assessing entrance rates).

Only two tailrace-released lamprey successfully entered a fishway collection gallery (one on the east side, one on the west side), as indicated by detections on the antenna located on the inside of the fishway entrance.

Fishway releases

Of the 20 lamprey released into the fishway, three fish either died or shed their tags based upon insufficient detections for characterization of their tracks. Passage efficiency was evaluated for the remaining lamprey. Of the 17 'active' fishway-released lamprey, 4 passed the dam (23.5%), with the remaining fish either rejecting the fishway (many of which did so after encountering the trapping area) or ceasing migration. One of these lamprey (Tag #6) moved downstream out of the fishway, re-entered, commenced an ascent, encountered the trap, dropped back to 'Weir 1',

then resumed its upstream movements and ascended successfully. Two of the successful lamprey ascended the fishway upon release (Tags #2 and #8), were recaptured en-route, and resumed their ascent upon re-release. The last of these lamprey (Tag #22) successfully ascended the fishway without being recaptured en route.

Seven of the remaining 'active' lamprey ascended the fishway at least as far as the 'below trap' zone, but were ultimately not successful at dam passage. Two of these seven fish (Tags #7 and #9) ascended to the 'below trap' zone, and then dropped back out of the fishway (Tag #7 dropped out directly; Tag #9 dropped back to the first turn for 53 days, and took a total of 73 days to reach the tailrace). Three others (Tags #18, #25 and #32) ascended to the trap, were recaptured, were released into the fishway mid-ladder, and then dropped out of the fishway (Tag #18 was back into the tailrace within 18 minutes of release; Tag #25 dropped back into the AWS/'Weir 1' area where it was detected for 8 days and then disappeared; Tag #32 dropped back into the collection gallery, milled in the collection gallery, and then exited into the tailrace over 37 hours after release). Another lamprey (Tag #4) ascended to the trap, was recaptured, re-released in the collection gallery, resumed its ascent until it reached the 'below trap' zone, and then dropped back out of the fishway. The last of these lamprey (Tag #3) exited into the tailrace upon release, but later re-entered, started ascending the fishway, was recaptured, released, recaptured again, re-released, and then dropped back out into the tailrace.

The remaining six 'active' lamprey exited into the tailrace without ascending the ladder. These six lamprey took from < 1 hr to 2.6 d to leave the fishway into the tailrace. Their farthest upstream detection zones were 'Weir 1' (Tag #5), the collection gallery pier (Tags #26, #27 and #28), or the entry zone (Tags #10 and #31). One of these six subsequently re-entered the fishway, reached only as far as the 'entry inside' zone, and was back in the tailrace within half a minute.

Efficiencies

A total of 25 'active' lamprey were tracked in the tailrace during the study period (12 released there, 13 dropped back there after being released into the fishway). Of these, 15 approached a fishway entrance (11 tailrace releases, and 4 fishway releases) at least once, and 5 entered successfully (2 tailrace releases, and 3 fishway releases). This resulted in an entrance efficiency of 33% (18% for tailrace releases, 75% for fishway releases). The low sample size precluded meaningful comparisons of success rate between the west and east fishway entrances.

Each of the four fish that entered the upper fishway subsequently exited the fishway into the forebay. Thus the upper fishway passage efficiency was 100%.

Complete Fishway Passage

One fish (Tag #6) made a complete ascent of the east fishway (Appendix A). This fish was released into the east collection gallery, and within 8 hours had dropped out into the tailrace. It then returned to the fishway, and took 3.6 hours to move as far as the 'below trap' zone. It subsequently dropped back down into the collection gallery (possibly through the AWS), and it took 22.4 hours before it resumed its ascent. During this second attempt, the fish took 3 hours to reach the upper fishway. After an additional 2.5 hours passed, it had exited the fishway into the forebay.

Lower Fishway Passage

A total of 19 'active' lamprey were tracked through the lower fishways (17 'active' fishway releases, and 2 tailrace fish that entered volitionally). Examination of the detection histories of these fish revealed a total of 20 sequences that included drop back (Table 6.3-4). In one sequence, a fish (Tag #3) was released mid-ladder (above the trap) after recapture, it moved downstream and was recaptured a second time. In another sequence, a fish (Tag #25) was released mid-ladder after recapture, it moved down to the AWS/'Weir 1' area, and was not detected 8 days later (its fate is unknown). There were ten instances in which a fish moved directly downstream and out of the fishway upon release (7 had been released into the collection gallery, and 3 had been released mid-ladder after recapture). There were eight instances in which a fish was moving upstream, but then dropped back. In six of these instances, the fish dropped all the way into the tailrace (two had reached the 'below trap' zone, one had reached Weir 1, one had reached the 'collection gallery pier' zone, and two had gotten only as far as the entrance). In the other two instances, the fish reached the 'below trap' zone, and then dropped to either Weir 1 (this fish later resumed ascent and passed into the forebay), or to the first turn in the fishway (this fish waited 53 days then resumed its drop back into the tailrace).

