PACIFIC LAMPREY (*LAMPETRA TRIDENTATA*) PASSAGE PATTERNS PAST BONNEVILLE DAM AND INCIDENTAL OBSERVATIONS OF LAMPREY AT THE PORTLAND DISTRICT COLUMBIA RIVER DAMS IN 1993

by

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EXECUTIVE SUMMARY

The numbers of Pacific lamprey (*Lampetra tridentata*) passing Corps of Engineer dams on the Columbia River have appeared to be fewer in recent years than in the past. There is, however, no firm data on whether or not this impression is accurate. The Fish Field Unit (FFU) was assigned to evaluate the passage of lamprey past Bonneville Dam and to identify specific areas the Portland District Columbia River projects that could cause difficulties for lamprey.

The evaluation consisted of several parts: 1) A literature review on the life history of lamprey in general and the Pacific lamprey in particular; 2) A request to National Marine Fisheries Service and Corps project personnel to note and record lamprey they observed while they conducted their normal duties; 3) An evaluation of past lamprey counts (1939-1969) to determine patterns of passage and whether or not their was any correlation between passage and selected river conditions such as flow or turbidity; 4) Estimates (not counts) of lamprey passage made by the fish counters; 5) Direct sampling of lamprey passage; 6) Sampling of video-taped night passage; and 7) Data compilation on passage of juvenile lamprey from incidental catch by the National Marine Fisheries Service as they sampled smolts.

Lamprey have a long life cycle. They may spend up to six years (seven years in certain Idaho streams) as larvae in the burrows. Experimental evidence indicated time spent in the ocean could be as long as three and one-half years. After returning to the river, lamprey spend a year in freshwater before spawning.

As ladders are dewatered, lamprey may seek out the receding water and find their way into areas inaccessible to humans. Lamprey have died when this occurred. The projects are attempting to block off lamprey access as the routes are discovered. Areas in the fish ladders needing special attention were diffuser gratings and the area around the auxiliary water system in the Washington shore ladder at Bonneville. Turbine dewatering may result in juvenile lamprey mortality. Screens designed to protect salmonid smolts may be a problem for juvenile lamprey.

Past counts of lamprey were found to be highly variable from year to year, from day to day, and from hour to hour. Only five years of hourly count data were available to analyze. In general, passage tended to be higher at dawn and dusk. When total ladder passage was high, more lamprey passed in the middle of the day than when ladder passage was low. No correlation of lamprey passage was found with selected river conditions or with total salmonid passage.

The fish counters’ estimates were used to determine an approximation of the 1993 population passing Bonneville Dam. The estimates were approximately 22,000. This estimate was lower than the past-years' counts. Statistical analysis of the estimates as compared with past-years' hourly counts also indicated the 1993 passage was low. Seasonal passage had a bimodal distribution with the peaks occurring in late May-early June and again in late July-early

August. Total diel passage showed the highest numbers to be in the first and last hours of counting. When taken as a whole, the Bradford Island ladder estimates and the Washington Shore ladder estimates were similar. In general the Bradford Island estimates were higher at times in May and early June and the Washington Shore estimates stayed higher late in the season. For most of the season, morning passage was higher at the Bradford Island count station and evening passage was higher at the Washington Shore count station.

The passage samples taken by the FFU were too few to be able to determine a population estimate. Observations were made of lamprey behavior at night (2100 to midnight). Lamprey activity, in general, increases after dark. Lamprey pass downstream as well as upstream, and after dark this behavior is pronounced. Some of the night hours sampled showed a negative count. Lack of time and manpower prevented completion of reviewing of the 1992 and 1993 video tapes of the night counts. Those tapes reviewed showed an up-and-down movement similar to that seen by the FFU personnel in sampling night counts, as well as some negative count. Counts for most of the other hours were low.

Estimates of juvenile lamprey captured at the Bonneville first powerhouse downstream migrant sampler indicate lower numbers in the years since 1989. Each year showed differences in timing of the downstream migration.

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INTRODUCTION

Background

The presence of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River system has been taken for granted. These native anadromous fish spawn in streams where the young (ammocoetes) stay burrowed in the mud for up to six or seven years (Scott and Crossman, 1973; Hammond, 1979). They then migrate downstream to the ocean where they spend up to three and one-half years (Beamish, 1980) as external parasites on fish. To complete the cycle, they migrate back up the Columbia River to the streams for spawning. While in freshwater Pacific lamprey are not parasitic.[1]

Observers of the Columbia River fish runs have the impression that the numbers of lamprey passing Bonneville Dam and other dams have been declining in recent years. Indians, who have traditionally used lamprey as food, have recently expressed concern over their perception of a decline in the lamprey runs (Parker, personal communication). In the 1970's and early 1980's, the National Marine Fisheries Service (NMFS), collected lamprey for the Indians' personal use at Bonneville Dam. In recent years, fewer lamprey have been available than in the past. No lamprey were collected in 1992 or 1993 (Johnson, personal communication). Observers at the fish viewing windows and fish counting stations have noticed fewer lamprey in recent years. Other anecdotal evidence that the lamprey have declined includes observations by NMFS workers, who have been conducting fish guidance efficiency (FGE) tests since the late 1960's for juvenile salmonids, that far fewer juvenile lamprey have been seen recently when compared to past years (Monk, personal communication). Despite these impressions, there is no hard evidence on the status of the lamprey population. Lamprey were counted at Bonneville from 1939 up to the end of 1969. For the last twenty years, however, little data have been collected on lamprey passage.

A further consideration of lamprey passage is the lack of information on whether or not lamprey experience any problems in passing the dams. There are no data on whether or not lamprey are delayed by dams, and, if so, where problem areas might be located.

The Fish Field Unit (FFU) was assigned to develop information that may be used to improve passage, and on the numbers of a species that may -- at some point in the future -- be the subject of special attention. The purpose of this study, therefore, was two-fold. First, was to determine areas around the Portland District Columbia River dams where lamprey might be delayed or injured. Second, was to develop baseline data on lamprey passage past Bonneville Dam. If baseline data were established, it may be possible over time to determine if lamprey numbers are indeed declining. Because of the lack of recent data concerning numbers and

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[1] While it is true that adult Pacific lamprey are not parasitic in freshwater, downstream migrating juveniles may, if they are mature enough as they near the estuary, attach themselves to smolts (Parker, personal communication).

diel patterns of passage, the principal emphases this year were on determining the best methods of sampling lamprey passage and determining problem areas around the dams.

Objectives

1. Conduct a literature review on the life history of lamprey.

2. Determine areas of Bonneville, The Dalles, and John Day dams where adult and juvenile lamprey may be inadvertently trapped, delayed, adversely impacted, or where, other than the fish ladder, adults or juveniles may be passing the project. Recommend solutions to any noted problems of passage by lamprey.

3. Determine the characteristics of past runs of adult lamprey over Bonneville, The Dalles, and John Day dams including: 1) numbers passing the lower Columbia River projects by year, month, day, and hour; and 2) correlations with salmonid passage and with river flows, water clarity, water temperature, and weather conditions as measured at Bonneville Dam.

4. Obtain estimates for current patterns of diel and seasonal lamprey passage and determine the best method of sampling adult lamprey passage.

5. Determine patterns of juvenile lamprey passage past Bonneville Dam.

METHODS

Life History

We conducted a literature review on the life history of the lamprey (Lampetra sp.) and, more specifically, the Pacific lamprey.

Areas that May Impact Lamprey

Determining areas of Portland District Columbia River projects where adult and juvenile lamprey may be inadvertently trapped or delayed, or otherwise impacted was of immediate concern. To this end, we requested that FFU and Corps project personnel and personnel from those fisheries agencies working at Portland District Columbia River projects note the numbers of adult and juvenile lamprey they observed incidental to their work. Specific instances included: 1) Research and monitoring of juvenile salmonid passage; 2) Dewatering of fish ladders, juvenile bypass systems, and turbines; 3) Inspection of fishways; and 4) Performance of other operational and maintenance activities, especially maintenance of submerged traveling screens (STS's).

We distributed a data sheet for recording data. Information requested included: 1) Estimates of the numbers of lamprey; 2) The life stage of the lamprey; 3) The date and time of day; 4) The location where lamprey were found; and 5) Specific problems such as mortality, difficulty in rescue (in the case of dewatering), and possible delay.

Information on both juvenile downstream migration and adult fallback was collected weekly from NMFS personnel operating the downstream migrant sampler at the Bonneville first powerhouse. The observations of adults were handled separately from those of juveniles. Juvenile observations are discussed under "Juvenile Lamprey Passage Patterns."

In addition to collecting the observations made in 1993, past Corps records were examined for references to lamprey. The Fishway Status Reports for Bonneville Dam and The Dalles/John Day project covering the 1993-1994 winter dewatering period were also examined.

Observations were compiled and categorized according to type of facility and location for analysis.

Past Runs of Adult Lamprey

We examined past lamprey counts over Bonneville, The Dalles, and John Day dams. Yearly count information was available in the Annual Fish Passage Reports (Corps of Engineers, 1948-1969) for the years 1938-1968. Monthly and daily count information was found for the years 1939-1969 (Corps of Engineers, 1939-1969). Counting of lamprey was discontinued after 1969. For five randomly selected years, daily lamprey passage was plotted with flow (total river discharge), river temperature, water transparency (turbidity), barometric pressure, and cloud cover. The river and weather data were obtained from the Annual Fish Passage Reports and past daily count sheets (Corps of Engineers, 1939-1969). These years were 1949, 1953, 1956, 1962, and 1968. Separate plots were prepared to look at the passage from May 1 - July 31 for three years in which high counts of lamprey passage occurred in May or early June: 1940, 1963, 1969. Such lamprey counts were plotted with water flow for all three years, and water transparency for 1963 and 1969. A Pearson[2] correlation between lamprey passage and passage of all salmonids, by year, was calculated for the years 1938-1969.

Hourly count data for four years (1956, 1966, 1967, and 1968) for the Washington shore and 1968 for Bradford were also located among the Corps' past records (Corps of Engineers, 1956, 1966, 1967, 1968). From these data, the diel passage pattern (excluding eight hours at night) was determined.

When the fish counters were finished estimating lamprey passage for the season, we interviewed them for their subjective impressions of this years' passage compared to past years. Each of the seven fish counters working at Bonneville Dam were interviewed separately and each gave her answers independently. The length of time each counter has worked varied from 20 years to less than two; most have worked at least eight years.

1993 Seasonal and Diel Patterns of Lamprey Passage Past Bonneville Dam

Fish Counter Estimates

The fish counters at Bonneville were asked to estimate lamprey passage each 50-minute count period. The counters selected one of a set of ranges: 0 lamprey present, 1 to 10 lamprey present, 10 to 50 lamprey present, 50 to 300 lamprey present, and over 300 lamprey present. The ranges were set up in geometrical progression, taking into account human psychology and ease in deciding which range to choose. In making their estimates, the fish counters were not asked to account for downstream passage. The fish counters were also asked to record the number of lamprey present in the window at the end of each count-period for, what we termed, a snapshot count. Estimates were made for each of the 16 daily 50-minute count periods (corresponding to the fish counters' count schedule) from May 1 through October 5, 1993. The decision to end the collection of estimates was based on the decreasing number of hours in which the range of 10 to 50 lamprey were checked.

Initially, low and high estimates were calculated from the fish counters' estimates. The values used for the low estimates were 0, 1, 10, and 50; and for the high estimates the values were 0,

[2]The Pearson product moment correlation coefficient is the statistic most commonly used to measure the degree of relationship between two variables (Klugh, 1974).

10, 50, and 300. No value was used for the estimate range of more than 300 lamprey present, as that estimate range was never selected.

To obtain an estimate of total counts (trend data) past Bonneville Dam for comparison purposes, we assumed the average of the actual lamprey numbers seen in a given range was equal to one-third of the range. The reason for using a value one-third of the range was based on the assumption that the fish counters were as likely to check the next highest range if the actual numbers of lamprey seen were toward the high end of that range. To check the assumption that the value one-third of the range was a reasonable average, we looked at the sample data collected by the FFU. Averages were taken of all those hours sampled in which the net numbers passing fell within the range of 1 to 10 and within the range of 10 to 50. In only one hour did the net passage fall within the range of 50 to 300; that number was 51. Net negative passage was disregarded, as was 0 net passage. For purposes of this check, the value of 10 was placed in both ranges because a fish counter could have checked either range when observing 10 lamprey passing. The average of net passage in the 1 to 10 range was 3.80 and for the 10 to 50 range was 22.74. This compares favorably with the lower one-third value in each range: 4 and 23. Because only eleven estimate hours for the 50 to 300 range (or 0.22%) were checked by the fish counters, the lack of a sample average for that range would not change the results significantly. Therefore, additional calculations were made using the lower one-third of each range for the values. These were: 0, 4, 23, and 133. A rough estimate of the numbers passing the Bonneville Dam count windows was thus obtained.

To compare diel activity between the two ladders from May 1 through October 5, the 1993 season was divided into six periods based on apparent changes (either increasing or decreasing) in the character of the run. These dates are: May 1-29, May 30-June 19, June 20-July 12, July 13-August 13, August 14-September 4, and September 5-October 5. Charts were prepared showing diel activity each ladder for each period.

Sampling of Lamprey Passage

From May 1 through September 24, we sampled lamprey passage. Lamprey passage was sampled for one hour at a time; both upstream and downstream movement were counted and net passage for the hour determined. Hours to be counted were selected using a stratified random method. The passage season was divided into eight 3-week periods. Within each 3-week period, six days were randomly selected for sampling. The Bradford Island ladder was sampled for three days and the Washington shore ladder was sampled for three days. The days a given ladder was sampled were determined by the toss of a coin. For each sampling day, three hours were sampled. These were determined by dividing each day into three equal periods (morning, afternoon, and evening) and randomly selecting an hour from each period. Thus, for each ladder and each 3-week period, nine total hours were scheduled. Originally, it was planned to sample from May 1 through October 15. By the end of September, so few lamprey were being seen we decided to stop at the end of the seventh three-week sampling period. Total hours scheduled for each ladder were 72. Actual hours sampled were: for Bradford Island, 63; and for the Washington shore, 62. A sample for August 9 at 0600 at the Washington shore was missing for unknown reasons. Of the hours scheduled to be sampled, time changes occurred ten times because of illness, unavoidable meetings, or other consideration. Whenever an unexpected contingency necessitated a schedule change, the new sampling hour was at the same time of day and within two days of the original day. In one case, two sets of sampling hours were inadvertently scheduled for the same day (September 13). A replacement set of sampling hours was rescheduled for a day (September 17) that was in between September 13 and the next scheduled sampling day. Times for sampling ranged from the 0600-0700 hour to the 2300-midnight hour. In comparison, the fish counters counted from 0500-2050.

To test the stability[3] of the above sampling technique, an F-test was applied to the 1956, 1966, 1967 Cascade Island ladder counts. Two samples were taken from each year's count, one using the 1993 Washington shore random sample hours and the other using the Bradford Island hours.

Comparison of 1993 Data with Historical Counts

At the Columbia River Dams, the fish counters count for two eight hour shifts during the main part of the salmon runs, and for one eight hour shift during the beginning and ending of the runs. The dates for the start and end of counting varies from dam to dam. Counters count for 50 minutes each hour (starting on the hour and ending 50 minutes past the hour) and apply a factor of 1.2 to the previous hour's counts. As far as we know, this counting procedure was also used in past years, including the years 1939-1969, the years from which total lamprey count data were available.

To determine the probability that the counts (and 1993 fish counters' estimates) followed approximately the same passage pattern each year, fish counters' estimates were analyzed along with those past counts in which hourly counts were available (1956, 1966, 1967, and 1968 for the Washington shore and 1968 for Bradford Island). For those days in which at least one hour had estimates or counts of 10 lamprey per hour or more, the significance of the variance was obtained by applying simple probability estimates (chi-square type) to those counts. The same procedure was applied for days in which at least one hour had estimates or counts of 50 lamprey per hour or more, and for days in which at least one hour had estimates or counts of 300 lamprey per hour or more.

To determine the probability of difference in the diel count pattern, the number of times hourly counts (and 1993 estimates) increased or decreased from one range to another were found. An average pattern of hour to hour drops for all years was created and each year's pattern was compared to the average, using a chi-square analysis. The same procedure was

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[3] A data set that has little variance is said to be stable, while a data set that has much variance is unstable.

applied for range increases. Changes to or from zero lamprey present were not included in the calculations.

Scattergrams were created for the 1993 sampling data from each ladder. Scattergrams were then created for each of the past years for which hourly counts exist to show what the results would have been if the same sampling technique had been used then. Lines were drawn on the charts where apparent natural differences, such as clusters of negative numbers or large numbers, existed. The groups of numbers on either side of each line were compared by means of chi-square analyses.

In all the years for which hourly counts are available, there were strong variations in count numbers, even from hour to hour. A step-by-step chi-square analysis was done of unbroken groups of hours where the count (or estimate for 1993) equaled or exceeded 10 lamprey each hour. This was done for each year, including 1993, and for each ladder.

Video-Taped Night Counts

To determine night passage of sockeye salmon (Snake River sockeye being an endangered species) from June 1 through August 15, passage past Bonneville Dam was video taped from 2048 to 0502. These were the hours the fish counters were off duty. At our request, one tape per ladder per week was saved that we might count lamprey. Each tape held two consecutive nights.

Reviewing of the video tapes was begun; however, lack of manpower and time, and the necessity to complete the preparation of this report meant that complete analysis of the 1993 video-taped night could not be included. We expect to have a supplemental report on that data at a later time. For the 1993 tapes already reviewed (the nights of June 7-8 and 8-9, the Bradford Island ladder), the full hour was reviewed. Numbers of lamprey moving upstream and downstream were counted and the net count determined.

Two tapes were available from 1992. These were the nights of June 15 through June 19 for the Bradford Island ladder and the night of June 29 for the Washington shore ladder. These tapes were read near the beginning of the study and only 15 minutes of each hour were read. The start time of each 15 minute sample was chosen randomly. Upstream, downstream, and net movement were determined and the net count was expanded.

Juvenile Lamprey Passage Patterns

The NMFS began operating the downstream migrant sampler at the Bonneville first powerhouse on March 17. Every hour of each day was sampled. At the FFU's request, NMFS sent us copies of their incidental catch data sheets which had the numbers of lamprey caught in the sampler, and the hour they were caught. We received these data through September 23, at which point the number of lamprey captured was six (including two adults) since August 29. The data, along with the sampling rates (where applicable), were entered into a spreadsheet. We also received data from NMFS on the incidental lamprey caught during their smolt monitoring at the John Day Dam and on their observations of lamprey while conducting FGE tests at the Bonneville Dam second powerhouse. Charts were created showing the seasonal and diel patterns of capture. Information on past capture data was obtained from the Columbia River Fish Management Plan 1991 All-Species Review (Parties to U.S. v. Oregon, 1991) and from NMFS (Martinson, personal communication). Comparisons were then made.

RESULTS

Life History

This review is not intended to be an exhaustive study of the life history of the Pacific lamprey, but rather is a brief overview. We obtained the following information from certain authors, including those (in particular, Scott and Crossman, 1973) who have done a literature search.

The Pacific lamprey spawns from April to October (Pletcher, 1963, from Scott and Crossman, 1973). The lamprey move upstream from where they have overwintered (in freshwater streams) to the headwaters, sometimes for hundreds of miles. They spawn in sandy gravel at the edge of riffles, building their nests by digging in the sand with body movements and by moving rocks with their suctorial discs. Mean estimated fecundity is 3,000 eggs per female, but can go as high as 106,000 in a 16-inch individual. The adults usually die from one to 13 days after spawning (Scott and Crossman, 1973).

After the eggs hatch in two to three weeks (ibid.), the juveniles (called ammocoetes) leave the nest gravel and migrate to ammocoete beds. Habitat for ammocoetes include the following characteristics: soft substrate, slow and constant current, protection from major environmental fluctuations, and plentiful food supply of diatoms. As they grow, ammocoetes may find new areas to burrow in, colonizing areas downstream (Hardesty and Potter, 1971). They spend a maximum of five to seven years in the burrows (Scott and Crossman, 1973; Hammond 1979), after which, they metamorphose. The evidence for a seven year larval period was found in the Potlatch River in Idaho (Hammond, 1979). Metamorphosis for at least one population begins in July and is completed by October (Richards, 1980, from Beamish, 1980). After metamorphosis, lamprey move to silt covered large gravel in moderate currents (Beamish, 1980).

Many lamprey migrate downstream after metamorphosing to the adult form, although many others migrate when the transformation is only partially complete (Scott and Crossman, 1973). There appears to be no clear agreement when they begin downstream migration. The timing seems to depend on the river (Beamish, 1980). At Bonneville Dam, data from 1989 and 1990 indicate the timing of run peaks may vary from year to year (Parties to U.S. v. Oregon, 1991).

Sources differed on the amount of time the adult Pacific lamprey spends in the ocean. Scott and Crossman (1973) stated that the downstream migrants "move to the estuary, where, in the spring and summer, following downward migration, they begin a parasitic life and spend 12-20 months as parasites before migrating upstream to spawn." According to Beamish (1980), "the length of time spent by Pacific lamprey at sea is unknown and possibly is different for different stocks." He reports on a laboratory study in which adult Pacific lamprey were captured and held in salt water until they died, "If the laboratory observations are representative of a natural cycle, Pacific lamprey remain and feed in salt water for a period up to three and one-half years..." Including the time spent in the estuary, Pacific lamprey probably spend from one and one-half to three and one-half years in the ocean. It is possible that some stocks of lamprey migrate considerable distances. It is also possible the size of returning adult lamprey may be related to the length of time in saltwater (Beamish, 1980).

The timing of adult migration varies (Scott and Crossman , 1973; Beamish, 1980. At Bonneville Dam, the timing also varies, but passage usually occurs in the spring and summer (Annual Fish Passage Reports). Adult lamprey hold in freshwater over winter, hidden under rocks, and spawn the following spring. They spend up to a year in freshwater as adults (Beamish, 1980; Scott and Crossman, 1973). The sources did not totally agree on whether or not lamprey return to their home streams. Hardesty and Potter (1971) stated there was no conclusive evidence lamprey (no particular species mentioned) did so. Beamish, however, noted that the larger individuals are found in particular rivers, such as the Skeena, and thought it probable that at least some Pacific lamprey return to their native streams to spawn.

Areas that May Impact Lamprey

Prior to the winter dewaterings, incidental observations of adult lamprey were few. Most were in the vicinity of the fish counting stations. During the 1993-94 dewaterings, there were a number of observations of adult lamprey. In past MFR's (1985-1994), lamprey were seldom mentioned. Juvenile lamprey were noted by the NMFS personnel during the monitoring of juvenile salmonid passage. From these sources, a few areas of the dams were found to cause potential problems for lamprey survival and passage. Following are discussions of such areas.

Adult Fish Passage Facilities

Bonneville Dam, General Observations on Numbers - No lamprey were observed when the first powerhouse fishways were dewatered during the 1993-94 winter maintenance period. In contrast, when the second powerhouse was dewatered during the same period, about 100 lamprey were observed.

Bonneville Dam, Washington Shore Auxiliary Water Supply **-** When the Washington shore ladder at Bonneville Dam was dewatered in the winter of 1992-93, lamprey (between one and two dozen) were found in the sliding track for the louvered bulkhead that is located in the auxiliary supply water area adjacent to the counting station. Many froze to death. The area had been checked and some fish rescued as soon as the ladder was dewatered. The next day, however, the frozen lamprey were discovered during a routine fishway inspection. A similar incident occurred in December 1991.

