Adult Salmon Migration Monitoring, Suisun Marsh Salinity Control Gates, September – November 2002

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U.S. Environmental Protection Agency

National Marine Fisheries Service

Summary

This study is a continuation of the 2001 adult chinook salmon (*Oncorhynchus tshawytscha*) passge study conducted September 24 to November 1 at the Suisun Marsh Salinity Control Gates (SMSCG) in Montezuma Slough. The 2001 SMSCG study focused on using the structures' existing boat lock as an alternate means of adult salmon passage during normal operation of the salinity control gates. The study spanned 3 experimental operational phases: Phase I – flashboards out, gates in up position, boat lock closed; Phase II – flashboards in, gates operating, boat lock open; Phase III – flashboards in, gates operating, boat lock closed. Each operational phase lasted 2 weeks.

Results from the 2001 study found that Phase II had the highest percentage of fish passage (77%), though not significantly different when compared with Phase I and Phase III. Phase II had an average delay time of 25.5 hours which was significantly different from Phase III (47.4 hours) but not significantly different from Phase I (15.3 hours). During Phase II when the boat lock was available for passge, 32 % of the fish that passed the gates used the boat lock.

Results from the 2002 study found that Phase II had the lowest percentage of fish passage (36%) which was significantly different when compared with Phase I (58%) but not significant when compared with Phase III (47%). Phase II had an average delay time of 78 hours which was significantly different when compared with Phase I (20 hours) and Phase III (36 hours). During Phase II when the boat lock was available for passage, 35% of the fish that passed the gates used the boat lock.

There was a skewed distribution of salmon lengths during 2002 with a greater number of smaller individuals tagged (<700mm) compared with the 2001 study.

Introduction

The 2002 adult salmon passage study is the second year of a planned 3 year program to continue monitoring the passage rate and passage times of migrating salmon past the Suisun Marsh Salinity Control Gates (SMSCG) in Montezuma Slough. Telemetry studies were started in 1993 (Tillman *et al* 1996; Edwards *et al* 1996) to assess the effects of the SMSCG on migrating adult salmon, particularly federally listed winter-run, which may be present in Montezuma Slough during the peak operating times of the gates, October through May. These studies concluded that the SMSCG hinders salmon movement through Montezuma Slough. The structure consists of a section of removable flashboards, 3 radial gates, and a boat lock (Figure 1). By raising the radial gates during ebb flow and lowering the gates during flood flow, the structure tidally pumps water from the Sacramento River through Montezuma Slough. During normal operations, the gates open and close twice per tidal day (~24.8 hours long), opening on the ebb flow for about 6 hours and closing on the flood flow for about the same length of time. This action moves less saline water from the Sacramento River downstream through Montezuma Slough, making it available to the interior of Suisun Marsh (DWR 1997).