Table 6.3-4 Types (and numbers) of observed drop back movements in the lower fishways of Wells Dam, 2008.

			Duration (d)		
Direction	Drop back Sequence	n	Min	Max	Average
Downstream	Release → out	7	0.00	2.59	0.56
	Re-release → out	3	0.01	1.55	0.53
	Re-release → vanish	1	8.61	8.61	8.61
Down, then Upstream	Re-release, drop to trap, recap	1	0.00	0.00	0.00
Up, then Downstream	Moved upstream to Below Trap → Weir 1	1	0.00	0.00	0.00
	Moved upstream to Below Trap → 1st Turn	1	53.17	53.17	53.17
	Moved upstream to Below Trap → out	2	0.00	0.73	0.37
	Moved upstream to Weir 1 → out	1	0.08	0.08	0.08
	Moved upstream to Gallery Pier → out	1	0.00	0.00	0.00
	Moved upstream into the Entry → out	2	0.00	0.00	0.00

A majority (12 of 14, or 85.7%) of radio-tagged lamprey that encountered the trapping area were effectively blocked, indicated by either a recapture (8 fish) or by drop back (4 fish were subsequently detected on downstream receivers). The remaining lamprey (2 fish) passed the trapping area without being captured (both successfully ascended the fishway).

The trapping area caused problems for lower fishway passage. Passage success from release to the 'above trap' zone was 21% (4 of 19 lamprey), yet 58% of the lamprey successfully ascended as far as the 'below trap' zone. Median passage time from release to the 'above trap' zone was 1.8 d (range 0.4 – 2.9 d; n= 4), including time spent in traps, and time spent dropping back and recovering from encounters with traps. In contrast, median passage time during periods of committed upstream movement (measured from the collection gallery pier to the 'below trap' zone) was 3.2 h (range 1.7 – 5.5 h; n = 8).

Upper Fishway Passage

A total of four tagged lamprey successfully ascended through an upper fishway (3 in the east ladder, 1 in the west ladder) at Wells Dam in 2008. One fish (Tag #2) was released on 13 August into the west collection gallery. It was later recaptured, and on 15 August it was re-released mid-ladder. It resumed its ascent, and reached the fishway exit on 16 August. Another fish (Tag #6) was released into the east collection gallery on 15 August. On 16 August, it dropped out of the fishway into the tailrace, on 17 August, it re-entered, ascended to the trap area, and then dropped back to 'Weir 1', and on 18 August, it resumed its ascent and exited the fishway. A third fish (Tag #8) was released into the east collection gallery on 15 August. It was recaptured on 16 August, re-released on 18 August, and exited the fishway on 19 August. The fourth fish (Tag #22), released into the east collection gallery on 3 September, progressed upwards and exited on 4 September.

Upper fishway passage times for the four successful fish, in ascending order, were 2.6, 3.4, 3.7 and 15.1 hours (Table 6.3-5). Given that the upper fishway is comprised of 27 pools, these passage times translate into average ascent rates of 5.7, 7.6, 8.3 and 33.6 minutes per pool. One lamprey was notably slower than the other three. Examination of passage times within individual fishway segments (Table 6.3-6) showed that biggest difference between the slow and fast lamprey occurred in the 'above trap' to 'below video' reach, which took the slow lamprey ~14 h to pass, and which the fast fish passed in 2-3 h. The slow lamprey's travel times through other reaches of the upper fishway were similar to those of the three other fish (Table 6.3-6). Three of the four lamprey were detected in the video bypass zone, but none showed the prolonged delays that were observed for some fish in the bypass in 2007 (LGL and DCPUD, 2008): in 2008, lamprey passage times between the first detection in the bypass and the first detection at the fishway exit ranged from 19.5 to 49.5 minutes (Table 6.3-6). The slow lamprey was the only one of the four fish whose upper fishway passage included daylight hours. As lamprey are nocturnal, the extended period of time required for this fish to reach the 'below video' detection zone could have included some daylight hours spent resting. This same fish passed the above video zone just after midnight, and quickly passed through the remaining part of the upper fishway in a few night-time hours.