During dewatering in January 1994, a second possible problem area in the vicinity of the auxiliary water supply became apparent. The barrier between the fishway and the auxiliary water channel consists of two walls with the width between them being great enough to accommodate a catwalk. The space between the two walls is partitioned, creating a series of chambers. From the interior of the walled chambers there are openings, covered with bar screens, to the fishway and slot-shaped openings to the auxiliary water channel. During the dewatering, lamprey were observed slipping through a gap at the bottom of the bar screen into these chambers. The next day, the auxiliary water channel was checked and one lamprey was found. It is not known if the lamprey came from inside the walled chambers, but it is possible. An attempt was made to inspect the inside of the walled chambers by peering through the slots; no lamprey or other fish were seen. The failure to see any lamprey or fish does not mean there were none; it was difficult to see clearly into the chambers and the water was turbid.

Prior to the 1994 dewatering and in response to the problems of lamprey (and other fish) getting into the inaccessible areas near the Washington shore counting station, the project removed the louvered bulkhead located just upstream and behind the crowder. This allowed access for the rescue of fish. The day after dewatering, however, a dead lamprey was observed with its head caught under this bulkhead.

Bonneville Dam, the Adult Fish Collection and Monitoring Facility (AFF) at the Washington Shore Ladder - This facility is adjacent to the Washington shore ladder at Bonneville Dam. There were three observations of lamprey in this vicinity in 1993 and four such observations taken from MFR's (1985-1994) of past dewaterings. Of the observations where numbers were specified, the following two involved the highest numbers of adult lamprey: August 1993 and May 1986. The 1993 observation involved 15 lamprey seen when the water was lowered in the entrance ladder area to clean the fish viewing window. The May 1986 MFR stated that between 200 and 250 lamprey were found. There was no indication the lamprey were stressed. The NMFS had previously collected lamprey in this area for the tribes.

Bonneville and The Dalles Dams, Crowders - In the summer of 1993 at Bonneville Dam, lamprey were observed caught under or at the side of the crowders at both the Washington shore and Bradford Island counting stations. In one case, a lamprey appeared to be moving under the crowder of its own accord. For a total of seven observations involving eight lamprey, five dead and three live lamprey were seen. During an inspection the day following the dewatering of the north ladder at The Dalles Dam, November 1992, several lamprey that had been stranded and died were discovered. There was an approximately three inch gap underneath and alongside the crowder box into which lamprey had moved. In 1993 at The Dalles Dam, lamprey were observed moving in and out from under the crowders at the fish counting stations on numerous occasions.

John Day Dam, Diffusers and Gratings - Two observations at John Day that indicated problems with the diffusers and diffuser gratings were noted in January 1983 and January 1993. In the first instance, live and dead lamprey were found under the diffuser grating at the lower end of the south ladder near the junction pool. In the second instance, about 75 lamprey were rescued from the south ladder near the diffuser pool and released into the river. The next day (same dewatering), about 35 lamprey were rescued from the diffuser pool by opening the drain. The observer suspected that additional lamprey were in the diffuser supply lines, but determined that a rescue operation would not be practical. Lamprey have occasionally been found behind diffuser gratings during other dewaterings.

John Day Dam, Flow Modifications in the Diffuser Area of the South Ladder - In 1993, wooden miters were placed in the corners of the diffuser area to improve the flow. Some were not flush with the floor, thereby leaving gaps into which an unknown number of lamprey entered during dewatering. Pounding on the miters induced some of the lamprey to come out on their own; those that did were removed in good condition. Two dead lamprey were found on the fishway floor a week later.

Dewatering Practices for all Projects - Current practice is to crowd the fish to the bottom of the ladder as it is dewatered. Lamprey overlooked during the dewatering process and left in dry areas tended to seek water. Some, as mentioned above, entered areas inaccessible to humans.

Problem-Free Rescue of Lamprey During Fishway Dewatering - Large numbers of lamprey were found and successfully rescued during the 1993-1994 winter dewatering of adult fish facilities. At Bonneville Dam, nearly all of the lamprey were found in the Washington shore ladder. Approximately 100 lamprey were found in the upper part of the Washington shore ladder, mostly in scattered small groups in the vicinity of the fish viewing building. They (along with all other fish) were removed to the section of the ladder below the diffuser pool. The north upstream and downstream entrances were left open to allow the fish to leave on their own. (See Beck, et al, 1992, for terminology of fish facilities.) During the two days following the dewatering, a total of eight lamprey were successfully recovered. One of these lamprey was an ammocoete left stranded upon a mat of plant material in the junction pool.

When the upper part of the John Day south ladder was dewatered, approximately 1,500 lamprey were successfully placed into bags and released into the forebay. When the lower part of the south ladder was dewatered, 15 lamprey were successfully recovered and released into the forebay in good condition (Dach, 1994). When the upper part of the north ladder was dewatered, approximately 100 lamprey were crowded down the ladder. On the second inspection, 23 lamprey were recovered and placed in the tailrace. The FFU workers said these numbers were comparable to those found in the 1992-93 winter maintenance season.

When The Dalles north ladder was dewatered in December, 1993, one lamprey was found in a pool in the rocky-substrate area. There was sufficient water in the pool to safely leave the lamprey. Approximately 300 were successfully recovered from the lower section. The FFU workers said this number appeared to be more than was seen the previous year.

Turbines

Draft Tubes - Information from both MFR's (1985-1994) and 1993 incidental observations show that lamprey are found in the draft tubes when they are dewatered. Past dewatering information (prior to 1993, all at Bonneville) are as follows: March 1985, lamprey were removed, numbers and condition unknown, to "prevent clogging of the grizzly;" July 1991, "several" lamprey, condition not known; and August 1991, four lamprey, three alive and one dead. In 1993, 28 lamprey were removed from unit 9 at the Bonneville Dam first powerhouse and one was removed from unit 15 at The Dalles Dam. All were alive. In those dewaterings for which numbers are known, one lamprey was dead out of a total of 33 found.

Scroll Case, John Day Dam - In May 1993, approximately 100 juvenile lamprey were found in the scroll case area of unit 6 at John Day Dam. They were especially numerous in and around the wicket gates. Most of these lamprey were left in the scroll case because it was considered too difficult to rescue them. The lamprey likely died because there was no escape and an inadequate amount of water was left. No other fish were found. Although the gatewell was dipped prior to dewatering and many lamprey were netted, those left behind had moved through the mesh of the net (Dach, personal communication).

Juvenile Fish Guidance Systems

Lamprey Observed by NMFS During Smolt Monitoring and FGE Testing - In 1993, NMFS sampled juvenile salmonids at the downstream migrant sampler at the Bonneville first powerhouse. Actual numbers of incidental catch of juvenile lamprey for each 24-hour period from March 17 to September 10 ranged from 0 to 28, with the total being 513. A total of 18 adult lamprey were captured as well. The expanded estimate (using the same sampling rates as for the juveniles) is 111 (Table 1). The condition of the lamprey (whether dead or alive) was not noted on the incidental catch sheets. Nine lamprey, representing 90 estimated, were captured during the first major peak in numbers, as estimated by the fish counters, and five, representing six, were captured during the second major peak.

Additional observations of lamprey were made by NMFS in 1993 when they were conducting the FGE tests at the Bonneville second powerhouse. Between April 20 and May 28, 26 such observations were recorded. A total of 1,697 lamprey were observed. Of these, one was an adult, described as "very sick-looking" and possibly moribund, and the rest were juveniles. Of the juveniles, 34 were recorded as being dead. The remaining 1,662 juvenile lamprey are presumed to have been alive.

Details of the juvenile lamprey passing Bonneville and John Day dams will be under **Juvenile Lamprey Passage Patterns**.

Bonneville Dam, the Ice & Trash Sluiceway at the Second Powerhouse - In December of 1993, one adult lamprey, along with several other dead and decomposed fish, were found on the auxiliary water supply's intake bar screen for the ice and trash sluiceway. Because of the state of decomposition of the fish and the fact the sluiceway had been in operation for only a week after the previous inspection, the observer felt it was apparent that the fish had been dead for some time (Kuskie, 1994).

The Dalles Dam, Extended Bar Screens (EBS) - Although there was only one recorded observation of the EBS (during fish guiding efficiency tests on May 26, 1993), the numbers of juvenile lamprey involved were large. Between 50 and 100 dead juveniles were found impinged on the EBS. The lamprey were actually imbedded in the screen and could not be dislodged by brooms, sweepers, or manually tugging.

Table 1: Adult lamprey captured by NMFS in the downstream migrant sampler at the Bonneville Dam first powerhouse in 1993.

Date*	Time	Numbers	Sample Rate	Estimates
May 16	19:00	1	0.023	43
May 26	13:00	1	0.287	3
Jun 1	9:00	1	0.100	10
Jun 2	16:00	1	0.141	7
Jun 4	2:00	1	0.150	7
Jun 9	11 & 22:00	2	0.200	10
Jun 14	20:00	1	0.200	5
Jun 17	13:00	1	0.200	5
Jul 4	23 & 1:00	2	0.200	10
Jul 16	6:00	1	0.667	1
Jul 22	10:00	1	0.654	2
Aug 8	1:00	1	0.667	1
Aug 14	16:00	1	0.667	1
Aug 20	4:00	1	0.667	1
Sep 8	6:00	1	0.667	1
Sep 12	12:00	1	0.667	1
Totals		18		111

**Date is beginning of 24-hr sampling period, starting at 8:00.*

Submerged Traveling Screens (STS's) - Whenever the STS's were pulled for periodic inspection and maintenance during the juvenile lamprey migration (which starts in late winter or early spring and continues through the summer) at John Day Dam, dead juvenile lamprey would be found impinged on them. In 1993, not every screen had lamprey. For those that did, the estimated number was 20 to 30 per screen (Dach, personal communication).

Navigation Lock

Two navigation locks, the one at John Day Dam and the old navigation lock at Bonneville Dam, were dewatered in the spring of 1994. The only lamprey found were six dead juveniles at the John Dam.

Past Runs of Adult Lamprey

Lamprey counts were highly variable from year to year (Figure 1) and from day to day. Yearly counts over Bonneville Dam showed definite periods of high return and low return with the peaks occurring in 1938-1939, 1948, 1959, followed by a higher peak in 1961, and 1969, the last year of counting. The periods of low return occurred in 1945, 1950 followed by a similar low in 1952, 1963, and 1966-1967. Fish counting over The Dalles Dam began in 1957. From 1957 through 1960, total yearly counts of lamprey over The Dalles Dam exceeded those over Bonneville Dam, although the pattern of counts over the two dams for those years was similar. The count over The Dalles Dam in 1969 was less than half that over Bonneville Dam. There were only two years of counting over John Day Dam. The highest count over Bonneville Dam was 379,500 in 1969 and the lowest count was 26,200 in 1952. The highest count over The Dalles Dam was 352,400 in 1961 and 28,300 in 1967. Total yearly counts over Bonneville Dam, 1938-1969, are presented in Table 2.

The daily counts over Bonneville are even more variable (Appendix A). From 1939 through 1969, no count pattern resembles another pattern. (Charts showing each year's count pattern are available at the Fish Field Unit office at Bonneville Dam.) Periods of high return and low return are seen, as in the yearly counts. Variations of bimodal curves are often seen.

Table 2: Total Pacific lamprey counts over Bonneville Dam for each year, 1938-1969

Year	Yearly Totals	Year	Yearly Totals	Year	Yearly Totals	Year	Yearly Totals
1938	227,627	1946	75,497	1954	40,986	1962	101,426
1939	229,675	1947	96,848	1955	42,603	1963	87,937
1940	159,133	1948	143,815	1956	49,911	1964	104,337
1941	66,240	1949	57,928	1957	53,031	1965	108,987
1942	52,661	1950	32,693	1958	98,419	1966	67,914
1943	57,641	1951	45,110	1959	215,083	1967	66,171
1944	49,239	1952	26,203	1960	177,898	1968	109,029
1945	36,721	1953	47,129	1961	364,805	1969	379,509

The earliest peak started about May 8 in 1940, and the second earliest peaks started about May 21 in 1963 and 1968. An example of extreme swings in the daily counts occurring early in the season was in 1969. The counts started to increase about May 22, reached a peak of 14,348 on May 29, descended to 584 on May 30 and immediately proceeded to climb again to new peaks of 10,094 on June 3 and 15,606 on June 4. The latest peak in the season was in 1961: there was a sharp peak on September 3 of 10,939, which declined to 2,950 on September 4, then fell abruptly to 454.

Figure 1: Lamprey passage over Portland District Dams, 1938-1969.

There appears to be no relation between the time the higher counts started and ended and the length of time most of the lamprey passed. In 1940 when the first peak began in early May, the last peak ended in mid-August; and in 1961 when the earliest peak began in mid-June, the last peak ended in early September,. The year that had the greatest spread between periods of high counts was 1940 with the first peak beginning about May 8 and the last peak ending about August 12.

The year with the shortest period of high counts is 1951 which had two major peaks. The first started about July 9, the second peak started about July 19, ending about July 25. Two other examples of count patterns with short periods of high lamprey passage are 1949 and 1950.

The years with the contracted high count periods also have some of the lowest total counts. The converse is not necessarily true. In 1952, the year with the lowest total counts, counts start rising to the first peak about June 18 and start declining from the last peak about August 14. In 1966, another year with a lower total count (67,914), the period of higher counts started in mid-May and ended in early August. Except for the observation that years with a contracted high count period had a lower total count, no other relationship between seasonal count pattern and total count can be seen.

Yearly counts, 1938-1969, for lamprey and all salmonids were plotted (Figure B-1) and a correlation calculated. The correlation was $R = 0.16$, which is low. For the 32 pairs of variables calculated, a correlation of 0.3 is considered significant. Thus, there is no relation between the total salmonid count and the lamprey count.

Lamprey counts and selected river conditions for the five randomly selected years (1949, 1953, 1956, 1962, and 1968) were plotted and compared (Figures B-2 through B-6). It is usual for flow in the Columbia River to be high in May and June when the snow is melting in the mountains and the spring freshet occurs. Flow usually decreases in July, becoming low in the fall (Annual Fish Passage Reports, 1939-1992). In looking at the years 1949, 1953, 1956, and 1962, it appears the high lamprey counts typically began after the high river flow had subsided. In 1968, there was high passage of lamprey in mid-May, as the flow was rising. To take a closer look at flow and lamprey counts, plots were made of the two parameters during the time, May 1 - July 31, for the three years (1940, 1963, and 1969) in which high lamprey counts began in May or early June (Figures B-7 through B-10). No relationship can be seen between flow and lamprey counts.

Water temperature in the Columbia River typically is cool in the spring, warms in July and August, and then starts cooling again in mid or late September. For the years plotted, no relationship can be seen between water temperature and lamprey counts.

At Columbia River dams, water transparency is measured, in feet, by a Secchi disk reading. This information is distributed with the daily fish counts. The lower the reading, the less transparent the water. Transparency is typically low in the spring as the spring freshet washes silt into the rivers that are tributary to the Columbia. As the flow decreases and the silt settles out or is washed away, the water transparency and the Secchi depth increases (Annual Fish

Passage Reports, 1939-1992). Storms occurring in the river basin during the year can lower the water transparency for several days. For the years plotted, water transparency generally increased as flow decreased, as might be expected. For those years in which high lamprey counts started later, the higher counts coincided with increasing water transparency (Figures B-2 through B-6). For 1949, 1953, and 1956, lamprey passage was minimal during the time of low water transparency. In 1969, water transparency varied during the early minimal lamprey passage. In 1968, two peaks in lamprey passage (late May and early July) appeared to be independent of water transparency. For 1963 and 1969, two years in which lamprey passage was high early in the season, passage and water transparency during May 1 - July 31 for 1963 and 1969 (Figures B-11 and B-12) indicates no relation between lamprey passage and water transparency.

Both barometer readings and cloud cover were plotted with lamprey passage for the years 1949, 1953, 1956, and 1962. Barometer readings and cloud cover varied from day to day with no relationship at all with lamprey passage (Figures B-2 through B-6).

The subjective impressions of the fish counters at Bonneville Dam indicated the lamprey runs were far heavier in the recent past than they were in 1993. Large lamprey runs apparently occurred in the mid and late 1980's. The years 1987 and 1988 were mentioned in particular. The numbers appeared to be fewer within the previous two or three years (1990, 1991, and 1992) and 1993 numbers were much fewer than those for 1992.

1993 Seasonal and Diel Patterns of Lamprey Passage Past Bonneville Dam

Fish Counter Estimates

Total Estimates - The results from the fish counters' estimates are summarized in Table 3. These results include the three sets of estimates that were calculated as described in **METHODS**. For ease in handling the data and in noting changes as the run progressed, the season was divided into three-week periods that corresponded to the lamprey count sampling periods. The figure of 22,366 (rounded to 22,000) that was calculated using values one-third of the ranges checked may be a possible approximation of the actual numbers of lamprey that passed the Bonneville Dam count windows during the 16-hour fish counters' shifts from May 1 through October 5. (See **METHODS**, page 5, for the rational behind this statement.) This estimate is lower than the lowest count recorded by counters in the past: 26,000 in 1952. All the daily estimates, based on values one-third the estimate range, for each ladder and daily totals are presented in Table C-1. The season's totals for each ladder are nearly the same; the estimate is about 1,000 more lamprey passed over the Washington shore ladder than over the Bradford Island ladder.

Table 3: Estimates of lamprey passage past Bonneville Dam based on ranges checked by the fish counters.

Three-Week Period	Point in Range Where Calculated		
	Maximum	Minimum	One-Third
May 1-May 21	3,880	508	1,624
May 22-Jun 11	9,850	1,395	4,190
Jun 12-Jul 2	9,090	1,264	3,850
Jul 3-Jul 23	7,300	970	3,064
Jul 24-Aug 13	10,600	1,605	4,573
Aug 14-Sep 3	6,900	980	2,934
Sep 4-Sep 24	3,460	426	1,432
Sep 25-Oct 5*	1,710	196	699
TOTALS	52,790	7,344	22,366
AVE PER DAY	334	46	142

**The last sampling period was 11 days, ending October 5.*

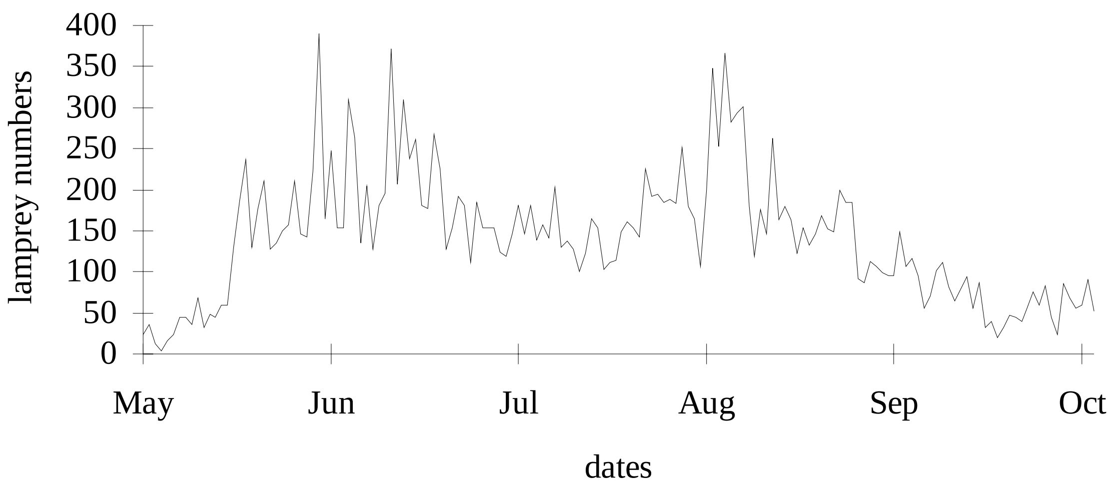

Figure 2: Total estimates of lamprey passage past Bonneville Dam in 1993, using as values one-third the estimate range.

. Figure 3: Comparison of lamprey passage estimates in 1993 between the Bradford Island and the Washington shore ladders.

Total combined estimates, from both the Bradford Island and Washington shore ladders, of lamprey past Bonneville Dam are presented in Figure 2. The estimate pattern shows the same periods of high return and low return from day to day as is evident in the estimate patterns from past years. Even taking into account the sharp periods of high return and low return, a bimodal distribution can be seen. The two peak periods occur from the end of May to early June and from late July to early August.

Estimates for Each Ladder - The estimates for each ladder, plotted separately, are shown in Figure 3. Despite the similarity in total numbers for each ladder, each has its own passage pattern for the season. To sum up the principal differences: 1) Washington shore passage began to increase sooner in May than did the Bradford Island passage, but remained at a moderate level through most of June, while Bradford Island passage showed high peaks; 2) From late June to mid-July, the Washington shore numbers showed two high peaks that the Bradford Island numbers lacked; 3) In late August, estimates at Bradford Island generally fell before those at the Washington shore.

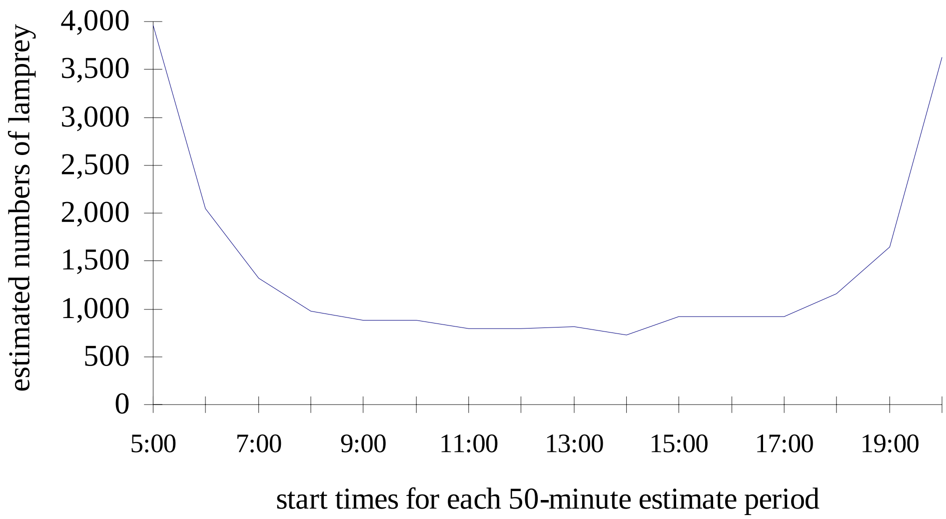

Figure 4: Total estimated diel lamprey passage past Bonneville Dam in 1993 using as values one-third the estimate range.

Diel passage - Combined estimated diel passage for both ladders is high for the first two hours and last two hours of the counting day (Figure 4). Considering the difference between the Washington shore and Bradford Island ladders (Figure 5), the passage was higher in the morning at the Bradford Island ladder and higher in the evening at the Washington shore ladder.

The passage for each ladder during different periods of the season show even greater differences between the ladders (Figures C-1 through C-6). To summarize: 1) For two periods, occurring in the early half of the season, more lamprey passed the Washington Shore ladder throughout the day than passed the Bradford Island ladder; 2) Bradford Island never showed the higher passage consistently throughout the day for any periods; 3) Bradford Island shows higher passage in the morning than does Washington shore for four periods; 4) Washington shore shows higher passage in the evening for five periods, the exception being during the May 30-June 19 period when Bradford Island's passage was showing a number of very high peaks; 5) Bradford Island showed passage higher at 15:00 than for the hour preceding or following for four periods, with these peaks varying in size (for the period of August 14-September 4, the peak appeared at 16:00 instead of 15:00.). A number of times throughout the season, diel passage at one ladder would show a peak at the same time passage at the other ladder showed a dip.

