Biological Evaluations of the Fish Screens at the Glenn-Colusa Irrigation District's Sacramento River Pump Station

2002 - 2007

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PROJECT LOCATION

The Glenn-Colusa Irrigation District's (GCID) Sacramento River pumping station is located near Hamilton City approximately 100 miles north of the city of Sacramento on the west side of the main stem Sacramento River and 206 river miles upstream from San Francisco Bay (Figure 1). It is located on an oxbow off the main river channel with fish screens positioned upstream of the pumping plant. A Fish Screen Improvement Project (Project) was constructed at the site which included (among other features): 1) an extension of the flat-plate screens; 2) an upgrade to the existing facility; 3) an internal fish bypass system to route fish through pipes and back to an oxbow outlet channel a short distance downstream of the new screens; 4) a rock training wall on the river bank opposite the screens to enhance sweeping velocities past the screens, 5) a flow-control weir in the oxbow channel; and 6) reconfiguration of the oxbow outlet channel to route fish back to the Sacramento River. Additionally, a large-scale gradient facility was constructed on the main stem Sacramento River near the diversion site to ensure long-term reliability of the fish protective facilities (Figure 2).

INTRODUCTION

A Fish Protection Evaluation and Monitoring Program (FPEMP) was established prior to completion of the GCID Project. A Guidance Manual was developed for the FPEMP to identify the experimental design, field methods, and equipment necessary to evaluate the biological performance of the new fish screen structure and gradient facility. The cooperating agencies developed and agreed to its contents at the GCID Technical Oversight Committee (TOC) Meeting No. 4 on January 30, 2001. The Guidance Manual outlined studies to evaluate overall fish survival at the fish screens, assess fish passage at the gradient facility, and determine relative abundance and distribution of predatory fish at the gradient site and nearby areas. Specifically, field tests were structured to provide empirical data in determining the effectiveness of the fish screen improvements. Biological field testing at the site (using live fish) was performed under a range of riverine and pumping conditions to ensure the Project provides sufficient protection for fish under future, naturally occurring conditions. "The field tests are designed to determine if maximal survival of fish and optimal fish passage conditions are achieved as a result of the fish screen improvement project" (Montgomery Watson et al. 2000).

A critical design flow condition was determined during project development: 7,000 cfs in the river upstream of the oxbow and 3,000 cfs pumping flows which produces the greatest flow through the screens at the lowest associated water level resulting in the highest approach velocities and lowest sweeping velocities. Other flows are also of concern because they could produce different hydraulic conditions. The intent of the evaluation program was to perform screen tests according to the FPEMP at four combinations of river and pumping flows (Table 1) with the internal fish screen bypasses opened and closed. The main factors affecting juvenile fish at the screen are the approach and sweeping velocities, internal fish bypass operation (i.e., open or closed), and potential predation throughout the facility. Because of the screen design and subsequent testing, entrainment is probably no longer a significant source of fish mortality.

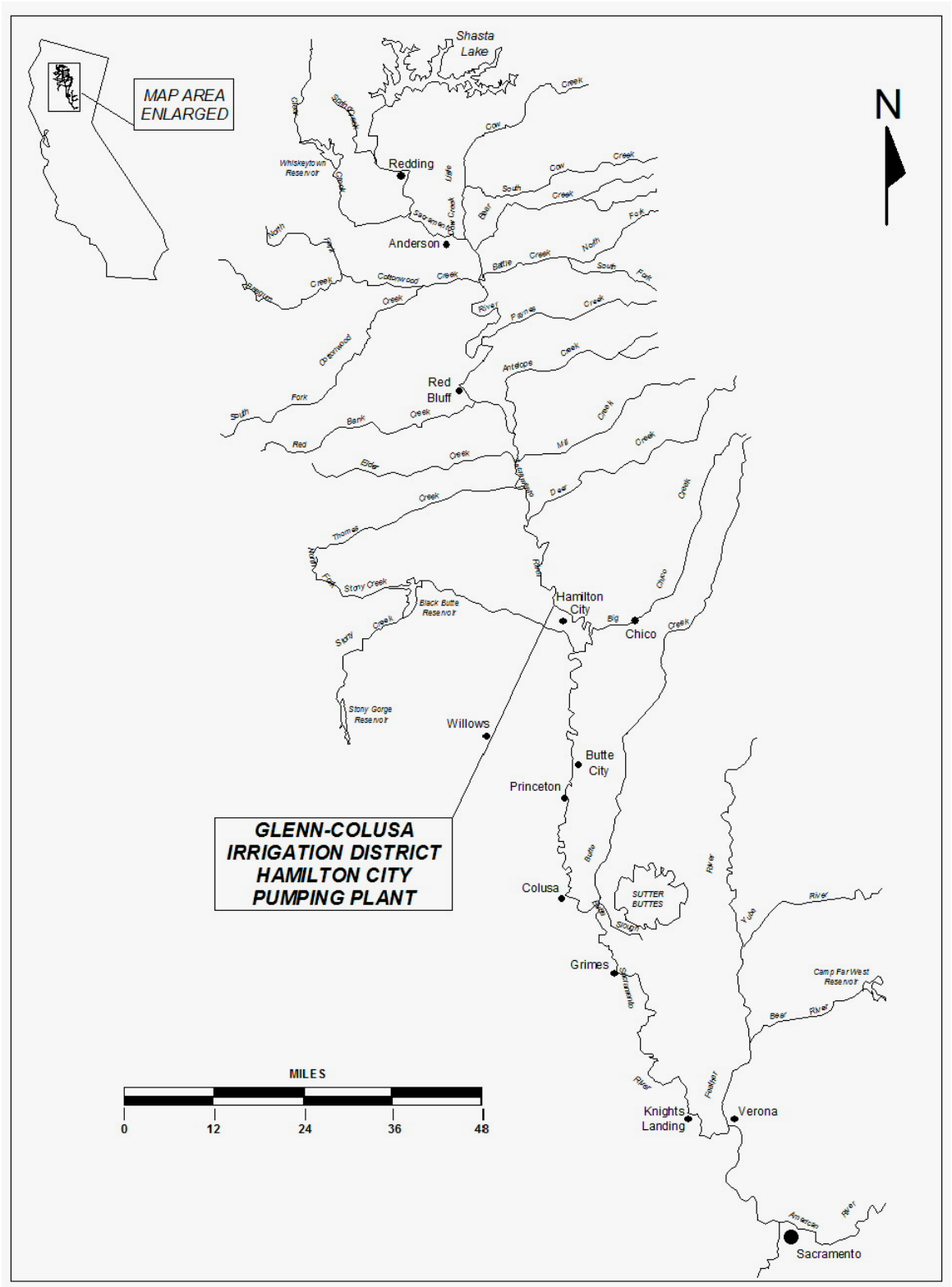

Figure 1. Location of the Glenn-Colusa Irrigation District Hamilton City Pumping Plant on the Sacramento River.

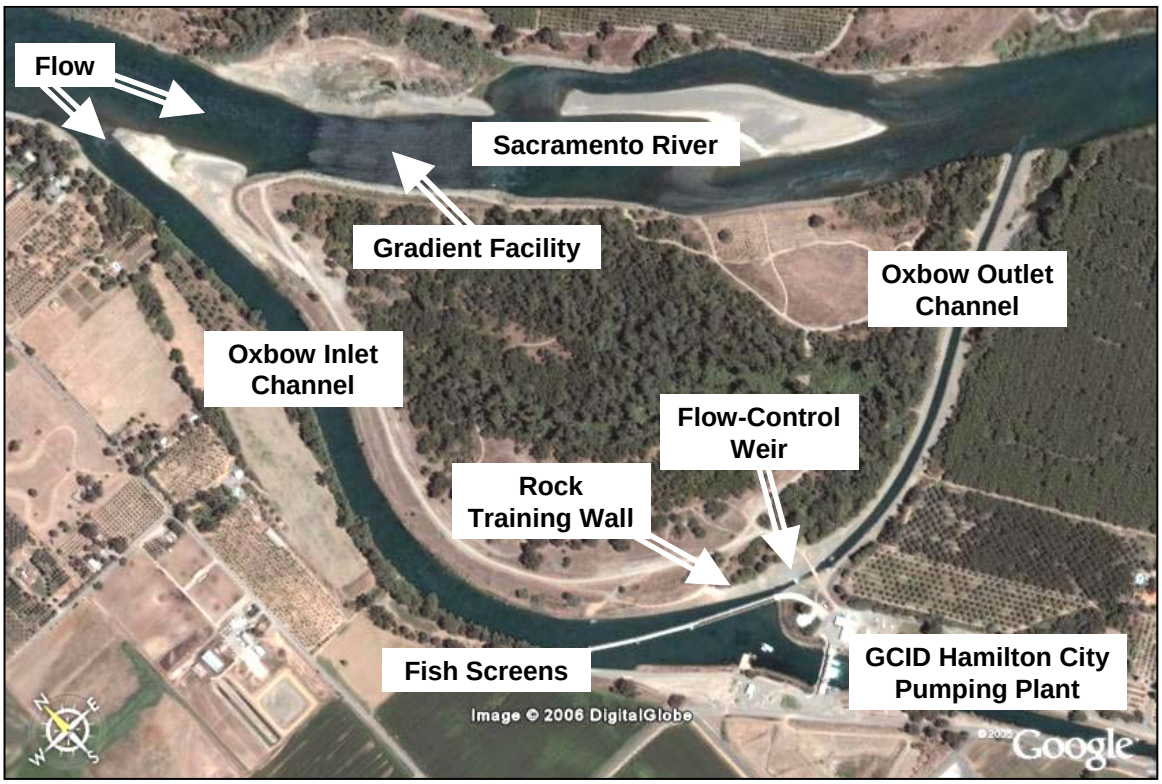

Figure 2. The GCID Hamilton City Pumping Plant and associated features of the Fish Screen Improvement Project.

Table 1. Range of river flows and pumping flows (cfs) identified in the FPEMP Guidance Manual for the GCID Fish Screen Improvement Project. River flow location is upstream of the GCID oxbow inlet channel

Test Condition	Pump Flow (cfs)	River Flow (cfs)
No. 1 Low Pump - High River	500 – 1,000	>15,000
No. 2 High Pump - Low River (Design Case)	>2,600	7,000 – 9,000
No. 3 Normal Pump - Normal River	1,800 – 2,600	10,000 – 13,000
No. 4 Low Pump – Low River	500 – 1,000	<9,000

Testing of fish survival at the screens was conducted during 2002 - 2006 and reported by Vogel 2003, 2005a, 2005b, 2006, and 2007 respectively. Results of testing conducted in 2007 are included in this report while details on past years of study are provided in prior annual reports. This report summarizes the results of the biological evaluation of the screens conducted during 2002 through 2007. Study results were previously reported and discussed at TOC meetings.

METHODS

The biological tests to estimate overall fish survival by fish mark/recapture were performed by releasing a known number of differently marked fish just upstream of the screens (test group) and outlet channel (control group), then recapturing portions of all groups in a large fyke net structure and two rotary screw traps in the lower oxbow outlet channel. The numbers of fish used for each experiment were determined from initial pilot testing conducted during 2001. Based on testing of fish screen survival conducted during 2002, the TOC decided to add an additional, separate group of fish to be released just downstream from the flow-control weir for each experiment performed during 2003 through 2007 (Figure 3). The weir group was added to compare with test group results. It was assumed that the fish released immediately downstream of the weir could not swim upstream past the weir because of high water velocities. During each experiment, control, weir, and test groups of fish were released in sequence from downstream to upstream to minimize disturbance of downstream fish movements. Control fish were released from a boat, weir fish were released from a catwalk suspended over the weir, and test fish were released from buckets gently lowered into the water off the upstream end of the fish screen structure to minimize potential attraction of predatory fish.

Because pumping and river flow conditions could not be accurately predicted in advance of fish testing, experiments were performed by scheduling two daytime and two nighttime mark/recapture tests each week during the spring and summer to encompass the range of pumping and river flow conditions available. The number of experiments conducted each week was largely a function of allowing sufficient time for marked fish to move through the system and the number of different marks available to avoid compromising subsequent experiments.

Fish handling protocols are described in the FPEMP Guidance Manual (Montgomery Watson et al. 2000). All Chinook salmon used for individual test, weir, and control groups were identified through use of a photonic marking device. This equipment employs high pressure injection of a fluorescent material into specific locations on the fins of the fish. Different color marks at different fin placements allowed discrimination between groups of fish after re-capture.

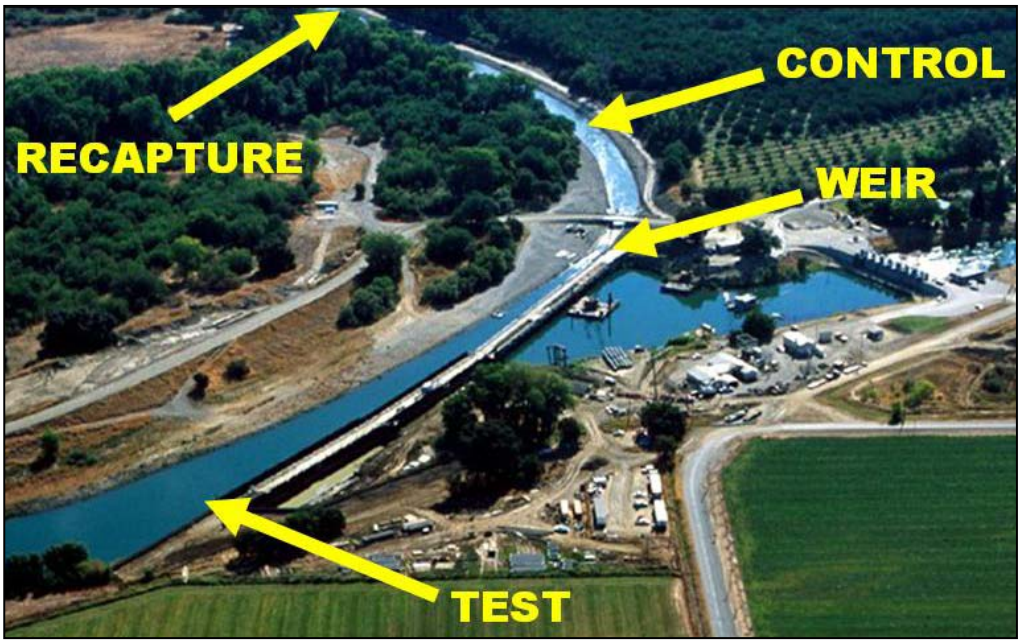

Figure 3. Location of three fish release sites: test group, weir group, control group and the recapture location for the three groups of fish in the GCID oxbow channel. Water flow is from lower left to top of picture. The GCID pump station is shown on the far right. Note that this aerial photograph was taken when the new fish screens were under construction and the pump station forebay had not yet been completely excavated.

Test, weir, and control groups of fish were recaptured in an 18-ft. wide by 10-ft. deep by 60-ft. long fyke net at the lower end of the oxbow outlet channel. In 2003 - 2007, two additional 8-ft. diameter rotary screw traps were added to the site to increase the numbers of fish recaptured for each experiment and to reduce sampling variability observed during the 2002 testing program (Figures 4 and 5). All recaptured fish were examined for marks and portions of each mark group had fork lengths recorded. The numbers of unmarked salmonids[1] (e.g., wild salmon or unmarked hatchery fish) and other fish species captured were also recorded and the data were provided to the California Department of Fish and Game (CDFG).

[1] Up to 25 fish per sampling period were measured for fork lengths.

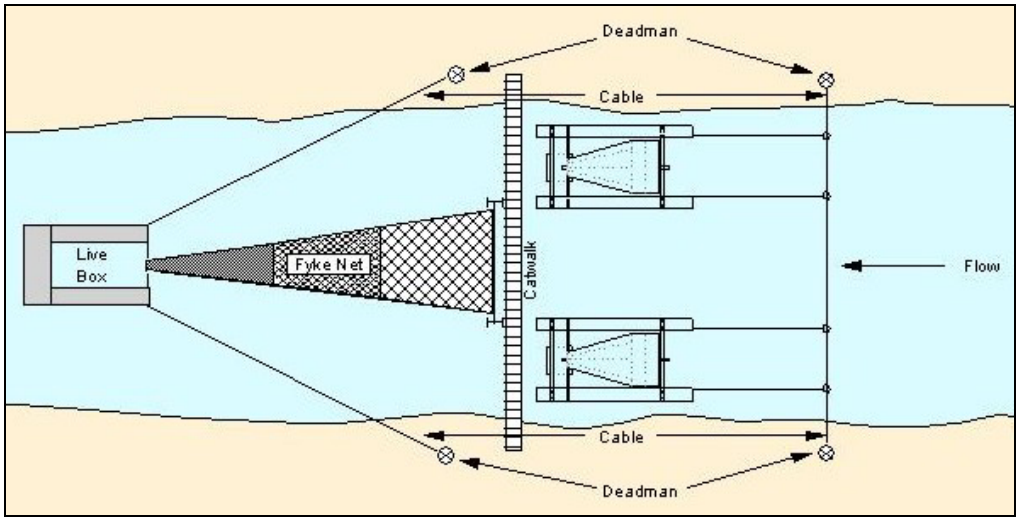

Figure 4. Plan-view schematic of the fyke net apparatus and two rotary screw traps used to recapture test, weir, and control groups of fish in the oxbow outlet channel.