Table 6.3-5 Benchmark times during upper fishway passage for radio-tagged lamprey that successfully passed Wells Dam, 2008.

Tag	Fish-way	Benchmark Times: 1st detection Above Trap	1st detection Below Video	1st detection at Video Bypass	1st detection Above Video	1st detection at Exit	Last detection at Exit	Upper Fishway Passage time (h)
2	West	15 Aug 21:44	16 Aug 0:36	16 Aug 0:42	-	16 Aug 1:19	16 Aug 1:28	3.7
6	East	18 Aug 2:21	18 Aug 4:22	18 Aug 4:28	18 Aug 4:31	18 Aug 4:48	18 Aug 4:56	2.6
8	East	18 Aug 10:45	19 Aug 0:44	19 Aug 0:50	-	19 Aug 1:39	19 Aug 1:54	15.1
22	East	3 Sep 23:13	-	-	4 Sep 0:54	4 Sep 2:23	4 Sep 2:37	3.4

Table 6.3-6 Segmented upper fishway passage times (h:mm:ss) of radio-tagged lamprey that successfully passed Wells Dam, 2008.

Tag	Fish-way	Passage Times: Above Trap → Below Video	Below Video → Video Bypass	Previous zone → Above Video	Previous zone → Exit	Residence at Exit	Total
2	West	2:52:40	0:05:55	-	0:36:14 [c]	0:09:34	3:44:23
6	East	2:00:22	0:06:39	0:02:55 [a]	0:16:39 [d]	0:08:30	2:35:05
8	East	13:59:20	0:05:30	-	0:49:29 [c]	0:14:39	15:08:58
22	East	-	-	1:41:28 [b]	1:28:30 [d]	0:14:14	3:24:12

a: video bypass to above video; b: above trap to above video; c: video bypass to exit; d: above video to exit.

Upper fishway passage times can be divided into four segments: 1) the time between the first detection at the above trap antenna and the first detection at the below video count window antenna (17 pools: Pools 47-63); 2) the time between the first detection at the below video count window antenna and the first detection at the above video count window antenna (Pool 64); 3) the time between the first detection at the above video count window antenna and the first detection at the exit (8 pools: Pools 65-72); and, 4) the time between the first detection at the exit and the last detection at the exit (Pool 73). The first segment of the fishway (between the above trap and below video count window antennas) includes 17 of the 27 (63%) pools, and accounted for 77-92 % of the total upper fishway passage times (n=3, Table 6.3-7). Ascent rates in this segment were slower than the overall upper-fishway ascent rates for each lamprey (Table 6.3-8). The time spent in the second segment (between the below video and above video antennas), accounted for 2% of the total upper fishway passage time for the one fish that was detected in both zones (Tag #6; Table 6.3-7). The ascent rate (2 min/pool) for the fish in this segment was faster than its overall upper-fishway ascent rate (5.7 min/pool; Table 6.3-8). Time spent in segment three (between the first detection at the above video count window antenna and the first detection at the exit) accounted for 11 to 43% of the total upper fishway passage time (n = 2; Table 6.3-7), and ascent rates (2 and 11 min/pool) were faster than the overall upper-fishway ascent rates for each lamprey (Table 6.3-8). Time spent in the last segment (within the detection zone of the fishway exit antenna) accounted for 2 to 7% of the total upper fishway passage time (n = 4; Table 6.3-7), and all four fish passed through the zone in under 15 minutes (Table 6.3-8). Ascent rates in this segment ranged from 8 to 14 min/pool (Table 6.3-8).

Table 6.3-7 Segmented upper fishway passage times, shown as a percent of the total passage time for each individual, 2008.

		Percent of Total Passage Times					
Tag	Fish-way	Above Trap → Below Video	Below Video → Video Bypass	Previous zone → Above Video	Previous zone → Exit	Residence at Exit	Total
2	West	77%	3%	-	16% [c]	4%	100%
6	East	78%	4%	2% [a]	11% [d]	5%	100%
8	East	92%	1%	-	5% [c]	2%	100%
22	East	-	-	50% [b]	43% [d]	7%	100%

a: video bypass to above video; b: above trap to above video; c: video bypass to exit; d: above video to exit.