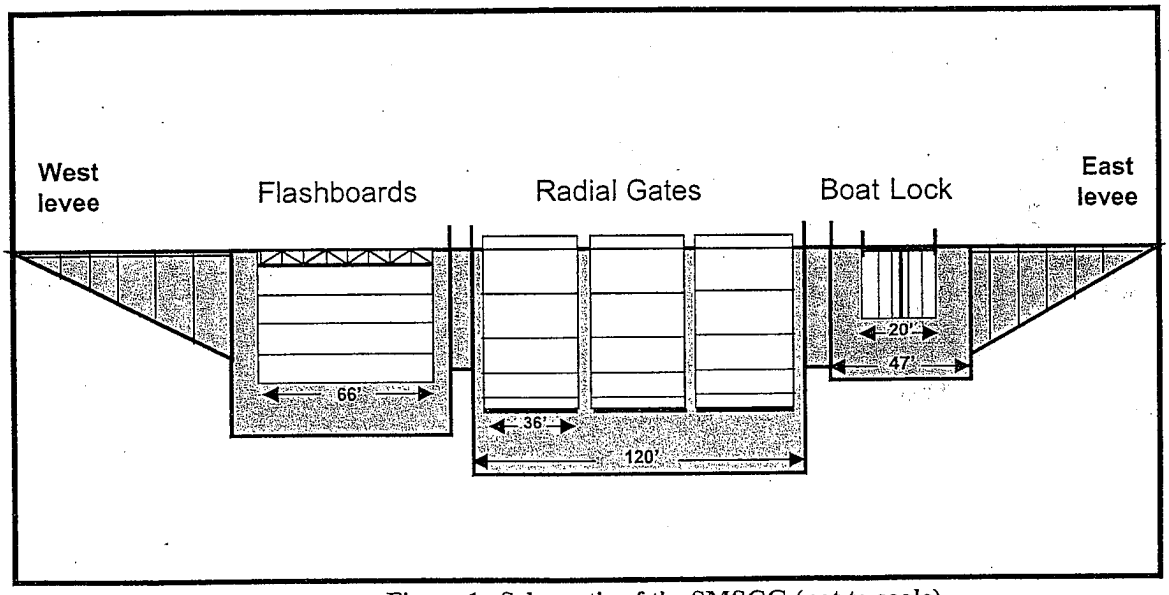

Figure 1. Schematic of the SMSCG (not to scale)

Telemetry studies conducted in 1998 and 1999 focused on the modification of the flashboard structure with openings to allow passge of migrating salmon during normal operation of the SMSCG. Results from these studies found that the modified flashboards had the opposite effect on salmon migration and recorded the lowest passge rate and longest delay time for both years (Vincik *et al* 2003).

The 2001 study focused on the use of the existing boat lock as a fish passageway that was already an existing component of the SMSCG structure and could be held open during gate operations to allow an alternate salmon passage when the flashboards were installed and the radial gates closed during flood tides (*2001 Suisun Marsh Salinity Control Gates*

Salmon Passage Evaluation Report.
http://iep.water.ca.gov/suisun/dataReports/index.html).

Methods

Adult Fall-run chinook salmon were captured using a large mesh gill net, tagged internally with an ultrasonic transmitter, and externally with a Floy® t-bar tag. A return address for the Department of Fish and Game in Stockton was imprinted on each external tag for angler response.

Each ultrasonic tag was coded with a unique pulse interval and frequency to identify individual fish. The signals were picked up by stationary monitoring sites consisting of a hydrophone, receiver, and palmtop computer to detect and record the location of tagged fish and the time located. Monitoring sites were located upstream, downstream, and in the boat lock (Figure 2). Additional monitoring sites were set up further upstream to detect salmon migration towards the Sacramento River and downstream past the release site to detect salmon moving back downstream after tagging.