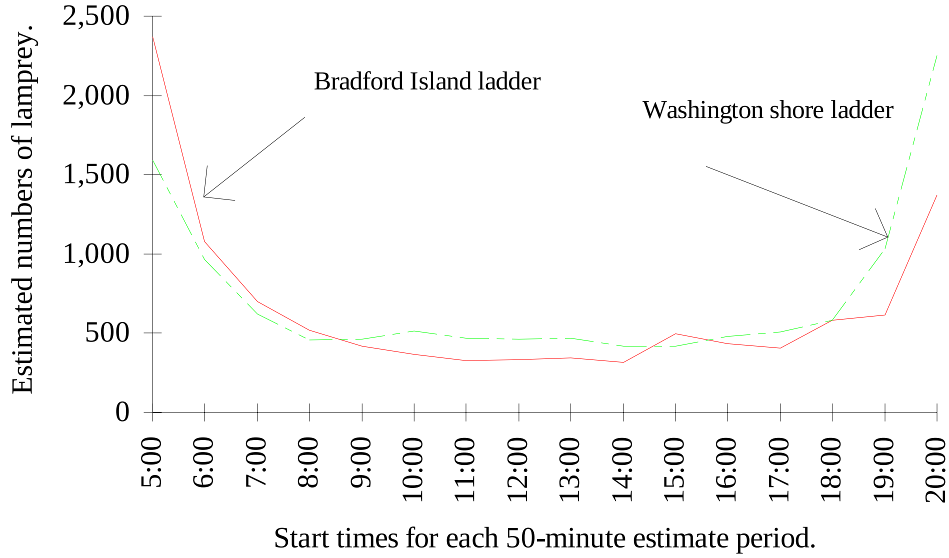

Figure 5: Estimated diel lamprey passage past the Washington shore and Bradford Island ladders in 1993, using as values one-third the estimate range.

Snapshot Observations - The results from fish counters' snapshot observations at 50 minutes past the hour are shown in figures C-7 and C-8. A Pearson correlation was run between the total snapshot observations for each day and the total estimates for each day. The correlation was 0.550, which is highly significant. Correlations were also run between the snapshot observations and the estimates for each ladder. The results were: Bradford Island, 0.421; and the Washington shore, 0.434. These results are, again, highly significant.

Table 4: Lamprey movement past the Bradford Island ladder, Bonneville Dam, as obtained from FFU sampling in 1993. Each sample was one hour.

	Upstream Activity			Downstream Activity			Net Activity			Combined Daily Activity		
Sampling Dates*	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Upstream	Downstream	Net
May 3	0	0	0	0	0	0	0	0	0	0	0	0
May 11	0	0	0	0	0	0	0	0	0	0	0	0
May 21	57	1	83	6	1	107	51	0	-24	141	114	27
May 25	49	4	294	4	1	274	45	3	20	347	279	68
Jun 4	6	17	364	6	8	367	0	9	-3	387	381	6
Jun 8	5	4	41	1	6	29	4	-2	12	50	36	14
Jun 14	3	6	170	3	4	266	0	2	-96	179	273	-94
Jun 24	2	2	472	0	2	468	2	0	4	476	470	6
Jun 29	4	6	33	1	3	29	3	3	4	43	33	10
Jul 9, 11	11	0	116	5	2	111	6	-2	5	127	118	9
Jul 16, 18	1	5	181	0	3	164	1	2	17	187	167	20
Jul 21	1	4	157	1	1	153	0	3	4	162	155	7
Jul 26	2	0	86	0	0	80	2	0	6	88	80	8
Aug 2	4	10	30	2	0	14	2	10	16	44	16	28
Aug 6, 7	50	3	10	11	0	7	39	3	3	63	18	45
Aug 17,18	8	7	37	0	4	32	8	3	5	52	36	16
Aug 23	27	5	45	11	1	35	16	4	10	77	47	30
Aug 29, 30	13	0	6	5	0	4	8	0	2	19	9	10
Sep 10	2	2	1	0	0	0	2	2	1	5	0	5
Sep 17	2	0	0	0	0	0	2	0	0	2	0	2
Sep 24	1	0	2	1	0	2	0	0	0	3	3	0

**For some dates, sampling was missed for one of the hours on the date scheduled. Sampling was rescheduled for a day following as soon as possible.*

Table 5: Lamprey movement past the Washington shore ladder, Bonneville Dam, as obtained from FFU sampling in 1993. Each sample was one hour.

	Upstream Activity			Downstream Activity			Net Activity			Combined Daily Activity		
Sampling Dates*	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Morning	Afternoon	Evening	Upstream	Downstream	Net
May 6	4	3	12	0	0	9	4	3	3	19	9	10
May 17	40	9	69	20	2	66	20	7	3	118	88	30
May 18, 19	105	11	105	65	8	97	40	3	8	221	170	51
May 31	10	5	218	7	4	262	3	1	-44	233	273	-40
Jun 3	11	8	128	8	8	183	3	0	-55	147	199	-52
Jun 9	54	7	12	30	7	15	24	0	-3	73	52	21
Jun 19	11	6	90	6	4	84	5	2	6	107	94	13
Jun 23	14	4	555	8	3	700	6	1	-145	573	711	-138
Jun 26	10	17	441	7	15	513	3	2	-72	468	535	-67
Jul 3	12	1	431	1	2	439	11	-1	-8	444	442	2
Jul 12	2	0	309	2	1	302	0	-1	7	311	305	6
Jul 19, 21	2	1	17	2	0	7	0	1	10	20	9	11
Jul 24	2	2	209	1	0	194	1	2	15	213	195	18
Jul 29, 30	42	24	407	25	15	499	17	9	-92	473	539	-66
Aug 9	no count+	2	306	no count+	1	347	no count+	1	-41	308	348	-40
Aug 13, 16	2	2	105	2	1	94	0	1	11	109	97	12
Aug 21	2	0	471	2	1	449	0	-1	22	473	452	21
Aug 26, 27	62	7	18	47	4	15	15	3	3	87	66	21
Sep 8	0	3	352	0	0	326	0	3	26	355	326	29
Sep 13	1	1	209	1	1	164	0	0	45	211	166	45
Sep 22	13	1	2	13	0	2	0	1	0	16	15	1

**For some dates, sampling was missed one of the hours on the date scheduled. Sampling was rescheduled for a day following as soon as possible.*
+Sampling was scheduled, but not done.

Comparison between the Washington shore and Bradford Island ladders (Figure C-7) show that, except for the early part of the season prior to late June, more lamprey were observed in the Washington shore window at 50 minutes past the hour than in the Bradford Island window. Comparison between the AM and PM fish counting shifts (Figure C-8) show that the preponderance of lamprey observed at 50 minutes past the hour was in the PM shift. The principal exception was for several days in late May and early June.

Sampling of Lamprey Passage

Total Sampling Data - The results of the sampling by FFU personnel are presented in tables 4 and 5. Figure D-1 shows the total (upstream, downstream, and net) lamprey movement we observed passing the Bonneville project, and figures D-2 and D-9 shows total lamprey movement observed passing the Bradford Island and Washington shore ladders. While there were periods of high return and low return from day to day, pronounced increases and decreases in passage throughout the season do not appear to be evident. In examining the patterns for upstream and downstream movement (but not the net passage), it may appear there were increases and decreases in movement about the same time as was seen for the fish counter estimates. The greatest differences between the two methods seem to be from mid-June to mid-July, in that numbers estimated by the fish counters decreased, while numbers obtained from sampling, for the most part, did not.

Considering lamprey movement for both ladders (figures D-2 and D-9), it appears for the days sampled, that many of those days on which there was the greatest upstream movement, there was also the greatest downstream movement. This often resulted in a net negative, or net downstream, movement. Those days with a positive net passage often showed lower upstream and downstream movement.

Comparison of Sampling Data for Each Ladder - When analyzing the sampling data, it is necessary to keep in mind that the sampling effort was limited. Even so, when the Bradford Island and the Washington shore ladder movements are considered separately, it appears differences exist. The Bradford Island total upstream and downstream movement was greatest in the earlier part of the season, from mid-May to late June. Net passage was, except for a sharp drop in mid-June, generally positive. The Washington shore upstream and downstream movement appeared to be quite different. The greatest numbers were in mid-June to early July. After a drop in mid-July, the numbers fluctuate in August and September. Net passage dropped to negative movement three times. These correspond to the periods of greatest upstream and downstream movement.

We saw a great deal of difference in passage at different times of the day. This is illustrated in figures D-3 through D-9. Figures D-3, D-4, D-5 show the Bradford Island ladder morning, afternoon, and evening passage and figures D-7, D-8, and D-9 show the Washington shore ladder passage.

For the Bradford Island ladder, net positive movement was highest in the morning (usually the 6:00-7:00 hour), especially in the early and late parts of the season. Net negative movement occurred twice: -24 in the evening of May 21 and -96 in the evening of June 8. Both upstream and downstream movement was highest in the evening, especially in the hours after 20:00. Afternoon movement was negligible.

For the Washington shore ladder, morning movement (upstream, downstream, and net) peaked in mid-May, early June, late July, and late September. There was no net negative morning movement at the Washington shore. As at Bradford Island, the greatest net positive movement occurred in the earliest hours of the morning. Numbers for afternoon movement were low. Evening upstream and downstream movement was high, with the greatest upstream number being 555 and the greatest downstream number being 700. The greatest net passage was negative which was -145 lamprey on June 23. The high was lamprey on September 13. Most of the evening movement was in the later hours.

Correlation between FFU Sampling and Fish Counters' Estimates - We made a correlation calculation between the fish counters' estimates and FFU sampling for the same date. Where a sampling set had occurred over two days, a value was obtained by taking a proportion of each of the two days' estimates and adding them. The correlation between fish counters' estimates and net passage was -0.08, or no significance. When only upstream movement is correlated with the fish counters' estimates, the correlation, 0.27, is much better, being significant, if only slightly.

Check of the Stability of the Sampling Technique - The check of the stability of the FFU sampling technique, in which we applied an F-test comparing the 1993 hourly samples to the 1956, 1966, and 1967 hourly ladder counts, produced the following:

	F-test	
1956	1.09	ns
1966	1.04	ns
1967	5.58	$p<.01$, $df=37/35$

in which ns = not significant, p = probability, and df = degrees of freedom. While the results for 1956 and 1966 show no significance, the result for 1967 shows that the sampling technique is unstable. It appears that the samples were too few and the data set too variable to be able to estimate numbers of the lamprey population. As a further test of the past data, the F test was applied to compare past years with each other. When that was done, no significance was found. A more complete description of this technique is in Appendix E.
All of the analyses appear to show the presence of run-pulses, sometimes lasting only a few hours at a time, within the seasonal run. Lamprey passage appears to be highly variable, both daily and hourly. Although the fish counters' estimates (and past counts) indicated the presence of such pulses, the FFU sampling technique could not detect all of them because of the limited number of samples. The sampling technique did, however, provide an unbiased

estimate of changes in the presence and duration of pulses when used together with the fish counters' estimates. See Appendix E for details of this statistical analysis.

Comparison of 1993 Data with Historical Counts

***Numbers of Days with High-Count Hours* -** Fish counters' estimates were compared with hourly counts in 1956, 1966, 1967 (Cascades Island -- the old Washington shore -- only), and 1968 (Both Bradford Island and Cascades Island). The number of days in which, for at least one hour during that day, counts or estimates were at least 10 or 50 or 300 lamprey are presented in Table 6. Statistical analysis of the variability of the days in which counts exceeded 10, 50, or 300 is in Appendix E.

For both ladders in 1993, days with counts exceeding 10 were greater than those for the Cascades Island ladder for all four years. The number of 1993 days were less than for the 1968 Bradford Island count.

In 1993, the numbers of days in which there was at least one hour of estimates for 50 or more lamprey were three for the Washington shore and eight for Bradford Island. Estimated lamprey numbers of 50 or more passed during only one hour in each of those days. For the past Cascades Island hourly counts of at least 50 lamprey, the number of days ranged from 24 (38 hours) to 54 (94 hours). The Bradford Island 1968 counts total 335 hours in which lamprey counts were at least 50, these hours being within 53 days.

In 1993 and 1956, there were zero days in which the lamprey count (or estimate) was at least 300 in an hour. In 1966, there were four such days (six hours) and in 1967, one day (one hour). The greatest number of days for this peak passage occurred in 1968 at both the Cascades Island and Bradford Island ladders, with the greater number being at Bradford Island.

Relation of Hourly Counts and Ladder Passage - Total ladder passage for each ladder and year were compared with hourly counts and estimates. Pearson correlations were calculated for: ladder passage and number of hours in which lamprey counts or estimates were 50 or more; ladder passage and number of days in which at least one hourly count or estimate was 50 or more; and ladder passage and number of hours in which lamprey counts or estimates were more than 300. The results are presented in Table 7.

These results show a high correlation between ladder count or estimate and the number of hours with counts or estimates of at least 50 lamprey or at least 300 lamprey. There is less, but still significant, correlation between ladder count or estimate and the number of days in which at least one hour had a count or estimate of 50 lamprey or more. The number of hours with these high passages of lamprey would enable comparison of ladder passage from year to year.

Count Patterns - The diel patterns (Figure 6) were similar to the 1993 estimates in that passage is generally higher in the morning and evening than it is in the middle of the day. Statistical analysis reveals subtle differences in the diel pattern among the various ladder counts (and estimates). Analysis (described in Appendix E) indicates that, for those years hourly counts were available, the 1968 Bradford Island passage had a greater proportion of passage in the middle of the day than did the average of all the years and ladders. The same analysis indicates that the 1993 estimates for both ladders had a higher proportion of passage near the beginning and ends of the fish counting shifts than the average of all counts.

Table 6: Number of days, for those years that hourly counts were available and for 1993 in which, for at least one hour, the numbers of lamprey passing exceeded 10, 50, or 300.

	Days w/hrs Exceeding 10 Lamprey		
Year	Cascades Island (WA) Ladder	Bradford Island Ladder	Washington Shore Ladder
1956	57 d		
1966	88 d		
1967	50 d		
1968	79 d	106 d	
1993		101 d	100 d

	Days w/hrs Exceeding 50 Lamprey		
Year	Cascades Island (WA) Ladder	Bradford Island Ladder	Washington Shore Ladder
1956	24 d (38 h)		
1966	54 d (94 h)		
1967	20 d (51 h)		
1968	44 d (89 h)	53 d (335 h)	
1993		8 d (8 h)	3 d (3 h)

	Days w/hrs Exceeding 300 Lamprey		
Year	Cascades Island (WA) Ladder	Bradford Island Ladder	Washington Shore Ladder
1956	0 d		
1966	4 d (6 h)		
1967	1 d (1 h)		
1968	4 d (21 h)	11 d (33 h)	
1993		0 d	0 d

Figure 6: Diel patterns of historical lamprey counts past Bonneville Dam.

Table 7: Comparison of ladder passage with numbers of hours in which lamprey counts were greater than 50 and greater than 300 per hour.

Comparison of hours in which lamprey counts were at least 50 per hour:

CASCADES ISLAND			
1956	38 hours	24 days	9,752 ladder passage
1966	94 hours	54 days	19,254 ladder passage
1967	51 hours	20 days	9,084 ladder passage
1968	89 hours	44 days	39,859 ladder passage
BRADFORD ISLAND			
1968	335 hours	53 days	69,900 ladder passage
1993	8 hours	8 days	10,675 ladder estimate
WASHINGTON SHORE			
1993	3 hours	3 days	11,691 ladder estimate

Comparison of hours in which lamprey counts were at least 300 per hour:

CASCADES ISLAND			
1956	0 hours	0 days	9,752 ladder passage
1966	6 hours	6 days	19,254 ladder passage
1967	1 hours	1 day	9,084 ladder passage
1968	21 hours	4 days	39,859 ladder passage
BRADFORD ISLAND			
1968	33 hours	11 days	69,900 ladder passage
1993	0 hours	0 days	10,675 ladder estimate
WASHINGTON SHORE			
1993	0 hours	0 days	11,691 ladder estimate

Pearson correlations:

BETWEEN LADDER COUNTS & NO. OF HRS. W/50 OR MORE LAMPREY:
$\underline{r = 0.9369}$, degrees of freedom = 6, probability<.005.

BETWEEN LADDER COUNTS & NO. OF HRS. W/300 OR MORE LAMPREY:
$\underline{r = 0.990811}$, degrees of freedom = 6, probability<.005.

BETWEEN LADDER COUNTS & NO. OF DAYS W/50 OR MORE LAMPREY IN ONE HR.:
$\underline{r = 0.702976}$, degrees of freedom = 6, probability<.05.

Duration of Run-Pulses - Table 8 shows the numbers of run-pulses, according to hours of duration, for all years with hourly counts or estimates. The duration for run-pulses is significant at $p<.001$ (Chi square, $df=54$).

The results of a statistical analysis show that the duration of pulses was generally up in 1968, especially for Bradford Island, and almost uniformly down in 1993 for both ladders. The details of this analysis is presented in Appendix E.

Table 8: Numbers of run-pulses of lamprey for years hourly counts or estimates are available, presented by hours of duration.

		--------------- Hours of Duration ----------------									
Year	Ladder	1	2	3	4	5	6	7	8	9	10-16
1956	Casc Isl	53	29	9	4	4	3	4	1	2	1
1966	Casc Isl	76	37	9	6	8	7	3	5	2	0
1967	Casc Isl	47	14	4	7	2	4	6	0	3	3
1968	Casc Isl	63	30	10	10	3	8	6	2	3	16
1968	Brad Isl	56	30	24	16	13	9	7	4	2	27
1993	Wash Sh	93	34	8	1	0	0	0	0	0	0
1993	Brad Isl	91	29	7	3	1	0	0	0	0	0

Video-Taped Night Counts

Tapes from 1993 - Preliminary review of these tapes has begun (See **METHODS**). Review is being done only of those hours that the fish counters were not on duty. Only two nights (June 7-8 and June 8-9 at Bradford Island) have so far been reviewed for a total of 16 hours. It appears that the upstream and downstream movement noted at dusk and dawn during sampling by the FFU continues during the night hours. The net count varied from a high of 51 for the hour starting 2:50 on June 8 to a low of -84 for the hour starting 00:50 on June 9. Four of the hours had a negative net count.

Tapes from 1992 - Tapes from only four nights (June 15-16 through June 18-19) of Bradford Island passage were available for review. The results are presented in Table 9 and figures F-1 through F-4. Again, considerable upstream and downstream activity were noted (figures F-5 through F-8). For the four nights sampled, net activity was always positive. The highest net passage per 15 minutes sampled was 296 during the hour starting 21:00 on June 15. There is a possibility of an error for the first hour of this sample. The video tape reviewer was learning the process. For three of the four nights, net passage was higher in the hours prior to or

Table 9: Upstream, downstream, and net passage of lamprey past the Bradford Island ladder in 1993 for the nights of June 15-16 through June 18-19 as seen on videotape. Fifteen minutes of each hour were counted and the results expanded for the whole hour.

Date Counted	Hour Counted	Start Time	End Time	Upstream Passage	Dnstream Passage	Net Passage	Hourly Estimate
6/15/92	21:00	21:30	21:45	371	75	296	1,184
	22:00	22:07	22:22	254	77	177	708
	23:00	23:06	23:21	299	59	240	960
6/16/92	0:00	0:27	0:42	279	78	201	804
	1:00	1:18	1:33	238	65	173	692
	2:00	2:17	2:32	224	80	144	576
	3:00	3:53	4:08	128	103	25	100
	4:00	4:49	5:01	54	37	17	68
	21:00	21:48	22:03	229	81	148	592
	22:00	22:31	22:46	193	71	122	488
	23:00	23:23	23:38	265	91	174	696
6/17/92	0:00	0:42	0:57	248	130	118	472
	1:00	1:09	1:24	255	117	138	552
	2:00	2:47	3:02	154	109	45	180
	3:00	3:13	3:28	146	91	55	220
	4:00	4:19	4:34	95	77	18	72
	21:00	21:24	21:39	175	90	85	340
	22:00	22:46	23:01	184	54	130	520
	23:00	23:44	23:59	225	113	112	448
6/18/92	0:00	0:26	0:11	261	115	146	584
	1:00	1:42	1:57	215	155	60	240
	2:00	2:18	2:33	183	131	52	208
	3:00	3:30	3:45	142	91	51	204
	4:00	4:04	4:19	108	71	37	148
	21:00	21:49	22:04	193	114	79	316
	22:00	22:20	22:35	201	107	94	376
	23:00	23:02	23:17	250	133	117	468
6/19/92	0:00	0:39	0:54	191	137	54	216
	1:00	1:01	1:16	245	122	123	492
	2:00	2:34	2:49	221	140	81	324
	3:00	3:23	3:38	208	114	94	376
	4:00	4:14	4:29	133	91	42	168

total estimates for night of June 15-16*	1,847	574	1,273	5,092
total estimates for night of June 16-17	1,585	767	818	3,272
total estimates for night of June 17-18	1,493	820	673	2,692
total estimates for night of June 18-19	1,642	958	684	2,736

*possible error the first hour

around midnight, the exception being the night of June 18-19. For all four nights, all activity, decreased toward dawn.

Juvenile Lamprey Passage Patterns

The Bonneville Dam First Powerhouse Downstream Migrant Sampler

In 1993, NMFS sampled juvenile salmomids at the downstream migrant sampler at the Bonneville first powerhouse. Incidental catch of juvenile lamprey for each 24-hour period from March 17 to September 10 ranged from 0 to 28, with the total being 513. The condition of the lamprey (whether dead or alive) was not noted on the incidental catch sheets. The daily sampling rate varied throughout the season. We multiplied the number captured by the average sampling rate for each day and added the results to obtain the estimated number that passed the Bonneville Dam first powerhouse. This result was 5,838. See Table G-1.[4] The numbers NMFS captured for the whole season (which was longer than the dates stated above) was 523, and their figure for the collection total (expanded by the sampling rate) was approximately 6,900.

The capture pattern of juvenile lamprey March 17 through July 15 at the Bonneville first powerhouse is presented in Figure G-1, and the diel pattern is presented in Figure G-2. Numbers were generally low except for a surge from mid-May to early June and a smaller increase in March. From mid-July until September 23, only one to three juvenile lamprey were captured every week or ten days. In September, the intervals between a capture were even longer. Diel distribution shows the highest capture at night, with most between 22:00 and 02:00.

The Bonneville Dam Second Powerhouse FGE Studies

Additional observations of juvenile lamprey were made by NMFS during their FGE work at the Bonneville second powerhouse. This work involved the use of fyke nets. Between April 20 and May 28, 26 such observations were recorded. A total of 1,696 juvenile lamprey were observed. Of these, 34 were recorded as being dead. The remaining 1,662 juvenile lamprey are presumed to have been alive. Turbines sampled (at various times) were: 17A, 17B, 12A, 12B, 15A, and 15B. Each night's sampling was two hours.

The numbers of juvenile lamprey captured by NMFS and mortalities they observed are presented in Table G-2. Total numbers are presented in chart form in Figure G-2. Because of the breaks in sampling and the missing data, these numbers do not show a complete picture of

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[4] Because NMFS operated the downstream migrant sampler for a period longer than we collected the incidental catch sheets, NMFS numbers were larger than ours. Their actual numbers were 523 and the expanded numbers were approximately 6,900. We used our numbers to determine the seasonal and diel pattern, and the NMFS numbers to compare 1993 passage with previous years' passage.

the pattern of juvenile passage past the Bonneville Dam second powerhouse. It can be noted, however that a large increase was seen in the last two nights of sampling at the end of May.

The NMFS Smolt Sampling at John Day Dam

The NMFS provided the numbers of juvenile lamprey they observed during their smolt monitoring at John Day Dam. These lamprey had been guided into the juvenile bypass system. Data were obtained from April 6 through August 31. The turbine units sampled were 3B and 3C; turbine unit 3C was not in operation from May 14 through June 18. The results are presented in Table G-3 and figures G-4 and G-5. Numbers of lamprey captured were: 3B, 4,486; 3C 3,151; and total, 7,637. There was no sampling rate; the numbers are a one-to-one ratio and are actual numbers (Martinson, personal communication).