Figure 5. Fyke net and two rotary screw traps used to recapture test, weir, and control groups of fish during the 2003 - 2007 biological evaluations at GCID. In 2002, the two rotary fish traps were not used. Prior to release of fish, the 60-ft. long fyke net was lowered in the water by crane into the H-pile slots. Recaptured fish were accumulated in the floating live box attached to the end of the fyke net and rotary screw trap live boxes, and then examined for marks to identify initial release location.

The survival of test groups of fish was estimated by comparing the proportion of test fish recovered with the proportion of control fish recovered:

$$\hat{S}_s = \frac{m_s / R_s}{m_c / R_c}$$

where m_s is the number of fish released upstream of the screens subsequently captured in the lower oxbow fish traps, R_s is the number of fish released upstream of the screens, m_c is the number of control fish subsequently recaptured in the fish traps, and R_c is the number of control fish released.

Similarly, the survival of weir groups of fish was estimated by comparing the proportion of weir fish recovered with the proportion of control fish recovered:

$$\hat{S}_w = \frac{m_w / R_w}{m_c / R_c}$$

where m_w is the number of fish released at the flow-control weir subsequently captured in the lower oxbow fish traps, R_w is the number of fish released at the weir, m_c is the number of control fish subsequently recaptured in the fish traps, and R_c is the number of control fish released.

Based on protocols developed by the TOC, only those tests resulting in greater than or equal to 50% recapture of the number released were used to compute fish survival for both the screen and weir groups of fish. The control groups of fish were released in relative close proximity to the fish traps where it was assumed no mortality would occur between the release and recapture locations. The User Specified Estimation Routine developed by the University of Washington Fisheries College (Lady et al. 2003) was used to develop profile likelihood confidence intervals at the 5% level for the estimates using maximum likelihood estimation methods.

Additional tests were conducted in 2005 using acoustic-tagged juvenile salmon. Miniature acoustic transmitters were surgically implanted in juvenile salmon, released just upstream of the screens or into the internal fish screen bypasses and monitored with acoustic receivers placed at the upstream end of the screens, downstream of the flow-control weir, and in the oxbow outlet channel. Methods are described in the annual report for the 2005 experiments (Vogel 2006).

In 2007, a DIDSON (dual-frequency identification sonar) camera mounted on a boat was used to observe predatory fish behavior at the fish screens.

RESULTS AND DISCUSSION

Fish Mark/Recapture Survival Tests

From 2002 through 2007, 237 fish mark/recapture tests meeting the TOC criteria were conducted at the fish screens. Among those tests, 67 (28%) occurred with the bypasses opened; 32 (14%) during the daytime and 35 (15%) during the nighttime. One-hundred seventy (72%) occurred with the bypasses closed; 84 (35%) during the daytime and 86 (36%) during the nighttime (Table 2).

Table 2. Number of fish mark/recapture tests conducted at the GCID fish screens in 2002 through 2007 with the internal fish screen bypasses open or closed and during day or night.

Bypasses Open		Bypasses Closed	
Day	**Night**	**Day**	**Night**
32	36	84	86

FPEMP Test Matrix

Table 3 provides the categories where the 237 tests performed in 2002 through 2007 fit within the FPEMP Guidance Manual testing matrix. During the February 25, 2003 GCID TOC meeting, it was determined that the combination of river flow and pumping flow conditions encountered or anticipated during most of the tests did not fit well into the original matrix described in the Guidance Manual. Therefore, the TOC decided to use pumping flow as the primary variable to determine where each testing condition fits into the matrix category numbers 1-4 shown in Table 1 (page 4) of this report. The majority (81%) of those tests were conducted under test condition no. 3, with the remainder under test conditions no. 2 (11%), no. 4 (7%), and no. 1 (<1%). This circumstance was attributable to a combination of typical river conditions present during the time of experiments, the timing of fish availability, GCID diversion (pumping) timing, and logistical constraints precluding fish testing at the screens during high river flows. Figures 6 - 7 show the riverine and pumping conditions occurring during all of the experiments conducted in 2002 – 2007.

Table 3. Range of conditions occurring during the fish survival experiments conducted during 2002 - 2007. Testing categories nos. 1-4 are based on pump flow. Note: Bypasses were closed throughout the 2006 and 2007 testing periods.

FPEMP Guidance Manual Test Condition (Pump Only)	Bypasses Open								Bypasses Closed											
	Day				Night				Day						Night					
	02	03	04	05	02	03	04	05	02	03	04	05	06	07	02	03	04	05	06	07
No. 1 (500-1,000 cfs) (high river)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
No. 2 (>2,600 cfs)	1	0	1	1	0	0	1	1	3	0	1	0	0	6	4	0	1	0	0	7
No. 3 (1,800-2,600 cfs)	1	10	10	5	0	11	10	7	2	7	15	16	15	15	4	7	15	14	16	12
No. 4 (500-1,000 cfs) (low river)	0	0	3	0	0	0	5	0	0	0	0	1	0	2	0	3	1	1	0	1

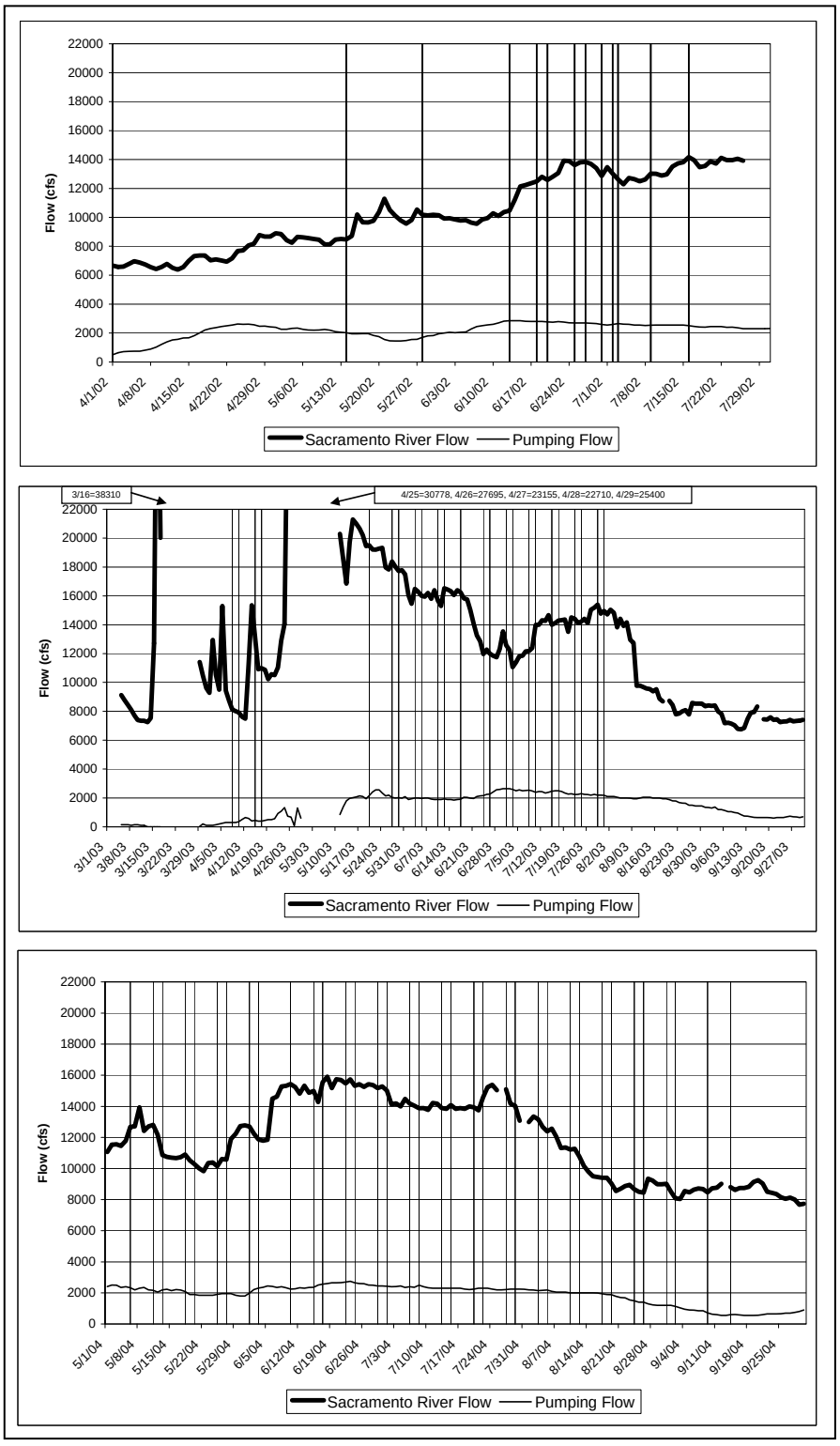

Figure 6. Range of river and pumping flow conditions during each of the mark/recapture experiments during 2002 - 2004. Vertical lines show date of experiments. Some dates designated by a vertical line had a day and night experiment in the same 24-hour period. Sacramento River flow location is upstream of the GCID oxbow inlet channel.

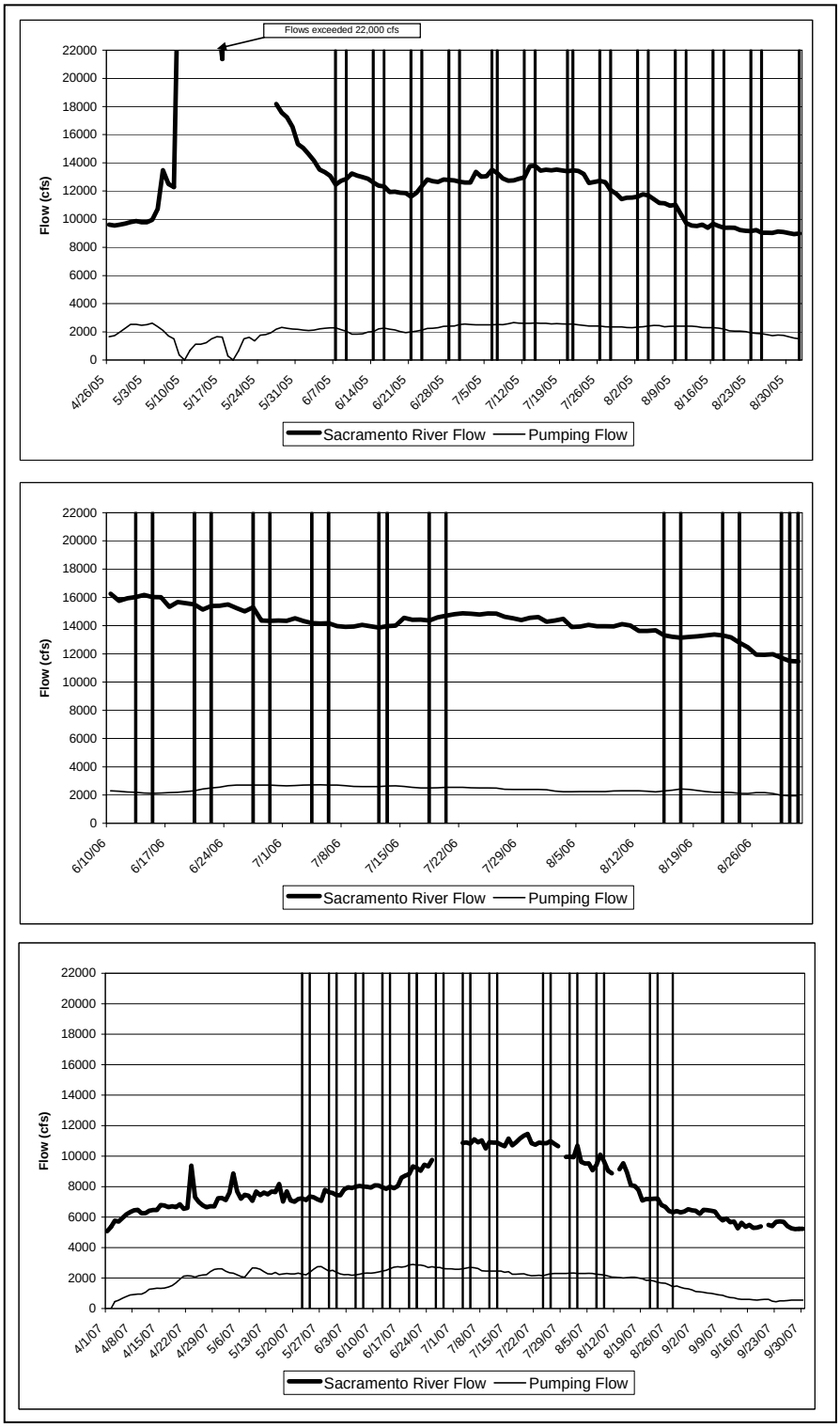

Figure 7. Range of river and pumping flow conditions during each of the mark/recapture experiments during 2005 - 2007. Vertical lines show date of experiments. Some dates designated by a vertical line had a day and night experiment in the same 24-hour period. Sacramento River flow location is upstream of the GCID oxbow inlet channel.

Estimated Fish Survival

Appendix Tables 1 – 16 provide results for each of the 237 mark/recapture experiments conducted at the fish screens. Overall fish recaptures were consistently high for screen, weir, and control groups of fish. Some variability between tests was evident and in some instances, a higher proportion of upstream fish release groups compared to downstream fish release groups were recaptured in the lower oxbow resulting in a calculated survival greater than 1.0 (i.e., >100%). For example, 38 of the 237 groups of fish released upstream of the fish screens (16%), were recaptured in a higher proportion compared to control fish. However, in most instances, those differences were small. Interestingly, the majority of those cases (22 or 58%) occurred in 2007 after the weir blocks at the flow-control weir (Figure 8) had been removed.[2] During the 2007 experiments, problems were encountered with fish diseases among the test fish at the hatchery which may, in part, explain the anomalous results during the 2007 experiments. Although the assumption was made that all fish release groups at the screens and weir would have the same recapture probability having survived the reach down to the control fish release location, this could not be empirically determined. Although control groups of fish were assumed to have a higher survival than fish released further upstream, there may have been instances where, in actuality, survival was lower. For example, fish groups were released in a sequential downstream to upstream direction. If predators consumed control fish first and became satiated, fish released further upstream could have a higher probability of reaching the recapture site. In 2007, the predator/prey dynamics in the oxbow channel may have changed with removal of the weir blocks causing a re-distribution of predators to areas further downstream in the oxbow channel, although this could not be determined. Predation in the oxbow outlet channel further downstream from the flow-control weir was not evaluated during these studies.

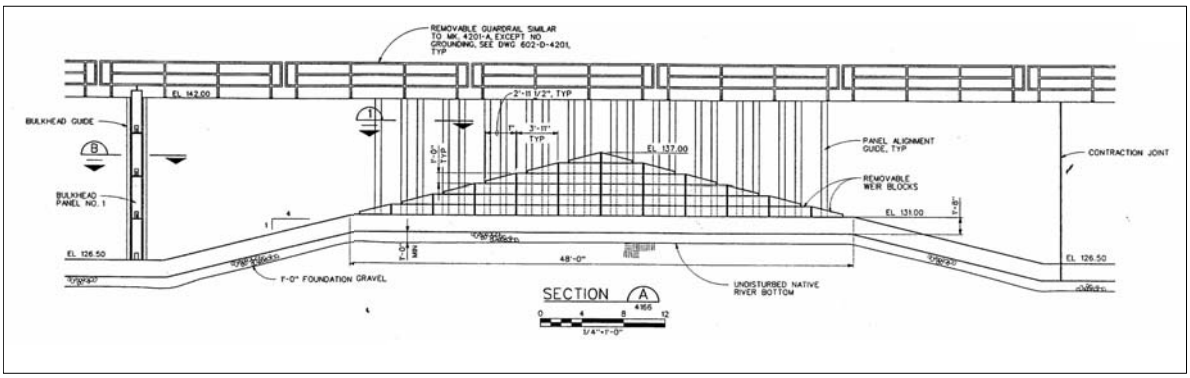

Figure 8. Longitudinal profile of the flow-control weir showing the removable weir blocks.

2 With the concurrence of the GCID TOC, the flow-control weir blocks were removed on August 7, 2006, to evaluate a potential measure to reduce concentrations of predatory fish residing just downstream of the weir.