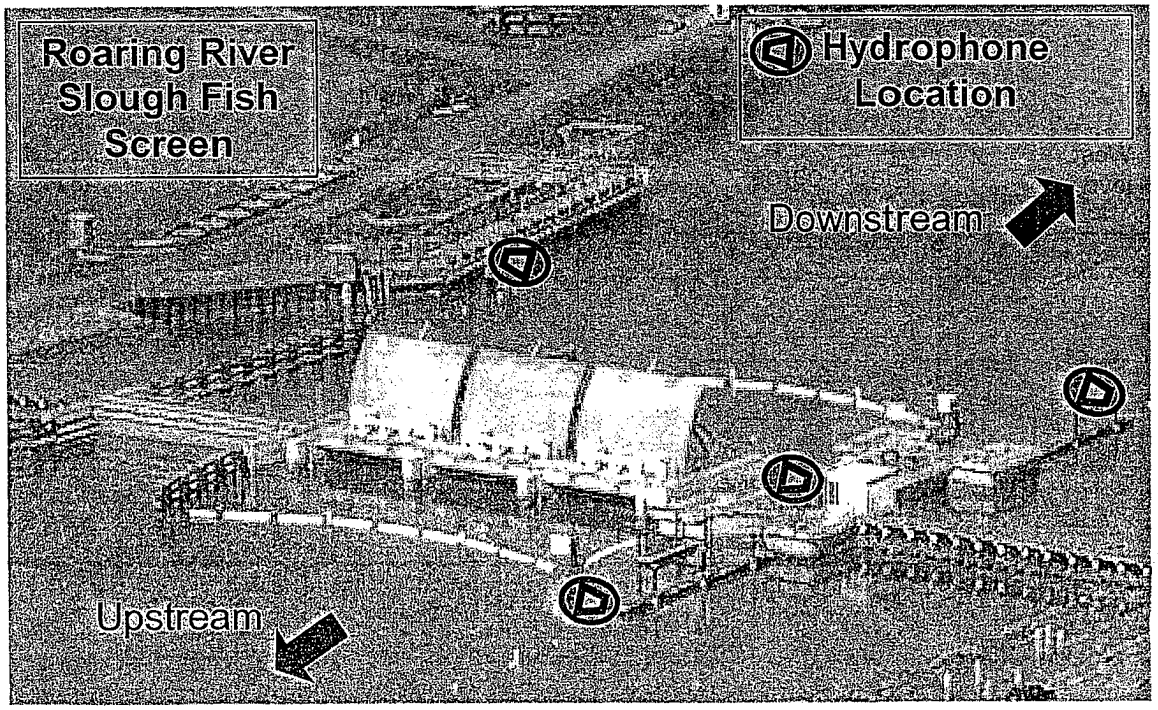

Figure 2. Hydrophone Locations at the SMSCG, Sept – Nov 2002

Fish passage through the gates was monitored during three operational configurations including: Phase I - flashboards installed, gates operating, boat lock closed, (Full bore) Phase II - flashboards out, gates held open, boat lock closed (Full open), Phase III - flashboards installed, gates operating, boat lock open (Modified operation) (Figure 3). These 3 gate configurations are the same used in the 2001 study with the order of the operation changed to determine if timing of the adult chinook migration had any affect on passage.