The greatest numbers were captured from early May to mid-May, although numbers remained fairly high (a few over 100) until late May. Another peak was in early April. After July 24, no more than 7 per day (and often, none) were captured until the end of data collection.

Past Juvenile Lamprey Passage Patterns

At the Bonneville Dam first powerhouse in 1989, the estimated numbers of juvenile lamprey passing were 34,747; in 1990, they were 1,780; in 1991, 4,568; and in 1992, 526.

The passage pattern in 1989 (Figure G-6) showed a sharp high peak in the last part of March and the first part of April. A much smaller peak occurred in mid-May. In 1990 (Figure G-7) the high numbers occur after the first of June, but before the middle of June. In 1990, an increase in flow began just before the peak in juvenile lamprey passage. In 1989, however, the flow increased after the peak in passage (Parties to U.S. v. Oregon, 1993).

DISCUSSION

Life History

The most notable discovery in the literature search was the lack of solid information on life history cycles of the Pacific lamprey, especially on the Columbia River populations. Using figures of five to seven years maximum time (no minimum time was found) in the burrows, one and one-half to three and one-half years in the ocean and one year in freshwater before spawning, it can be seen that the life-cycle of Pacific lamprey could vary from seven to eleven years. It is possible that there is variation among populations of lamprey, depending on where they spawn and where they spend their time in the ocean.

Uncertainty about whether or not Pacific lamprey return to their natal streams is another confounding factor in assessing status of lamprey populations. When authors stated that lamprey probably do not (or may not) home, they did not say if they meant the lamprey do not necessarily home to the specific tributary where they were spawned, or they do not necessarily home to the major river system where they were spawned.

The uncertainty about years in the life-cycle and in the homing behavior should be taken into consideration when trying to determine if lamprey populations have decreased in recent years.

Areas that May Impact Lamprey

Adult Fish Passage Facilities

General Observations on Lamprey in the Fishways - In general, it appears that lamprey will enter any small crack, crevice, gap, or aperture. Lamprey are able to slip through openings as small as an inch, and possibly smaller. It is not clear the exact size required to exclude lamprey. Lamprey crawling into apertures especially become a problem during dewatering. As the water recedes, some of them tend to move to small enclosures inaccessible to humans. The implications for the project are that, when making modifications, leaving gaps or cracks should be avoided.

Bonneville Dam, Washington Shore Auxiliary Water Supply - Lamprey have been seen trapped in an area, directly upstream from the crowder box assembly, that is enclosed on all sides. A louvered bulkhead provides worker access to the area. An opening under the louvered bulkhead permitted lamprey to move into the enclosed area. Two other ways that lamprey may move into or out of this inaccessible area are: through the picketed leads by the count station and under the crowder itself. In order to exit from there to the auxiliary water supply area (where they were found in the winter of 1992-93) by way of the picketed leads or underneath the crowder would, however, require that lamprey move a lengthy distance. Considering the extreme cold that winter, it was probably unlikely the lamprey traveled far after the ladder was dewatered. Thus, these routes were unlikely to have been used in this particular incident.

During the winter maintenance period in January, 1994, the project covered, with angle iron, some of the gaps that lamprey had been using. These were: the gap under the louvered bulkheads and four gaps under the bar screens of the walled chambers separating the auxiliary water supply from the ladder. These measures should reduce the movement of lamprey into areas difficult to access. Gaps in the walls between the auxiliary water system and the ladder still exist, however, and lamprey could still gain access to the chambers. Lamprey will continue to go through the picketed leads to become trapped either behind the crowder or in the auxiliary water system.

Bonneville and The Dalles Dam, Crowders - Crowders may trap lamprey. The crowders have gaps, some as large as three inches, underneath. Throughout the passage season at Bonneville Dam, we occasionally observed lamprey caught under the crowder. On five occasions, the lamprey were dead. It is not known if the lamprey had died before being washed under the crowder, or if they had become caught and then died. Lamprey dying from natural causes could, hypothetically, wash downstream (the NMFS personnel conducting the FGE testing at Bonneville Dam second powerhouse captured a possibly moribund adult), but it seems unlikely that, considering the relative inaccessibility of the area underneath the crowder, dead lamprey could be passively swept there very often. Live lamprey were seen under the crowder, and they sometimes appeared to be struggling. When the crowder was moved back, they could free themselves. If any fish are found dead in Corps fishways, the cause should be determined and, as much as possible, the situation corrected.

John Day Dam, Diffusers and Gratings - Although lamprey may be found behind diffuser gratings at any project, John Day was the project where this problem was particularly noted. Lamprey could be getting into the diffuser system by more than one route. They are able to move behind loose gratings and through the grating openings. Lamprey may be especially prone to moving behind the gratings (by whatever route) when the water is lowered during dewatering, particularly in the area of the collection channel. Some may possibly be falling back through the auxiliary water conduits on the forebay side.

After the January 1993 dewatering incident during which lamprey were found in the diffuser system, the project repaired all loose diffuser gratings as soon as they were discovered.

Past procedure, as stated in the previous Fish Passage Plans (1993, U.S. Army Corps of Engineers) called for dewatering the diffuser areas every 10 years with one underwater inspection in between dewaterings. Except for areas that the project has been unable to dewater, this procedure was being followed by The Dalles/John Day Project. The 1994 Fish Passage Plan (1994, U.S. Army Corps of Engineers) called for inspecting diffusers once a year.[5] It should be noted that the Bonneville Project inspected many of the diffuser areas when they dewatered during the 1993-94 winter maintenance period. They are attempting to use video cameras to inspect between dewaterings, although, according to the project biologists, it is difficult to use the cameras during the fish passage season and still keep the fishways in criteria. The diffusers in the powerhouse collection channels have been inspected less frequently than those elsewhere.

Areas of Low Water Flow - Near the adult fish collection and monitoring facility (AFF) at the Washington Shore ladder, Bonneville Dam, is an extensive area of low flow or slackwater. Lamprey have been observed in this area. Lamprey are weak swimmers compared to salmomids and shad (Bell, 1991[6]). It may be that lamprey are attracted to this area by the lower flows, but then become trapped, unable to find their way out. Lamprey in areas of low flow may be delayed.

It is not known if delay has an adverse effect on lamprey. They hold in freshwater for up to a year prior to spawning and delay caused by a dam may or may not harm their chances for survival. Lamprey are found in the ladders during the winter dewatering, and they are especially numerous at John Day Dam.

Dewatering Practices at all Projects - Lamprey may not move down the ladder as most other fish do during dewatering. They tend to cling to the surfaces of the fishway with their suctorial disks and do not always respond to crowding. During the 1994 dewatering at Bonneville, it was found that lamprey tended to release themselves if grasped gently behind the head for about half a minute. There was no need to forcibly pry them free. It may be important to rescue lamprey as soon as possible. If there is delay in rescuing lamprey, there is risk they will move into inaccessible areas, including diffuser chambers. Experience in recent dewaterings indicates there need be no loss of time in rescuing salmonids if they are crowded, not handled. Project personnel have developed efficient and effective methods which can be adapted to the needs of lamprey.

Numbers of Lamprey Found While Dewatering - Virtually all of the 100 lamprey rescued during dewatering of the Bonneville Dam fishways in the 1993-94 winter maintenance season were found in the Washington shore ladder. This past winter more lamprey were rescued than were in the 1992-93 maintenance period. Again, most of these

[5] The NMFS Biological Opinion on the 1994-1998 Operation of the Federal Columbia River Power Systems (FCRPS) required the Corps of Engineers submit a plan to NMFS providing for the mid-season inspection of diffuser areas of special concern. These are areas where there is a history of problems with diffuser gratings or where the lack of problems has not been demonstrated (Patterson, 1994).

[6] According to Bell, the cruising speed of lamprey is 1 ft/sec, the sustained speed is nearly 3 ft/sec, and the darting speed is about 7 ft/sec. This compares with the speed of salmonids passing Columbia River dams: cruising, 4 ft/sec; sustained, 11 ft/sec (steelhead is more); and darting, over 20 ft/sec.

were in the Washington shore ladder, especially around the count station, crowder, and auxiliary water supply (Schwartz, personal communication).

According to the FFU workers at The Dalles Dam, the number rescued there (approximately 300) during the 1993-94 winter also appeared to be more than that rescued the previous winter. At John Day Dam, however, there was no great difference in numbers between this past winter and the previous winter. Approximately 1,600 lamprey were rescued from both ladders at the John Day Dam. Of these, only a little over 100 were found in the north ladder, the rest being found in the south ladder. Of the fishways in the three Corps operated dams, the John Day south ladder appears to be preferred by overwintering lamprey.

The lamprey run of 1993 as compared to past runs is discussed in detail under **Current Seasonal and Diel Pattern of Lamprey Activity Past Bonneville Dam** in this section. Suffice to say here that the 1993 run did not appear to be a large one. Therefore, it is interesting that more lamprey were rescued from The Dalles and Bonneville dam fishways after the 1993 run than after the 1992 run. This could mean that more lamprey began to migrate upriver late in the season (late September, October, November) in 1993 than did in 1992, but the total run in 1993 was not necessarily greater. At the Bonneville Dam Washington shore, the fish counters' estimates were increasing slightly at the end of September and early October (the estimates being: for September 30, 70; October 1, 24; October 2 and 3, 36 each day; October 4, 75; and October 5, 40) prior to the ending of data collection. Another explanation is that the apparent difference in lamprey rescued could simply be due to chance.

Turbines

Both adults and juveniles have been found in turbines when they have been dewatered. The adults have been found more often in the draft tubes and the juveniles in the scroll cases. If any juveniles were present in the draft tubes, it is unlikely they would have been seen because of the darkness of the facility. Further, the juveniles could have easily escaped notice because of the size of the net used in the rescue and the fact that the draft tubes drain into the grizzlies. It appears that adult lamprey, for the most part, are being rescued successfully from the draft tubes. Better than successful rescue, however, would be to prevent the lamprey from needing rescue in the first place. Procedures that are followed to benefit sturgeon should also benefit lamprey. The juveniles in the scroll case are another matter. It may have been expedient, if not totally desirable, to leave the 100 or so juvenile lamprey in the scroll case at John Day Dam in May 1993. Efforts need to be made to either prevent juvenile lamprey from being stranded when a turbine is dewatered or to effectively rescue them should they become stranded.

Juvenile Fish Guidance Systems

Lamprey Captured by NMFS During Smolt Monitoring and FGE Studies - The lamprey captured in the downstream migrant sampler at the Bonneville Dam first powerhouse had been guided into the juvenile bypass system. In contrast, some of the lamprey intercepted at the Bonneville Dam second powerhouse during FGE studies likely would have gone through the turbines had they not been captured. The bottom three nets in the fyke net array were low in the gatewell and animals caught in these were heading for the turbines (Monk, personal communication). Hammond (1979) cited Long (1968), who found that juvenile lamprey are concentrated toward the center and bottom of the turbine intakes. Survival of juvenile lamprey passing through turbines is not known.

The 19 adult lamprey captured in the downstream migrant system at the Bonneville first powerhouse and the single adult captured in the FGE testing at the Bonneville second powerhouse provide evidence that there is fallback of adults. There may be a relationship between fallback and flow; nearly half (47.4%) the actual numbers and 77.9% of the estimates (based on the sampling rate) were captured during the period of mid-May to mid-June when river flows and spill were high. Further study is required. The single adult captured in the FGE testing at the second powerhouse was apparently ill or injured. Total samples at the second powerhouse were too few to be able come to any conclusion concerning fallback on the Washington side.

Bonneville Dam, the Ice & Trash Sluiceway at the Second Powerhouse - It is likely that the dead lamprey and other fish found on the auxiliary water supply's intake bar screen had died before being washed into the channel for the ice and trash sluiceway. Fallback of live lamprey through the ice and trash sluiceway is unknown.

The Dalles Dam, the EBS - There are definite problems with the EBS for survival of juvenile lamprey. In the one instance in which the effects of the EBS on juvenile lamprey were observed, mortality was 100%.

STS's - It is likely that the STS's have an impact on juvenile lamprey, which may be severe. There is evidence of the lethal effect of the STS's in that, when the screens are pulled during the time of the lamprey downstream migration, lamprey are found impinged on them. How this mortality may affect the population of lamprey is not known, but it may be something to be concerned about. The impacts of STS's on juvenile lamprey should be further studied.

Navigation Lock

There is no evidence that the navigation locks have a substantial negative impact on lamprey. They may provide an alternative passage past the dams.

Past Runs of Adult Lamprey

If, as some assume, lamprey in the Columbia River have a seven year cycle, and assuming that the very heavy-run year of 1969 was a peak, then the previous peak years should have been 1962, 1955, 1948, and 1941. In 1962, however, the numbers had dropped after a peak in 1961. The year 1955 was one of several years during the 1950's in which the numbers were fairly low. In 1948, there was a small peak. In 1941, the numbers were low. While the comparison between Bonneville Dam counts and The Dalles Dam counts indicates that lamprey were either under counted at Bonneville Dam or over counted at The Dalles Dam (as more were counted over The Dalles than over Bonneville in the late 1950's and early 1960's)[7], the patterns of lamprey counts over the two dams are similar.

In looking at the actual pattern of run numbers over the 30 years the Corps counted lamprey (Figure 1), peaks in lamprey passage with intervals of from eight to ten years, rather than seven, is suggested. It seems less clear that low passage varies in any regular pattern. As discussed in the life history section, lamprey have a long life cycle. If there was little overlap in runs from various streams, it might be possible past years of high peaks were years in which the natural cycle for the Columbia River system were high.

The last year of counting, 1969, was a year in which the counts were extremely high. We examined possible run-cycles in various permutations of seven, eight, nine, and ten years, starting with 1969 which we assumed was the high year of a run-cycle (Table 10.) For the purposes of this exercise, we assumed that a year mid-way between two high years was the low year in the cycle. In looking at a total of 68 permutations, it appears that 1993 is a low year for five permutations, a high year for 14 permutations, and neither a high nor low year for 49 of the 68 permutations. It is unlikely, therefore, that Pacific lamprey in the Columbia River system have any regular cycle in their populations.

There is yearly variability in the timing of the runs and run-peaks as well in the total numbers (Table A-2, Figures A-1 through A-31). When considering daily passage throughout the season, the variability in lamprey passage is also high. Even during a peak in the run, numbers can be low one day and high the next. The low correlation of lamprey passage numbers and parameters in the river conditions shows evidence that time of lamprey passage is more dependent on factors intrinsic to the animal itself or to daily conditions at the dams (or to both) than on conditions in the river. Whether or not there is a relationship between turbine discharge and lamprey passage should be explored. But there is a strong likelihood that lamprey passage behavior is, at least in part, dependent on characteristics of the lamprey population.

The chaotic pattern of past runs suggests the possibility that, rather than just one run of lamprey into the Columbia River, there may be many sub-runs. The sub-runs could possibly

[7] Salmonids and shad have also sometimes shown higher counts at The Dalles Dam than at Bonneville Dam. Shad counts are frequently higher at The Dalles Dam (Annual Fish Passage Reports, U.S. Army Corps of Engineers).

consist of populations that spawn in particular drainages or of populations that enter the river at a particular time, independent of where they spawn.

Table 10: Permutations of various possible run-cycles of lamprey past Bonneville Dam showing two high years and one low year. The study year, 1993, is shown in boldface.

	High Years		
Permutation	First	Second	Low Yr
7 7 7 7	1990	1997	**1993**
7 7 7 8	1990	1998	1994
7 7 8 7	1991	1998	1994
7 8 7 7	1991	1998	1994
8 7 7 7	1991	1998	1994
7 7 7 9	1990	1999	1994
7 7 9 7	1992	1999	1995
7 7 7 9	1990	1999	1994
7 7 7 10	1990	2000	1995
7 7 10	1983	**1993**	1988
7 10 7	1986	**1993**	1989
10 7 7	1986	**1993**	1989
7 7 8 8	1991	1999	1995
7 8 7 8	1991	1999	1995
8 7 8 7	1992	1999	1995
8 7 7 8	1991	1999	1995
7 8 8 7	1992	1999	1995
7 7 9 9	1992	2001	1996
7 9 7 9	1992	2001	1996
9 7 9	1985	1994	1989
7 9 9	1985	1994	1989
9 9 7	1987	1994	1990
9 7 7 9	1992	2001	1996
7 7 10	1983	**1993**	1988
7 10 7	1986	**1993**	1989
10 7 10	1986	1996	1991
7 10 10	1986	1996	1991
10 10 7	1989	1996	1992
10 7 7	1986	**1993**	1989
8 8 8	1985	**1993**	1989
8 8 9	1985	1994	1989
8 9 8	1986	1994	1990
9 8 8	1986	1994	1990
8 9 9	1986	1995	1990

	High Years		
Permutation	First	Second	Low Yr
9 8 9	1986	1995	1990
9 9 8	1987	1995	1991
8 8 10	1985	1995	1990
8 10 8	1987	1995	1991
10 8 8	1987	1995	1991
8 10 10	1987	1997	1992
10 8 10	1987	1997	1992
10 10 8	1989	1997	**1993**
9 9 9	1987	1996	1991
9 9 10	1987	1997	1992
9 10 9	1988	1997	1992
10 9 9	1988	1997	1992
9 10 10	1988	1998	**1993**
10 9 10	1988	1998	**1993**
10 10 9	1989	1998	**1993**
10 10 10	1989	1999	1994
7 8 9	1984	**1993**	1988
8 7 9	1984	**1993**	1988
8 9 7	1986	**1993**	1989
7 8 10	1985	**1993**	1989
8 7 10	1984	1994	1988
8 10 7	1987	1994	1990
7 9 8	1985	**1993**	1989
9 7 8	1985	**1993**	1989
9 8 7	1986	**1993**	1989
7 10 8	1986	1994	1990
10 7 8	1986	1994	1990
10 8 7	1987	1994	1990
8 9 10	1986	1996	1992
9 8 10	1986	1996	1992
9 10 8	1988	1996	1992
8 10 9	1987	1996	1991
10 8 9	1987	1996	1991
10 9 8	1988	1996	1992

In considering any of the past counts, it should be kept in mind that they are not absolute figures, but only estimates. Lamprey can pass Bonneville without being counted. Slipping through the picketed leads or passing through the navigation lock are two possible routes. Further, the difficulty in counting large numbers of lamprey with their back-and-forth movement and habit of resting for long periods of time make it unlikely the numbers given as counts are the actual passage numbers. We do not know how much the past fish counters took this downstream movement into consideration. In the past, flashboard, rather than vertical slots were used in fish counting stations at Bonneville Dam. The flashboard system permitted more lamprey to pass the dam without being observed by the fish counters (Johnson, personal communication). It should also be noted that the counters actually count for only 50 minutes out of the hour. A 1.2 factor is applied to each hour's count to estimate the number of fish passing during the 10 minute hourly break. There is also the probability of fallback occurring, as was observed in 1993. Fallback might account for the count at The Dalles Dam being higher than the Bonneville count in the 1950's. Another factor is the high activity of lamprey at night, as observed by FFU personnel. Much of that activity might have been downstream, but there was likely a net upstream passage. Because of night passage, it is possible past counts are less than the actual numbers of lamprey that have passed Bonneville Dam. The past counts of lamprey, while estimates, are still useful for comparison purposes and can be used to determine population trends from 1938 through 1969.

1993 Seasonal and Diel Patterns of Lamprey Activity Past Bonneville Dam.

Fish Counter Estimates

The fish counters estimates should be used with the understanding that they are not actual passage numbers, but rather an index with which to compare annual trends. Estimation of numbers, even in checking a range of numbers, is a subjective process and each individual fish counter would approach it in a different way. Downstream movement was not asked for.

The total estimate of approximately 22,000 that was obtained by using the values of one-third the range checked is lower than any of the past annual counts. An assumption the actual values were always the maximum value in a range (unlikely) would yield 52,790, low compared to past counts. Only ten years (1942, 1944, 1945, 1950-1956) have lower counts. As further evidence that the 1993 lamprey run was probably low, the fish counters seldom (11 times or 0.57%) checked the range of 50 to 300 lamprey present. The range of 10 to 50 lamprey present was checked 19.27% and the range of over 300 lamprey present was never checked. (The range of 1 to 10 lamprey was checked 61.02% of the time; the range of zero lamprey present was checked 20.14% of the time. Further statistical comparison of the 1993 estimates with past counts (Appendix E) provides additional evidence that the 1993 estimated passage was low. Finally, there is the subjective evidence of the fish counters' impressions that the 1993 run was lower than recent past runs.

The differences in the seasonal passage pattern between Bradford Island and the Washington shore could have two explanations, one of which can easily be tested. During the season there were times, especially during salmon smolt passage, when the second powerhouse turbines were not operating. The difference in flow between the powerhouses may have influenced which ladder had the most lamprey passing at the time. For future studies, comparisons can be made between turbine discharge and lamprey passage at each ladder. Past data should be analyzed also. A second reason for the differences in passage could be that sub-runs of the population may have preferences for traveling one side of the river or the other. If passage over one ladder had been consistently lower than over the other, it could have been assumed that there was something in the ladders that either encouraged or discouraged passage. But such consistency did not occur.

Passage was generally highest in the first and last hours of the fish counting shifts. Comparing diel passage of the two ladders throughout the season shows there are differences. There was no consistency, either, with one ladder always showing one pattern and the other showing another.

Differences in passage could be explained by differences between the ladders during particular times during the season. That there may be differences between the ladders at different times during the season is possible. Turbine discharge from each powerhouse differed throughout the season. There may be other, more subtle, differences, as well. Correlation between turbine discharge and hourly estimates of lamprey passage can be tested. Such information might provide evidence of which conditions in the ladder and at ladder entrances are better for lamprey passage.

The statistical comparison of the 1993 hourly estimates with past hourly counts indicates differences in diel passage among all the years analyzed. The 1968 hourly count over Bradford Island showed a heavier midday passage than did the average of all years in which hourly counts or estimates are available. That year was a high passage year, although the following year, 1969, was even higher. The 1993 estimates showed a greater shift in passage to dawn and dusk than the average of all years. The year 1993 was an apparent low passage year. It could be inferred that, with higher numbers, more lamprey are apt to pass in the middle of the day than when the numbers are low. When the numbers are very low, even fewer lamprey appear to pass in the middle of the day, with comparatively more passing at dawn and dusk. In general, passage appears to be higher in the first and last few hours of counting. Even the Bradford Island 1968 count, which had higher mid-day passage than the other hourly counts, showed the typical U-shape with higher passage at dawn and dusk (Figure 7).

Sampling of Lamprey Passage

Sampling of lamprey passage by the FFU was not successful in determining an estimate of passage numbers. This was because of the high variability in both hourly passage and daily passage and the small number of sampling hours. Because of this high variability, it may have been difficult to devise any adequate number of sampling hours. The attempt to sample was useful, nevertheless. The samples were used to determine the average number of lamprey passing within each range as checked by the fish counters. Further, insights were obtained on lamprey behavior as they passed the fish count windows: back-and-forth movement was highest at dusk and at night, all activity was highest during night, evening, and early morning hours, lamprey rested for long periods of time either by clinging to the glass of the window or the bottom of the fish ladder, lamprey would swim at any height of the fish count window, they would often go downstream after a period of rest, often when moving downstream they appear to be swept involuntary by the current in a vertical position, and some would move upstream with their suctorial disks fastened to the bottom and their bodies at a 45 degree angle. Lamprey would also vary in size and, occasionally their colors would appear to vary, with some being darker or lighter in shade.