Table 6.3-8 Ascent rates in segmented upper fishway reaches, by individual, 2008.

		Ascent Rate (minutes per pool)				
Tag	Fish-way	Above Trap → Below Video	Below Video → Above Video	Above Video → Exit	Residence at Exit	Total
2	West	10.1	-	-	9.0	8.3
6	East	7.1	2.0	2.0	8.0	5.7
8	East	49.4	-	-	14.0	33.6
22	East	-	-	11.0	14.0	7.6

Video Bypass

In total, four radio-tagged fish passed through the upper fishway. Radio-detections indicated that 3 of the 4 lamprey bypassed the video counting area. The one fish that was detected passing through the video area was in fact counted by the video-data processors. These results indicate that the video-processing is accurate (n = 1) when the fish pass in front of the counting window, but that ~75% of the lamprey do not pass through the field of view. Note that with low sample sizes, one cannot be confident in the precision of the estimates of video-processing accuracy or the video bypass rate, although these results correspond with findings in 2007 (73% bypass rate).

Trapping Efficiency

Trapping efficiency was assessed by dividing the number of fish caught in the traps by the number known to have encountered them. Trapping efforts resulted in 24 lamprey being caught at Wells Dam (16 untagged fish were trapped; and 8 radio-tagged fish were recaptured). In addition, 2 radio-tagged fish passed the trapping area without being caught.

Additionally, several 'untagged' lamprey passed the trap without being caught. Of the 6 lamprey that were recorded by the video-counting staff during the trapping period (2 August to 15 October), one passed at the same time as a radio-tagged fish and was likely the same individual. These data suggest that a minimum of 5 lamprey passed the traps without being captured (thus maximum trapping efficiency = 77%), but the true number should be calculated by dividing this number by the video bypass rate. Since the video bypass rate was relatively uncertain in 2008 (based on a sample size of 4 lamprey), the total trapping efficiency could not be calculated with

much certainty. By using 75% as the video-bypass rate, the number of untagged lamprey that passed the traps without being caught would be 20, and the total trapping efficiency would be 52%.

Successful Fishway Passage

Four radio-tagged lamprey successfully passed the dam. All four had been trapped at Rocky Reach Dam. Three were released in collection gallery of the east fishway, and one was released in the collection gallery of the west fishway. No downstream passage events were observed during the monitoring period.

Two of the four successful lamprey were later detected entering the Methow River by Douglas PUD fixed stations or USFWS mobile tracking efforts. One fish (Tag #2) reached the fishway exit on 16 August, was detected entering the Methow River on 21 August, and was last detected on 20 September at the mouth of the Chewuch River. Another fish (Tag #6) exited the fishway on 18 August, was detected entering the Methow River on 20 August, and was last detected downstream of Libby Creek on 29 October.

7.0 DISCUSSION

Discussion of Objectives 1 through 4 is detailed in the 2007 report entitled: *Adult Pacific Lamprey Passage and Behavior Study (Adult Lamprey Passage Study): Wells Hydroelectric Project, FERC No. 2149* (LGL and DCPUD, 2008). The 2008 study specifically focused on Objectives 5 and 6.

7.1 Objective 5: Where Sample Size is Adequate, Estimate Passage Metrics Including Fishway Passage Times and Efficiencies, Residence Time Between Detection Zones, and Downstream Passage Events and Drop Back

Thirty-eight adult lamprey were radio-tagged and released at Wells Dam in 2008 in order to supplement sample size and adequately address the last two objectives of the Adult Lamprey Passage Study. Twenty-one lamprey were tagged in 2007, bringing the two-year total to 59 lamprey; 19 more than the original target in the FERC approved study plan for adult lamprey (LGL and DCPUD, 2008). Fifteen lamprey were tracked in the tailrace near a fishway entrance during 2008, raising the two-year total for assessing entrance efficiency to 22 fish. Four fish ascended through the upper fishway into the Wells Dam forebay during 2008, raising the total sample size for assessing upper fishway passage metrics to 15 fish.