Table 4 provides a summary of data provided in Appendix Tables 1 - 16. As stated in the Methods section, an additional group of differently marked fish was released immediately downstream of the flow-control weir during each experiment after 2002. The intent was to determine potential differences between estimated survival rates of test fish released upstream of the fish screens and fish released downstream of the weir. There was also a concern that a small portion of fish released upstream of the screens could swim in an upstream direction out of the inlet channel and not be subject to recapture as compared to control fish released in the oxbow outlet channel. Although this latter possibility could not be directly tested, it was assumed that releasing an additional group of fish immediately downstream of the weir would provide additional data and insights into fish behavior and potential fish mortality. The results indicate that there was, on average, an incremental source of fish mortality between the test, weir, and control fish release sites. These results suggest that most of the overall estimated fish mortality occurred just downstream of the flow-control weir. In all years, except 2007, predatory fish were observed downstream of the weir where the concrete structure flares out into the oxbow outlet channel. Additionally, underwater videography taken below the weir in 2005 showed that striped bass were found in the area just downstream of the internal fish screen bypass outfall. During 2005, all 16 acoustic-tagged juvenile salmon released into the internal fish screen bypasses were eaten by predatory fish just downstream of the flow-control weir (Vogel 2006). However, unlike prior years, fish survival for fish released downstream of the weir in 2006 increased later in the testing season (after the weir blocks had been removed).

The experiments did not reveal dramatic differences in day versus night or bypasses opened versus closed. Although there were some slight differences, on average, the high variability among tests and overlap among confidence intervals indicates the differences were not significant. It is hypothesized that this circumstance was attributable to the mortality primarily caused by predation downstream of the flow-control weir (discussed below). For example, regardless if the internal fish bypasses were opened or closed, all downstream migrating fish would be exposed to predators accumulated below the weir. Fish passing over the weir or entering and exiting the bypasses would all be exposed to the same predators. Therefore, it is likely that the fish mortality just downstream of the weir precluded the ability to measure any differences in bypass position. Surprisingly, there were only small differences between day versus night tests, possibly attributable to lights on the structure at night.

A consistent pattern of declining fish survival during the summer months was evident during 2003 to 2005, but not evident in 2006 or 2007 (Appendix Tables 1 - 16). Observations of predation were noted during the 2003 and 2004 testing seasons (Carly 2005) and again during 2005 and 2006. Predation was believed to be the primary source of fish mortality. Removal of the weir blocks in August 2006 is believed to have improved fish survival by reducing predation.

Table 4. Summary results of fish mark/recapture experiments at the GCID fish screens to estimate fish survival (1.00 = 100%).

Year	Overall Survival from Screen to Control				Survival from Screen to Weir				Survival from Weir to Control			
	Day		Night		Day		Night		Day		Night	
	Bypasses Open	Bypasses Closed	Bypasses Open	Bypasses Closed	Bypasses Open	Bypasses Closed	Bypasses Open	Bypasses Closed	Bypasses Open	Bypasses Closed	Bypasses Open	Bypasses Closed
2007	N/A	**1.01** *N=23*	N/A	**1.03** *N=20*	N/A	**1.02** *N=23*	N/A	**1.02** *N=20*	N/A	**1.00** *N=23*	N/A	**1.01** *N=20*
2006	N/A	**0.85** *N=15*	N/A	**0.93** *N=16*	N/A	**0.91** *N=15*	N/A	**0.94** *N=16*	N/A	**0.94** *N=15*	N/A	**1.00** *N=16*
2005	**0.77** *N=6*	**0.82** *N=17*	**0.76** *N=8*	**0.81** *N=15*	**0.96** *N=6*	**0.98** *N=17*	**0.90** *N=8*	**0.99** *N=15*	**0.80** *N=6*	**0.84** *N=17*	**0.85** *N=8*	**0.82** *N=15*
2004	**0.79** *N=14*	**0.75** *N=16*	**0.84** *N=16*	**0.86** *N=17*	**0.96** *N=14*	**0.90** *N=16*	**0.96** *N=16*	**0.93** *N=17*	**0.83** *N=14*	**0.84** *N=16*	**0.88** *N=16*	**0.93** *N=17*
2003	**0.84** *N=10*	**0.94** *N=8*	**0.82** *N=11*	**0.88** *N=10*	**0.84** *N=10*	**1.01** *N=8*	**0.90** *N=11*	**0.91** *N=10*	**0.99** *N=10*	**0.93** *N=8*	**0.92** *N=11*	**0.97** *N=10*
2002	**0.91** *N=2*	**0.89** *N=5*	N/A	**0.98** *N=8*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Fish Size

Figures 9 and 10 show the size of fish used for the mark/recapture experiments. The use of small-sized fish was limited by the availability of hatchery fish from Feather River Hatchery or Coleman National Fish Hatchery at the time needed for the experiments. The FPEMP Guidance Manual identified that the tests be conducted using both fry-sized fish (30-50 mm FL) and larger juvenile and smolt-sized fish. Coleman Hatchery's late-fall Chinook proved to be the best source for the testing program during the summer months. However, Endangered Species Act issues required that fish released at GCID be coded-wire tagged. Coded-wire tagging the fish required that the fish be reared to a sufficiently large size at the hatchery. As a result, the testing program was unable to perform experiments with fry smaller than 50 mm FL (Figures 9 and 10).

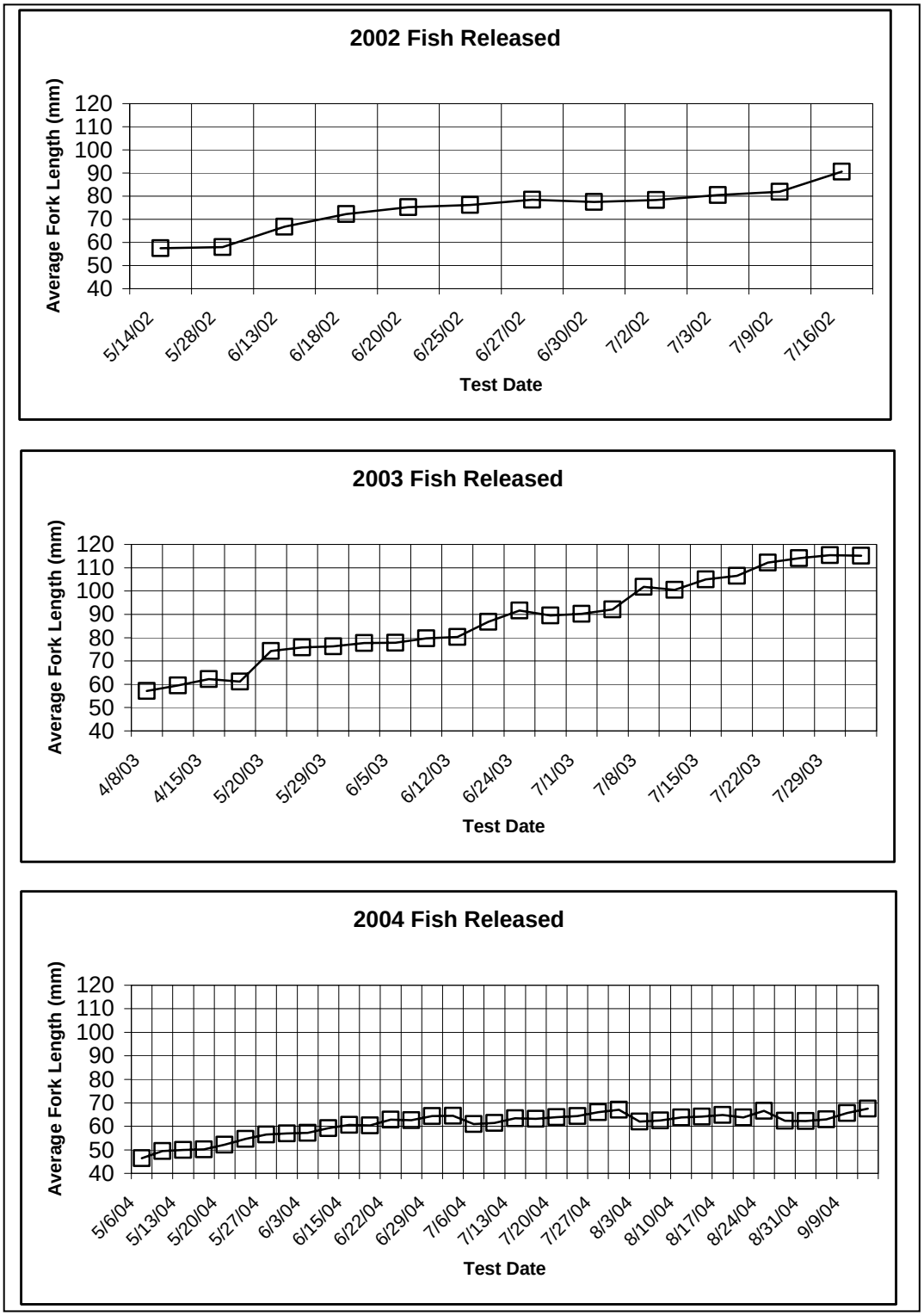

Figure 9. Juvenile salmon size (fork length in mm) used for the GCID fish screen tests during 2002 – 2004.

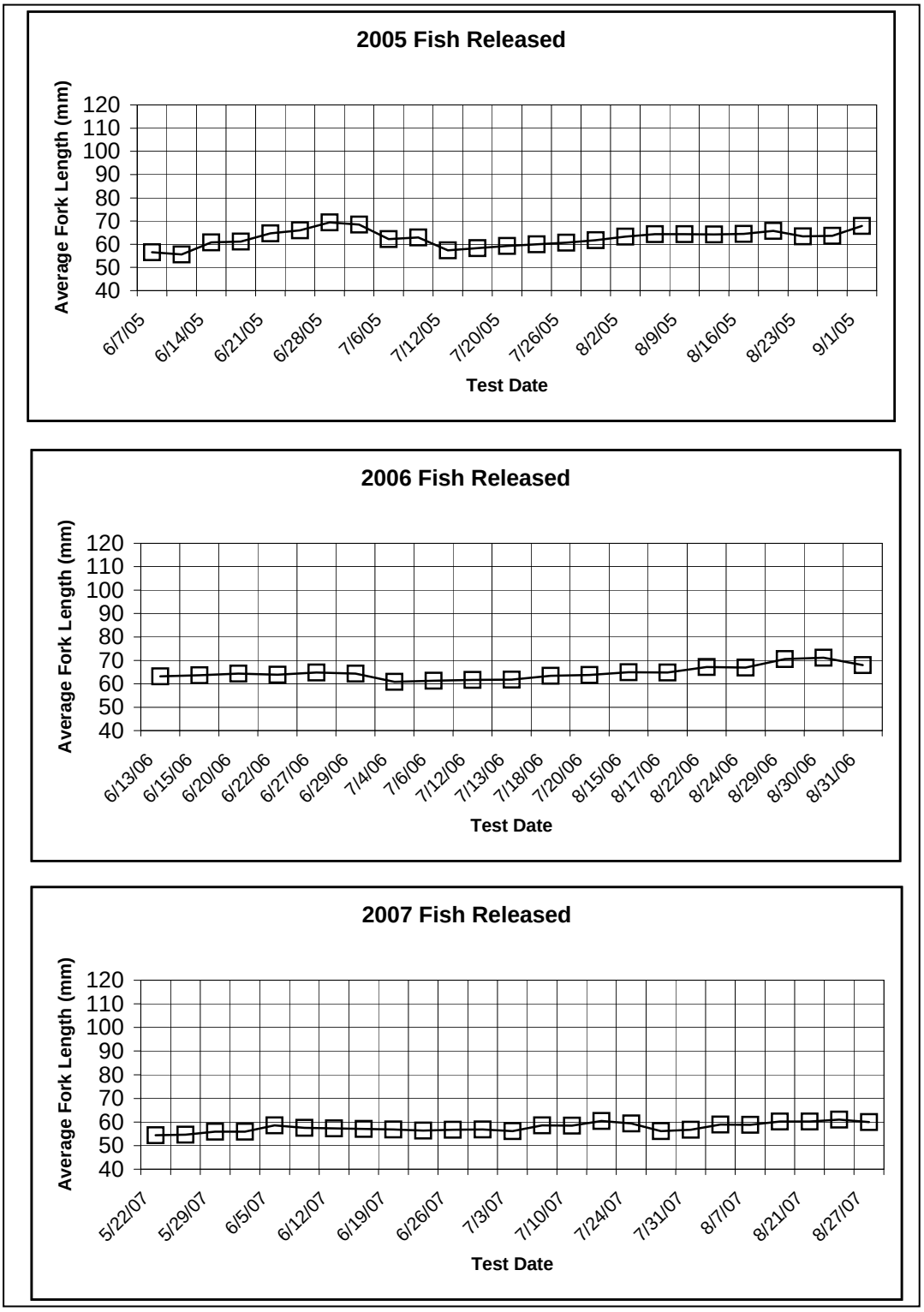

Figure 10. Juvenile salmon size (fork length in mm) used for the GCID fish screen tests during 2005 – 2007.

Acoustic Telemetry Experiments

In 2005, additional experiments were conducted at the fish screens by tagging and releasing juvenile salmon with surgically implanted acoustic transmitters. These tests were primarily performed to determine fish transit time from just upstream of the screens to just downstream of the flow-control weir and through the three internal fish screen bypasses. Additionally, the tests provided information on fish mortality believed to be attributable to predation.

For the first experiment, of the 30 acoustic-tagged salmon released upstream of the screens, 19 fish (63%) were detected to have passed the flow-control weir, including 4 fish preyed upon at the weir. Fifteen (50%) of the 30 released fish reached the lower oxbow outlet channel, including 8 fish caught in the fyke trap. The remaining fish were assumed to have either been eaten by predators near the release site or swam upstream out of detection range. In this initial experiment, the acoustic receiver place upstream of the fish screens stopped functioning so transit times could not be accurately determined.

In the second experiment, 16 of 20 acoustic-tagged salmon (80%) migrated between the release site just upstream of the fish screens to just downstream of the flow-control weir in an average time of 24 minutes (range of 8 minutes to 1 hour, 36 minutes). The average migration rate for these fish was 1.45 ft/s (range of 0.22 ft/s to 2.7 ft/s). Four of the 20 fish (20 %) were believed to have been preyed upon near the release site and one fish (5 %) was preyed upon just downstream of the weir.

In the third experiment, 17 of the 29 fish (59%) released were assumed to have been preyed upon near the release site. Six fish (21%) were assumed to have been preyed upon just downstream of the flow-control weir and only six fish (21%) reached the lower oxbow outlet channel. Average transit time to the weir was 1 hour, 32 minutes (range of 11 minutes to 3 hours, 54 minutes). Average migration rate was 1.02 ft/s (range of 0.09 ft/s to 1.99 ft/s).

The fourth experiment was conducted by releasing acoustic-tagged salmon directly into the internal fish screen bypasses to determine transit times to the bypass outfall located just downstream of the flow-control weir. Transit times are provided in Table 5.

Table 5. Transit times for 16 acoustic-tagged juvenile Chinook salmon through the internal GCID fish screen bypasses. Bypass no. 1 is the upstream-most bypass.			
Bypass Number	**Fish Number**	**Elapsed Time (min:sec)**	**Average Time (min:sec)**
1	1014	7:52	**15:43**
	1035	5:04	
	1042	11:13	
	1063	12:32	
	1098	5:07	
	1105	52:32	
2	1000	5:18	**12:29**
	1007	41:40	
	1021	7:17	
	1056	3:47	
	1084	4:22	
3	1028	23:49	**18:17**
	1049	5:33	
	1070	45:52	
	1077	11:32	
	1091	4:39	

Bypass no. 3 is the shortest bypass and fish transit times would likely be the shortest compared to the other upstream bypasses; however, the average transit time was the longest. Individual data acquired for each fish revealed that each bypass had one or more fish exhibit unexpectedly long transit times (e.g., >10 minutes) suggesting potential problems in delay by fish lingering at unknown locations in the internal bypass system. The most-probable location is the lower-most section of the pipe that flares out prior to entering the oxbow outlet channel. Such delays could be unfavorable for fish passage because the juvenile salmon could be more prone to predation.

An unanticipated (but highly informative) result occurred from these tests. Upon examination of data collected on the receivers positioned in the main river at the oxbow outlet channel, a distinctive pattern was evident for three of the acoustic-tagged salmon. Using the acoustic tag data processing software program[3] to determine arrival time for each of the tagged salmon it was evident that three of the fish arrived at the main river confluence at the same time to the nearest second. Similarities in specific movements among fish are not readily apparent because the software program is designed to view data for each fish code individually. Because of the improbability of three tagged salmon arriving at the river confluence at the same second after being released at different times and different bypasses, the specific pattern seen in the software program for each fish was re-evaluated in relation to each other. These data clearly demonstrated the movements of a single predator that had consumed the three tagged salmon. Based on this finding, the data were re-examined which determined all of the salmon had been eaten by predators; one predator had eaten five of the acoustic-tagged salmon. The primary predatory fish present at this site of sufficient size to consume juvenile salmon used for the

3 Hydroacoustic Technology, Inc. *MarkTags* program.

experiments are striped bass and Sacramento pikeminnow. Because of the relatively large size of test fish, and the occurrence of multiple predation events by a single fish, striped bass likely consumed the salmon. These large predators were known to be present in the vicinity at the time of year these tests were conducted.