The FFU sampling included hours in which the fish counters were not on duty, these being from 2100 to midnight. Except for those periods in which lamprey passage estimates were very low or nearly zero (notably the Bradford Island ladder in the latter half of September), lamprey activity was high at night. Not all of this activity resulted in net upstream passage during the hour counted, however. Out of a total of 62 (17.7%) hours sampled at the Washington shore, net activity was downstream for 11 hours. For the Bradford Island ladder, there were five hours out of 63 sampled (7.9%) of net downstream passage. The highest net negative numbers were toward midnight. In at least one instance when the observer could distinguish an individual (because of a distinguishing mark), it passed back and forth at least twice.

Comparison of 1993 Data with Historical Counts

The analysis of the numbers of hours in which passage exceeded 50 or 300 lamprey provides further evidence of the relatively few numbers of lamprey in the 1993 run. In 1993, the numbers of hours in which passage exceeded 50 lamprey was 11, the lowest ever for those years in which hourly counts were available. The previous such low was in 1956 at the Cascades Island ladder, in which 38 hours had counts of 50 or more lamprey. When considering hours in which there were counts of at least 300 lamprey, only two years had zero such hours. These were 1993 and 1956. The 1956 Cascades Island ladder count was similar to passage estimates for both ladders in 1993. The Pearson correlations between total ladder counts (or estimates) and the number of hours with counts exceeding 50 (r=0.9369) or counts exceeding 300 (r=0.990811) are high.

Two things should be noted: the present day Washington shore ladder is an entirely different facility than the old Cascades Island ladder, and the fish counters' estimates may have noted lamprey activity, but not necessarily net passage. The differences in the Washington shore ladder between 1993 and the earlier years may make comparison difficult and the fact that net passage was not necessarily reflected in the estimates may mean that actual passage was less than indicated by the estimates. Neither the historic counts nor the 1993 estimates covered the hours between 2000 and 0500, therefore night passage was not counted.

Video-Taped Night Counts

Night passage was taped using lapse-time photography, in the 48 hour mode (recording intervals being 0.4 seconds). Because of this, the camera sometimes filmed a lamprey for only one frame. Such a lamprey would suddenly appear in mid-screen and then disappear, with no indication whether it was headed upstream or downstream. Further, the camera did not take in the full height of the window with the result that movement at the very top or bottom of the window was sometimes obscure. In addition, lighting at the bottom of the window was poor, such that the lamprey would often not be visible except when they moved. Add to these problems the usual difficulty in counting lamprey: movement back and forth, fast speeds and slow, and long periods of lamprey clinging to the window. The video-tapes can provide only estimates of lamprey passage at night. The estimates are likely good, however, and, if done over time, could provide information on trends. They also show the pattern of lamprey movement at night.

Only a few observations were made of the video-taped night passage for 1992 and 1993. What was seen was the same type of back-and-forth movement as was seen by the FFU observations. While total activity was high, net passage was low and, for some hours, negative. Both activity and net passage appeared to be greater in 1992 than in 1993, although the two years are not directly comparable because the 1992 video-taped counts were about a week later in June than those 1993 counts that have already been read. Further, in 1992 sampling for 15 minutes of each hour was done, and in 1993 the whole hour was counted. From even the slight evidence of observers, however, it is evident that lamprey become more active at night. This conforms with the literature, cited by Hardesty and Potter (1971), that stated lamprey prefer to migrate in darkness.

Conclusions about 1993 Lamprey Passage Past Bonneville

Numbers and Possible Population Trends - Lamprey passage in 1993 was probably low. All the evidence supports the reality of a low lamprey run: 1) low fish counter estimates, both in the total estimated value (whether using the maximum figure or the value derived from one-third the estimate range) and the extremely low number of hours that large numbers of lamprey passed; 2) the subjective impressions of the fish counters when asked to compare the run in 1993 with past runs they have observed; 3) the sampling by the FFU which, while not being adequate to estimate total population numbers, did show considerable net downstream movement in the late evenings; and 4) the video-taped night counts which supported the observation of high downstream movement and suggested possibly fewer lamprey in 1993 than in 1992. With the possible exception of the fish counter estimates, none of these by itself is adequate to show whether or not 1993 passage was low. Considering all these data and observations together, however, we conclude the 1993 lamprey run was among the low runs over Bonneville when compared with the historical data.

What cannot be said, however, is that the 1993 run was the lowest on record. Past counts are not absolute numbers on the lamprey population passing Bonneville Dam: lamprey slipping through the picketed leads or otherwise avoiding the fish count window would have caused an undercount, and possible failure on the fish counter's part to adequately account for downstream movement (when the runs were heavy, the fish counters could only estimate the numbers passing the fish count windows) would have caused an overcount. Fallback, if the lamprey re-ascended the ladders, would have also caused an overcount. This makes it difficult to compare any current estimates with past data. The 1993 data are not absolute numbers on the lamprey population, either, and this should always be kept in mind when considering the 1993 run. There were years in which the numbers were low in the past, especially some of the years in the 1950's. Past sources from the years after lamprey counting was stopped at Corps dams, indicate an impression of decline in lamprey numbers. Hammond (1979) stated that lamprey numbers, along with those of the anadromous salmon, have been declining since construction of the hydroelectric dams on the Columbia River system. This statement was made ten years after the high count year of 1969.

One year's worth of data is insufficient to determine a population trend. In considering the data from 1993, several possibilities come to mind: 1) 1993 was the year in which the lamprey were at the bottom of a cycle and greater numbers will, therefore, pass in subsequent years; 2) the 1993 run was an anomaly in a period when lamprey numbers are at least moderate; or 3) 1993 was part of a decline, perhaps serious, in which numbers will remain low or become even lower. The only way to determine which way the population trends are going is to continue evaluating lamprey passage for several more years. To do a full life-cycle evaluation, which would be best, could take as long as ten years. At minimum, the evaluation should be done for two or three more years.

Possible causes of the relatively low passage in 1993 are many. We know that lamprey successfully migrated both upstream and downstream until at least 1969, which was the last year the Corps counted them. The run in 1969 was exceptionally heavy. Any causes (other than assuming the 1993 run was part of the natural variation) would have to consider factors that are different now than they were in the first 30 years of Bonneville Dam's operation. The possibility of cumulative effects should also be considered. One or two or three dams might not cause a problem, but six or seven or eight might.[8] Moderate timber harvest in the watersheds where they spawn might not cause a problem, but extensive clear-cutting might. One factor alone might not cause a decline, but several combined might.

[8] There are four Corps operated dams on the Columbia River below the confluence with the Snake River and four more Corps-operated dams on the Snake River upstream from the Columbia River. Between Grand Coulee Dam and the Snake River there are six dams. That there were substantial numbers of lamprey spawning in the Snake River tributaries is illustrated by the tribal name of Asotin Creek, which enters the Clearwater River a few miles above the confluence of the Clearwater and the Snake rivers. The tribal name for that creek is Hasotino which means "The great eel fishery." (Parker, personal communication) Further evidence of lamprey in the Snake River prior to 1970 is the count of lamprey passing over Ice Harbor Dam, which ranged from nearly 5,000 in 1967 to over 49,000 in 1963 (Corps of Army Engineers, 1970).

Possible causes for a decline in a lamprey population can be divided into natural causes and manmade causes. Natural causes would include the effects of the recent El Niño current and the changes in the ocean which have affected many species of anadromous fish. Another possible natural cause is predation by marine mammals, particularly pinnipeds. Cooper and Johnson (1992) cited Roffe and Mate (1984) on the feeding habits of the California sea lion (*Zalophus californianus*), Stellar sea lion (*Eumetopias jubatus*), and Pacific harbor seal (*Phoca vitulina*). The principal food of those animals in the Rogue River (Oregon), by weight and frequency, was the Pacific lamprey. The principal manmade causes could be the dams, both mainstem and tributary, and habitat destruction. It should be kept in mind that, while natural causes, such as the El Nino, may be a contributing factor in any possible population decline, natural adverse effects are far worse on a population weakened from man-made causes than on an otherwise healthy population.

If dams significantly affect lamprey survival, there could be several causes. The reservoirs themselves may cause a problem. It is possible that lamprey juveniles are similar to salmonid smolts in that they rely on river flow to migrate to the ocean. Predation also may affect juveniles; given the opportunity northern squawfish (Ptychocheilus oregonensis) will take lamprey ammocoetes (Parker, personal communication) and Poe, et al, (1988) found lamprey, at a frequency of 1.1% occurrence, in the stomachs of northern squawfish caught in John Day reservoir. It is not known if passage through turbines adversely affects juvenile lamprey. Nitrogen supersaturation could adversely affect both adults and juveniles. Heavy flows from either spill, turbine discharge, or both, could cause delay and exhaustion. Exhaustion from ascending the fish ladders could cause some adults to fall back and, eventually die. Delay at the dams could increase the exposure of lamprey to disease. Hammond (1979) cited sources (Collins et al., 1975; Donaldson, 1979; Wallace, 1979) that indicated nitrogen supersaturation, turbines (including those that have STS's), delay of juveniles and adults, exhaustion, and disease might be responsible for death of lamprey and reduction in their numbers. Our direct observation of dead adults indicates that some adult mortality is a direct result of conditions at the dams, but it is not known if these losses could contribute significantly to any possible decline.

Except possibly for nitrogen supersaturation, the above factors have not changed significantly since the Corps stopped counting lamprey in 1969. The only difference in these factors has been that the number of dams in the Columbia River system increased after 1969. But they have not increased by many. Of the Corps operated dams on the Columbia-Snake system, only Little Goose and Lower Granite were not yet on line by 1969. Assuming a three year stay in the ocean for Columbia River basin lamprey, it is likely that dams built after 1966 would have had no effect on the 1969 run at the time they migrated as juveniles. Two dams, John Day (on the Columbia River) and Lower Monumental (on the Snake River) were built after 1966. The Bonneville Dam second powerhouse came on line in 1982.

It is thought that lamprey are not strong swimmers, at least on a sustained basis. They spend much time resting, holding onto a surface with their suctorial disks. Hypothetically, a strong flow, such as that at the dams could impede lamprey progress upstream and cause fallback. Natural rivers, however, also had areas of high flow, especially in rapids or waterfalls. Lamprey appeared to be able to negotiate these natural areas satisfactorily prior to the dams being built. There are differences between natural rapids and fish ladders. Fish ladders are longer and possibly provide fewer opportunities to rest. Analyzing the correlation between discharge and lamprey estimates (or counts, should that happen) could be done to determine if turbine discharge and spill have an effect on adult lamprey passage.

One factor that has changed since 1969 has been the installation of juvenile by-pass systems for smolts on many of the Columbia and Snake river dams. The STS's associated with the by-pass systems cause mortality of juvenile lamprey. What is not known is how much mortality they cause and if it could be a significant contribution to decline in populations. The effect of STS's and bar screens on juvenile lamprey mortality should be investigated further.

Habitat destruction could also be another possible cause of any population decline. Lamprey spawn in the headwaters where land use activities such as timber harvest or grazing occurs. For successful reproduction and juvenile rearing, lamprey require sandy gravel for spawning and silt, located in a stable environment with a slow and constant current, for rearing. The juveniles remain in the burrows for up to seven years. Thus any abrupt catastrophic change in the environment such as an earth slide could affect several year classes. Timber harvest increases the chances of earth slides and extremes in flooding or drought. The total annual timber harvest increased in Washington State from four or five million board feet prior to 1962 to over six and seven million board feet in the years (excepting 1981) 1962 through 1992 (Larsen, 1994). It is likely that timber harvest would show a similar increase in the other Pacific Northwest states. Further, the habitat changed by the annual timber harvest each year is in addition to habitat changed by timber harvest in previous years. To determine the possible effects of habitat changes on lamprey populations is beyond the scope of the Corps, but it would be well if a fisheries agency or land management agency were to investigate the situation.

There is risk in assuming that 1993 was simply the low point natural fluctuations. As Lawson (1993) stated in a discussion on the cycles of returning coho, these cycles can mask the decline in a population. During the natural high point of a cycle, it may appear the population is more abundant than it really is. When the natural low is reached, the low may be so low that the situation is critical, as is now the case with the Oregon coastal coho. When measures are taken to increase a population, the success or failure of such measures may not be immediately measured accurately because the natural cycle masks the effect of these measures. The possibility of a natural cycle occurring with the lamprey strengthens the case for the necessity of continuing the evaluation for a number of years.

Night Passage - In 1993, there was strong evidence that lamprey activity increased at night. Much of that activity, however, did not result in upstream migration. It is not known if this back-and-forth activity is typical of lamprey migration, whether in the river or in the fishway, or is caused by some factor in the fishway. Two factors to be considered are flow and light.

Personnel from the FFU noticed that sampling counts at dawn were more likely to be net upstream movement than sampling counts at dusk and at night prior to midnight. This suggests another possibility. The lamprey may, as a natural part of their migration, move restlessly back and forth at dusk prior to their night's migration upstream.

Thus, the back-and-forth movement seen at night should be observed further. Efforts should be made to determine if this movement is a natural part of the lamprey's migration or if there is a condition in the fishway that is impeding their progress.

Juvenile Lamprey Passage Patterns

Expanded numbers of juvenile lamprey captured at the Bonneville Dam first powerhouse downstream migrant sampler in the years since 1989 are sharply down. Even the slight increases in 1991 and 1993 (approximately 4,600 and 6,900, using NMFS' figures) do not indicate any real upturn. In 1992, the number was less than 600.

The expanded numbers of juveniles captured at the first powerhouse are probably a good representation of the actual numbers going through the downstream migrant system at the first powerhouse. They do not include lamprey going over the spillway, past the second powerhouse, or through the ice and trash sluiceway or turbines in the first powerhouse. Care should be taken in comparing these numbers from year to year. The proportion of juvenile lamprey going through the downstream migrant system to those passing the dam by another route may not be constant from year to year. In 1992, the project increased average daily spill from 30-35% of flow to 50% of flow (Maslen, personal communication). This could explain the abrupt drop in juveniles lamprey captured in 1992, as more juveniles may have gone over the spillway. It does not explain why the numbers increased in 1993. The difference between the 34,747 estimated lamprey in 1989 and the 526 estimated lamprey in 1992 (or even the approximately 5,800 to 6,900 in 1993) is of such a magnitude it seems possible that a real drop in juvenile migration is being demonstrated.

The apparent decline in lamprey numbers for the past few years may be part of a natural cycle, with the numbers eventually increasing. It may also be possible that 1989 was an unusually high year for downstream migration. If so, the adults from that migration should have returned in the time period from late 1990 to late 1992 or early 1993. Only anecdotal evidence exists for those lamprey runs. The fish counters remembered the years in the mid-1980's as being heavy lamprey migration years. Although, in their impressions, more lamprey returned in 1992 than in 1993 (two mentioned having to blow[9] them off the fish count window several times), the fish counters indicated that in the last two years the lamprey return was comparatively low. This, admittedly, sketchy evidence seems to indicate that either the

[9] At the Washington shore ladder, there was a device that blew compressed air across the facie of the window when it was activated by the fish counters. The purpose of the devise was to discourage lamprey from clinging to the window and blocking the fish counters' view of the fish.

1989 juvenile migration was not unusually high, or if it was, there was a high mortality on these lampreys.

Comparing the seasonal passage pattern of juvenile lamprey for 1989, 1990, and 1993 shows striking differences among these years. Each year differed in the month the highest seasonal peak occurred: from late March-early April to the first half of June. It is possible that each year's juvenile migration is from a different population, each with a different timing in its migration (Parties to U.S. v. Oregon). Diel data on the 1993 capture at the Bonneville Dam first powerhouse showed the highest numbers in the middle of the night, indicating a preference for migrating at night.

RECOMMENDATIONS

These recommendations are presented in two categories: recommended adjustments in structures and maintenance procedures that would affect lamprey and recommended areas of further study, including observations and record keeping.

Adjustments in Structures and Maintenance Procedures

Adult Fish Passage Facilities

Dewatering Practices - Because the behavior and morphology of lamprey differs from other fish, we recommend that some adjustments be made in the practices for dewatering the adult fish facilities. Except for lamprey that are freely swimming, we recommend that, at first, no attempt be made to forcibly remove them. Lamprey not swimming freely should then be gently removed from the surface to which they are attached, collected as they are found, and placed into water-filled containers for release into the forebay. This could be done by a worker following those crowding the other fish down the fishway; the worker would collect lamprey (and other fish) and hand them up to a person on the deck.

To discourage lamprey from slipping into inaccessible areas during ladder dewaterings, we recommend the following changes in dewatering practices be tried. Safety pools should be left in the ladder with water sufficient to allow safe rescue of lamprey, keeping in mind that they may try to seek more water or attempt to hide if the level gets too low. It should also be kept in mind that, without close scrutiny, it might be easy to miss the presence of lamprey, especially considering the water turbidity and dark color of the animals. Under the current practice in which radios are used to coordinate actions, stopping the pumping should be no problem, provided the pumping is being attended. Suggested depths, to be adjusted as experience determines: 1) at each weir, 6 inches; and 2) in the diffuser pools, varying depths starting at 2 feet, going down to 1 foot, then to 6 inches. At each depth, efforts should be made to net as many lamprey and other fish as possible. With this procedure, more lamprey could be rescued before they have a chance to move into inaccessible areas, such as below diffuser gratings. We recommend that measures be taken so that no area of the ladder is accidentally pumped dry before fish can be rescued.

It is recommended that during dewatering of the fish ladders, the crowder box assemblies be checked for lamprey as soon as the water level is safe to work in. If necessary, those sections of the picketed leads near the fish counting windows should be removed. This would permit access for rescuing lamprey in the vicinity of the crowder box assembly.

Because the chambered walls between the auxiliary water supply and the ladder at the Bonneville Dam Washington shore ladder may still be a potential problem for lamprey, we recommend that during or immediately after dewatering, the walled chambers be checked for the presence of lamprey. If there are any, they can be removed. If lamprey are consistently found inside the walled chambers, the project should explore additional methods to prevent the lamprey from gaining access to them.

A post-dewatering inspection or observation is also recommended to reduce mortality. This is important because lamprey tend to slip into inaccessible areas from which they may emerge later. In those instances in which there has been a post dewatering inspection, fish, including lamprey when they were abundant, have invariably been found. The areas in and around the crowders, especially in the auxiliary water supply area of the Bonneville Washington shore ladder and the area in the modified flow control section of the John Day south ladder, should be given close attention. An inspection should occur fairly soon after the dewatering if at all possible; waiting until the next day may be too late. The project could either send someone back to check the area after the dewatering or station someone to observe the area. The latter would be preferred, at least at first, in order to determine where the lamprey had been concealed and how long after dewatering they moved out. If the temperature was likely to drop below freezing during the night, it would be particularly important to have the post-dewatering observation the same day as the dewatering.

Structural Adjustments and Maintenance - Because it appears that lamprey will take advantage of any opening, projects should do all that is possible to prevent unnecessary gaps when making modifications to adult fishways. As an example, structures on the floor of the fishway should be flush with the floor. Corrective actions are recommended for the following areas of concern that have become apparent during the last two seasons of dewatering.

Bonneville Dam - The Bonneville project has made improvements in the Washington shore auxiliary water system. If numerous lamprey are still being found in that cul-de-sac by the fish crowder window slot, a barrier to prevent the lamprey from slipping through the picketed leads should be devised. We suggest that screening with a mesh of one-half to three- fourth inches be attached to the picketed leads in this and all locations. The other locations are: the picketed leads by the Bradford Island count station and the entrance to the old Cascades Island ladder.

John Day Dam - When the wooden miters (used as temporary flow modifications) were installed in the south ladder, some were not flush with the fishway floor and lamprey crawled into the gaps thus formed. The project has since sealed the gaps. A permanent solution would be best. Therefore we recommend that the project replace the temporary wooden structures with concrete ones as soon as it has been determined they are indeed beneficial in reducing fish holding or jumping (or both).

All Projects - There should be a continuation of the exploration of methods to locate and close gaps to prevent lamprey from moving under the crowders.

The projects have been diligent about fixing loose and torn gratings when found and this should continue. We recommend the projects also take measures, through frequent inspections, to prevent the occurrence of loose and torn gratings. A suggestion is to note in MFR's the number of torn and loose gratings and the number of times lamprey are found behind them.

Turbines

Dewatering Procedures - The first recommendation is to continue the procedure of immediately dropping the headgates and placing the tail logs when a turbine unit is turned off. This procedure, instituted to discourage sturgeon from entering the turbine draft tube could also discourage the same behavior in lamprey. We suggest, however, that a modification of this procedure be explored. The suggested steps would be as follows: 1) As is current procedure, if the turbine has been off for a period of time, start it again until there is a flow sufficient to flush fish out; 2) Remove the tail logs from the storage pit and place them in readiness on the deck.; 3) Partially lower the first tail log; 4) Stop the turbine in the normal manner; 5) Lower the tail log until it is in place; 6) Working as quickly as is safely possible, lower the rest of the tail logs alternately such that both bottom logs in each slot are in place first; and 7) Concurrently and as rapidly as possible, drop the headgates and bulkhead and dip the gatewell.

Dewatering of turbines in the summer during the downstream migration of lamprey juveniles will continue. We have two recommendations: 1) to prevent lamprey from getting down into the scroll case, the projects should use a finer mesh in the basket for dipping the gatewells; and 2) to salvage lamprey that do get into the scroll case, a method to more easily rescue lamprey from the turbine units should be developed.

Structural Adjustments - A further recommendation concerns the drains (also called grizzlies). The fast flow of water through the drains as the turbine is being dewatered impinges lamprey and other fish. If the diameter of the drain (but not the screen spacing) were made larger, the flow velocity would be reduced, thus decreasing the likelihood of impingement. It should be noted that the project has submitted a Quality Improvement Procedure (QIP) document that suggests doing this.

Juvenile Fish Guidance Systems

These appear to have a seriously negative effect on juvenile lamprey.

Submerged Traveling Screens (STS's) - For the present, we recommend that whenever STS's are pulled for maintenance or repair, the numbers of juvenile lamprey impinged be estimated and reported. Incidental catch of juvenile lamprey by the personnel involved in the smolt monitoring program should also be reported during the season. This includes lamprey observed in the downstream migrant sampler at the Bonneville first powerhouse and those caught in the FGE monitoring.

Extended Bar Screen (EBS) - We recommend that, considering the numbers that were impinged in 1993, the effect of the EBS on juvenile lamprey be a part of the EBS evaluation in future years.

FURTHER EVALUATIONS, OBSERVATION, AND RECORD KEEPING

Incidental Observations

We recommend that all lamprey observations on each project continue to be noted and reported for use in further study.

Possible Problem Areas

During future maintenance periods, all incidences in which lamprey are observed should be noted and reported for use in further studies. Further, we recommend that MFR's written on each dewatering include a description of the situation any lamprey are found and an evaluation of the results of the dewatering and rescue procedures. Of particular importance would be any incidences in which lamprey were observed slipping through any openings or lamprey were found trapped. Recommendations for improvements from project personnel should be encouraged.

Following are specific areas that should be observed to determine if they are problems for lamprey:

- We suggest the continued observation for the presence of lamprey, during the course of regular duties, in areas where there is low water flow. The area in the vicinity of the AFF at Bonneville Dam should especially be noted. At some future time, more intense observations to better determine the effect of low water flow on lamprey may be desirable. Any cul-de-sacs within the fish passage facilities should also be checked for the presence of lamprey.

- We suggest that the effect of crowders on lamprey be monitored to determine if significant numbers of lamprey become caught under them. It also should be determined if the lamprey die after being trapped, or if they are able to free themselves and pass upstream. The possibility of the lamprey already being dead and then washed under the crowders also needs to be explored.