Median passage times through the fishways were fast, especially when excluding daylight hours during which the nocturnal lamprey are less active. The only lower fishway ascent in 2007 took 6.1 h (LGL and DCPUD, 2008), and, though lower fishway ascents were hindered by trapping in 2008, the median time from the collection gallery pier to the 'below trap' zone was 3.2 h. Median upper fishway passage times were 7.9 h in 2007 (LGL and DCPUD, 2008), 3.6 h in 2008, and 6.7 h altogether (n=15). When passage only included night-time hours, median upper fishway passage times were 6.3 h in 2007 (LGL and DCPUD, 2008), 3.4 h in 2008, and 5.2 h altogether (n = 11). Total fishway passage time in 2007 and 2008 took 31.5 h and 32.7 h, respectively (though the ascent in 2007 took only 12.5 h, if time spent at the trapping area was excluded; LGL and DCPUD, 2008). These passage times are excellent compared to studies at other Columbia Basin dams, where median passage times ranged up to 7.6 days (Keefer et al., 2008). These results suggest that once inside the fishway, adult lamprey are able to sufficiently negotiate Wells Dam.

Metrics used to determine potential impediments of the adult lamprey migration through Wells Dam included: approach rate; and entrance, lower fishway, and upper fishway passage efficiencies. Lamprey in the tailrace made multiple approaches to fishway entrances both years, indicating that tailrace conditions and ability to locate the fishways were not a limiting factor to passage success. However, entrance efficiencies ranged from 14% in 2007 (LGL and DCPUD, 2008) to 33% in 2008, for a two-year average of 27%. This result is higher than observed at Bonneville Dam in 2008 (6 to 32%), lower than results from Priest Rapids in 2001-2002 (56%; Nass et al. 2003), and lower than estimates observed at Ice Harbor and McNary in 2007 (59.1% and 61.5% respectively; Cummings et al. 2008).

In 2008, three of the five 'successful entrants' rejected the fishway within ~30 minutes of entry, indicating that lamprey are having difficulty negotiating the fishway entrance. Lower fishway passage efficiency was 33% over the two-year study, though trapping operations in 2008 substantially biased lower fishway performance. The installation of perforated orifice plates for the 2008 season increased trap effectiveness as intended, but the modification also obstructed normal fishway ascent. Twelve of the fourteen lamprey (86%) that encountered the trapping area were ultimately blocked, and 50% of all upstream-moving detection sequences that ended in a drop back did so below the trap. Upper fishway passage success was 100% for the second consecutive year, and no drop back was observed in this part of the fishway (two-year total = 15 fish). This suggests that lamprey are capable of negotiating the upper fishway with a high level of success. Wells Dam fallback rates following fishway exit (0% over 2 years; n = 15) were superior to those reported downstream, such as 17% at John Day Dam (Moser et al., 2002b), or 19% at Bonneville Dam (Johnson et al., 2008). Collectively, these results indicate that passage impediments within the fishways at Wells Dam are largely restricted to the entrance.

Despite these insightful results, there are new and substantive reasons to believe that radio-tagged lamprey do not represent behavior of untagged individuals. New research indicates that past laboratory studies often referenced to justify radio-tagging methodology as benign (Close et al., 2003; Mesa et al., 2003) failed to identify the significance of surgical radio-tag implantation on lamprey swimming performance in field applications. Recent technological advances have allowed researchers to use tagging systems that are much smaller and do not require extensive surgical procedures. These advances are allowing researchers to develop more detailed investigations of potential tag effects in a field setting. For example, Keefer et al. (2008) found that overall passage efficiency at Bonneville Dam was 22% for radio-tagged lamprey (n = 298), compared to 52% for HD PIT-tagged fish (n = 610). These results suggest that radio-telemetry tags substantially affect swim performance. Further, Moser et al. (2007) found that radio-tagged lamprey at lower Columbia dams had approach times and passage success rates that were significantly related to percent tag mass (relative to lamprey mass) and percent tag girth (relative to lamprey diameter). Based on results of their relatively large field study (> 800 fish), Moser et al. (2007) concluded that "the effect of prolonged swimming with relatively large transmitters may have resulted in eventual abandonment of migration or even death…" At Wells Dam, at least 24% of radio-tagged lamprey displayed either a lack of movement (potentially tag shed or mortality) or an absence of detections (indicating uncharacteristic movement out of the study area or tag failure). This relatively high proportion of uncharacteristic detection histories suggests that handling and surgical tagging had a considerable effect on lamprey performance in this study. Moreover, latent tagging effects, such as those described by Moser et al. (2007), may have impacted the performance of the 29 radio-tagged lamprey that were included in calculation of passage metrics, thus biasing results to underestimate passage success and to overestimate passage impediments.