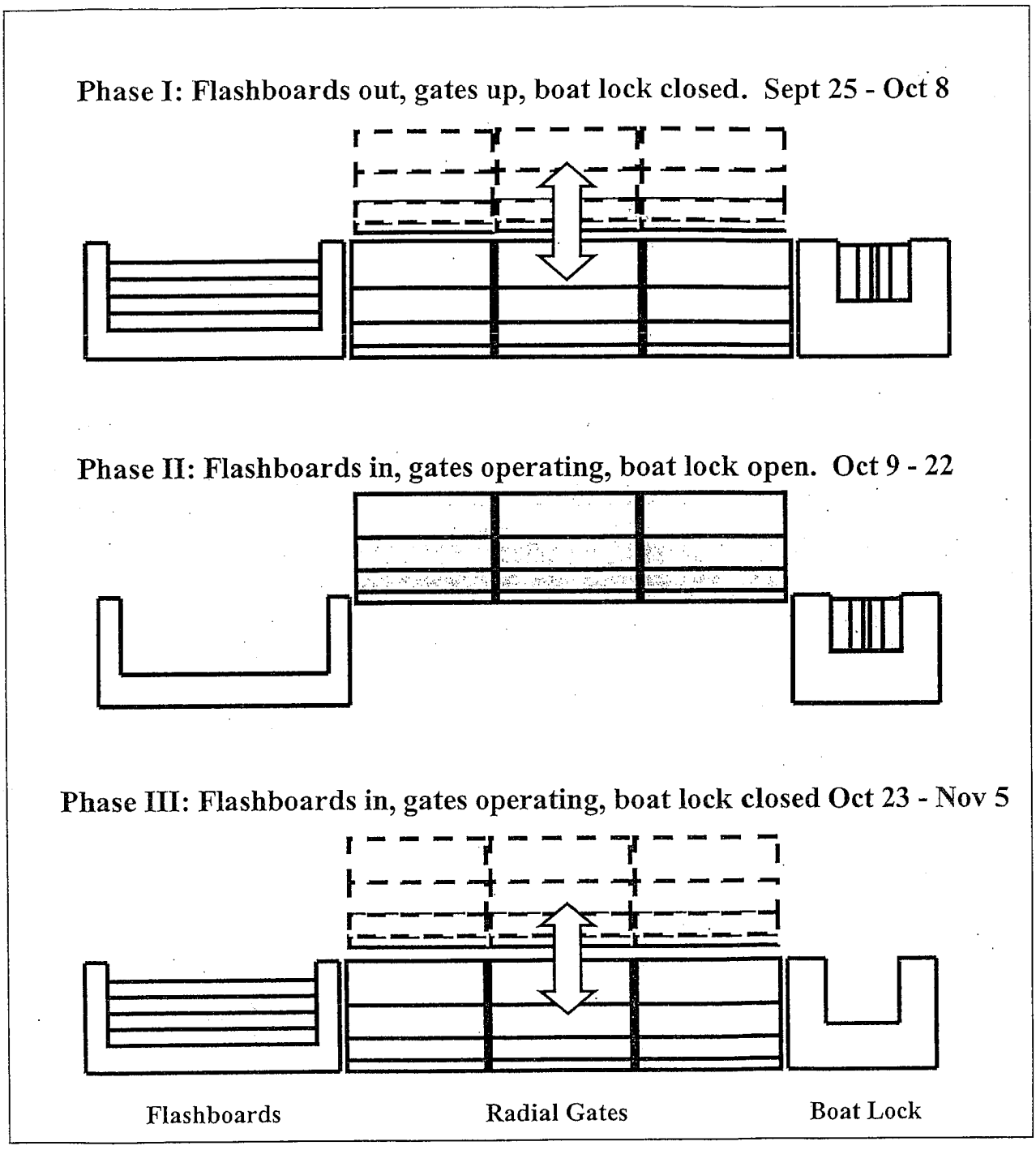

Figure 2. The 3 Operational Phases of the Salinity Control Gates for Sept – Nov 2002

Sixty-six tagged salmon were released at the beginning of each 2-week operational phase and monitored for their passge rate and passage time through the SMSCG. Mobile monitoring was used to track fish movement in Montezuma Slough and find fish that may have died after tagging. Abundant adult Fall-run salmon were used as a surrogate for federally listed Winter-run. Salmon capture and tagging took place during daylight hours.

A total of 198 adult fall-run chinook salmon were tagged and monitored during September 25 to November 5. Tagging was scheduled to begin September 23 but had to be delayed 2 days due to problems with getting the flashboards installed to begin the full operation configuration of the Salinity Control Gates. Although the delay pushed monitoring time into the first week of November, tagging was completed on October 26 and did not overlap with the time designated for the presence of Winter-run Chinook salmon.

Results

Eighty-four tagged salmon passed through the SMSCG during the 2002 tagging study, representing 42% of the 198 total tagged adult fish. Ninety-two tagged salmon did not pass the gates (47%) and 22 were removed from the sample population due to non-detection or having died after tagging (11%). The highest percentage of fish passed the gates during Phase II, (58%) and the lowest percent of passage was during Phase III (36%) (Figure 3). Tagged fish ranged in size from 600 to 1010mm with an average length of 705mm. Tagged fish were evenly distributed between male and female. A slightly higher percentage of tagged fish passed the gates during nighttime (54%). The average passage time for tagged fish ranged from 0.5 to 275.2 hours with Phase III (full operation, boat lock open) having the longest mean passage time (Figure 4.)