Monitoring Lamprey Passage

- To monitor lamprey populations, we recommend that, at minimum, an evaluation of lamprey runs using fish counters' estimates be continued for at least two more years, and probably three. As a better approach, we further recommend commitment to a study, lasting from seven to ten years, in which lamprey passing Bonneville Dam are counted (including upstream, downstream, and net passage) along with the other fish.

- We recommend analyzing the correlation between discharge, both turbine and spillway, and lamprey estimates or counts to determine if turbine discharge or spill have an effect on adult lamprey passage. This should be done for several years worth of data, including data (assuming they can be found) for the past years in which hourly counts are available.

- We recommend further observation of night passage at Bonneville Dam, either by direct counting or through the use of video tapes. Direct counting would provide a more accurate value for net passage at night. As a further measure, efforts should be made to determine if the back-and-forth movement is a natural part of the lamprey's migration or if there is a condition in the fishway, such as lights or flow, that may be impeding their progress.

- To improve monitoring of lamprey, we recommend the floor of the fish counting windows be painted white and the floor be cleaned regularly with a brush suitable for the purpose. These measures would improve the ability to see lamprey resting along the bottom of the fish count windows.

Long Range Studies on Survival

We recommend that there be a long range study of the survival of juvenile lamprey as they pass the dams by various routes. This study should also include survival through turbines.

We recommend there be a study of the effects of predation on lamprey populations. The study should consider possible effects of the dams on the opportunities for predation. The possible predation of birds on juveniles and pinnepeds on adults should be included.

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APPENDICES

APPENDIX A

DAILY COUNTS OF PACIFIC LAMPREY PAST BONNEVILLE DAM FOR THE YEARS 1939-1969

Table A-1: Daily lamprey counts past Bonneville Dam from April 1 through November 10 for the years 1939-1969.

Table A-1 (Cont): Daily lamprey counts past Bonneville Dam from April 1 through November 10 for the years 1939-1969.

Table A-1 (Cont): Daily lamprey counts past Bonneville Dam from April 1 through November 10 for the years 1939-1969.

Table A-1 (Cont): Daily lamprey counts past Bonneville Dam from April 1 through November 10 for the years 1939-1969.

APPENDIX B

RELATIONSHIPS OF PAST LAMPREY COUNTS WITH SALMONID COUNTS AND SELECTED RIVER AND WEATHER CONDITIONS

correlation = -0.16

Figure B-1: Correlation between salmonid and lamprey counts over Bonneville Dam for the years, 1938-1969.

Figure B-2: Relationship between lamprey counts over Bonneville Dam and selected river and weather conditions for 1949.

Figure B-3: Relationship between lamprey counts over Bonneville Dam and selected river and weather conditions for 1953.

Figure B-4: Relationship between lamprey counts over Bonneville Dam and selected river and weather conditions for 1956.

Figure B-5: Relationship between lamprey counts over Bonneville Dam and selected river and weather conditions for 1962.

Figure B-6: Relationship between lamprey counts over Bonneville Dam and selected river and weather conditions for 1968.

insert Figure B-7

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insert Figure B-12

APPENDIX C

FISH COUNTERS' ESTIMATES

Table C-1: Estimated lamprey passage based on one-third of the estimate range.

May 1-May 21				May 22-Jun 11				Jun 12-Jul 2				Jul 3-Jul 23			
	Ladder				Ladder				Ladder				Ladder		
Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total
May 01	0	24	24	May 22	56	71	127	Jun 12	94	113	207	Jul 03	52	94	146
May 02	0	36	36	May 23	56	79	135	Jun 13	250	60	310	Jul 04	98	83	181
May 03	0	12	12	May 24	75	75	150	Jun 14	155	83	238	Jul 05	60	79	139
May 04	0	4	4	May 25	63	94	157	Jun 15	121	140	261	Jul 06	67	90	157
May 05	0	16	16	May 26	98	113	211	Jun 16	60	121	181	Jul 07	51	90	141
May 06	0	24	24	May 27	48	98	146	Jun 17	79	98	177	Jul 08	63	140	203
May 07	0	44	44	May 28	75	67	142	Jun 18	170	98	268	Jul 09	63	67	130
May 08	0	44	44	May 29	140	83	223	Jun 19	86	140	226	Jul 10	59	79	138
May 09	0	36	36	May 30	269	121	390	Jun 20	63	64	127	Jul 11	71	56	127
May 10	8	60	68	May 31	67	98	165	Jun 21	71	83	154	Jul 12	52	48	100
May 11	0	32	32	Jun 01	177	71	248	Jun 22	90	102	192	Jul 13	71	52	123
May 12	4	44	48	Jun 02	71	83	154	Jun 23	117	64	181	Jul 14	82	83	165
May 13	16	28	44	Jun 03	79	75	154	Jun 24	60	52	112	Jul 15	90	64	154
May 14	16	44	60	Jun 04	246	64	310	Jun 25	44	140	184	Jul 16	63	40	103
May 15	16	44	60	Jun 05	151	113	264	Jun 26	71	83	154	Jul 17	75	36	111
May 16	32	98	130	Jun 06	56	79	135	Jun 27	71	83	154	Jul 18	55	59	114
May 17	32	155	187	Jun 07	121	83	204	Jun 28	75	79	154	Jul 19	78	71	149
May 18	59	178	237	Jun 08	71	56	127	Jun 29	64	60	124	Jul 20	44	117	161
May 19	40	90	130	Jun 09	79	102	181	Jun 30	36	83	119	Jul 21	56	98	154
May 20	56	121	177	Jun 10	98	98	196	Jul 01	63	83	146	Jul 22	52	90	142
May 21	94	117	211	Jun 11	288	83	371	Jul 02	102	79	181	Jul 23	132	94	226

Table C-1(Cont): Estimated lamprey passage based on one-third of the estimate range.

Jul 24-Aug 13				Aug 14-Sep 3				Sep 4-Sep 24				Sep 25-Oct 5			
	Ladder				Ladder				Ladder				Ladder		
Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total	Date	Brad Isl	Wa Shore	Daily Total
Jul 24	71	121	192	Aug 14	109	55	164	Sep 4	59	48	107	Sep 25	32	44	76
Jul 25	86	109	195	Aug 15	109	71	180	Sep 5	51	66	117	Sep 26	35	24	59
Jul 26	82	102	184	Aug 16	101	63	164	Sep 6	36	59	95	Sep 27	43	40	83
Jul 27	67	121	188	Aug 17	59	63	122	Sep 7	28	28	56	Sep 28	16	28	44
Jul 28	43	140	183	Aug 18	90	63	153	Sep 8	24	47	71	Sep 29	4	20	24
Jul 29	78	174	252	Aug 19	66	67	133	Sep 9	47	55	102	Sep 30	16	70	86
Jul 30	94	86	180	Aug 20	90	56	146	Sep 10	67	44	111	Oct 01	44	24	68
Jul 31	86	79	165	Aug 21	128	40	168	Sep 11	51	31	82	Oct 02	20	36	56
Aug 01	59	48	107	Aug 22	62	90	152	Sep 12	20	44	64	Oct 03	24	36	60
Aug 02	136	63	199	Aug 23	78	71	149	Sep 13	47	32	79	Oct 04	16	75	91
Aug 03	231	117	348	Aug 24	97	102	199	Sep 14	24	70	94	Oct 05	12	40	52
Aug 04	132	121	253	Aug 25	101	83	184	Sep 15	28	28	56	Totals	10,675	11,691	22,366
Aug 05	140	227	367	Aug 26	86	98	184	Sep 16	43	44	87				
Aug 06	59	223	282	Aug 27	40	52	92	Sep 17	8	24	32				
Aug 07	75	219	294	Aug 28	28	59	87	Sep 18	12	28	40				
Aug 08	192	109	301	Aug 29	12	101	113	Sep 19	4	16	20				
Aug 09	101	78	179	Aug 30	40	67	107	Sep 20	12	20	32				
Aug 10	71	48	119	Aug 31	32	67	99	Sep 21	0	47	47				
Aug 11	98	78	176	Sep 01	28	67	95	Sep 22	8	36	44				
Aug 12	90	56	146	Sep 02	20	75	95	Sep 23	0	40	40				
Aug 13	227	36	263	Sep 03	93	55	148	Sep 24	24	32	56				

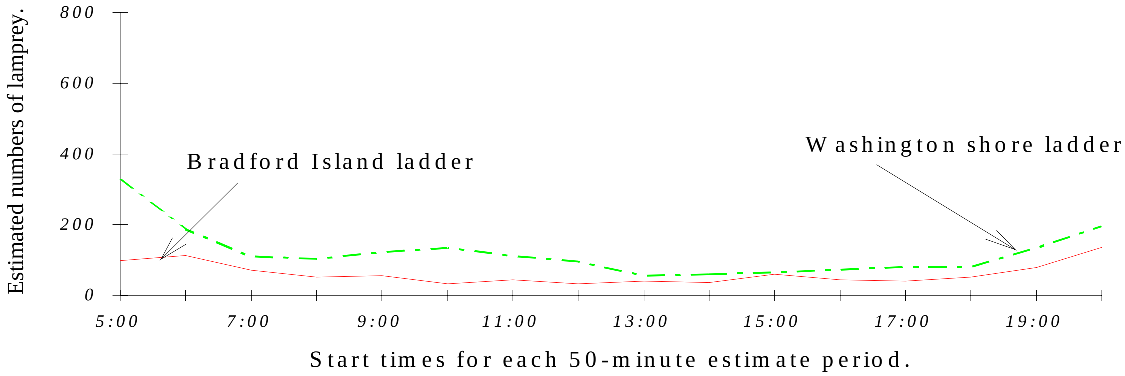

Figure C-1: Comparison of Bradford Island and Washington shore diel passage of lamprey for May 1-29, 1993.

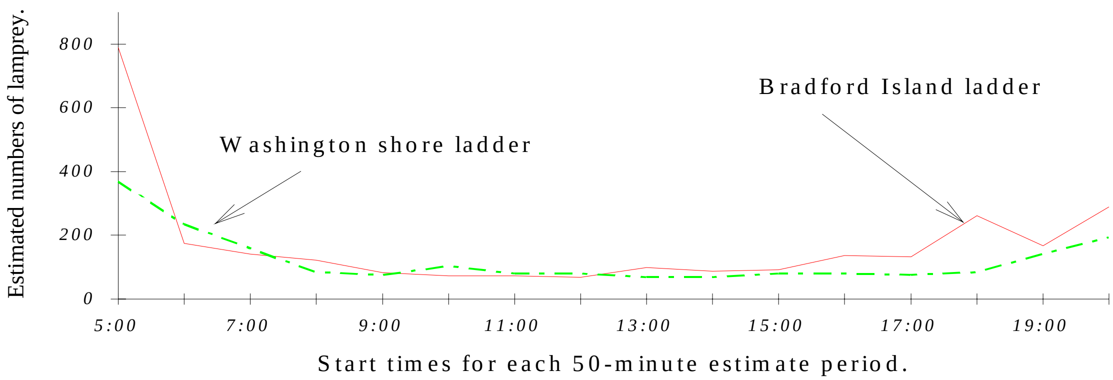

Figure C-2:Comparison of Bradford Island and Washington shore diel passage of lamprey for May 30-June 19, 1993.

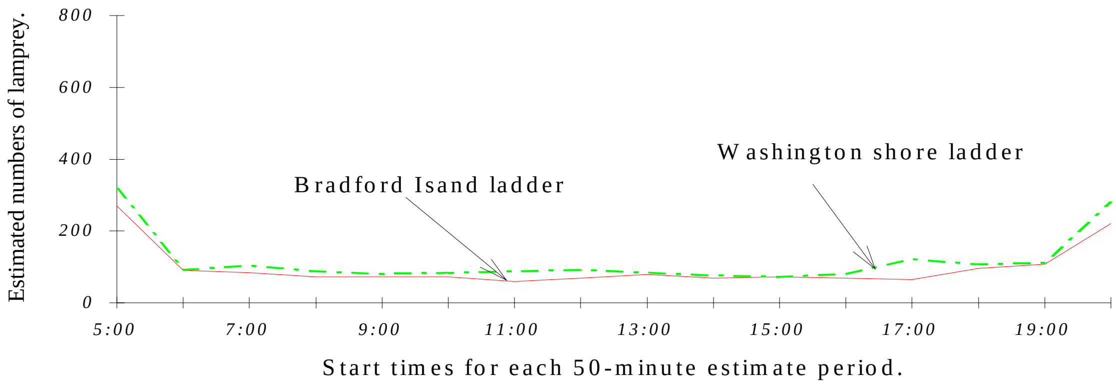

Figure C-3:Comparison of Bradford Island and Washington shore diel passage of lamprey for June 20-July12, 1993.

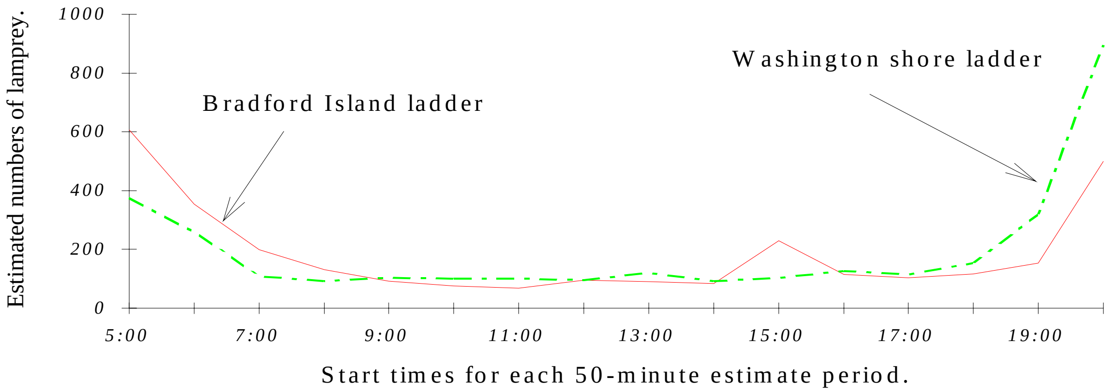

Figure C-4: Comparison of Bradford Island and Washington shore diel passage of lamprey for July 13-August 13, 1993.

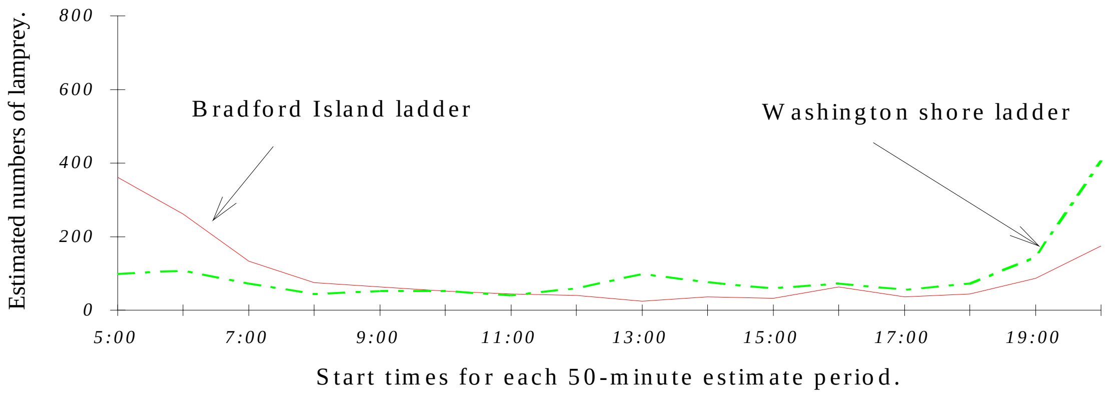

Figure C-5: Comparison of Bradford Island and Washington shore diel passage of lamprey for August 14-September 4, 1993.

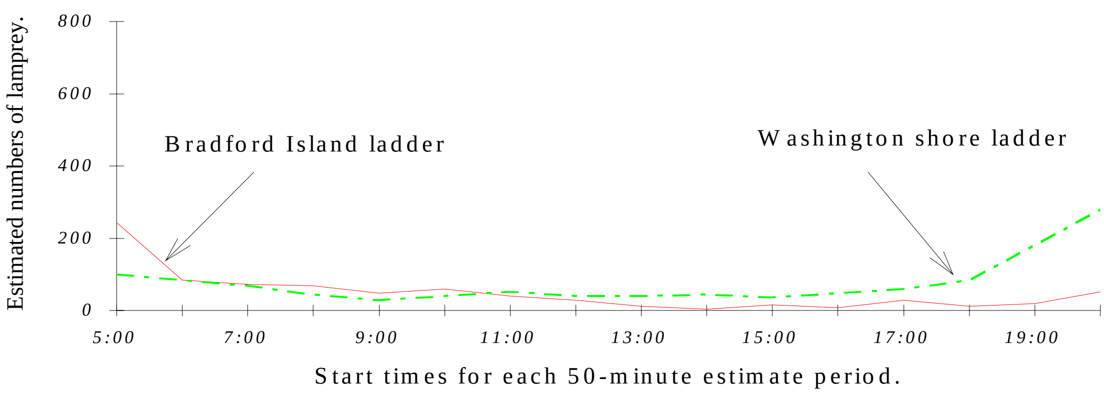

Figure C-6: Comparison of Bradford Island and Washington shore diel passage of lamprey for September 5-October 5, 1993.

insert Figure C-7

insert Figure C-8

APPENDIX D

SAMPLING BY THE FISHERIES FIELD UNIT

Insert Figure D-1.

Insert Figure D-2

Insert Figure D-3

Insert Figure D-4

Insert Figure D-5

Insert Figure D-6

Insert Figure D-7

Insert Figure D-8

Insert Figure D-9

APPENDIX E

STATISTICAL ANALYSES: STABILITY TEST OF THE RANDOM SAMPLING TECHNIQUE, NUMBER OF DAYS WITH HIGH COUNT HOURS, VARIABILITY OF COUNTS, COUNT PATTERNS, AND DURATION OF RUN-PULSES

STABILITY TEST OF THE RANDOM SAMPLING TECHNIQUE

The FFU random sampling technique consisted of selecting 18 samples for every three week period for each ladder which can be tested for stability by applying it to a past count year for which a full hourly count is available. When this sampling method is applied to a past count by drawing two samples (one being the 1993 Bradford Island sampling hours and the other being the 1993 Washington shore sampling hours) from the same set of numbers, the two samples should contain F-test type within groups variance only. In other words, the two sets of numbers should not vary significantly from each other. Six scattergrams (figures E-1 through E-6) that display the results of drawing two samples from the same data set were prepared for the 1956, 1966, and 1967 old Cascades Island samples. Within groups variance, presented as an F ratio, for each of these pairs of samples is:

	F test	
1956	1.09	ns
1966	1.04	ns
1967	5.58	$p<.01$, df=37/35

in which ns = not significant, p = probability, and df = degrees of freedom, as was presented in the results. The 18 samples per three weeks per ladder were insufficient.

NUMBER OF DAYS WITH HIGH COUNT HOURS

A total of 10 scattergrams were prepared, two each for the Cascade Island counts 1956, 1966, and 1967, and one each for each ladder for 1968 and 1993. For the 1956, 1966, and 1967 counts, the sampled hours of both the 1993 data, Washington shore and Bradford Island were used. For 1968 and 1993, only the sampled hours of each corresponding ladder were used. Circled numbers in the scattergrams are contiguously connected to run-pulses of at least one hour duration. The number and average duration, in hours, of the run-pulses for each year detected by the 1993 sampling technique are presented in Table E-1.

A correction factor of 0.73 (66 divided by 90) was then added to each number in the duration column because 66 of the total 90 pulses were contiguous to samples greater than 10, indicating the presence of the small run within that sample hour. Because a small run could not be said to have been revealed in a sample count of less than 10 lamprey, circled scattergram samples of less than 10 were subtracted out. The results are presented in Table E-2.

Table E-1: Run-pulses, in number and average duration, detected by the 1993 sampling method for each year and ladder.

Year	Ladder	Duration	Number
1956	Casc Isl	4.8	14
1966	Casc Isl	4.4	23
1967	Casc Isl	6.9	12
1968	Casc Isl	7.1	12
1968	Brad Isl	9.4	18
1993	Brad Isl	2.2	4
1993	Wash Sh	2	7

Table E-2: Run-pulses detected by the sampling method with the correction factor of 0.73 and subtracting out samples of less than 10.

Year	Ladder	Duration	Number
1956	Casc Isl	4.4	11
1966	Casc Isl	5.2	16
1967	Casc Isl	7.9	9
1968	Casc Isl	10	8
1968	Brad Isl	10.1	15
1993	Brad Isl	2.0	3
1993	Wash Sh	2.0	4

A 1.0 correction has been added to each number in the duration column because all detecting samples are greater than 10, and are part of the small run. The actual number and duration of the run-pulses present in these years can be seen in Table E-3.

Numbers of lamprey in each pulse detected by the random sampling method are presented in Table E-4. These include pulses of only one hour duration and are for all years and ladders for which there are hourly counts or estimates. Because hourly runs were available only for the Cascades Island ladder in 1956, 1966, and 1967, both the Bradford Island and Washington shore sampling hours are used for these years. Only Bradford Island sampling hours are used for Bradford Island counts and estimates in 1968 and 1993, and only Washington shore sampling hours are used for Cascades Island counts in 1968 and Washington shore estimates in 1993.

Table E-3: Actual number and average duration of run-pulses for those years and ladders hourly counts or estimates are available.

Year	Ladder	Duration	Number
1956	Casc Isl	2.3	110
1966	Casc Isl	2.4	153
1967	Casc Isl	2.8	90
1968	Casc Isl	3.6	151
1968	Brad Isl	4.5	189
1993	Brad Isl	1.4	136
1993	Wash Sh	1.4	131

The scattergrams were then used to determine to determine how well the FFU samples and the fish counter's estimates correlate for the hour sampled. Lines drawn in the figures break significantly different groups of numbers as explained in **METHODS**. Circles indicate that a count (or, in 1993, estimate) of 10 or greater preceded or followed that hour. The hours before or after the sampling hour were used in this analysis to avoid the possibility that the presence of the sampler from the FFU might have biased the fish counter's estimate.

Using the Pearson product moment correlation, fish counters' estimates correlate r=.67 (significant) with sample counts at the Washington shore ladder and r=.66 (significant) with sample counts at the Bradford Island ladder. For prior year counts, circled counts correlate between r=.6 and r=.7 (all significant) with the greater of the preceding or following count. Therefore, the estimates correlate well with the samples.

VARIABILITY OF COUNTS

The numbers of days for each ladder and year for counts exceeding 10 are significantly variable (Chi square, 35.5; p <.01). Calculating the four Cascade Island numbers and the numbers for the three contiguous Cascade Island years separately shows these to be also significantly variable (Chi squares, 14.1 and 10.0; p<.01). Days for counts exceeding 50 and 300 are also significantly variable for all years and ladders.

Table E-4: Numbers of lamprey in each run-pulse detected by the random sampling method as applied to all years for which hourly counts or estimates are available. Application of Bradford Island 1993 sampling hours and the Washington shore 1993 sampling hours are presented separately.