As discussed during prior TOC meetings, the fish mark/recapture survival experiments probably result in higher survival estimates than would be expected to occur for wild juvenile salmon migrating past the site (Vogel 2007). This circumstance is attributable to the fact that wild fish exhibit a more-protracted migration timing and do not migrate *en masse* like the simultaneous release of hundreds of marked hatchery fish for the short-term survival experiments. Predatory fish in the GCID oxbow channel could more readily consume greater numbers of wild fish "trickling" downstream through the oxbow as compared to an instantaneous release of hundreds of juvenile salmon that move rapidly past the site during a very short period. The acoustic telemetry experiments provided some empirical evidence of this phenomenon. Seasonally, large numbers of wild fish enter the oxbow inlet channel and become concentrated into a lesser amount of flow by the time the fish pass the flow-control weir because the majority of water is removed from the channel through the fish screens. Notably, this time period includes the early portion of endangered juvenile winter-run Chinook salmon migration (Vogel 2006).

Internal Fish Screen Bypasses

During late September and early October 2004, after fish screen survival experiments ended that year, tests of fyke nets placed over the three fish bypass outfalls (Figure 11) were conducted to determine the effectiveness of capturing fish exiting the internal fish screen bypass system. The tests sufficiently assessed the equipment and techniques for the TOC in order to recommend and begin evaluating fish utilization of the internal bypasses. Table 6 provides the results of eight tests conducted by releasing marked juvenile salmon > 50 mm FL at the upstream end of the fish screens and recapturing a portion of those fish at each bypass outfall. The proportion of fish utilizing the bypasses was low, but pumping flow was also low. The average size of fish used for the tests was 93 mm FL (S.D. = 22 mm). The proportion of fry-sized fish (< 50 mm FL) and fish of all size ranges utilizing the bypasses during high pumping flows was not tested during the program. The original plan was to continue the bypass testing in subsequent years under a wider range of pumping flows and fish sizes. However, it was determined by the TOC that element of the FPEMP could not be performed because the NOAA Fisheries Biological Opinion could not be amended in sufficient time to conduct the field tests. Additionally, once the flow-control weir blocks were removed, the internal bypasses became non-functional.

Figure 11. One of three fyke nets used to capture juvenile salmon utilizing the three internal fish screen bypasses.

Table 6. Proportion of marked juvenile salmon released upstream of the fish screens exiting each of the three internal fish screen bypasses.

Date	9/21/04	9/21/04	9/23/04	9/23/04	10/05/04	10/05/04	10/07/04	10/07/04
Time of Day	Day	Night	Day	Night	Day	Night	Day	Night
Pumping Flow (cfs)	600	600	650	650	850	850	1,000	1,000
Bypass Flow (cfs)	879	879	821	821	698	698	683	683
Percent of Fish Entering Upstream Bypass	0%	1%	1%	0%	1%	1%	0%	0%
Percent of Fish Entering Middle Bypass	1%	3%	2%	2%	1%	2%	1%	2%
Percent of Fish Entering Downstream Bypass	1%	3%	2%	2%	1%	2%	1%	2%
Total Percent of Fish Entering All Bypasses	2%	7%	5%	4%	3%	5%	2%	4%

Flow-Control Weir

The mark/recapture experiments and acoustic telemetry experiments indicated that the primary problem for fish passage was attributable to predation just downstream of the flow-control weir (prior to removal) and, secondarily, along the fish screens. Of the overall mortality estimated from the mark/recapture experiments, the majority occurred just downstream of the flow-control weir. These experiments suggest that mortality of wild salmon migrating past the site was probably high during the summer and early fall with the flow-control weir in place.

In 2005, using an underwater video camera, predators were observed at the two locations shown in Figure 12. It appears that conditions immediately downstream of the weir created an ideal environment for predation on juvenile salmon. Due to high velocities, predatory fish are unlikely to pass upstream over the weir and may accumulate in areas just downstream. The concentrated, downstream-migrating juvenile fish passing over the weir were exposed to high velocity and turbulent water providing ideal conditions for predatory fish just downstream of the weir. Additionally, any fish passing through the internal fish screen bypasses exit into the area where predators may be accumulated. These circumstances would make the salmon more vulnerable to predation than compared to a natural riverine environment.

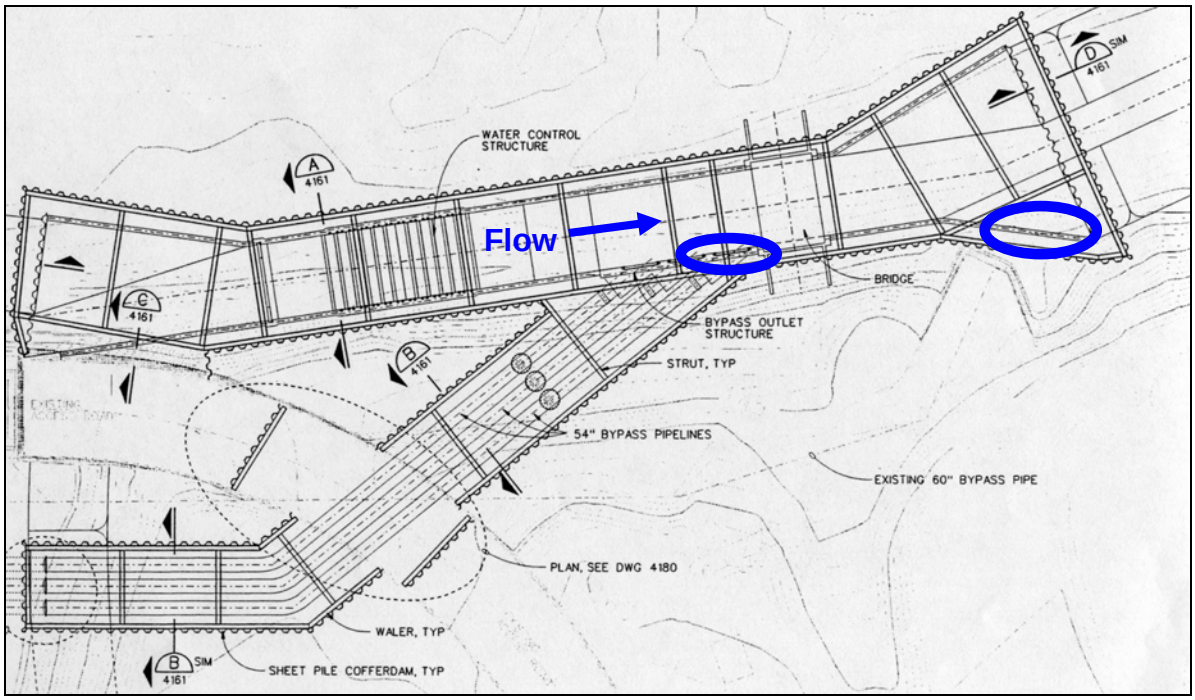

Figure 12. Plan view of the GCID flow-control weir (water control structure) and internal fish screen bypass outfall showing locations where striped bass and Sacramento pikeminnow have been observed with an underwater camera (ovals).

Predatory Fish at the Upstream End of the Fish Screens

As noted during experiments during 2003 through 2006 (Vogel 2005a, 2005b, 2006, 2007), striped bass predation on test fish released just upstream of the fish screens (Figure 13) was observed during mid- to late-summer. It was hypothesized that the routine release of test fish four times a week may have caused a buildup of predatory fish at the release site resulting from a conditioned feeding response. Although this assumption is speculative, it is plausible based on experiments conducted elsewhere (e.g., fish experiments at Red Bluff Diversion Dam and fish salvage releases in the Delta). In 2004 – 2007, the test fish were not released from a boat (as was done in 2003) under the assumption that it would reduce the possible conditioned feeding response of predatory fish. This potentially significant issue remained unresolved during the testing program.

Figure 13. Concentrations of predatory fish near the GCID fish screen

During 2007, a DIDSON camera was used along the fish screens to determine the location and relative abundance of predatory fish. Figure 14 shows a schematic of how the sonar camera ensonifies submerged objects and how those objects are depicted using the DIDSON software. Figures 15 and 16 show example still images of the footage taken at the fish screens. DIDSON imaging of the fish screens was shown to the TOC (in the case of this draft report, will be shown to the TOC). Several noteworthy observations were made as a result of those surveys. The sonar imaging confirmed the presence of predatory fish at the upstream end of the screens and near the dredge bay. A scour hole and woody debris in the scour hole appear to create good holding habitat conditions for predatory fish. Water velocity and depth profiles of this area in 2004 showed the scour hole and slow-moving water (Vogel 2005). The species of fish could not be determined with the sonar camera but were likely Sacramento pikeminnow and striped bass based on their size, images, and behavior. A large portion of the sediment at the base of the fish

screen structure had been scoured revealing the convoluted sheet pile (Figure 15). These areas appeared to create good conditions for predator holding habitat. Prior to construction of the new fish screens, the old screen structure's vertical sheet pile was found to harbor predatory fish. That finding led to the recommendation that the new screen structure have flat-plate steel welded over the irregular sheet pile to eliminate back eddies and predator habitat (Vogel and Marine 1995) (Figure 17). Figure 18 shows the sheet pile used during construction to de-water the site and form the concrete base of the structure. Although it could not be quantified, it appeared that predatory fish in this locale exhibited residency behavior, at least during the late summer period. Four surveys were performed during August and September, and each time, about one to two dozen predatory fish were present. The predators were present more than three weeks after the last mark/recapture experiments ended. Feeding activity of the predators on small fish was also observed. Several experiments were conducted by releasing hatchery juvenile salmon in the usual manner as performed during the typical mark/recapture experiments and vigorous feeding activity by predators on those fish was evident. It was also noted that some of the young salmon moving down the face of the fish screens positioned themselves behind the moving fish screen wiper blades (Figure 19) presumably seeking velocity refugia. A few predatory fish keyed in on the area behind the wiper blade preying on salmon as the blade moved both in a downstream and upstream direction.

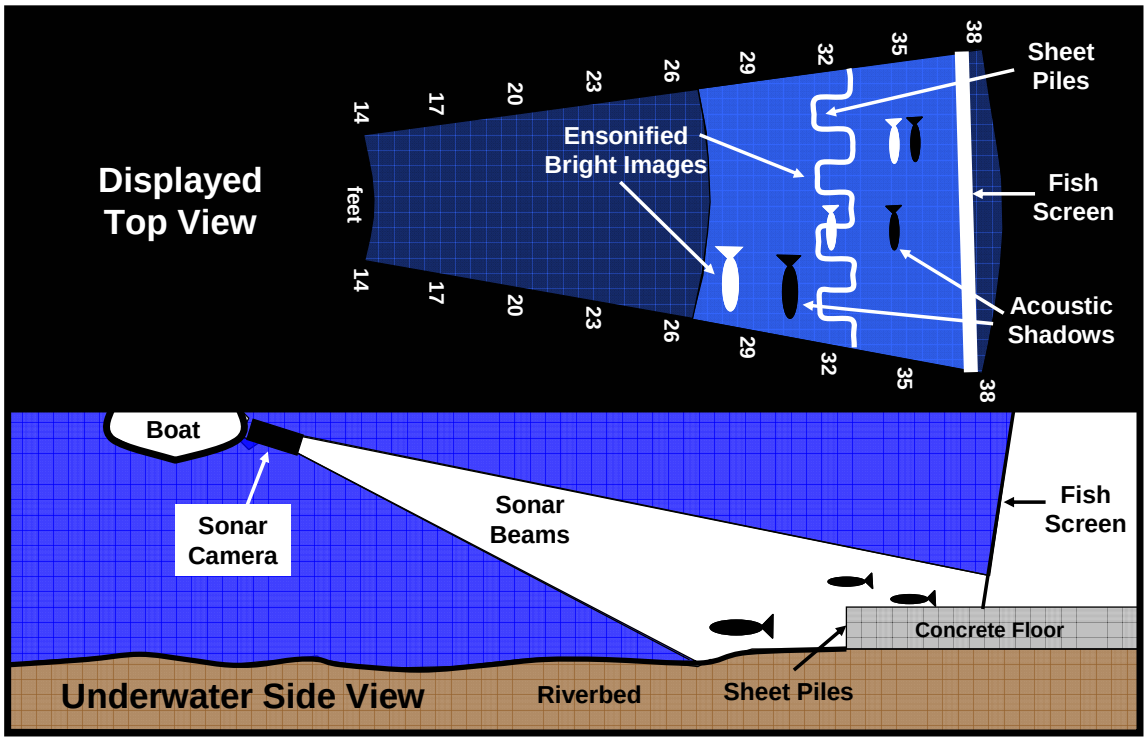

Figure 14. Schematic of DIDSON imaging at the GCID fish screens. Bottom diagram shows orientation of sonar beams from the acoustic camera off the side of a boat and submerged objects at the fish screens. Top diagram shows the resultant corresponding sonar imaging of objects ensonified with acoustic shadows from the objects.

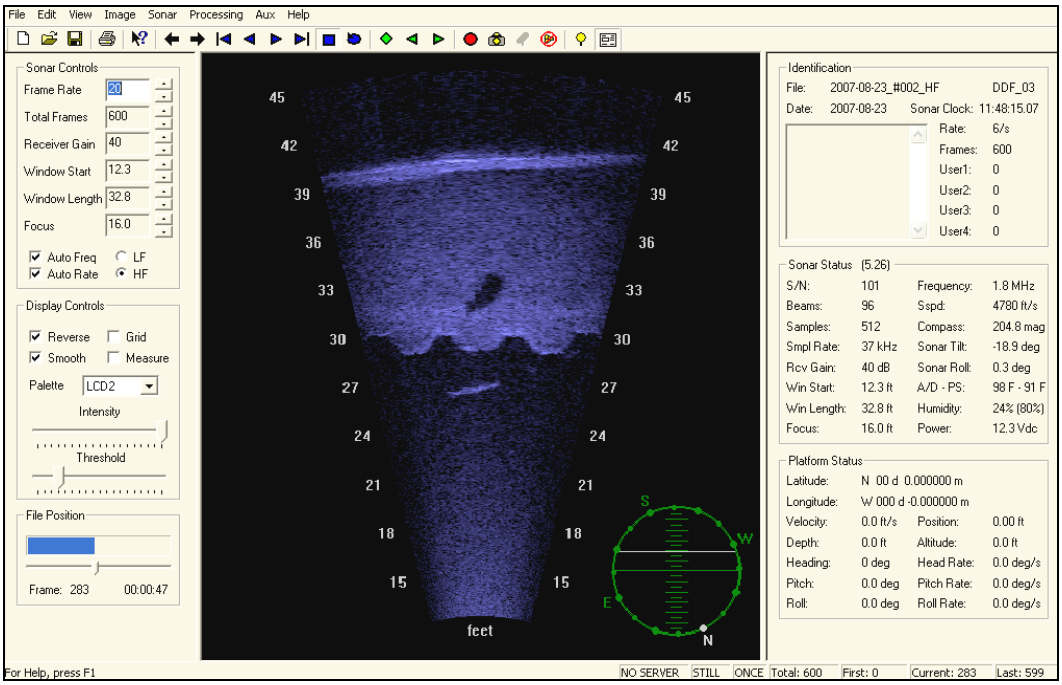

Figure 15. DIDSON image of the base of the GCID fish screen showing a large fish and its acoustic shadow cast on the horizontal concrete base of the fish screen structure. The bright line across the top of the image is the base of the fish screen.

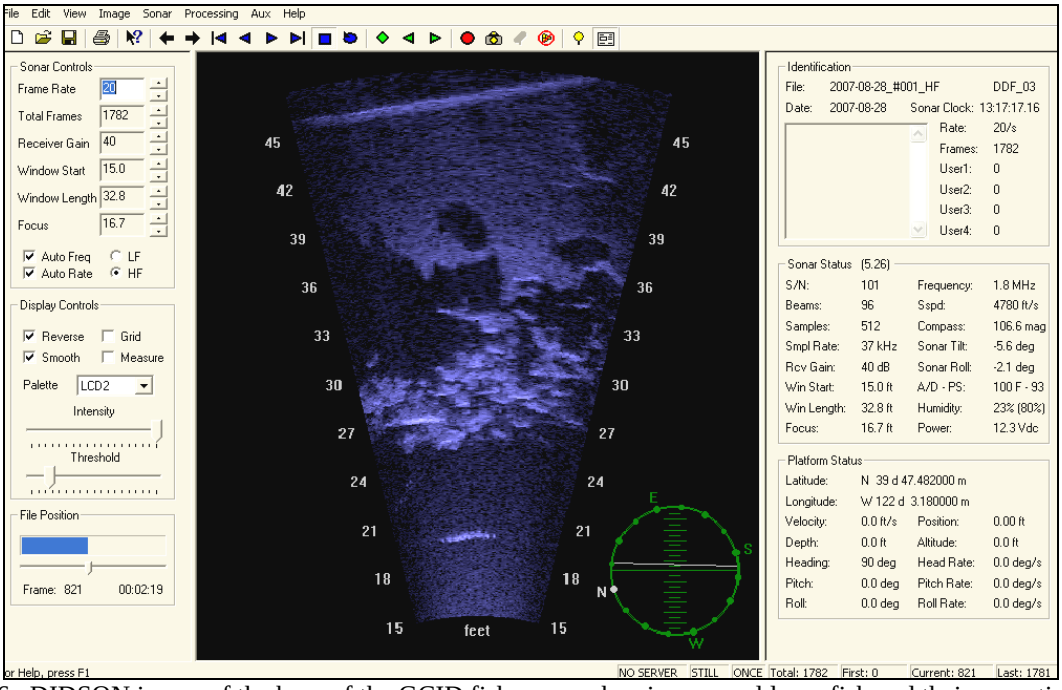

Figure 16. DIDSON image of the base of the GCID fish screen showing several large fish and their acoustic shadows cast on the horizontal concrete base of the fish screen structure. Bright line across the top of the image is the base of the fish screen.