Distance upstream, as related to fish bioenergetics, and seasonality are two additional factors that also should be considered when comparing results to those reported in previous studies at downriver dams. For example, the research conducted at Lower Columbia River dams that led to the establishment of the '~ 50% passage standard' of adult lamprey selectively tagged only the largest adult lamprey collected from the traps at Bonneville Dam. Moser et al. (2005) reported "due to the abundance of lamprey in 2002, we selected the largest fish to minimize tag effects."

The fish used for these studies had a mean weight from 590 g (males) to 627 g (females), and roughly 50% of all tagged fish had girths ≥ 12.5 cm. In comparison, lamprey tagged at Wells Dam averaged 369 g (range 270-560 g) and 10.2 cm in girth (range 9-12 cm). Fish captured at Wells Dam have substantially lower energetic reserves (i.e., thinner fish) due to the distance travelled (370 miles upstream of Bonneville) and the energy used to pass seven additional hydroelectric projects prior to capture. Though researchers are currently exploring the relationship between bioenergetics and passage success in lamprey (Ho et al., 2008), a positive correlation between fish size and swimming performance has already been identified (Moser et al., 2007). Further, different median passage dates at Bonneville Dam (week 31, average temperature = 21.1 °C, increasing temperature regime) compared to Wells Dam (week 37, average temperature = 19.0 °C, decreasing temperature regime) have implications for lamprey migratory behavior, especially as it relates to water temperatures and the time at which migration pauses for the winter (years 2000-2007 from DART, 2008; Groves, 2001). Therefore, radio-telemetry studies of lamprey behavior at Wells Dam is likely substantially more susceptible to tag induced bias when compared to studies conducted at downriver dams with larger and healthier fish.

7.2 Objective 6: If Necessary, Identify Potential Areas of Improvement to Existing Upstream Fish Passage Facilities for the Protection and Enhancement of Adult Lamprey at the Wells Project

The greatest impediment to successful passage of adult lamprey at Wells Dam appears to be the conditions at the fishway entrance, probably related to water velocities that limit swimming and attachment capabilities. Data collected during the Fish Passage Center's (FPC, 2008) Fish Facility Inspections at Wells Dam indicated that the head differential averages 0.46 m (range 0.30 to 0.58 m) at both fishway entrances, which produces average velocities in the vicinity of 3.0 m/s (as high as 3.4 m/s; R. Wielick, PE, Jacobs, personal communication). These values are considerably higher than averages from other downstream dams, with lower velocity entrances generally having better entrance efficiencies (FPC, 2008). For example, entrance efficiency measured at Bonneville using the same technology and run of fish as research at Wells Dam ranged from 6 to 32% (Keefer et al. 2008), while velocities from the numerous, and unique, entrances ranged from 2.2 m/s to over 3.6 m/s based on velocity calculations from fishway inspections conducted in 2008 (FPC, 2008). Entrance success documented at Bonneville Dam was clearly lower at higher velocity entrances (e.g., Washington shore entrances). Mesa et al. (2003) estimated the critical swimming speed of radio-tagged lamprey at 0.82 m/s. Similarly, Daigle et al. (2005) reported swimming ability of lamprey from previous studies ranging from sustainable speeds of 0.9 m/s up to bursts of 2.1 m/s. Entrance tests performed by Daigle et al. (2005) showed no lamprey passing through a simulated fishway entrance with 0.46 m of head differential (though lamprey have clearly entered Wells Dam fishways under similar conditions), ultimately stating that "the single most important factor affecting passage success appeared to be water velocity." A reduction in velocity in the Wells Dam fishway could significantly improve lamprey entrance efficiency. The reduction could be restricted to the fishway entrance (i.e., not the remaining portion of the fishways) and nighttime hours during the lamprey migratory period (August to September).

An equally significant impediment to successful passage of adult lamprey at Wells Dam in 2008, but not in 2007, was the installation of perforated plates on the floor of the weir orifices in an effort to increase trapping efficiency. When comparing results between 2007 and 2008 it is apparent that the addition of the perforated plates did increase trapping efficiency but was also responsible for reducing the number of fish recruiting into the upper fishway, decreasing lower fishway passage efficiency. Removal of the perforated plates in the orifice passage ways and reduction or elimination of mid-ladder trapping efforts should provide an improved route of passage for lamprey and will likely enhance upstream passage rates observed in unobstructed areas of the fishway with identical flow characteristics (e.g., upper fishway = 100% passage success over both years).