Bradford Island Ladder Sampling Hours

Cascades Island Ladder (WA)			*Bradford Island Ladder*	
1956	1966	1967	1968	1993
21	31	36	30	51
13	26	41	15	45
57	19	29	14	12
32	34	10	119	10
	17		38	16
	16		57	39
	75		86	16
	51		78	
	32		21	
			137	
			46	
			11	
			17	

Washington Shore Ladder Sampling

Cascades Island Ladder (WA)				*WA Shore*
1956	1966	1967	1968	1993
15	16	27	27	20
33	51	26	13	40
16	37	136	20	24
10	35	31	103	11
18	20	29	14	10
12	61		124	15
10	21		39	17
141			20	11
				15

Bradford Island Samples, Numbers Averaged

Cascades Island Ladder (WA)			*Bradford Island Ladder*	
1956	1966	1967	1968	1993
30.8	33.4	29.0	68.4	27.0

Washington Shore Samples, Numbers Averaged

Cascades Island Ladder (WA)				*WA Shore*
1956	1966	1967	1968	1993
31.9	34.4	49.8	45.0	18.1

COUNT PATTERNS

Lamprey swimming through the Bonneville ladders were counted 16 hours each day. This presented 15 opportunities each day for the counts to change from one range to another. Range drops (changes from a higher range of estimates to a lower range) for all ranges occurred in the patterns presented in Table E-5. In the table, hour 2 represents the change from the hour beginning 05:00 to the hour beginning 06:00, hour 3 represents the change from the hour beginning 06:00 to the hour beginning 07:00, and so on until hour 16 which represents the change from the hour beginning 19:00 to the hour beginning 20:00.

Table E-5: Total number of times lamprey numbers changed from a higher range to a lower range for each year and ladder.

	Hour that Range Changes Ended														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1956/Casc Isl	17	10	4	1	1	3	2	2	3	4	5	2	5	2	0
1966/Casc Isl	37	6	3	1	0	2	0	2	2	4	5	3	7	3	1
1967/Casc Isl	12	10	6	8	0	2	1	0	1	2	2	2	4	2	0
1968/Casc Isl	25	9	7	10	2	3	1	6	6	3	4	10	4	4	2
1968/Brad Isl	24	25	16	20	17	11	6	7	5	7	4	5	13	2	3
1993/Wash Sh	34	16	7	0	2	2	0	2	1	0	0	1	1	2	0
1993/Brad Isl	43	24	9	3	1	0	0	0	2	0	3	4	1	3	2

The above patterns were combined and averaged and the resulting average compared to each year's pattern. The results (Table E-6) show that the 1968 Bradford Island counts shifted from the average toward the center and both 1993 estimates shifted from the average toward the edge, or the first hours of counting.

Table E-6: Significance ($p<.01$ as standard) of shifts away from the averaged patterns of range decreases, combined.

1956/Casc Isl	19.21	(ns)
1966/Casc Isl	27.18	(ns)
1967/Casc Isl	26.14	(ns)
1968/Casc Isl	25.69	(ns)
1968/Brad Isl	51.1	($p<.01$, df=14) shift toward center
1993/Wash Sh	33.35	($p<.01$, df=14) shift toward edge
1993/Brad Isl	27.32	(ns) (at $p<.02$), shift toward edge

The shifts in 1968 for the Bradford Island ladder and in 1993 for both ladders mean that there was a significant difference in these patterns from the average of all patterns.

Range increases for all ranges occurred in the following patterns, as presented in Table E-7. As in Table E-5, hour 2 represents the change from the hour beginning at 05:00 to the hour beginning 06:00, and so on.

Table E-7: Total number of times lamprey numbers changed from a lower range to a higher range for each year and ladder.

	Hour that Range Changes Ended														
	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1956/Casc Isl	2	1	2	2	0	3	7	4	7	8	8	6	3	18	32
1966/Casc Isl	0	0	1	1	0	0	5	7	11	11	11	9	10	36	60
1967/Casc Isl	4	5	3	1	2	2	4	1	9	6	4	9	4	10	25
1968/Casc Isl	0	2	7	2	9	3	10	7	12	13	16	11	9	16	38
1968/Brad Isl	5	8	10	8	8	3	7	12	18	12	8	12	13	17	30
1993/Wash Sh	1	2	1	2	2	0	0	2	0	0	1	3	1	19	50
1993/Brad Isl	4	4	1	0	0	0	0	3	0	2	4	2	4	7	33

The same procedure was done for the above patterns. These results (Table E-8) again show that the 1968 Bradford Island counts shifted from the average toward the center and both 1993 estimates shifted from the average toward the edge, or, in this case, the last hours of counting.

Table E-8: Significance (p<.01 as standard) of shifts away from the averaged patterns of range increases, combined.

1956/Casc Isl	12.25	(ns)
1966/Casc Isl	15.65	(ns)
1967/Casc Isl	16.14	(ns)
1968/Casc Isl	23.92	(ns)
1968/Brad Isl	31.69	(p<.01, df=14) shift toward center
1993/Wash Sh	46.62	(p<.01, df=14) shift toward edge
1993/Brad Isl	36.08	(p<.01, df=14) shift toward edge

These results indicate that for 1993, in comparison with the average of all years and ladders, activity was highest in the early morning hours and late evening. In contrast, for 1968 in comparison with the average, activity was higher in the middle of the day. When the range increases and decreases for those ranges with higher numbers (50 to 300 and greater than 300) are arranged in the same manner, the patterns of diel differences become even more pronounced.

Range drops from the 50-300 and greater than 300 ranges are presented in the following table.

Table E-9: Number of times lamprey numbers dropped from either the 50-300 or greater than 300 ranges to a lower range, for each year and ladder.

Hour that Range Changes Ended

	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1956/Casc Isl	2										1	1	1	1	
1966/Casc Isl	8	1								1	1		1		1
1967/Casc Isl	1	3										1	2	1	
1968/Casc Isl	3	2	2	1	3			2		1		5	1		1
1968/Brad Isl	8	8	4	7	8	1	4	2	1	1	2		4	3	2
1993/Wash Sh															
1993/Brad Isl	5										1			1	

Range increases from the 50-300 and greater than 300 ranges are presented in the following table.

Table E-10: Number of times lamprey numbers increased from either the 50-300 or greater than 300 ranges to a higher range, for each year and ladder.

Hour that Range Changes Ended

	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1956/Casc Isl										1	3	1		5	15
1966/Casc Isl									2	1	2	1	2	11	41
1967/Casc Isl							1		2			3	1	4	11
1968/Casc Isl			3				2	1	4	3	9	1	2	5	21
1968/Brad Isl	3	2	4	1	2	1	3	4	6	4	2	6	6	10	11
1993/Wash Sh															3
1993/Brad Isl											1		1		1

These patterns show not only differences among the years, but also differences between the 1993 Washington shore and Bradford Island ladders. The higher activity for Bradford Island in the first hour as compared with the rest of the day is especially pronounced. It is apparent that the 1968 Bradford Island passage (a year in which the count was the highest of all the past counts) had much shifting into and out of the higher ranges all through the day.

DURATION OF RUN-PULSES

Table 7, presented in **RESULTS**, shows the number and duration of run-pulse for each year and ladder for which hourly counts or estimates are available. When these years are compared to each other to determine the significance and direction of duration changes, the following Chi square values, presented in Table E-11, were obtained.

Table E-11: Determination of significance and direction of duration of changes when years and ladders are compared with each other, in Chi square values.

Year	Ladder	1956 Casc Isl	1966 Casc Isl	1967 Casc Isl	1968 Casc Isl	1968 Brad Isl	1993 Wash Sh	1993 Brad Isl
1956	Casc Isl	----	4.50	8.63	13.99	30.35	25.75	21.55
1966	Casc Isl		----	17.68	23.81	42.15	29.57	24.45
1967	Casc Isl			----	7.20	26.69	39.56	31.49
1968	Casc Isl				----	13.76	50.96	44.21
1968	Brad Isl					-----	86.63	78.24
1993	Wash Sh						----	2.19
1993	Brad Isl							-----

Further analyses are presented in Tables E-12 through E-14.

Table E-12: Statistical analysis comparing years and ladders with each other to determine the significance and direction of changes in duration of the run-pulses: associated degrees of freedom.

Year	Ladder	1956 Casc Isl	1966 Casc Isl	1967 Casc Isl	1968 Casc Isl	1968 Brad Isl	1993 Wash Sh	1993 Brad Isl
1956	Casc Isl	----	8	8	9	9	7	7
1966	Casc Isl		----	9	9	9	7	7
1967	Casc Isl			----	8	9	7	8
1968	Casc Isl				----	9	8	8
1968	Brad Isl					-----	8	8
1993	Wash Sh						----	3
1993	Brad Isl							-----

(For many of these comparisons, to maintain required duration estimates of at least 1 as required by these test, duration ranges had to be expanded, thereby reducing the values for degrees of freedom.)

Table E-13: Statistical analysis comparing years and ladders with each other to determine the significance and direction of changes in duration of the run-pulses: significance.

Year	Ladder	1956 Casc Isl	1966 Casc Isl	1967 Casc Isl	1968 Casc Isl	1968 Brad Isl	1993 Wash Sh	1993 Brad Isl
1956	Casc Isl	----	ns	ns	ns	p<.001	p<.001	ns
1966	Casc Isl		----	ns	ns	p<.001	p<.001	p<.001
1967	Casc Isl			----	ns	ns	p<.001	p<.001
1968	Casc Isl				----	ns	p<.001	p<.001
1968	Brad Isl					-----	p<.001	p<.001
1993	Wash Sh						----	ns
1993	Brad Isl							-----

Table E-14: Statistical analysis comparing years and ladders with each other to determine the significance and direction of changes in duration of the run-pulses: direction of significance.

Year	Ladder	1956 Casc Isl	1966 Casc Isl	1967 Casc Isl	1968 Casc Isl	1968 Brad Isl	1993 Wash Sh	1993 Brad Isl
1956	Casc Isl	----				up	down	(down)
1966	Casc Isl		----		(up)	up	down	down
1967	Casc Isl			----		(up)	down	down
1968	Casc Isl				----		down	down
1968	Brad Isl					-----	down	down
1993	Wash Sh						----	
1993	Brad Isl							-----

Directions in parenthesis were significant at the .01 level.

The figures on the following pages (E-1 though E-10) are the scattergrams used in the analyses of high-count hours and number and duration of pulse-runs.

	--- May ---					--- June ---					--- July ---						--- August ---								--- Sept ---		
hours:	**3**	**11**	**21**	**25**	**26**	**4**	**8**	**14**	**24**	**29**	**9**	**11**	**16**	**18**	**21**	**26**	**2**	**6**	**7**	**17**	**18**	**23**	**29**	**30**	**10**	**17**	**24**
6			0	0					1		13							32				6					
7						0															6			0			
8							0																			0	
9																	0										1
10								0																	0		
11										2			0		8	1											
12				0					0	0												0					
13								0									0						0				
14			0			0	0																		0		
15														1		5			4								
16												1			57											4	
17																				7					0		0
18																			4								
19							0			21							1										
20																										6	

Figure E-1: Scattergram used in analyses of the old Washington shore ladder (Cascades Island ladder)1956 lamprey counts using the FFU 1993 sampling hours for the Bradford Island ladder.

	--- May ---					--- June ---					--- July ---							-- August --						--- Sept ---		
hours:	6	17	18	19	31	3	9	19	23	26	3	12	19	21	24	29	30	9	13	16	21	26	27	8	13	22
6				0			0									4						4				
7									0		1								12						0	0
8						0		0																		
9														16												
10		0								0		5			0											
11					0																0			0		
12						0		0		1													0			
13			0								0		3								3			0		
14									0						4			0								
15		0			0												18									
16																				10						0
17							0					15													0	
18													33									0				0
19							0	0																		
20		1	1												10					141						

Figure E-2: Scattergram used in analyses of the old Washington shore ladder (Cascades Island ladder)1956 lamprey counts using the FFU 1993 sampling hours for the Washington shore ladder.

hours:	May 3	May 11	May 21	May 25	May 26	June 4	June 8	June 14	June 24	June 29	July 9	July 11	July 16	July 18	July 21	July 26	Aug 2	Aug 6	Aug 7	Aug 17	Aug 18	Aug 23	Aug 29	Aug 30	Sept 10	Sept 17	Sept 24
6		0	3	0					1		19							75				2					
7	0					0															2			0			
8							4																			1	
9																	0										0
10								0																	0		
11										3			6		0	3											
12				0					4	7												0					
13		0						5									1						0				
14	0		0			0	3																		0		
15														17		9			51								
16												34			8											0	
17																				1					1		0
18																			32								
19							31			26							16										
20	0																									4	

Figure E-3: Scattergram used in analyses of the old Washington shore ladder (Cascades Island ladder) 1966 lamprey counts using the FFU 1993 sampling hours for the Bradford Island ladder.

hours:	May 6	May 17	May 18	May 19	May 31	June 3	June 9	June 19	June 23	June 26	July 3	July 12	July 19	July 21	July 24	July 29	July 30	Aug 9	Aug 13	Aug 16	Aug 21	Aug 26	Aug 27	Sept 8	Sept 13	Sept 22
6				1			2									8						1				
7									2		0								1						1	0
8	0					0		0																		
9														0												
10		0								0		2			2											
11					0																0			0		
12						0		1		5													0			
13			0								0		1								2			0		
14									2						1			4								
15		0			0												4									
16																				4						0
17	0						16					35													0	
18													20									1				0
19							51	37																		
20		0	0												61					21						

Figure E-4: Scattergram used in analyses of the old Washington shore ladder (Cascades Island ladder) 1966 lamprey counts using the FFU 1993 sampling hours for the Washington shore ladder.

	--- May ---					--- June ---					--- July ---						--- August ---								--- Sept ---		
hours:	3	11	21	25	26	4	8	14	24	29	9	11	16	18	21	26	2	6	7	17	18	23	29	30	10	17	24
6		1	6	0					1		2							3				2					
7						0															3			0			
8							0																			0	
9																	1										0
10								0																	0		
11										2			8		1	0											
12				0					2	2												0					
13		0						0									1						0				
14			7			1	0																		0		
15														41		3			1								
16												36			29											0	
17																				6					1		0
18																			2								
19							0			2							10										
20																										0	

Figure E-5: Scattergram used in the analyses of the old Washington shore ladder (Cascades Island ladder) 1967 lamprey counts using the FFU 1993 sampling hours for the Bradford Island ladder.

	--- May ---					--- June ---					--- July ---							--- August ---						--- Sept ---		
hours:	6	17	18	19	31	3	9	19	23	26	3	12	19	21	24	29	30	9	13	16	21	26	27	8	13	22
6				1			0									1						0				
7									1		1								29						0	0
8	0					0		4																		
9														2												
10		0								0		2			0											
11					0																1			0		
12						1		0		3													1			
13			0								3		26								0			0		
14									1						8			0								
15		0			0												7									
16																				2						0
17	0						0					27													0	
18													136									0				0
19							0	0																		
20		3	6												31					14						

Figure E-6: Scattergram used in the analyses of the old Washington shore ladder (Cascades Island ladder) 1967 lamprey counts using the FFU 1993 sampling hours for the Washington shore ladder.

--- May --- --- June --- --- July --- --- August --- ---- Sept --

hours:	3	11	21	25	26	4	8	14	24	29	9	11	16	18	21	26	2	6	7	17	18	23	29	30	10	17	24
6			1	15					1		78							36				1					
7						8															11			17			
8							38																			0	
9																	137										0
10								1																	0		
11										0			2		1	13											
12				14					1	0												1					
13								5									46						1				
14			30			119	57																		1		
15														5		4			8								
16												7			21											0	
17																				0					0		1
18																			4								
19							86			1							289										
20																										2	

Figure E-7: Scattergram used in the analyses of the Bradford Island ladder 1968 lamprey counts using the FFU 1993 sampling hours for the Bradford Island ladder.

	--- May ---					**--- June ---**					**--- July ---**							**--- August ---**						**--- Sept ---**		
hours:	6	17	18	19	31	3	9	19	23	26	3	12	19	21	24	29	30	9	13	16	21	26	27	8	13	22
6				1			6									124						0				
7									0		0								20						0	0
8	0					4		0																		
9														2												
10		1								1		20			1											
11					2																0			0		
12						27		0		2													0			
13			0								13		4								0			0		
14									0						1			0								
15		3			3												39									
16																				1						0
17	0						6					103													0	
18													14									0				0
19							8	3																		
20		2	2												31					0						

Figure E-8: Scattergram used in the analyses of the Old Washington shore ladder (Cascades Island ladder) 1968 lamprey counts using the FFU 1993 sampling hours for the Washington shore ladder.

	--- May ---					--- June ---					--- July ----						--- August ---								--- Sept ---		
hours:	3	11	21	25	26	4	8	14	24	29	9	11	16	18	21	26	2	6	7	17	18	23	29	30	10	17	24
6		0	51	45					2		6							39				16					
7	0					0															8			8			
8							4																			2	
9																	2										0
10								0																	2		
11										3			1		0	2											
12				3					0	3												4					
13		0						2									10						0				
14	0		0			9	-2																		2		
15														2		0			3								
16												-2			3											0	
17																				3					2		0
18																			3								
19							12			4							16										
20	0																									0	
21								-96							4	6						10	2				
22			-22			-3																					
23		0			20				4			5		17						5							0

Figure E-9: FFU 1993 sample lamprey counts for the Bradford Island ladder.

	--- May ---					--- June ---					--- July ---							--- August ---						--- Sept ---		
hours:	6	17	18	19	31	3	9	19	23	26	3	12	19	21	24	29	30	9	13	16	21	26	27	8	13	22
6				40			24									17						15				
7									6		11								0						0	0
8	4					3		5																		
9														0												
10		20								3		0			1											
11					3																0			0		
12						0		2		2													3			
13			3								-1		1								-1			3		
14									1						2			1								
15		7			1												9									
16																				1						0
17	3						0					-1													0	
18													10									3				0
19							-3	6																		
20		3	8												15					11						
21	3				-44					-72														26		
22									-145			7									22				45	
23						-55					-8						-92	-41								

Figure E-10: FFU 1993 sample lamprey counts for the Washington shore ladder.

APPENDIX F

VIDEO-TAPED NIGHT COUNTS FOR 1992

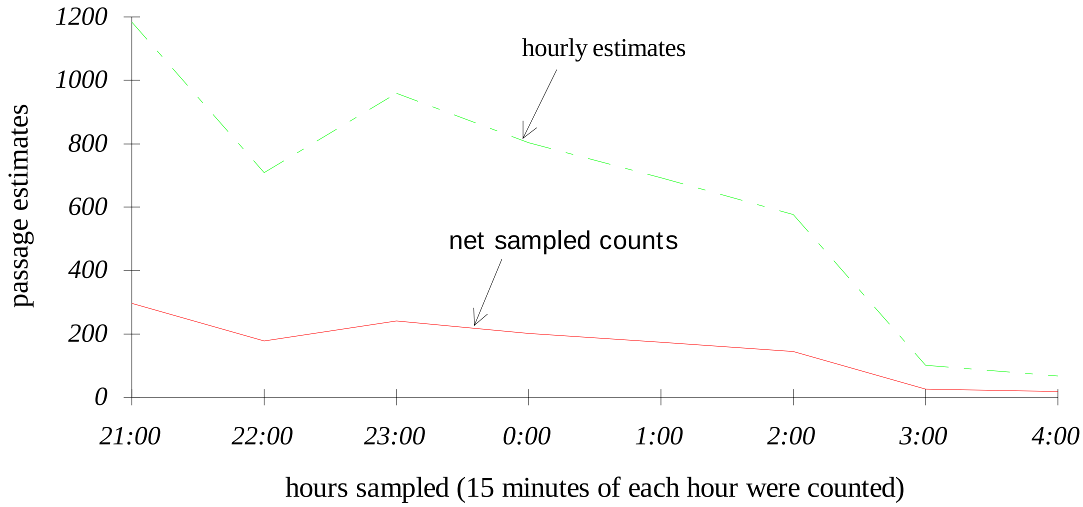

Figure F-1: Lamprey passage estimates past the Bradford Island ladder past Bonneville Dam, as seen on videotape, for the night of June 15-16, 1992.

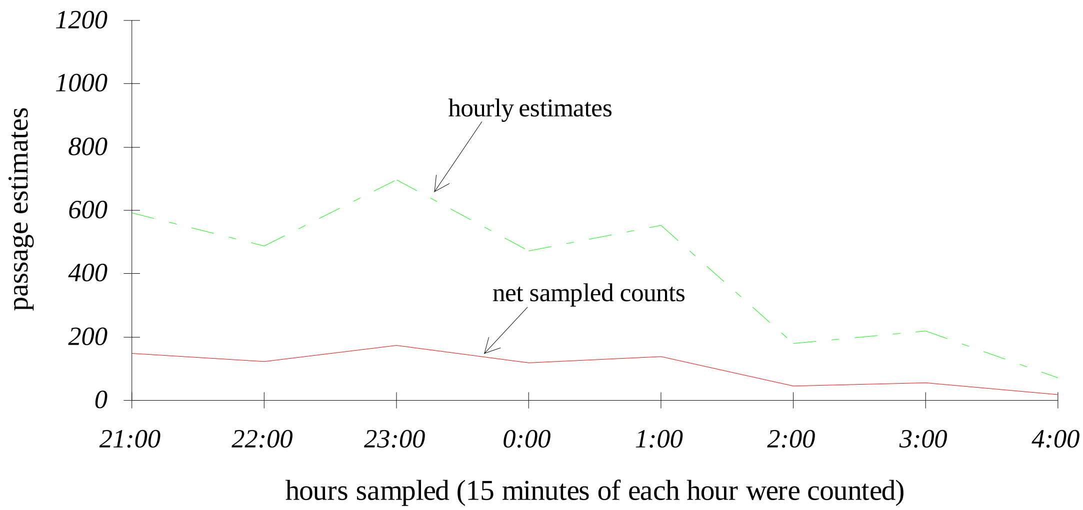

Figure F-2: Lamprey passage estimates past the Bradford Island ladder at Bonneville Dam, as seen on videotape, for the night of June 16-17, 1992.

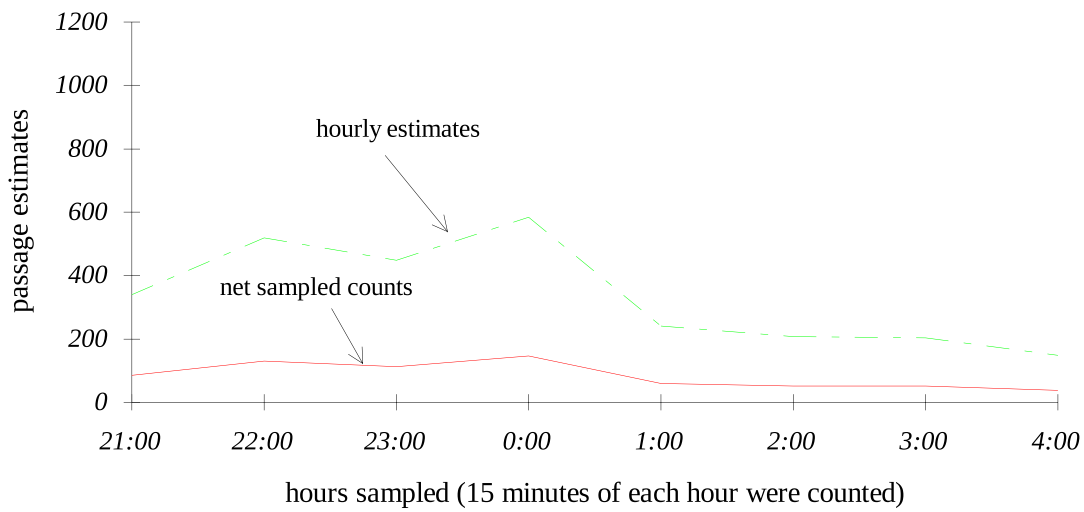

Figure F-3: Lamprey passage estimates past the Bradford Island ladder at Bonneville Dam, as seen on videotape, for the night of June 17-18, 1992.