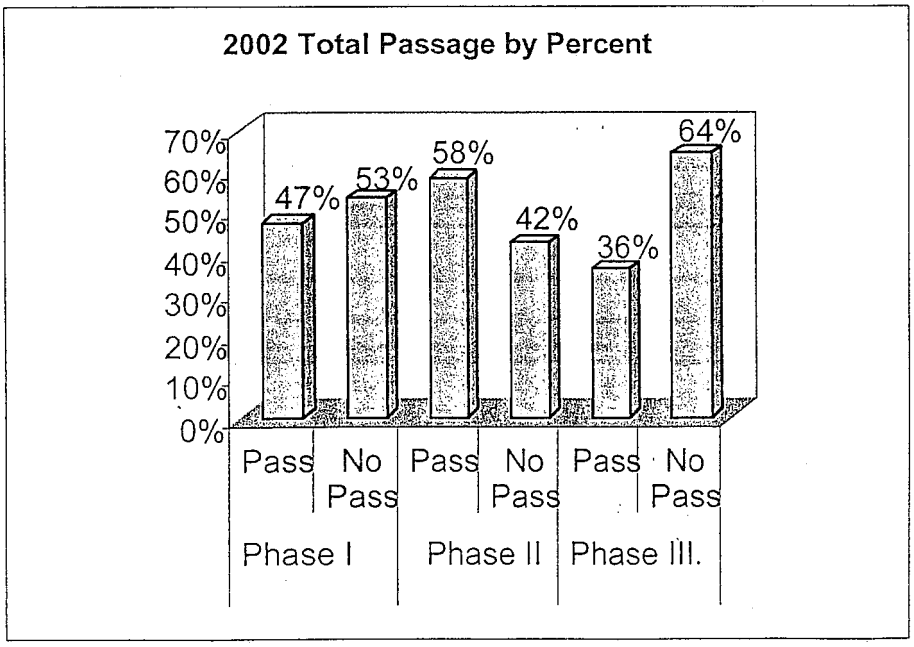

Figure 4. 2002 Total Passage by Percent

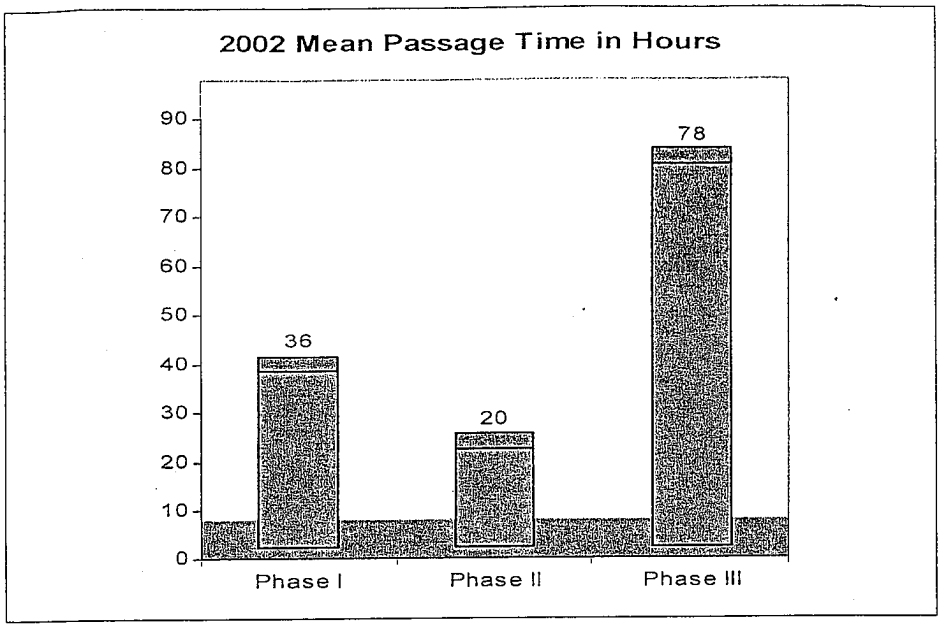

Figure 5. 2002 Mean Passage Time in Hours.

Passage by Phase

Phase I (Full operation boat lock closed) – 47% passed the gates (53% no pass) with an average time of 36 hours (3.6 to 105.8). Of these 31% passed and went upstream, 12% passed and moved back downstream, 45% moved downstream and 12 % had no records.

Phase II (Full open) – 58% passed the gates (42% no pass) with an average time of 20 hours (0.5 to 143.6). Of these, 32% passed and went upstream, 21% passed and moved back downstream, 38% moved downstream and 9% had no records.

Phase III Full operation boat lock open) – 36% passed the gates (64% no pass) with an average passage time of 78 hours (2.8 to 275.2). Of these, 27% passed and went upstream, 5% passed and moved back downstream, 54% moved downstream and 14% had no records.

The full open phase had the best passage as expected but the real surprise was the significantly different poor passage results from the full operation with the boat lock open phase (Table 1). The boat lock open phase not only had the lowest passage percentage, but also the longest delay time (significantly longer) between phases (Table 2).

Table 1.
Chi-square and probability (one tailed) for passage rates.