8.0 RECOMMENDATIONS

The following recommendations are based on results detailed in this report:

- Implement a reduction in fishway head differential to reduce entrance velocities to levels within the swimming capabilities of Pacific lamprey (0.8 to 2.1 m/s). These proposed flow reductions should be restricted to hours of peak lamprey activity (i.e., nighttime) and within their primary migratory period at Wells Dam (August-September).
- Remove perforated plates from orifice floors at the current trapping locations and discontinue trapping efforts at Wells Dam.
- Consider using monitoring tools such as half-duplex PIT tags, DISDON and other less intrusive monitoring techniques that do not require the collection of fish from the ladders at Wells Dam and minimize the surgical implantation of tags in fish that are nearing their physiological and energetic limits.

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Appendix A

Lamprey Tagged at Wells Dam, 2008

Table A1-1 Summary of tagged lamprey release, passage times (h:mm), and location last detected.

Tag #	Release Date	Release Location	Passage times			Bypass	Last Location	Notes
			Upper	Lower	Total			
4	8/13	East Gallery					East Tailrace	recaptured once
5	8/15	East Gallery					West Tailrace	
6	8/15	East Gallery	2:35	28:53	31:28	Yes	Methow	complete ascent
8	8/15	East Gallery	15:08			Yes	Exit	recaptured once
22	9/3	East Gallery	3:24			No	Exit	
25	9/5	East Gallery					East AWS Up	recaptured once
26	9/5	East Gallery					East Tailrace	
27	9/5	East Gallery					East Tailrace	
28	9/5	East Gallery					East Tailrace	
2	8/13	West Gallery	3:44			Yes	Methow	
3	8/13	West Gallery					East Tailrace	recaptured twice
7	8/15	West Gallery					East Tailrace	
9	8/15	West Gallery					W. Entrance	
10	8/15	West Gallery					W. Entrance	
18	8/27	West Gallery					W. Entrance	recaptured once
31	9/6	West Gallery					West Tailrace	
32	9/6	West Gallery					West Tailrace	recaptured once
1	8/6	East Alcove					East Tailrace	
13	8/18	East Alcove					East Tailrace	
19	9/3	East Alcove					W. Entrance	
20	9/3	East Alcove					East Tailrace	
21	9/3	East Alcove					East Tailrace	
36	9/10	East Alcove					West Tailrace	
37	9/12	East Alcove					East Tailrace	
38	9/19	East Alcove					West Tailrace	
16	8/22	West Alcove					East Tailrace	
23	9/3	West Alcove					East Tailrace	
24	9/3	West Alcove					West Tailrace	
30	9/5	West Alcove					West Tailrace	

Table A1-2 Summary of tagging and biometric data for each lamprey radio-tagged at Wells Dam, 2008.