Figure 17. Sheet pile at the GCID fish screen structure showing how the submerged portions of the irregular surface had flat-plate steel welded to the surface to eliminate back eddies and predator habitat.

Figure 18. Base of the de-watered GCID fish screen during construction. Fish screen is on the right. After construction, the irregular-shaped sheet pile shown on the left was severed flush with the concrete floor inundating the area shown to a summer-time depth of about 15 feet.

Figure 19. A wiper blade on the GCID fish screens. Picture was taken during construction at the de-watered structure. After construction, this area was inundated to a summertime depth of about 15 feet.

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Appendix Table 1. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2002.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
9N	5/14/2002	Night	Closed	609	308	319	173	0.93	0.82 - 1.06
12D	5/28/2002	Day	Open	1187	665	628	331	1.06	0.97 - 1.16
17D	6/13/2002	Day	Open	556	332	311	248	0.75	0.69 - 0.82
18D	6/18/2002	Day	Closed	610	333	288	191	0.82	0.74 - 0.92
18N	6/18/2002	Night	Closed	576	339	319	183	1.02	0.91 - 1.15
19N	6/20/2002	Night	Closed	613	355	319	203	0.91	0.82 - 1.01
20D	6/25/2002	Day	Closed	601	321	325	217	0.80	0.72 - 0.89
20N	6/25/2002	Night	Closed	584	302	315	173	0.94	0.83 - 1.07
21D	6/27/2002	Day	Closed	587	335	322	260	0.71	0.65 - 0.77
22N	6/30/2002	Night	Closed	600	362	319	159	1.21	1.07 - 1.38
23D	7/2/2002	Day	Closed	588	356	325	181	1.09	0.97 - 1.23
24N	7/3/2002	Night	Closed	625	380	312	230	0.82	0.75 - 0.91
25D	7/9/2002	Day	Closed	614	378	324	197	1.01	0.91 - 1.13
25N	7/9/2002	Night	Closed	621	349	325	203	0.90	0.81 - 1.01
27N	7/16/2002	Night	Closed	593	380	350	204	1.10	0.99 - 1.23

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 2. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2003.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
5N	4/8/2003	Night	Closed	514	386	253	210	0.90	0.84 - 0.98
6N	4/10/2003	Night	Closed	514	382	264	213	0.92	0.85 - 1.00
7D	4/15/2003	Day	Closed	514	379	265	216	0.90	0.84 - 0.98
8N	4/17/2003	Night	Closed	515	359	265	231	0.80	0.74 - 0.86
9D	5/20/2003	Day	Closed	505	395	265	226	0.92	0.86 - 0.98
9N	5/20/2003	Night	Closed	484	281	259	174	0.86	0.77 - 0.97
11D	5/27/2003	Day	Closed	514	392	258	207	0.95	0.88 - 1.03
11N	5/27/2003	Night	Closed	505	273	260	140	1.00	0.88 - 1.16
12D	5/29/2003	Day	Closed	513	430	265	240	0.93	0.88 - 0.98
12N	5/29/2003	Night	Closed	443	256	254	177	0.83	0.74 - 0.93
13D	6/3/2003	Day	Closed	514	445	258	236	0.95	0.90 - 1.00
13N	6/3/2003	Night	Closed	501	350	242	209	0.81	0.75 - 0.87
14D	6/5/2003	Day	Closed	504	461	253	240	0.96	0.93 - 1.01
14N	6/5/2003	Night	Closed	474	364	265	248	0.82	0.77 - 0.87

15D	6/10/2003	Day	Closed	514	487	252	250	0.96	0.93 - 0.98
15N	6/10/2003	Night	Closed	505	411	260	232	0.91	0.86 - 0.97
16D	6/12/2003	Day	Closed	493	460	250	249	0.94	0.91 - 0.96
16N	6/12/2003	Night	Closed	488	361	247	203	0.90	0.83 - 0.98
17D	6/17/2003	Day	Open	514	451	260	227	1.00	0.95 - 1.07
17N	6/17/2003	Night	Open	507	401	246	229	0.85	0.80 - 0.90
18D	6/24/2003	Day	Open	513	463	256	242	0.95	0.92 - 1.00
18N	6/24/2003	Night	Open	476	374	263	218	0.95	0.88 - 1.02
19D	6/26/2003	Day	Open	512	468	263	253	0.95	0.92 - 0.99
19N	6/26/2003	Night	Open	492	407	265	247	0.89	0.84 - 0.94
20D	7/1/2003	Day	Open	513	415	260	237	0.89	0.84 - 0.94
21D	7/3/2003	Day	Open	502	409	265	175	1.23	1.13 - 1.36
21N	7/3/2003	Night	Open	477	321	258	234	0.74	0.69 - 0.80
22D	7/8/2003	Day	Open	501	381	252	215	0.89	0.83 - 0.96
22N	7/8/2003	Night	Open	515	440	256	244	0.90	0.86 - 0.94
23D	7/10/2003	Day	Open	471	271	222	221	0.58	0.53 - 0.62
23N	7/10/2003	Night	Open	481	361	246	241	0.77	0.72 - 0.81
24D	7/15/2003	Day	Open	512	334	254	216	0.77	0.71 - 0.83
24N	7/15/2003	Night	Open	496	331	252	205	0.82	0.75 - 0.90
25D	7/17/2003	Day	Open	492	268	260	244	0.58	0.53 - 0.63
25N	7/17/2003	Night	Open	495	359	257	220	0.85	0.79 - 0.91
26D	7/22/2003	Day	Open	440	232	255	241	0.56	0.51 - 0.61
27N	7/24/2003	Night	Open	509	327	128	108	0.76	0.69 - 0.85
28N	7/29/2003	Night	Open	511	286	335	251	0.75	0.68 - 0.82
29N	7/31/2003	Night	Open	478	303	257	221	0.74	0.68 - 0.80

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 3. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2003.

Release #	Date	Time of Release	Bypass Position	Screen Group		Weir Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_w	m_w		
5N	4/8/2003	Night	Closed	514	386	265	222	0.90	0.83 - 0.97
6N	4/10/2003	Night	Closed	514	382	260	208	0.93	0.86 - 1.01
7D	4/15/2003	Day	Closed	514	379	260	168	1.14	1.03 - 1.27
8N	4/17/2003	Night	Closed	515	359	260	195	0.93	0.85 - 1.02
9D	5/20/2003	Day	Closed	505	395	265	211	0.98	0.91 - 1.06
9N	5/20/2003	Night	Closed	484	281	261	171	0.89	0.79 - 1.00
11D	5/27/2003	Day	Closed	514	392	251	200	0.96	0.89 - 1.04
11N	5/27/2003	Night	Closed	505	273	265	149	0.96	0.84 - 1.10
12D	5/29/2003	Day	Closed	513	430	251	203	1.04	0.97 - 1.12
12N	5/29/2003	Night	Closed	443	256	239	189	0.73	0.66 - 0.81

13D	6/3/2003	Day	Closed	514	445	258	235	0.95	0.90 - 1.00
13N	6/3/2003	Night	Closed	501	350	265	204	0.91	0.83 - 0.99
14D	6/5/2003	Day	Closed	504	461	260	236	1.01	0.96 - 1.06
14N	6/5/2003	Night	Closed	474	364	253	219	0.89	0.83 - 0.95
15D	6/10/2003	Day	Closed	514	487	259	243	1.01	0.97 - 1.05
15N	6/10/2003	Night	Closed	505	411	265	213	1.01	0.94 - 1.09
16D	6/12/2003	Day	Closed	493	460	258	243	0.99	0.95 - 1.03
16N	6/12/2003	Night	Closed	488	361	257	204	0.93	0.86 - 1.01
17D	6/17/2003	Day	Open	514	451	241	203	1.04	0.98 - 1.11
17N	6/17/2003	Night	Open	507	401	263	229	0.91	0.85 - 0.97
18D	6/24/2003	Day	Open	513	463	265	238	1.00	0.96 - 1.06
18N	6/24/2003	Night	Open	476	374	260	251	0.81	0.77 - 0.86
19D	6/26/2003	Day	Open	512	468	252	240	0.96	0.92 - 1.00
19N	6/26/2003	Night	Open	492	407	259	213	1.01	0.94 - 1.08
20D	7/1/2003	Day	Open	513	415	260	234	0.90	0.85 - 0.95
21D	7/3/2003	Day	Open	502	409	258	216	0.97	0.91 - 1.04
21N	7/3/2003	Night	Open	477	321	254	204	0.84	0.77 - 0.92
22D	7/8/2003	Day	Open	501	381	257	224	0.87	0.82 - 0.94
22N	7/8/2003	Night	Open	515	440	252	230	0.94	0.89 - 0.99
23D	7/10/2003	Day	Open	471	271	256	224	0.66	0.60 - 0.72
23N	7/10/2003	Night	Open	481	361	243	197	0.93	0.86 - 1.01
24D	7/15/2003	Day	Open	512	334	253	238	0.69	0.65 - 0.74
24N	7/15/2003	Night	Open	496	331	258	209	0.82	0.76 - 0.90
25D	7/17/2003	Day	Open	492	268	253	211	0.65	0.59 - 0.72
25N	7/17/2003	Night	Open	495	359	258	194	0.96	0.88 - 1.06
26D	7/22/2003	Day	Open	440	232	247	208	0.63	0.56 - 0.69
27N	7/24/2003	Night	Open	509	327	158	124	0.82	0.74 - 0.91
28N	7/29/2003	Night	Open	511	286	264	188	0.79	0.71 - 0.88
29N	7/31/2003	Night	Open	478	303	265	163	1.03	0.92 - 1.16

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the weir

Appendix Table 4. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2003.

Release #	Date	Time of Release	Bypass Position	Weir Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_w	m_w	R_c	m_c		
5N	4/8/2003	Night	Closed	265	222	253	210	1.01	0.93 - 1.09
6N	4/10/2003	Night	Closed	260	208	264	213	0.99	0.91 - 1.08
7D	4/15/2003	Day	Closed	260	168	265	216	0.79	0.71 - 0.88
8N	4/17/2003	Night	Closed	260	195	265	231	0.86	0.79 - 0.93
9D	5/20/2003	Day	Closed	265	211	265	226	0.93	0.86 - 1.01
9N	5/20/2003	Night	Closed	261	171	259	174	0.98	0.86 - 1.10

11D	5/27/2003	Day	Closed	251	200	258	207	0.99	0.91 - 1.08
11N	5/27/2003	Night	Closed	265	149	260	140	1.04	0.89 - 1.22
12D	5/29/2003	Day	Closed	251	203	265	240	0.89	0.83 - 0.96
12N	5/29/2003	Night	Closed	239	189	254	177	1.13	1.02 - 1.26
13D	6/3/2003	Day	Closed	258	235	258	236	1.00	0.94 - 1.05
13N	6/3/2003	Night	Closed	265	204	242	209	0.89	0.82 - 0.97
14D	6/5/2003	Day	Closed	260	236	253	240	0.96	0.91 - 1.00
14N	6/5/2003	Night	Closed	253	219	265	248	0.92	0.87 - 0.98
15D	6/10/2003	Day	Closed	259	243	252	250	0.95	0.91 - 0.97
15N	6/10/2003	Night	Closed	265	213	260	232	0.90	0.84 - 0.97
16D	6/12/2003	Day	Closed	258	243	250	249	0.95	0.91 - 0.97
16N	6/12/2003	Night	Closed	257	204	247	203	0.97	0.89 - 1.05
17D	6/17/2003	Day	Open	241	203	260	227	0.96	0.90 - 1.04
17N	6/17/2003	Night	Open	263	229	246	229	0.94	0.88 - 0.99
18D	6/24/2003	Day	Open	265	238	256	242	0.95	0.90 - 1.00
18N	6/24/2003	Night	Open	260	251	263	218	1.16	1.10 - 1.24
19D	6/26/2003	Day	Open	252	240	263	253	0.99	0.95 - 1.03
19N	6/26/2003	Night	Open	259	213	265	247	0.88	0.82 - 0.94
20D	7/1/2003	Day	Open	260	234	260	237	0.99	0.93 - 1.04
21D	7/3/2003	Day	Open	258	216	265	175	1.27	1.15 - 1.41
21N	7/3/2003	Night	Open	254	204	258	234	0.89	0.82 - 0.95
22D	7/8/2003	Day	Open	257	224	252	215	1.02	0.95 - 1.10
22N	7/8/2003	Night	Open	252	230	256	244	0.96	0.91 - 1.00
23D	7/10/2003	Day	Open	256	224	222	221	0.88	0.83 - 0.92
23N	7/10/2003	Night	Open	243	197	246	241	0.83	0.77 - 0.88
24D	7/15/2003	Day	Open	253	238	254	216	1.11	1.04 - 1.18
24N	7/15/2003	Night	Open	258	209	252	205	1.00	0.92 - 1.08
25D	7/17/2003	Day	Open	253	211	260	244	0.89	0.83 - 0.94
25N	7/17/2003	Night	Open	258	194	257	220	0.88	0.80 - 0.96
26D	7/22/2003	Day	Open	247	208	255	241	0.89	0.83 - 0.95
27N	7/24/2003	Night	Open	158	124	128	108	0.93	0.83 - 1.04
28N	7/29/2003	Night	Open	264	188	335	251	0.95	0.86 - 1.05
29N	7/31/2003	Night	Open	265	163	257	221	0.72	0.64 - 0.79

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage from the weir to the lower oxbow

Appendix Table 5. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2004.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
1D	5/6/2004	Day	Closed	1000	499	462	306	0.75	0.69 - 0.83

2N	5/11/2004	Night	Closed	500	337	257	184	0.94	0.86 - 1.04
3N	5/13/2004	Night	Closed	441	333	256	184	1.05	0.96 - 1.16
4D	5/18/2004	Day	Closed	513	273	251	209	0.64	0.58 - 0.70
4N	5/18/2004	Night	Closed	505	429	263	234	0.95	0.90 - 1.01
5N	5/20/2004	Night	Closed	494	378	248	181	1.05	0.96 - 1.15
6D	5/25/2004	Day	Closed	515	329	258	217	0.76	0.70 - 0.83
6N	5/25/2004	Night	Closed	514	383	265	233	0.85	0.79 - 0.91
7D	5/27/2004	Day	Open	491	272	265	214	0.69	0.62 - 0.76
7N	5/27/2004	Night	Open	486	345	254	185	0.97	0.89 - 1.07
8D	6/1/2004	Day	Open	515	357	264	257	0.71	0.67 - 0.76
8N	6/1/2004	Night	Open	515	374	260	228	0.83	0.77 - 0.89
9D	6/3/2004	Day	Closed	511	317	260	215	0.75	0.69 - 0.82
9N	6/3/2004	Night	Closed	502	421	261	228	0.96	0.91 - 1.02
10D	6/8/2004	Day	Closed	505	450	262	233	1.00	0.95 - 1.06
11N	6/10/2004	Night	Open	492	341	265	244	0.75	0.70 - 0.81
12D	6/15/2004	Day	Open	515	411	259	243	0.85	0.81 - 0.90
12N	6/15/2004	Night	Open	503	317	263	181	0.92	0.83 - 1.02
13D	6/17/2004	Day	Closed	515	387	260	241	0.81	0.76 - 0.86
13N	6/17/2004	Night	Closed	515	329	264	184	0.92	0.83 - 1.02
14D	6/22/2004	Day	Closed	510	421	264	257	0.85	0.81 - 0.89
14N	6/22/2004	Night	Closed	514	353	265	207	0.88	0.81 - 0.96
15D	6/24/2004	Day	Open	505	432	264	224	1.01	0.95 - 1.08
15N	6/24/2004	Night	Open	508	376	265	219	0.90	0.83 - 0.97
16D	6/29/2004	Day	Open	514	341	262	152	1.14	1.02 - 1.30
16N	6/29/2004	Night	Open	512	317	264	174	0.94	0.84 - 1.05
17D	7/1/2004	Day	Closed	515	318	265	216	0.76	0.69 - 0.83
17N	7/1/2004	Night	Closed	512	370	262	229	0.83	0.77 - 0.89
18D	7/6/2004	Day	Closed	505	404	261	259	0.81	0.77 - 0.84
18N	7/6/2004	Night	Closed	507	327	265	208	0.82	0.75 - 0.90
19D	7/8/2004	Day	Closed	511	410	263	255	0.83	0.79 - 0.87
19N	7/8/2004	Night	Closed	514	354	250	194	0.89	0.81 - 0.97
20D	7/13/2004	Day	Closed	513	333	258	238	0.70	0.65 - 0.76
20N	7/13/2004	Night	Closed	513	325	263	199	0.84	0.76 - 0.92
21D	7/15/2004	Day	Open	509	418	260	259	0.82	0.79 - 0.86
21N	7/15/2004	Night	Open	503	302	246	177	0.83	0.75 - 0.93
22D	7/20/2004	Day	Open	512	352	258	257	0.69	0.65 - 0.73
22N	7/20/2004	Night	Open	504	330	262	186	0.92	0.84 - 1.02
23D	7/22/2004	Day	Closed	512	329	262	259	0.65	0.61 - 0.69
23N	7/22/2004	Night	Closed	429	287	247	182	0.91	0.82 - 1.01
24D	7/27/2004	Day	Closed	508	358	256	245	0.74	0.69 - 0.78
24N	7/27/2004	Night	Closed	508	293	263	185	0.82	0.74 - 0.92
25D	7/29/2004	Day	Open	511	412	260	243	0.86	0.82 - 0.91
25N	7/29/2004	Night	Open	510	339	264	203	0.86	0.79 - 0.95
26D	8/3/2004	Day	Open	506	411	262	252	0.84	0.80 - 0.89
26N	8/3/2004	Night	Open	501	356	255	214	0.85	0.78 - 0.92
27D	8/5/2004	Day	Closed	509	301	262	253	0.61	0.57 - 0.66
27N	8/5/2004	Night	Closed	502	308	262	232	0.69	0.64 - 0.75
28D	8/10/2004	Day	Closed	505	338	264	252	0.70	0.65 - 0.75