Phase I vs. Phase II	$\chi^2 = 1.43$	$P = 0.232$
Phase I vs. Phase III	$\chi^2 = 1.53$	$P = 0.216$
Phase II vs. Phase III	$\chi^2 = 5.84$	$P = 0.016$*

Tukey Test

Phase I vs. II vs. III	$P = 0.368$

* Significant difference

Table 2.
Tukey test for probability on mean passage time

Phase I vs. Phase II	$P = 0.468$
Phase I vs. Phase III	$P = 0.019$*
Phase II vs. Phase III	$P = 0.001$*

T-test for probability on mean passage time

Phase I vs. Phase II	P = 0.151
Phase I vs. Phase III	$P = 0.019$*
Phase II vs. Phase III	$P = 0.033$*

*Significant difference

Salmon Usage of the Boat Lock

During the Phase III configuration (full operation, boat lock open), of the 21 tagged salmon to pass the gates 38% were recorded moving through the boat lock, compared with 32% passage in 2001 (Figure 5). The average time spent in the boat lock was 7 minutes for 2002 compared with 13 minute in 2001. All tagged fish recorded passing through the boat lock did so during an ebb tide (gates in the up position).

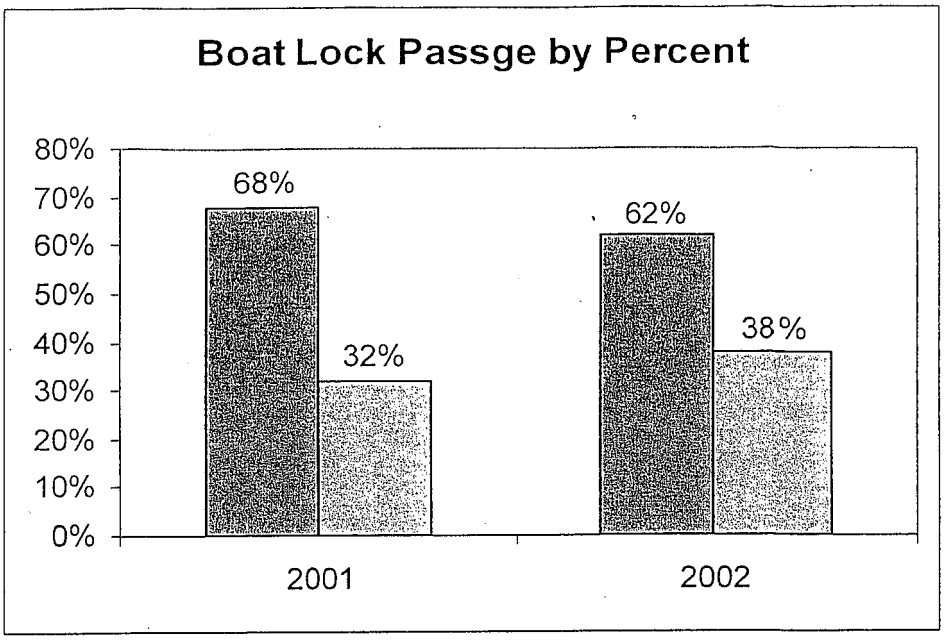

Figure 5. 2001 – 2002 Boat Lock Passage by Percent.

Discussion

Pacific salmon must rely solely on energy reserves to carry out their upriver migration, to complete their gonad development, and to spawn. Energy saving behaviors, such as the selection of low-velocity or reverse-current paths may thus be important migration tactics for these upriver migrants. This behavior may be particularly crucial at sites of difficult passage, where energetic demands may exceed the migrant's metabolic scope (Hinch and Bratty 2000).

The feasibility of using the boat lock for fish passage looked promising based on the results of the 2001 study when compared with past studies (Vincik 2002). However, results from the 2002 study did not confirm these findings, in fact were almost exactly opposite when comparing passage rates and times of tagged adult salmon through the boat lock open phase.