TAG No.	Tag Chan.	Tag Code	Capture Date	Capture Ladder	Trap	Tag Date	TL (cm)	Weight (kg)	Girth (cm)	Start Heavy Anesth.	Start Surg.	Start Recov.	Release Time	Release Location
1	1	131	8/6	East	Trap 4	8/6	58.0	0.334	-	15:43	15:47	15:55	17:03	E. Alcove
2	1	132	8/12	R. Reach	R. Reach	8/13	65.0	0.386	10.5	10:45	10:50	11:01	12:10	W. Gallery
3	1	133	8/12	R. Reach	R. Reach	8/13	64.0	-	10.5	11:18	11:23	11:30	12:10	W. Gallery
4	1	134	8/12	R. Reach	R. Reach	8/13	68.0	0.438	10.5	11:33	11:37	11:46	12:52	E. Gallery
5	1	135	8/14	R. Reach	R. Reach	8/15	63.0	0.342	9.5	10:50	10:56	11:03	13:31	E. Gallery
6	1	136	8/14	R. Reach	R. Reach	8/15	64.0	0.340	9.7	10:59	11:05	11:15	13:30	E. Gallery
7	1	137	8/14	R. Reach	R. Reach	8/15	72.0	0.516	11.5	11:16	11:22	11:29	14:10	W. Gallery
8	1	138	8/14	R. Reach	R. Reach	8/15	68.0	0.408	10.0	11:36	11:41	11:47	13:30	E. Gallery
9	1	139	8/14	R. Reach	R. Reach	8/15	65.0	0.406	10.2	11:55	12:01	12:06	14:10	W. Gallery
10	1	140	8/14	R. Reach	R. Reach	8/15	64.0	0.336	9.3	12:11	12:18	12:24	14:10	W. Gallery
11	1	141	8/14	East	Trap 3	8/15	59.0	0.352	9.9	12:44	12:49	12:54	14:45	E. Alcove
12	1	142	8/17	West	Trap 2	8/18	61.0	0.334	9.5	11:24	11:27	11:35	12:35	W. Alcove
13	1	143	8/18	East	Trap 4	8/18	62.0	0.334	9.5	11:37	11:42	11:47	13:03	E. Alcove
14	1	144	8/19	West	Trap 1	8/20	60.0	0.310	9.2	9:48	9:54	10:00	11:00	W. Alcove
15	1	145	8/21	West	Trap 2	8/22	66.0	0.410	10.2	9:35	9:39	9:44	11:00	W. Alcove
16	1	146	8/22	West	Trap 2	8/22	63.0	0.372	10.0	9:46	9:50	9:56	11:00	W. Alcove
17	1	147	8/23	West	Trap 2	8/25	67.0	0.476	11.1	10:28	10:33	10:38	11:40	W. Alcove
18	1	148	8/26	West	Trap 1	8/27	67.0	0.432	10.4	10:00	10:05	10:11	11:11	W. Gallery
19	1	149	9/3	East	Trap 4	9/3	62.0	0.346	9.5	10:39	10:43	10:48	13:06	E. Alcove
20	224	50	9/2	R. Reach	R. Reach	9/3	62.0	0.338	9.5	10:50	10:55	11:01	13:06	E. Alcove
21	224	51	9/2	R. Reach	R. Reach	9/3	61.0	-	10.0	11:01	11:06	11:13	13:06	E. Alcove
22	224	52	9/2	R. Reach	R. Reach	9/3	70.0	0.556	12.0	11:14	11:19	11:24	12:50	E. Gallery
23	224	53	9/2	R. Reach	R. Reach	9/3	62.0	0.296	9.4	11:46	11:50	11:55	13:34	W. Alcove
24	224	54	9/2	R. Reach	R. Reach	9/3	63.0	0.360	10.1	11:56	12:02	12:06	13:34	W. Alcove
25	224	55	9/4	R. Reach	R. Reach	9/5	65.0	0.392	10.0	11:10	11:16	11:20	13:25	E. Gallery
26	224	56	9/4	R. Reach	R. Reach	9/5	63.0	0.394	10.1	11:22	11:26	11:31	13:26	E. Gallery
27	224	57	9/4	R. Reach	R. Reach	9/5	63.0	0.396	10.4	11:33	11:40	11:45	13:30	E. Gallery
28	224	58	9/4	R. Reach	R. Reach	9/5	60.0	0.304	9.2	11:49	11:54	12:00	13:30	E. Gallery
29	224	59	9/4	R. Reach	R. Reach	9/5	63.0	0.352	9.8	12:10	12:14	12:19	14:00	W. Gallery

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Table A1-2 continued.

TAG No.	Tag Chan.	Tag Code	Capture Date	Capture Ladder	Trap	Tag Date	TL (cm)	Weight (kg)	Girth (cm)	Start Heavy Anesth.	Start Surg.	Start Recov.	Release Time	Release Location
30	224	60	9/3	West	Trap 2	9/5	65.0	0.420	10.6	12:25	12:29	12:34	14:06	W. Alcove
31	224	61	9/5	R. Reach	R. Reach	9/6	68.0	0.424	10.8	8:16	8:21	8:25	10:01	W. Gallery
32	224	62	9/5	R. Reach	R. Reach	9/6	61.0	0.362	9.9	8:26	8:30	8:36	10:01	W. Gallery
33	224	63	9/5	R. Reach	R. Reach	9/6	67.0	0.384	9.8	8:41	8:45	8:51	10:01	W. Gallery
34	224	64	9/5	R. Reach	R. Reach	9/6	61.0	0.312	9.1	8:56	9:00	9:05	10:06	W. In-ladder
35	224	65	9/7	West	Trap 2	9/8	67.0	0.452	10.5	9:50	9:53	9:59	10:59	W. Alcove
36	224	66	9/10	East	Trap 4	9/10	65.0	0.414	10.6	9:55	9:59	10:03	11:03	E. Alcove
37	224	67	9/12	East	Trap 3	9/12	61.0	0.356	10.0	9:11	9:14	9:19	10:19	E. Alcove
38	224	68	9/17	East	Trap 3	9/19	63.0	0.354	9.8	9:19	9:23	9:28	10:36	E. Alcove