29D	8/12/2004	Day	Open	511	374	260	232	0.82	0.77 - 0.88
30D	8/17/2004	Day	Open	509	313	260	252	0.63	0.59 - 0.68
30N	8/17/2004	Night	Open	498	276	265	217	0.68	0.61 - 0.75
31D	8/19/2004	Day	Closed	511	301	265	256	0.61	0.56 - 0.66
31N	8/19/2004	Night	Closed	511	279	264	224	0.64	0.58 - 0.71
32D	8/24/2004	Day	Open	515	329	260	249	0.67	0.62 - 0.71
32N	8/24/2004	Night	Open	512	308	265	179	0.89	0.80 - 1.00
33D	8/26/2004	Day	Open	512	335	264	235	0.74	0.68 - 0.79
33N	8/26/2004	Night	Open	513	331	258	176	0.95	0.85 - 1.05
34D	8/31/2004	Day	Open	504	257	262	223	0.60	0.54 - 0.66
34N	8/31/2004	Night	Open	505	250	265	194	0.68	0.60 - 0.76
35N	9/2/2004	Night	Closed	512	264	259	232	0.58	0.52 - 0.63
37N	9/9/2004	Night	Open	512	258	265	184	0.73	0.65 - 0.82
38N	9/14/2004	Night	Open	513	286	264	206	0.71	0.65 - 0.79

R_s = Number of fish released upstream of the fish screens
m_s = Number of fish recaptured in the lower oxbow
R_c = Number of fish released in the lower oxbow
m_c = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 6. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2004.

Release #	Date	Time of Release	Bypass Position	Screen Group		Weir Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_w	m_w		
1D	5/6/2004	Day	Closed	1000	499	462	306	0.73	0.67 - 0.79
2N	5/11/2004	Night	Closed	500	337	257	184	0.86	0.79 - 0.95
3N	5/13/2004	Night	Closed	441	333	256	184	0.91	0.84 - 0.98
4D	5/18/2004	Day	Closed	513	273	251	209	0.81	0.72 - 0.91
4N	5/18/2004	Night	Closed	505	429	263	234	1.22	1.12 - 1.34
5N	5/20/2004	Night	Closed	494	378	248	181	0.92	0.86 - 1.00
6D	5/25/2004	Day	Closed	515	329	258	217	0.85	0.77 - 0.94
6N	5/25/2004	Night	Closed	514	383	265	233	0.98	0.90 - 1.07
7D	5/27/2004	Day	Open	491	272	265	214	0.73	0.65 - 0.81
7N	5/27/2004	Night	Open	486	345	254	185	0.96	0.87 - 1.05
8D	6/1/2004	Day	Open	515	357	264	257	0.80	0.74 - 0.86
8N	6/1/2004	Night	Open	515	374	260	228	1.00	0.91 - 1.10
9D	6/3/2004	Day	Closed	511	317	260	215	0.76	0.70 - 0.83
9N	6/3/2004	Night	Closed	502	421	261	228	0.99	0.93 - 1.06
10D	6/8/2004	Day	Closed	505	450	262	233	1.00	0.95 - 1.06
11N	6/10/2004	Night	Open	492	341	265	244	0.99	0.90 - 1.09
12D	6/15/2004	Day	Open	515	411	259	243	0.91	0.85 - 0.97
12N	6/15/2004	Night	Open	503	317	263	181	1.02	0.91 - 1.16
13D	6/17/2004	Day	Closed	515	387	260	241	0.93	0.86 - 1.01
13N	6/17/2004	Night	Closed	515	329	264	184	0.89	0.81 - 0.99
14D	6/22/2004	Day	Closed	510	421	264	257	1.01	0.94 - 1.08

14N	6/22/2004	Night	Closed	514	353	265	207	0.93	0.85 - 1.03
15D	6/24/2004	Day	Open	505	432	264	224	1.08	1.00 - 1.16
15N	6/24/2004	Night	Open	508	376	265	219	1.01	0.93 - 1.11
16D	6/29/2004	Day	Open	514	341	262	152	1.01	0.91 - 1.13
16N	6/29/2004	Night	Open	512	317	264	174	1.14	1.01 - 1.31
17D	7/1/2004	Day	Closed	515	318	265	216	0.85	0.77 - 0.94
17N	7/1/2004	Night	Closed	512	370	262	229	1.02	0.93 - 1.13
18D	7/6/2004	Day	Closed	505	404	261	259	1.06	0.98 - 1.16
18N	7/6/2004	Night	Closed	507	327	265	208	0.94	0.85 - 1.05
19D	7/8/2004	Day	Closed	511	410	263	255	1.03	0.95 - 1.12
19N	7/8/2004	Night	Closed	514	354	250	194	0.88	0.81 - 0.97
20D	7/13/2004	Day	Closed	513	333	258	238	0.82	0.75 - 0.90
20N	7/13/2004	Night	Closed	513	325	263	199	0.94	0.85 - 1.05
21D	7/15/2004	Day	Open	509	418	260	259	0.85	0.81 - 0.89
21N	7/15/2004	Night	Open	503	302	246	177	0.90	0.81 - 1.01
22D	7/20/2004	Day	Open	512	352	258	257	0.87	0.80 - 0.94
22N	7/20/2004	Night	Open	504	330	262	186	1.07	0.96 - 1.21
23D	7/22/2004	Day	Closed	512	329	262	259	0.89	0.81 - 0.99
23N	7/22/2004	Night	Closed	429	287	247	182	0.93	0.84 - 1.03
24D	7/27/2004	Day	Closed	508	358	256	245	0.98	0.90 - 1.08
24N	7/27/2004	Night	Closed	508	293	263	185	0.89	0.79 - 1.00
25D	7/29/2004	Day	Open	511	412	260	243	1.06	0.98 - 1.15
25N	7/29/2004	Night	Open	510	339	264	203	1.08	0.97 - 1.21
26D	8/3/2004	Day	Open	506	411	262	252	1.13	1.04 - 1.23
26N	8/3/2004	Night	Open	501	356	255	214	0.96	0.88 - 1.06
27D	8/5/2004	Day	Closed	509	301	262	253	0.82	0.74 - 0.91
27N	8/5/2004	Night	Closed	502	308	262	232	0.85	0.77 - 0.94
28D	8/10/2004	Day	Closed	505	338	264	252	1.12	1.00 - 1.26
29D	8/12/2004	Day	Open	511	374	260	232	0.93	0.86 - 1.02
30D	8/17/2004	Day	Open	509	313	260	252	1.17	1.03 - 1.34
30N	8/17/2004	Night	Open	498	276	265	217	0.72	0.65 - 0.80
31D	8/19/2004	Day	Closed	511	301	265	256	0.74	0.67 - 0.81
31N	8/19/2004	Night	Closed	511	279	264	224	0.80	0.71 - 0.90
32D	8/24/2004	Day	Open	515	329	260	249	0.99	0.89 - 1.11
32N	8/24/2004	Night	Open	512	308	265	179	0.90	0.81 - 1.01
33D	8/26/2004	Day	Open	512	335	264	235	1.02	0.92 - 1.15
33N	8/26/2004	Night	Open	513	331	258	176	1.04	0.93 - 1.18
34D	8/31/2004	Day	Open	504	257	262	223	0.87	0.76 - 0.99
34N	8/31/2004	Night	Open	505	250	265	194	0.85	0.75 - 0.98
35N	9/2/2004	Night	Closed	512	264	259	232	0.80	0.71 - 0.91
37N	9/9/2004	Night	Open	512	258	265	184	0.80	0.71 - 0.92
38N	9/14/2004	Night	Open	513	286	264	206	0.90	0.80 - 1.02

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the weir

Appendix Table 7. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2004.

Release #	Date	Time of Release	Bypass Position	Weir Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_w	m_w	R_c	m_c		
1D	5/6/2004	Day	Closed	487	334	462	306	1.04	0.95 - 1.13
2N	5/11/2004	Night	Closed	264	206	257	184	1.09	0.99 - 1.21
3N	5/13/2004	Night	Closed	249	207	256	184	1.16	1.05 - 1.28
4D	5/18/2004	Day	Closed	265	174	251	209	0.79	0.71 - 0.87
4N	5/18/2004	Night	Closed	263	183	263	234	0.78	0.71 - 0.85
5N	5/20/2004	Night	Closed	263	218	248	181	1.14	1.04 - 1.25
6D	5/25/2004	Day	Closed	254	191	258	217	0.89	0.82 - 0.98
6N	5/25/2004	Night	Closed	265	201	265	233	0.86	0.79 - 0.93
7D	5/27/2004	Day	Open	257	196	265	214	0.94	0.86 - 1.03
7N	5/27/2004	Night	Open	257	191	254	185	1.02	0.92 - 1.13
8D	6/1/2004	Day	Open	265	231	264	257	0.90	0.85 - 0.94
8N	6/1/2004	Night	Open	265	193	260	228	0.83	0.76 - 0.90
9D	6/3/2004	Day	Closed	264	215	260	215	0.98	0.91 - 1.07
9N	6/3/2004	Night	Closed	265	225	261	228	0.97	0.91 - 1.04
10D	6/8/2004	Day	Closed	260	232	262	233	1.00	0.94 - 1.07
11N	6/10/2004	Night	Open	264	185	265	244	0.76	0.69 - 0.83
12D	6/15/2004	Day	Open	263	231	259	243	0.94	0.88 - 0.99
12N	6/15/2004	Night	Open	265	163	263	181	0.89	0.79 - 1.01
13D	6/17/2004	Day	Closed	265	214	260	241	0.87	0.81 - 0.93
13N	6/17/2004	Night	Closed	261	187	264	184	1.03	0.92 - 1.15
14D	6/22/2004	Day	Closed	264	216	264	257	0.84	0.79 - 0.89
14N	6/22/2004	Night	Closed	265	195	265	207	0.94	0.85 - 1.04
15D	6/24/2004	Day	Open	264	210	264	224	0.94	0.86 - 1.01
15N	6/24/2004	Night	Open	261	191	265	219	0.89	0.81 - 0.97
16D	6/29/2004	Day	Open	265	174	262	152	1.13	0.99 - 1.30
16N	6/29/2004	Night	Open	262	142	264	174	0.82	0.71 - 0.95
17D	7/1/2004	Day	Closed	265	193	265	216	0.89	0.81 - 0.98
17N	7/1/2004	Night	Closed	265	187	262	229	0.81	0.74 - 0.88
18D	7/6/2004	Day	Closed	259	195	261	259	0.76	0.70 - 0.81
18N	7/6/2004	Night	Closed	263	180	265	208	0.87	0.78 - 0.97
19D	7/8/2004	Day	Closed	244	190	263	255	0.80	0.74 - 0.86
19N	7/8/2004	Night	Closed	255	199	250	194	1.01	0.92 - 1.10
20D	7/13/2004	Day	Closed	263	208	258	238	0.86	0.80 - 0.92
20N	7/13/2004	Night	Closed	259	174	263	199	0.89	0.79 - 0.99
21D	7/15/2004	Day	Open	256	248	260	259	0.97	0.95 - 0.99
21N	7/15/2004	Night	Open	264	176	246	177	0.93	0.82 - 1.04
22D	7/20/2004	Day	Open	263	209	258	257	0.80	0.75 - 0.84
22N	7/20/2004	Night	Open	260	159	262	186	0.86	0.76 - 0.97
23D	7/22/2004	Day	Closed	264	190	262	259	0.73	0.67 - 0.78
23N	7/22/2004	Night	Closed	263	189	247	182	0.98	0.88 - 1.09
24D	7/27/2004	Day	Closed	265	190	256	245	0.75	0.69 - 0.81

24N	7/27/2004	Night	Closed	261	170	263	185	0.93	0.82 - 1.04
25D	7/29/2004	Day	Open	260	198	260	243	0.81	0.75 - 0.88
25N	7/29/2004	Night	Open	263	162	264	203	0.80	0.71 - 0.90
26D	8/3/2004	Day	Open	265	191	262	252	0.75	0.69 - 0.81
26N	8/3/2004	Night	Open	263	194	255	214	0.88	0.80 - 0.96
27D	8/5/2004	Day	Closed	264	190	262	253	0.75	0.69 - 0.80
27N	8/5/2004	Night	Closed	262	189	262	232	0.81	0.74 - 0.89
28D	8/10/2004	Day	Closed	261	156	264	252	0.63	0.56 - 0.69
29D	8/12/2004	Day	Open	263	206	260	232	0.88	0.81 - 0.95
30D	8/17/2004	Day	Open	264	139	260	252	0.54	0.48 - 0.61
30N	8/17/2004	Night	Open	258	198	265	217	0.94	0.86 - 1.02
31D	8/19/2004	Day	Closed	263	210	265	256	0.83	0.77 - 0.88
31N	8/19/2004	Night	Closed	259	177	264	224	0.81	0.73 - 0.89
32D	8/24/2004	Day	Open	265	171	260	249	0.67	0.61 - 0.74
32N	8/24/2004	Night	Open	261	174	265	179	0.99	0.87 - 1.11
33D	8/26/2004	Day	Open	263	168	264	235	0.72	0.65 - 0.79
33N	8/26/2004	Night	Open	257	159	258	176	0.91	0.80 - 1.03
34D	8/31/2004	Day	Open	262	154	262	223	0.69	0.61 - 0.77
34N	8/31/2004	Night	Open	265	154	265	194	0.79	0.70 - 0.90
35N	9/2/2004	Night	Closed	263	169	259	232	0.72	0.65 - 0.79
37N	9/9/2004	Night	Open	257	161	265	184	0.90	0.80 - 1.02
38N	9/14/2004	Night	Open	264	164	264	206	0.80	0.71 - 0.89

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage from the weir to the lower oxbow

Appendix Table 8. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2005.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
3D	6/7/2005	Day	Closed	515	393	265	254	0.80	0.75 - 0.84
3N	6/7/2005	Night	Closed	479	360	265	206	0.97	0.89 - 1.05
4D	6/9/2005	Day	Closed	515	413	265	264	0.80	0.77 - 0.84
4N	6/9/2005	Night	Closed	514	322	264	214	0.77	0.71 - 0.85
5D	6/14/2005	Day	Closed	515	448	265	262	0.88	0.85 - 0.91
5N	6/14/2005	Night	Closed	515	410	265	226	0.93	0.87 - 1.00
6D	6/16/2005	Day	Closed	515	429	265	226	0.98	0.92 - 1.04
7D	6/21/2005	Day	Closed	514	451	265	227	1.02	0.97 - 1.09
7N	6/21/2005	Night	Closed	515	336	264	238	0.72	0.67 - 0.78
8D	6/23/2005	Day	Closed	515	426	265	245	0.89	0.85 - 0.94
8N	6/23/2005	Night	Closed	515	338	265	208	0.84	0.77 - 0.92
9D	6/28/2005	Day	Closed	515	422	265	242	0.90	0.85 - 0.95
9N	6/28/2005	Night	Closed	505	381	265	226	0.88	0.82 - 0.95

10D	6/30/2005	Day	Closed	515	386	285	272	0.79	0.74 - 0.83
10N	6/30/2005	Night	Closed	515	324	265	221	0.75	0.69 - 0.82
11D	7/6/2005	Day	Closed	514	314	349	323	0.66	0.61 - 0.71
11N	7/6/2005	Night	Closed	506	300	260	205	0.75	0.68 - 0.83
12D	7/7/2005	Day	Closed	514	365	249	210	0.84	0.78 - 0.91
12N	7/7/2005	Night	Closed	396	238	260	198	0.79	0.71 - 0.88
13N	7/12/2005	Night	Open	515	343	265	215	0.82	0.75 - 0.89
14D	7/14/2005	Day	Open	515	425	264	254	0.86	0.82 - 0.90
14N	7/14/2005	Night	Open	510	300	265	201	0.78	0.70 - 0.86
15D	7/20/2005	Day	Closed	514	378	264	262	0.74	0.70 - 0.78
15N	7/20/2005	Night	Closed	513	340	265	207	0.85	0.78 - 0.93
16D	7/21/2005	Day	Closed	515	315	263	163	0.99	0.88 - 1.11
17D	7/26/2005	Day	Open	515	359	265	247	0.75	0.70 - 0.80
17N	7/26/2005	Night	Open	513	349	264	222	0.81	0.75 - 0.88
18D	7/28/2005	Day	Open	514	351	265	255	0.71	0.66 - 0.76
18N	7/28/2005	Night	Open	512	332	263	210	0.81	0.74 - 0.89
19D	8/2/2005	Day	Closed	505	370	263	239	0.81	0.75 - 0.86
19N	8/2/2005	Night	Closed	513	350	264	212	0.85	0.78 - 0.93
20D	8/4/2005	Day	Closed	515	390	249	239	0.79	0.75 - 0.83
20N	8/4/2005	Night	Closed	502	325	262	223	0.76	0.70 - 0.83
21D	8/9/2005	Day	Open	512	393	263	223	0.91	0.84 - 0.97
21N	8/9/2005	Night	Open	515	330	265	229	0.74	0.68 - 0.80
22N	8/11/2005	Night	Open	501	318	263	220	0.76	0.70 - 0.83
23D	8/16/2005	Day	Closed	508	336	260	241	0.71	0.66 - 0.77
23N	8/16/2005	Night	Closed	513	313	261	212	0.75	0.69 - 0.82
24D	8/18/2005	Day	Closed	500	318	263	251	0.67	0.62 - 0.71
24N	8/18/2005	Night	Closed	498	321	257	193	0.86	0.78 - 0.95
25D	8/23/2005	Day	Open	505	288	255	223	0.65	0.60 - 0.71
25N	8/23/2005	Night	Open	493	282	264	216	0.70	0.64 - 0.77
26D	8/25/2005	Day	Open	492	305	260	215	0.75	0.69 - 0.82
26N	8/25/2005	Night	Open	502	277	254	205	0.68	0.62 - 0.76
27D	9/1/2005	Day	Closed	512	287	265	228	0.65	0.59 - 0.71
27N	9/1/2005	Night	Closed	514	261	264	196	0.68	0.61 - 0.76

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 9. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2005.