There are a couple of events that may have influenced the differences between years in the 2 full operation phases with the boat lock open. In 2001, there was a delay in gate operation timing that would have created a stronger flow attraction in the boat lock, possibly bringing more fish through the locks. This was corrected during the 2002 study. The question of the effect of the delayed gate operation was raised and with it the issue of how to proceed in future studies. Do we attempt to recreate the modified gate operations of 2001 to test the effect of increased attraction flow on migration through the boat lock or do we continue the study using the 2002 normal gate operations? These options are being considered by the SMSCG Steering Committee along with the possibility of continuing the study through 2005 to get 3 consistent study years at each option.

In 2001, fish passage through the boat lock was equally divided between ebb and flood flows while in 2002 all tagged fish passed during an ebb tide (Table 3).

Table 3
Tagged Salmon Passage Through the Boat Lock 2001-2002

Study Year	Gate Open (Ebb)	Gate Closed (Flood)	Day	Night	Total
2001	43% (n=6)	57% (n=8)	50% (n=7)	50% (n=7)	n = 14
2002	100% (n=8)	0% (n=0)	25% (n=2)	75% (n=6)	n = 8

Also in 2002, records show that during the first couple of days of phase I (full operation, boat lock closed) one of the three gates was held open due to a mechanical problem while the other two were in the closed position giving more available passage space for salmon. Although this event only occurred during two tidal cycles it may have had an effect on passage rates and times.

An interesting observation was the comparative size distribution of tagged salmon between the 2001 and 2002 studies. In 2001 fish were evenly distributed with the majority of the sampled fish between 700 – 900 mm (Figure 6). Length at age analysis for chinook captured in rivermouth fisheries in the Sacramento river place these returning adult salmon at 3 to 4 years old (Healy 1991). In the 2002 SMSCG study, the majority of tagged salmon was 600 – 700 mm placing in an age range between 2.25 and 3 years old.

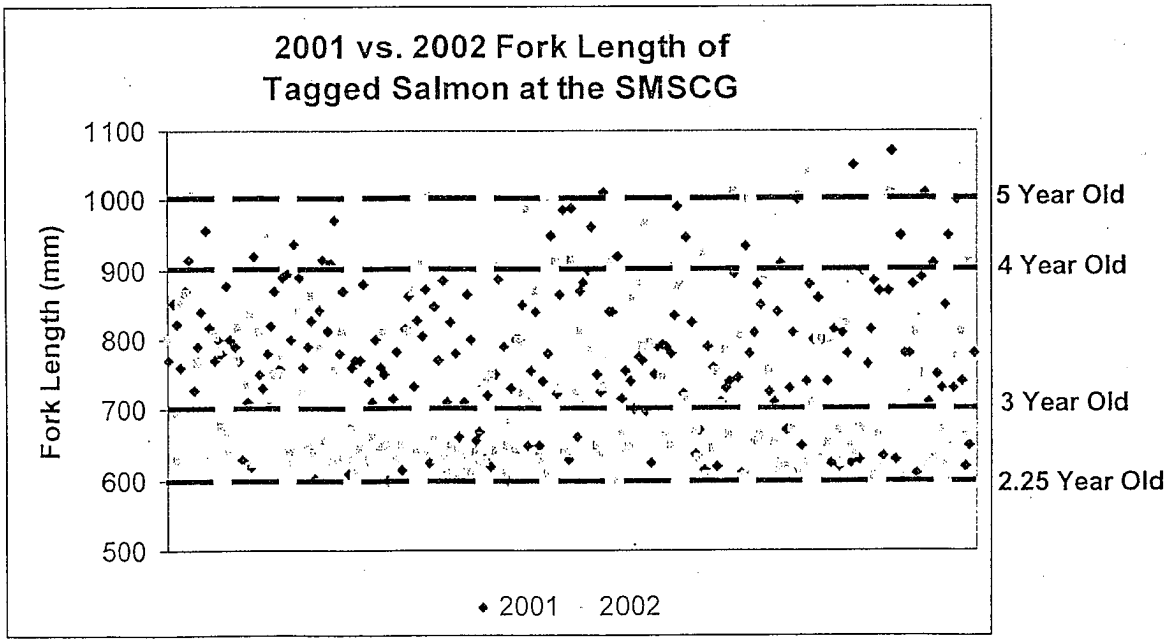

Figure 6. Fork Length of Tagged Salmon at the SMSCG

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