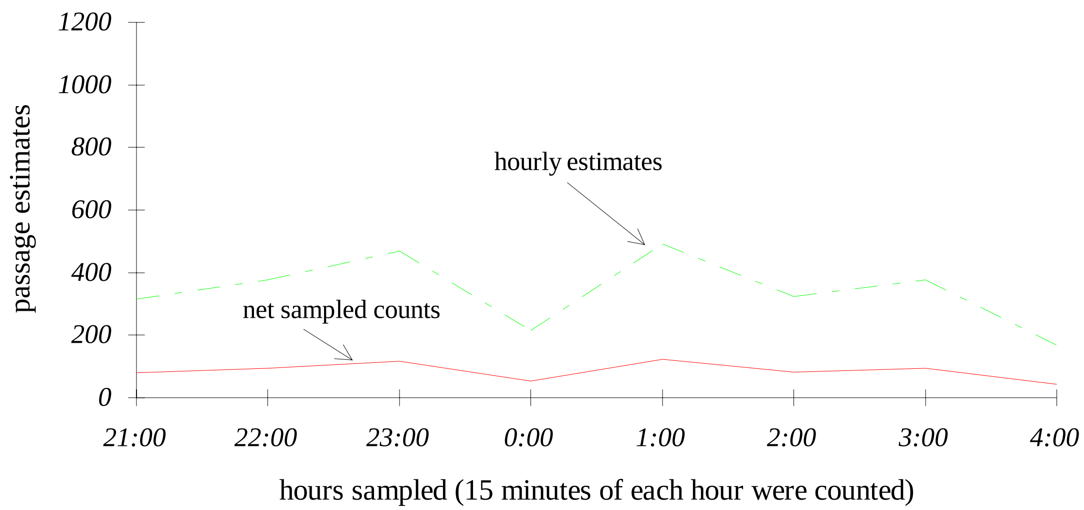

Figure F-4: Lamprey passage estimates past the Bradford Island ladder at Bonneville Dam, as seen on videotape, for the night of June 18-19.

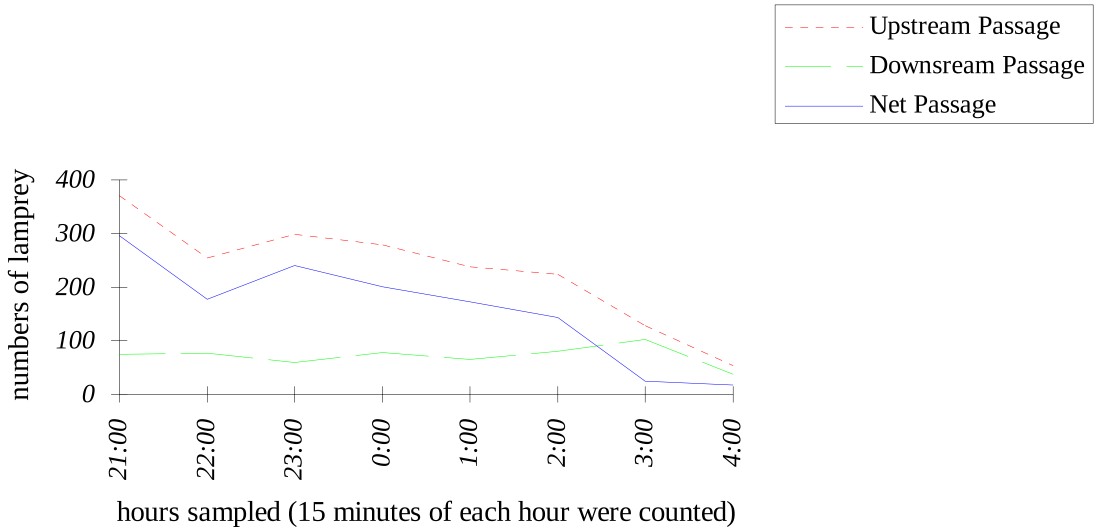

Figure F-5: Upstream, downstream, and net passage of lamprey past the Bradford Island ladder at Bonneville Dam on the night of June 15-16, 1992. Passage numbers are from sampling videotapes.

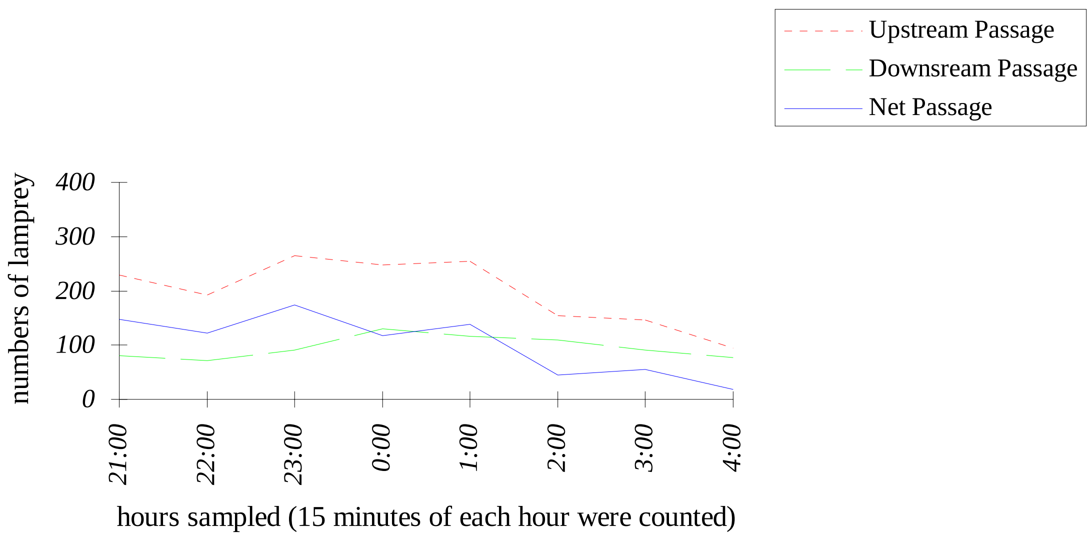

Figure F-6: Upstream, downstream, and net passage of lamprey past the Bradford Island ladder at Bonneville Dam on the night of June 16-17, 1992. Passage numbers are from sampling videotapes.

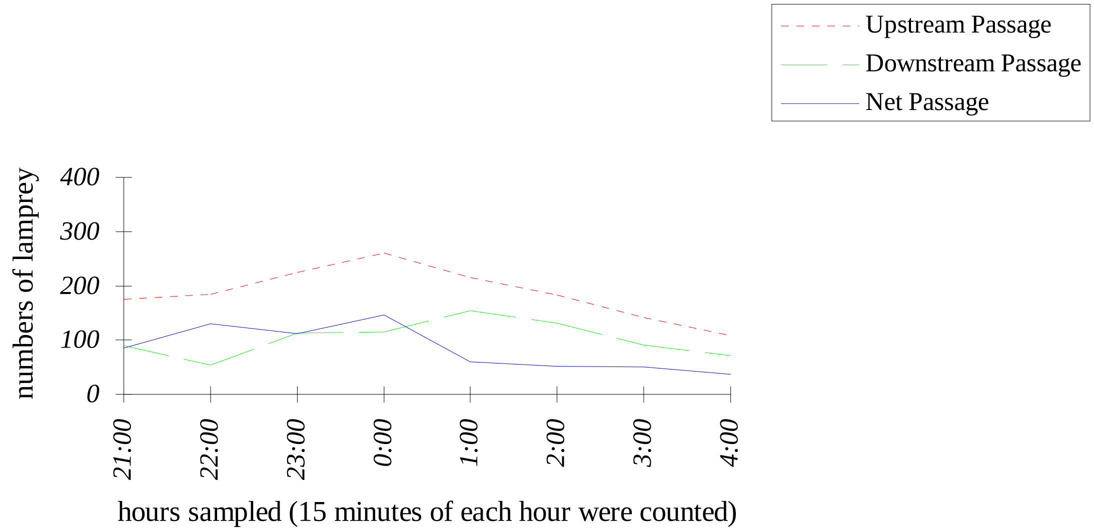

Figure F-7: Upstream, downstream, and net passage of lamprey past the Bradford Island ladder at Bonneville Dam on the night of June 17-18, 1992. Passage numbers are from sampling videotapes.

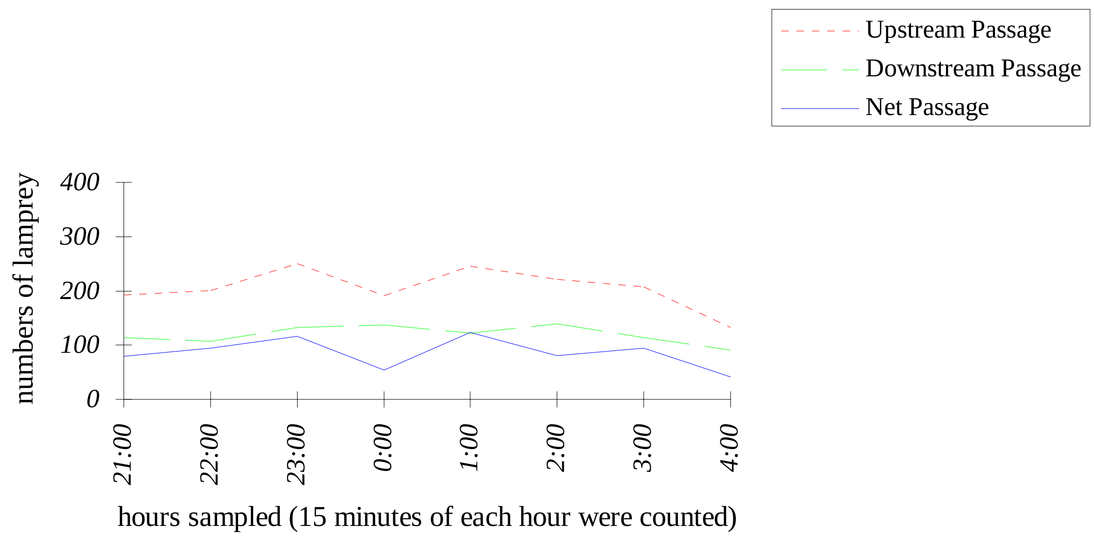

Figure F-8: Upstream, downstream, and net passage of lamprey past the Bradford Island ladder at Bonneville Dam on the night of June 18-19, 1992. Passage numbers are from sampling videotapes.

APPENDIX G

JUVENILE LAMPREY PASSAGE PATTERNS

Table G-1: Juvenile lamprey captured by the NMFS in the downstream migrant sampler at the Bonneville Dam first powerhouse in 1993. Included are numbers captured, sampling rate, and total estimates.

Date	Nos	Rate	Est	Date	Nos	Rate	Est	Date	Nos	Rate	Est	Date	Nos	Rate	Est
Mar 17	26	0.200	130	Mav 6	1	0.150	7	Jun 25	3	0.200	15	Aug 14	0	0.667	0
Mar 18	8	0.200	40	May 7	2	0.150	13	Jun 26	5	0.200	25	Aug 15	0	0.667	0
Mar 19	3	0.606	5	May 8	0	0.141	0	Jun 27	2	0.200	10	Aug 16	2	0.667	3
Mar 20	0	0.040	0	May 9	6	0.140	43	Jun 28	2	0.200	10	Aug 17	0	0.667	0
Mar 21	2	0.069	29	May 10	0			Jun 29	2	0.200	10	Aug 18	0	0.667	0
Mar 22	28	0.809	35	May 11	4	0.100	40	Jun 30	1	0.200	5	Aug 19	0	0.667	0
Mar 23	16	0.093	171	May 12	7	0.085	82	Jul 1	3	0.200	15	Aug 20	0	0.667	0
Mar 24	8	0.150	53	May 13	21	0.061	347	Jul 2	3	0.200	15	Aug 21	0	0.667	0
Mar 25	3	0.200	15	May 14	14	0.046	303	Jul 3	3	0.200	15	Aug 22	0	0.667	0
Mar 26	0	0.200	0	May 15	1	0.082	12	Jul 4	2	0.200	10	Aug 23	0	0.667	0
Mar 27	0	0.200	0	May 16	3	0.023	129	Jul 5	1	0.200	5	Aug 24	0	0.667	0
Mar 28	19	0.200	95	May 17	2	0.017	120	Jul 6	4	0.200	20	Aug 25	0	0.656	0
Mar 29	25	0.200	125	May 18	0			Jul 7	2	0.200	10	Aug 26	0	0.667	0
Mar 30	5	0.200	25	May 19	6	0.019	312	Jul 8	3	0.200	15	Aug 27	2	0.667	3
Mar 31	2	0.200	10	May 20	17	0.017	1020	Jul 9	0	0.200	0	Aug 28	1	0.667	1
Apr 1	6	0.200	30	May 21	7	0.017	420	Jul 10	2	0.400	5	Aug 29	0	0.667	0
Apr 2	3	0.200	15	May 22	0	0.017	0	Jul 11	0	0.400	0	Aug 30	0	0.667	0
Apr 3	2	0.200	10	May 23	0			Jul 12	3	0.363	8	Aug 31	0	0.667	0
Apr 4	2	0.200	10	May 24	1	0.018	57	Jul 13	0			Sep 1	0	0.659	0
Apr 5	2	0.200	10	May 25	20	0.037	537	Jul 14	1	0.500	2	Sep 2	0	0.667	0
Apr 6	1	0.200	5	May 26	3	0.029	104	Jul 15	4	0.500	8	Sep 3	0	0.667	0
Apr 7	1	0.200	5	May 27	8	0.046	175	Jul 16	4	0.667	6	Sep 4	0	0.667	0
Apr 8	4	0.200	20	May 28	7	0.050	140	Jul 17	2	0.667	3	Sep 5	0	0.667	0
Apr 9	5	0.200	25	May 29	2	0.050	40	Jul 18	1	0.667	1	Sep 6	0	0.667	0
Apr 10	8	0.200	40	May 30	7	0.088	80	Jul 19	0	0.654	0	Sep 7	0	0.667	0
Apr 11	7	0.200	35	May 31	3	0.087	34	Jul 20	0	0.652	0	Sep 8	0	0.667	0
Apr 12	5	0.200	25	Jun 1	5	0.100	50	Jul 21	0	0.644	0	Sep 9	0	0.667	0
Apr 13	5	0.200	25	Jun 2	5	0.141	36	Jul 22	0	0.654	0	Sep 10	0	0.667	0
Apr 14	1	0.200	5	Jun 3	3	0.150	20	Jul 23	0	0.667	0	Sep 11	0	0.667	0
Apr 15	1	0.200	5	Jun 4	0	0.150	0	Jul 24	0	0.655	0	Sep 12	1	0.667	1
Apr 16	0	0.038	0	Jun 5	1	0.141	7	Jul 25	0	0.663	0	Sep 13	0	0.667	0
Apr 17	0	0.049	0	Jun 6	1	0.187	5	Jul 26	1	0.667	1	Sep 14	1	0.667	1
Apr 18	0	0.050	0	Jun 7	7	0.200	35	Jul 27	0	0.646	0	Sep 15	0	0.667	0
Apr 19	1	0.098	10	Jun 8	5	0.200	25	Jul 28	1	0.667	1	Sep 16	0	0.667	0
Apr 20	1	0.150	7	Jun 9	0	0.200	0	Jul 29	0	0.616	0	Sep 17	0	0.667	0
Apr 21	0	0.150	0	Jun 10	6	0.200	30	Jul 30	0	0.667	0	Sep 18	0	0.667	0
Apr 22	0	0.200	0	Jun 11	13	0.200	65	Jul 31	0	0.667	0	Sep 19	0	0.667	0
Apr 23	0	0.200	0	Jun 12	5	0.200	25	Aug 1	2	0.667	3	Sep 20	0	0.602	0
Apr 24	1	0.200	5	Jun 13	10	0.200	50	Aug 2	0	0.667	0	Sep 21	0	0.667	0
Apr 25	1	0.200	5	Jun 14	1	0.200	5	Aug 3	0	0.667	0	Sep 22	1	0.667	1
Apr 26	1	0.200	5	Jun 15	3	0.200	15	Aug 4	0	0.667	0	Sep 23	0	0.667	0
Apr 27	0	0.200	0	Jun 16	6	0.200	30	Aug 5	0	0.667	0				
Apr 28	0	0.200	0	Jun 17	1	0.200	5	Aug 6	0	0.451	0	*Totals*	*513*		*5,838*
Apr 29	0	0.200	0	Jun 18	2	0.200	10	Aug 7	0	0.460	0				
Apr 30	0			Jun 19	0			Aug 8	0	0.667	0				
May 1	1	0.200	5	Jun 20	5	0.200	25	Aug 9	1	0.667	1				
May 2	2	0.174	11	Jun 21	1	0.200	5	Aug 10	0	0.667	0				
May 3	2	0.141	14	Jun 22	4	0.200	20	Aug 11	0	0.667	0				
May 4	2	0.201	10	Jun 23	2	0.200	10	Aug 12	0	0.667	0				
May 5	2	0.197	10	Jun 24	7	0.200	35	Aug 13	0	0.667	0				

Dates are start of 24-hour sampling

Table G-2: Incidental catch of juvenile lamprey by NMFS in the gatewells during their FGE studies at the Bonneville Dam second powerhouse in 1993.

	Numbers Collected in Gatewells						**Night**	<---------- **Mortalities** ---------->						**Number**
Date	**17A**	**17B**	**15A**	**15B**	**12A**	**12B**	**Totals**	**17A**	**17B**	**15A**	**15B**	**12A**	**12B**	**Survivals**
Apr 20	4	6					10		1					9
Apr 21	total numbers, only						20	2 (gatewell not specified)						18
Apr 22	total numbers, only						11							11
Apr 23	6	7					13							13
Apr 24	4	10					14							14
Apr 25	5	10					15							15
Apr 26	2	6					8	1						7
Apr 27	4	8					12							12
Apr 28	3	10					13		2					11
Apr 29	14	6					20	3						17
Apr 30					7	8	15						2	13
May 1	BREAK OR MISSING DATA													
May 2														
May 3					13	11	24					3		21
May 4			5	15			20				1			19
May 5			6	12			18							18
May 6			12	11			23				1			22
May 7	11	17					28							28
May 8	18	21					39							39
May 9	BREAK OR MISSING DATA													
May 10					9	15	24						1	23
May 11					21	17	38					1		37
May 12					30	25	55							55
May 13			38	52			90							90
May 14			43	50			93			2				91
May 15			48	46			94				5			89
May 16														
May 17														
May 18														
May 19														
May 20	BREAK OR MISSING DATA													
May 21														
May 22														
May 23														
May 24					45	50	95							95
May 25	BREAK OR MISSING DATA													
May 26														
May 27			282	317			599							599
May 28			*	305			305				9			296
						Total Numbers	1,696						Total Survival	1,662

**no data recorded*

INSERT Figure G-1 HERE

INSERT Figure G-2 HERE

Table G-3: Juvenile lamprey captured by the NMFS during sampling of smolts at John Day Dam in 1993.

	Turbine Unit			Turbine Unit			Turbine Unit			Turbine Unit			Turbine Unit	
Date	**3B**	**3C**	*Date*	**3B**	**3C**	*Date*	**3B**	**3C**	*Date*	**3B**	**3C**	*Date*	**3B**	**3C**
Apr 6	48	101	*May 6*	172	159	*Jun 5*	6		*Jul 5*	6	7	*Aug 4*		1
Apr 7	46	93	*May 7*	364	282	*Jun 6*	5		*Jul 6*	10	14	*Aug 5*	1	1
Apr 8	143	213	*May 8*	216	232	*Jun 7*	13		*Jul 7*	8	6	*Aug 6*	2	
Apr 9	78	82	*May 9*	183	128	*Jun 8*	19		*Jul 8*		1	*Aug 7*		3
Apr 10	58	96	*May 10*	148	227	*Jun 9*	24		*Jul 9*		2	*Aug 8*		1
Apr 11	38	64	*May 11*	148	150	*Jun 10*	24		*Jul 10*	1	2	*Aug 9*	1	
Apr 12	36	44	*May 12*	245	140	*Jun 11*	35		*Jul 11*	3	1	*Aug 10*		
Apr 13	18	36	*May 13*	110	22	*Jun 12*	54		*Jul 12*	2		*Aug 11*	1	
Apr 14	21	37	*May 14*			*Jun 13*	30		*Jul 13*	1	6	*Aug 12*	2	
Apr 15	13	27	*May 15*	24		*Jun 14*	12		*Jul 14*		5	*Aug 13*	3	1
Apr 16	10	26	*May 16*	86		*Jun 15*			*Jul 15*	4	3	*Aug 14*		
Apr 17	25	45	*May 17*	175		*Jun 16*			*Jul 16*	3	2	*Aug 15*	2	2
Apr 18	20	34	*May 18*	71		*Jun 17*			*Jul 17*	2	3	*Aug 16*	1	2
Apr 19	10	24	*May 19*	46		*Jun 18*			*Jul 18*		1	*Aug 17*	1	
Apr 20	12	19	*May 20*	54		*Jun 19*	4	4	*Jul 19*	1	1	*Aug 18*	2	1
Apr 21	15	38	*May 21*	31		*Jun 20*	1	3	*Jul 20*		1	*Aug 19*		
Apr 22	15	38	*May 22*	9		*Jun 21*	3		*Jul 21*	1	2	*Aug 20*		1
Apr 23	30	33	*May 23*	172		*Jun 22*	17	28	*Jul 22*	2	2	*Aug 21*		1
Apr 24	24	46	*May 24*	115		*Jun 23*	17	9	*Jul 23*	1		*Aug 22*		6
Apr 25	44	28	*May 25*	200		*Jun 24*	22	12	*Jul 24*	3	10	*Aug 23*		1
Apr 26	28	23	*May 26*	35		*Jun 25*	5	6	*Jul 25*	2	5	*Aug 24*		
Apr 27	26	17	*May 27*	115		*Jun 26*	2	5	*Jul 26*	2		*Aug 25*		6
Apr 28	37	16	*May 28*	94		*Jun 27*	4	2	*Jul 27*			*Aug 26*	1	
Apr 29	29	36	*May 29*	22		*Jun 28*	3	1	*Jul 28*	1	2	*Aug 27*		
Apr 30	36	30	*May 30*	65		*Jun 29*	5	10	*Jul 29*	3	1	*Aug 28*		
May 1	48	44	*May 31*	41		*Jun 30*	5	12	*Jul 30*	2	3	*Aug 29*		
May 2	30	39	*Jun 1*	14		*Jul 1*	1		*Jul 31*	3	2	*Aug 30*		
May 3	45	91	*Jun 2*	6		*Jul 2*	2		*Aug 1*	2	2	*Aug 31*		1
May 4	46	72	*Jun 3*	7		*Jul 3*	3	2	*Aug 2*		2			
May 5	73	104	*Jun 4*	8		*Jul 4*	12	7	*Aug 3*			Totals	4,486	3,151

Dates are end of 24-hour sampling period.

Totals for Both Units 7,637

Table G-4: Hours that unit 3 (both 3B and 3C) at John Day Dam was shut down thereby biasing the sample days. Unit 3B was shut down a total of 221 hours (the same number as total unit shutdown) and unit 3C was shutdown a total of 1,145 hours.*

Date	Hours	Biased Sample Days
5-May	1	
13-May	3	
14-May	22	**
15-May	14	**
22-May	2	
26-May	1	
15-Jun	23	**
16-Jun	24	**
17-Jun	24	**
18-Jun	24	**
19-Jun	16	**
8-Jul	1	
9-Jul	1	
3-Aug	24	**
4-Aug	8	**

Apr-Aug total hours. 188

*Total includes 33 hours in September and October.

Dates are end of 24-hour sampling period.

INSERT FIGURE G-3 ON THIS PAGE

Figure G- 4: passage pattern of juvenile lamprey based on captures by NMFS in the downstream migrant sampler at the Bonneville Dam first powerhouse in 1989. Lamprey passage is compared to flow.

Figure G-5: passage pattern of juvenile lamprey based on captures by NMFS in the downstream migrant sampler at the Bonneville Dam first powerhouse in 1990. Lamprey passage is compared to flow.