Release #	Date	Time of Release	Bypass Position	Screen Group		Weir Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_w	m_w		
3D	6/7/2005	Day	Closed	515	393	265	242	0.84	0.79 - 0.89
3N	6/7/2005	Night	Closed	479	360	260	198	0.99	0.91 - 1.08

4D	6/9/2005	Day	Closed	515	413	254	202	1.01	0.94 - 1.09
4N	6/9/2005	Night	Closed	514	322	260	163	1.00	0.89 - 1.13
5D	6/14/2005	Day	Closed	515	448	264	210	1.09	1.02 - 1.18
5N	6/14/2005	Night	Closed	515	410	259	212	0.97	0.91 - 1.05
6D	6/16/2005	Day	Closed	515	429	265	223	0.99	0.93 - 1.06
7D	6/21/2005	Day	Closed	514	451	264	228	1.02	0.96 - 1.08
7N	6/21/2005	Night	Closed	515	336	265	199	0.87	0.79 - 0.96
8D	6/23/2005	Day	Closed	515	426	265	232	0.94	0.89 - 1.01
8N	6/23/2005	Night	Closed	515	338	264	186	0.93	0.84 - 1.03
9D	6/28/2005	Day	Closed	515	422	264	250	0.87	0.82 - 0.91
9N	6/28/2005	Night	Closed	505	381	265	178	1.12	1.02 - 1.24
10D	6/30/2005	Day	Closed	515	386	260	221	0.88	0.82 - 0.95
10N	6/30/2005	Night	Closed	515	324	265	138	1.21	1.06 - 1.39
11D	7/6/2005	Day	Closed	514	314	264	219	0.74	0.67 - 0.80
11N	7/6/2005	Night	Closed	506	300	263	153	1.02	0.90 - 1.16
12D	7/7/2005	Day	Closed	514	365	261	177	1.05	0.95 - 1.16
12N	7/7/2005	Night	Closed	396	238	271	150	1.09	0.95 - 1.25
13N	7/12/2005	Night	Open	515	343	265	200	0.88	0.81 - 0.97
14D	7/14/2005	Day	Open	515	425	265	216	1.01	0.95 - 1.09
14N	7/14/2005	Night	Open	510	300	263	195	0.79	0.72 - 0.88
15D	7/20/2005	Day	Closed	514	378	260	184	1.04	0.95 - 1.15
15N	7/20/2005	Night	Closed	513	340	230	166	0.92	0.83 - 1.02
16D	7/21/2005	Day	Closed	515	315	259	160	0.99	0.88 - 1.12
17D	7/26/2005	Day	Open	515	359	259	201	0.90	0.82 - 0.98
17N	7/26/2005	Night	Open	513	349	265	177	1.02	0.92 - 1.13
18D	7/28/2005	Day	Open	514	351	264	201	0.90	0.82 - 0.98
18N	7/28/2005	Night	Open	512	332	259	191	0.88	0.80 - 0.97
19D	8/2/2005	Day	Closed	505	370	254	185	1.01	0.92 - 1.11
19N	8/2/2005	Night	Closed	513	350	259	165	1.07	0.96 - 1.20
20D	8/4/2005	Day	Closed	515	390	260	173	1.14	1.03 - 1.26
20N	8/4/2005	Night	Closed	502	325	259	186	0.90	0.82 - 1.00
21D	8/9/2005	Day	Open	512	393	265	204	1.00	0.92 - 1.08
21N	8/9/2005	Night	Open	515	330	264	177	0.96	0.86 - 1.07
22N	8/11/2005	Night	Open	501	318	265	202	0.83	0.76 - 0.92
23D	8/16/2005	Day	Closed	508	336	261	151	1.14	1.02 - 1.30
23N	8/16/2005	Night	Closed	513	313	265	151	1.07	0.95 - 1.22
24D	8/18/2005	Day	Closed	500	318	264	172	0.98	0.88 - 1.09
24N	8/18/2005	Night	Closed	498	321	262	190	0.89	0.81 - 0.98
25D	8/23/2005	Day	Open	505	288	257	136	1.08	0.94 - 1.24
25N	8/23/2005	Night	Open	493	282	262	155	0.97	0.85 - 1.10
26D	8/25/2005	Day	Open	492	305	260	178	0.91	0.81 - 1.01
26N	8/25/2005	Night	Open	502	277	265	172	0.85	0.76 - 0.96
27D	9/1/2005	Day	Closed	512	287	264	144	1.03	0.90 - 1.18
27N	9/1/2005	Night	Closed	514	261	263	157	0.85	0.75 - 0.97

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the weir

Appendix Table 10. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2005.

Release #	Date	Time of Release	Bypass Position	Weir Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_w	m_w	R_c	m_c		
3D	6/7/2005	Day	Closed	265	242	265	254	0.95	0.91 - 1.00
3N	6/7/2005	Night	Closed	260	198	265	206	0.98	0.89 - 1.08
4D	6/9/2005	Day	Closed	254	202	265	264	0.80	0.75 - 0.85
4N	6/9/2005	Night	Closed	260	163	264	214	0.77	0.69 - 0.86
5D	6/14/2005	Day	Closed	264	210	265	262	0.80	0.75 - 0.85
5N	6/14/2005	Night	Closed	259	212	265	226	0.96	0.89 - 1.04
6D	6/16/2005	Day	Closed	265	223	265	226	0.99	0.92 - 1.06
7D	6/21/2005	Day	Closed	264	228	265	227	1.01	0.94 - 1.08
7N	6/21/2005	Night	Closed	265	199	264	238	0.83	0.77 - 0.90
8D	6/23/2005	Day	Closed	265	232	265	245	0.95	0.89 - 1.00
8N	6/23/2005	Night	Closed	264	186	265	208	0.90	0.81 - 0.99
9D	6/28/2005	Day	Closed	264	250	265	242	1.04	0.99 - 1.09
9N	6/28/2005	Night	Closed	265	178	265	226	0.79	0.71 - 0.87
10D	6/30/2005	Day	Closed	260	221	285	272	0.89	0.84 - 0.94
10N	6/30/2005	Night	Closed	265	138	265	221	0.62	0.55 - 0.71
11D	7/6/2005	Day	Closed	264	219	349	323	0.90	0.84 - 0.95
11N	7/6/2005	Night	Closed	263	153	260	205	0.74	0.65 - 0.83
12D	7/7/2005	Day	Closed	261	177	249	210	0.80	0.73 - 0.89
12N	7/7/2005	Night	Closed	271	150	260	198	0.73	0.64 - 0.82
13N	7/12/2005	Night	Open	265	200	265	215	0.93	0.85 - 1.02
14D	7/14/2005	Day	Open	265	216	264	254	0.85	0.79 - 0.90
14N	7/14/2005	Night	Open	263	195	265	201	0.98	0.88 - 1.08
15D	7/20/2005	Day	Closed	260	184	264	262	0.71	0.66 - 0.77
15N	7/20/2005	Night	Closed	230	166	265	207	0.92	0.83 - 1.02
16D	7/21/2005	Day	Closed	259	160	263	163	1.00	0.87 - 1.14
17D	7/26/2005	Day	Open	259	201	265	247	0.83	0.77 - 0.89
17N	7/26/2005	Night	Open	265	177	264	222	0.79	0.72 - 0.88
18D	7/28/2005	Day	Open	264	201	265	255	0.79	0.73 - 0.85
18N	7/28/2005	Night	Open	259	191	263	210	0.92	0.84 - 1.01
19D	8/2/2005	Day	Closed	254	185	263	239	0.80	0.73 - 0.87
19N	8/2/2005	Night	Closed	259	165	264	212	0.79	0.71 - 0.88
20D	8/4/2005	Day	Closed	260	173	249	239	0.69	0.63 - 0.75
20N	8/4/2005	Night	Closed	259	186	262	223	0.84	0.77 - 0.92
21D	8/9/2005	Day	Open	265	204	263	223	0.91	0.83 - 0.99
21N	8/9/2005	Night	Open	264	177	265	229	0.78	0.70 - 0.85
22N	8/11/2005	Night	Open	265	202	263	220	0.91	0.83 - 0.99
23D	8/16/2005	Day	Closed	261	151	260	241	0.62	0.56 - 0.69
23N	8/16/2005	Night	Closed	265	151	261	212	0.70	0.62 - 0.79
24D	8/18/2005	Day	Closed	264	172	263	251	0.68	0.62 - 0.74

24N	8/18/2005	Night	Closed	262	190	257	193	0.97	0.87 - 1.07
25D	8/23/2005	Day	Open	257	136	255	223	0.61	0.53 - 0.68
25N	8/23/2005	Night	Open	262	155	264	216	0.72	0.64 - 0.81
26D	8/25/2005	Day	Open	260	178	260	215	0.83	0.75 - 0.91
26N	8/25/2005	Night	Open	265	172	254	205	0.80	0.72 - 0.89
27D	9/1/2005	Day	Closed	264	144	265	228	0.63	0.56 - 0.71
27N	9/1/2005	Night	Closed	263	157	264	196	0.80	0.71 - 0.91

R_w = Number of fish released at the weir
m_w = Number of fish recaptured in the lower oxbow
R_c = Number of fish released in the lower oxbow
m_c = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage from the weir to the lower oxbow

Appendix Table 11. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2006.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
1D	6/13/2006	Day	Closed	749	675	375	368	0.92	0.89 - 0.94
1N	6/13/2006	Night	Closed	750	523	374	198	1.32	1.19 - 1.47
2D	6/15/2006	Day	Closed	750	666	375	368	0.90	0.88 - 0.93
2N	6/15/2006	Night	Closed	747	532	375	275	0.97	0.90 - 1.05
3D	6/20/2006	Day	Closed	747	486	375	358	0.68	0.64 - 0.72
3N	6/20/2006	Night	Closed	708	531	375	288	0.98	0.91 - 1.05
4N	6/22/2006	Night	Closed	741	513	375	295	0.88	0.82 - 0.95
5D	6/27/2006	Day	Closed	747	633	374	359	0.88	0.85 - 0.92
5N	6/27/2006	Night	Closed	746	519	375	327	0.80	0.75 - 0.85
6D	6/29/2006	Day	Closed	745	560	375	304	0.93	0.87 - 0.99
6N	6/29/2006	Night	Closed	748	505	375	282	0.90	0.83 - 0.97
7D	7/4/2006	Day	Closed	746	546	375	300	0.91	0.86 - 0.98
8D	7/6/2006	Day	Closed	746	577	374	354	0.82	0.78 - 0.86
8N	7/6/2006	Night	Closed	748	470	374	283	0.83	0.77 - 0.90
9N	7/12/2006	Night	Closed	736	482	373	269	0.91	0.84 - 0.99
10N	7/13/2006	Night	Closed	680	439	373	254	0.95	0.87 - 1.04
11D	7/18/2006	Day	Closed	606	500	375	354	0.87	0.84 - 0.91
11N	7/18/2006	Night	Closed	750	522	361	298	0.84	0.79 - 0.90
12D	7/20/2006	Day	Closed	739	482	374	301	0.81	0.75 - 0.87
12N	7/20/2006	Night	Closed	706	443	371	251	0.93	0.85 - 1.02
13D	8/15/2006	Day	Closed	694	494	367	280	0.93	0.87 - 1.01
13N	8/15/2006	Night	Closed	721	422	374	239	0.92	0.83 - 1.01
14D	8/17/2006	Day	Closed	722	604	367	342	0.90	0.86 - 0.94
14N	8/17/2006	Night	Closed	744	441	292	174	0.99	0.89 - 1.12
15D	8/22/2006	Day	Closed	653	551	286	285	0.85	0.82 - 0.87
15N	8/22/2006	Night	Closed	745	402	374	240	0.84	0.76 - 0.93
16D	8/24/2006	Day	Closed	456	323	372	276	0.95	0.88 - 1.04
16N	8/24/2006	Night	Closed	746	409	369	226	0.90	0.81 - 1.00

17D	8/29/2006	Day	Closed	634	387	352	290	0.74	0.68 - 0.80
18N	8/30/2006	Night	Closed	735	404	373	212	0.97	0.87 - 1.08
19D	8/31/2006	Day	Closed	749	425	374	306	0.69	0.64 - 0.75

R_s = Number of fish released upstream of the fish screens
m_s = Number of fish recaptured in the lower oxbow
R_c = Number of fish released in the lower oxbow
m_c = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 12. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2006.

Release #	Date	Time of Release	Bypass Position	Screen Group		Weir Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_w	m_w		
1D	6/13/2006	Day	Closed	749	675	374	318	1.06	1.01 - 1.12
1N	6/13/2006	Night	Closed	750	523	374	265	0.98	0.91 - 1.07
2D	6/15/2006	Day	Closed	750	666	374	301	1.10	1.05 - 1.17
2N	6/15/2006	Night	Closed	747	532	375	264	1.01	0.94 - 1.10
3D	6/20/2006	Day	Closed	747	486	375	299	0.82	0.76 - 0.88
3N	6/20/2006	Night	Closed	708	531	375	306	0.92	0.86 - 0.98
4N	6/22/2006	Night	Closed	741	513	372	297	0.87	0.81 - 0.93
5D	6/27/2006	Day	Closed	747	633	374	321	0.99	0.94 - 1.04
5N	6/27/2006	Night	Closed	746	519	375	287	0.91	0.85 - 0.98
6D	6/29/2006	Day	Closed	745	560	371	283	0.99	0.92 - 1.06
6N	6/29/2006	Night	Closed	748	505	373	254	0.99	0.91 - 1.08
7D	7/4/2006	Day	Closed	746	546	374	267	1.03	0.95 - 1.11
8D	7/6/2006	Day	Closed	746	577	373	313	0.92	0.87 - 0.98
8N	7/6/2006	Night	Closed	748	470	372	271	0.86	0.79 - 0.94
9N	7/12/2006	Night	Closed	736	482	347	226	1.01	0.92 - 1.11
10N	7/13/2006	Night	Closed	680	439	371	264	0.91	0.83 - 0.99
11D	7/18/2006	Day	Closed	606	500	372	297	1.03	0.97 - 1.10
11N	7/18/2006	Night	Closed	750	522	343	243	0.98	0.91 - 1.07
12D	7/20/2006	Day	Closed	739	482	374	297	0.82	0.76 - 0.89
12N	7/20/2006	Night	Closed	706	443	322	217	0.93	0.85 - 1.03
13D	8/15/2006	Day	Closed	694	494	350	315	0.79	0.75 - 0.84
13N	8/15/2006	Night	Closed	721	422	375	245	0.90	0.81 - 0.99
14D	8/17/2006	Day	Closed	722	604	375	349	0.90	0.86 - 0.94
14N	8/17/2006	Night	Closed	744	441	356	191	1.10	0.99 - 1.24
15D	8/22/2006	Day	Closed	653	551	375	317	1.00	0.95 - 1.06
15N	8/22/2006	Night	Closed	745	402	372	236	0.85	0.77 - 0.94
16D	8/24/2006	Day	Closed	456	323	372	293	0.90	0.83 - 0.97
16N	8/24/2006	Night	Closed	746	409	357	209	0.94	0.84 - 1.05
17D	8/29/2006	Day	Closed	634	387	375	342	0.67	0.62 - 0.72
18N	8/30/2006	Night	Closed	735	404	372	241	0.85	0.77 - 0.94
19D	8/31/2006	Day	Closed	749	425	375	301	0.71	0.65 - 0.77

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow
R_w = Number of fish released at the weir
m_w = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the weir

Appendix Table 13. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2006.

Release #	Date	Time of Release	Bypass Position	Weir Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_w	m_w	R_c	m_c		
1D	6/13/2006	Day	Closed	374	318	375	368	0.87	0.83 - 0.90
1N	6/13/2006	Night	Closed	374	265	374	198	1.34	1.19 - 1.51
2D	6/15/2006	Day	Closed	374	301	375	368	0.82	0.78 - 0.86
2N	6/15/2006	Night	Closed	375	264	375	275	0.96	0.88 - 1.05
3D	6/20/2006	Day	Closed	375	299	375	358	0.84	0.79 - 0.88
3N	6/20/2006	Night	Closed	375	306	375	288	1.06	0.99 - 1.14
4N	6/22/2006	Night	Closed	372	297	375	295	1.01	0.94 - 1.09
5D	6/27/2006	Day	Closed	374	321	374	359	0.89	0.85 - 0.93
5N	6/27/2006	Night	Closed	375	287	375	327	0.88	0.82 - 0.94
6D	6/29/2006	Day	Closed	371	283	375	304	0.94	0.87 - 1.01
6N	6/29/2006	Night	Closed	373	254	375	282	0.91	0.83 - 0.99
7D	7/4/2006	Day	Closed	374	267	375	300	0.89	0.82 - 0.97
8D	7/6/2006	Day	Closed	373	313	374	354	0.89	0.84 - 0.93
8N	7/6/2006	Night	Closed	372	271	374	283	0.96	0.88 - 1.05
9N	7/12/2006	Night	Closed	347	226	373	269	0.90	0.82 - 1.00
10N	7/13/2006	Night	Closed	371	264	373	254	1.04	0.95 - 1.15
11D	7/18/2006	Day	Closed	372	297	375	354	0.85	0.80 - 0.89
11N	7/18/2006	Night	Closed	343	243	361	298	0.86	0.79 - 0.93
12D	7/20/2006	Day	Closed	374	297	374	301	0.99	0.92 - 1.06
12N	7/20/2006	Night	Closed	322	217	371	251	1.00	0.90 - 1.10
13D	8/15/2006	Day	Closed	350	315	367	280	1.18	1.10 - 1.26
13N	8/15/2006	Night	Closed	375	245	374	239	1.02	0.92 - 1.14
14D	8/17/2006	Day	Closed	375	349	367	342	1.00	0.96 - 1.04
14N	8/17/2006	Night	Closed	356	191	292	174	0.90	0.79 - 1.03
15D	8/22/2006	Day	Closed	375	317	286	285	0.85	0.81 - 0.88
15N	8/22/2006	Night	Closed	372	236	374	240	0.99	0.89 - 1.10
16D	8/24/2006	Day	Closed	372	293	372	276	1.06	0.98 - 1.15
16N	8/24/2006	Night	Closed	357	209	369	226	0.96	0.85 - 1.08
17D	8/29/2006	Day	Closed	375	342	352	290	1.11	1.05 - 1.18
18N	8/30/2006	Night	Closed	372	241	373	212	1.14	1.02 - 1.28
19D	8/31/2006	Day	Closed	375	301	374	306	0.98	0.91 - 1.05

R_w = Number of fish released at the weir
m_w = Number of fish recaptured in the lower oxbow
R_c = Number of fish released in the lower oxbow
m_c = Number of fish recaptured in the lower oxbow
$\hat{S}_s$ = Estimated survival for fish passage from the weir to the lower oxbow

Appendix Table 14. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2007.

Release #	Date	Time of Release	Bypass Position	Screen Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_c	m_c		
1D	5/22/2007	Day	Closed	504	294	233	152	0.89	0.80 - 1.01
1N	5/22/2007	Night	Closed	474	416	248	221	0.98	0.93 - 1.04
2D	5/24/2007	Day	Closed	454	304	265	146	1.22	1.07 - 1.39
2N	5/24/2007	Night	Closed	484	338	258	170	1.06	0.96 - 1.18
3D	5/29/2007	Day	Closed	504	295	265	237	0.65	0.60 - 0.71
3N	5/29/2007	Night	Closed	492	417	228	190	1.02	0.95 - 1.09
4D	5/31/2007	Day	Closed	484	363	257	245	0.79	0.74 - 0.83
4N	5/31/2007	Night	Closed	503	372	257	203	0.94	0.86 - 1.02
5D	6/5/2007	Day	Closed	515	428	254	155	1.36	1.23 - 1.52
5N	6/5/2007	Night	Closed	511	408	258	232	0.89	0.84 - 0.94
6D	6/7/2007	Day	Closed	504	451	254	231	0.98	0.94 - 1.04
6N	6/7/2007	Night	Closed	514	383	265	218	0.91	0.84 - 0.98
7D	6/12/2007	Day	Closed	511	460	260	253	0.93	0.89 - 0.96
7N	6/12/2007	Night	Closed	514	430	265	252	0.88	0.84 - 0.92
8D	6/14/2007	Day	Closed	510	495	259	197	1.28	1.20 - 1.38
8N	6/14/2007	Night	Closed	502	440	258	214	1.06	0.99 - 1.13
9D	6/19/2007	Day	Closed	510	489	252	241	1.00	0.97 - 1.04
9N	6/19/2007	Night	Closed	511	434	263	219	1.02	0.96 - 1.09
10D	6/21/2007	Day	Closed	515	495	248	247	0.97	0.95 - 0.98
10N	6/21/2007	Night	Closed	512	394	262	184	1.10	1.00 - 1.21
11D	6/26/2007	Day	Closed	515	495	260	258	0.97	0.95 - 0.99
11N	6/26/2007	Night	Closed	509	409	259	187	1.11	1.02 - 1.22
12D	6/28/2007	Day	Closed	507	432	259	225	0.98	0.93 - 1.04
12N	6/28/2007	Night	Closed	505	396	265	155	1.34	1.21 - 1.51
13D	7/3/2007	Day	Closed	507	460	253	250	0.92	0.89 - 0.95
14D	7/5/2007	Day	Closed	515	499	257	216	1.15	1.10 - 1.22
14N	7/5/2007	Night	Closed	504	344	265	200	0.90	0.83 - 0.99
15D	7/10/2007	Day	Closed	509	493	254	206	1.19	1.13 - 1.28
15N	7/10/2007	Night	Closed	513	368	264	183	1.03	0.94 - 1.14
16D	7/12/2007	Day	Closed	513	471	254	230	1.01	0.97 - 1.07
17D	7/24/2007	Day	Closed	497	405	252	216	0.95	0.89 - 1.02
17N	7/24/2007	Night	Closed	508	337	257	157	1.09	0.97 - 1.22
18D	7/26/2007	Day	Closed	500	380	259	199	0.99	0.91 - 1.08
19D	7/31/2007	Day	Closed	509	361	244	230	0.75	0.70 - 0.80
19N	7/31/2007	Night	Closed	503	378	261	188	1.04	0.96 - 1.15
20D	8/2/2007	Day	Closed	498	420	253	168	1.27	1.16 - 1.40
21N	8/7/2007	Night	Closed	511	397	261	184	1.10	1.01 - 1.21
22D	8/9/2007	Day	Closed	504	415	248	181	1.13	1.04 - 1.23
22N	8/9/2007	Night	Closed	478	307	204	151	0.87	0.78 - 0.97
23N	8/21/2007	Night	Closed	514	338	265	132	1.32	1.16 - 1.52
24D	8/23/2007	Day	Closed	429	298	263	226	0.81	0.75 - 0.88

24N	8/23/2007	Night	Closed	507	323	245	158	0.99	0.88 - 1.11
25D	8/27/2007	Day	Closed	465	342	228	156	1.07	0.97 - 1.20

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the lower oxbow

Appendix Table 15. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2007.

Release #	Date	Time of Release	Bypass Position	Screen Group		Weir Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_s	m_s	R_w	m_w		
1D	5/22/2007	Day	Closed	504	294	239	201	0.69	0.63 - 0.76
1N	5/22/2007	Night	Closed	474	416	254	242	0.92	0.88 - 0.96
2D	5/24/2007	Day	Closed	454	304	259	145	1.20	1.06 - 1.36
2N	5/24/2007	Night	Closed	484	338	264	171	1.08	0.97 - 1.20
3D	5/29/2007	Day	Closed	504	295	260	194	0.78	0.71 - 0.87
3N	5/29/2007	Night	Closed	492	417	249	169	1.25	1.14 - 1.38
4D	5/31/2007	Day	Closed	484	363	253	220	0.86	0.80 - 0.93
4N	5/31/2007	Night	Closed	503	372	258	221	0.86	0.80 - 0.93
5D	6/5/2007	Day	Closed	515	428	254	219	0.96	0.91 - 1.03
5N	6/5/2007	Night	Closed	511	408	264	223	0.95	0.88 - 1.01
6D	6/7/2007	Day	Closed	504	451	261	216	1.08	1.02 - 1.16
6N	6/7/2007	Night	Closed	514	383	264	212	0.93	0.86 - 1.01
7D	6/12/2007	Day	Closed	511	460	265	257	0.93	0.89 - 0.96
7N	6/12/2007	Night	Closed	514	430	264	235	0.94	0.89 - 1.00
8D	6/14/2007	Day	Closed	510	495	265	197	1.31	1.22 - 1.41
8N	6/14/2007	Night	Closed	502	440	263	215	1.07	1.01 - 1.15
9D	6/19/2007	Day	Closed	510	489	264	200	1.27	1.19 - 1.37
9N	6/19/2007	Night	Closed	511	434	263	214	1.04	0.98 - 1.12
10D	6/21/2007	Day	Closed	515	495	265	242	1.05	1.01 - 1.10
10N	6/21/2007	Night	Closed	512	394	264	200	1.02	0.94 - 1.11
11D	6/26/2007	Day	Closed	515	495	265	256	0.99	0.97 - 1.03
11N	6/26/2007	Night	Closed	509	409	259	207	1.01	0.94 - 1.09
12D	6/28/2007	Day	Closed	507	432	265	227	0.99	0.94 - 1.06
12N	6/28/2007	Night	Closed	505	396	264	189	1.10	1.01 - 1.20
13D	7/3/2007	Day	Closed	507	460	265	232	1.04	0.99 - 1.10
14D	7/5/2007	Day	Closed	515	499	265	245	1.05	1.01 - 1.09
14N	7/5/2007	Night	Closed	504	344	264	195	0.92	0.84 - 1.02
15D	7/10/2007	Day	Closed	509	493	228	184	1.20	1.13 - 1.29
15N	7/10/2007	Night	Closed	513	368	263	185	1.02	0.93 - 1.13
16D	7/12/2007	Day	Closed	513	471	262	226	1.06	1.01 - 1.13
17D	7/24/2007	Day	Closed	497	405	248	207	0.98	0.91 - 1.05
17N	7/24/2007	Night	Closed	508	337	257	161	1.06	0.95 - 1.19
18D	7/26/2007	Day	Closed	500	380	263	223	0.90	0.84 - 0.96

19D	7/31/2007	Day	Closed	509	361	253	190	0.94	0.86 - 1.04
19N	7/31/2007	Night	Closed	503	378	264	194	1.02	0.94 - 1.12
20D	8/2/2007	Day	Closed	498	420	219	166	1.11	1.03 - 1.22
21N	8/7/2007	Night	Closed	511	397	246	189	1.01	0.93 - 1.10
22D	8/9/2007	Day	Closed	504	415	265	212	1.03	0.96 - 1.11
22N	8/9/2007	Night	Closed	478	307	255	169	0.97	0.87 - 1.09
23N	8/21/2007	Night	Closed	514	338	263	152	1.14	1.01 - 1.29
24D	8/23/2007	Day	Closed	429	298	247	139	1.23	1.09 - 1.41
24N	8/23/2007	Night	Closed	507	323	258	142	1.16	1.02 - 1.32
25D	8/27/2007	Day	Closed	465	342	261	227	0.85	0.79 - 0.91

R_s = Number of fish released upstream of the fish screens

m_s = Number of fish recaptured in the lower oxbow

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage along the fish screens to the weir

Appendix Table 16. Mark-recapture experiment results for juvenile late-fall Chinook salmon released upstream and downstream of the GCID fish screens in 2007.

Release #	Date	Time of Release	Bypass Position	Weir Group		Control Group		$\hat{S}_s$	Confidence Interval $\alpha = 0.05$
				R_w	m_w	R_c	m_c		
1D	5/22/2007	Day	Closed	239	201	233	152	1.29	1.16 - 1.44
1N	5/22/2007	Night	Closed	254	242	248	221	1.07	1.02 - 1.13
2D	5/24/2007	Day	Closed	259	145	265	146	1.02	0.87 - 1.19
2N	5/24/2007	Night	Closed	264	171	258	170	0.98	0.87 - 1.11
3D	5/29/2007	Day	Closed	260	194	265	237	0.83	0.77 - 0.90
3N	5/29/2007	Night	Closed	249	169	228	190	0.81	0.73 - 0.90
4D	5/31/2007	Day	Closed	253	220	257	245	0.91	0.86 - 0.96
4N	5/31/2007	Night	Closed	258	221	257	203	1.08	1.00 - 1.18
5D	6/5/2007	Day	Closed	254	219	254	155	1.41	1.27 - 1.58
5N	6/5/2007	Night	Closed	264	223	258	232	0.94	0.88 - 1.00
6D	6/7/2007	Day	Closed	261	216	254	231	0.91	0.85 - 0.97
6N	6/7/2007	Night	Closed	264	212	265	218	0.98	0.90 - 1.06
7D	6/12/2007	Day	Closed	265	257	260	253	1.00	0.97 - 1.03
7N	6/12/2007	Night	Closed	264	235	265	252	0.94	0.89 - 0.98
8D	6/14/2007	Day	Closed	265	197	259	197	0.98	0.89 - 1.08
8N	6/14/2007	Night	Closed	263	215	258	214	0.99	0.91 - 1.07
9D	6/19/2007	Day	Closed	264	200	252	241	0.79	0.73 - 0.85
9N	6/19/2007	Night	Closed	263	214	263	219	0.98	0.90 - 1.06
10D	6/21/2007	Day	Closed	265	242	248	247	0.92	0.88 - 0.95
10N	6/21/2007	Night	Closed	264	200	262	184	1.08	0.97 - 1.20
11D	6/26/2007	Day	Closed	265	256	260	258	0.97	0.95 - 1.00
11N	6/26/2007	Night	Closed	259	207	259	187	1.11	1.01 - 1.22
12D	6/28/2007	Day	Closed	265	227	259	225	0.99	0.92 - 1.06
12N	6/28/2007	Night	Closed	264	189	265	155	1.22	1.08 - 1.39
13D	7/3/2007	Day	Closed	265	232	253	250	0.89	0.84 - 0.93

14D	7/5/2007	Day	Closed	265	245	257	216	1.10	1.03 - 1.18
14N	7/5/2007	Night	Closed	264	195	265	200	0.98	0.89 - 1.08
15D	7/10/2007	Day	Closed	228	184	254	206	1.00	0.91 - 1.09
15N	7/10/2007	Night	Closed	263	185	264	183	1.01	0.91 - 1.14
16D	7/12/2007	Day	Closed	262	226	254	230	0.95	0.89 - 1.01
17D	7/24/2007	Day	Closed	248	207	252	216	0.97	0.90 - 1.05
17N	7/24/2007	Night	Closed	257	161	257	157	1.03	0.89 - 1.18
18D	7/26/2007	Day	Closed	263	223	259	199	1.10	1.02 - 1.20
19D	7/31/2007	Day	Closed	253	190	244	230	0.80	0.73 - 0.86
19N	7/31/2007	Night	Closed	264	194	261	188	1.02	0.92 - 1.13
20D	8/2/2007	Day	Closed	219	166	253	168	1.14	1.02 - 1.28
21N	8/7/2007	Night	Closed	246	189	261	184	1.09	0.98 - 1.21
22D	8/9/2007	Day	Closed	265	212	248	181	1.10	1.00 - 1.21
22N	8/9/2007	Night	Closed	255	169	204	151	0.90	0.79 - 1.01
23N	8/21/2007	Night	Closed	263	152	265	132	1.16	0.99 - 1.36
24D	8/23/2007	Day	Closed	247	139	263	226	0.65	0.58 - 0.74
24N	8/23/2007	Night	Closed	258	142	245	158	0.85	0.74 - 0.98
25D	8/27/2007	Day	Closed	261	227	228	156	1.27	1.15 - 1.41

R_w = Number of fish released at the weir

m_w = Number of fish recaptured in the lower oxbow

R_c = Number of fish released in the lower oxbow

m_c = Number of fish recaptured in the lower oxbow

$\hat{S}_s$ = Estimated survival for fish passage from the weir to the lower oxbow