Outmigrant Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1999

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EXECUTIVE SUMMARY

We operated two rotary screw traps side-by-side in the lower Stanislaus River near Caswell State Park (river mile (RM) 8.6) from January 18 to June 30, 1999 to estimate an index of outmigration abundance for juvenile fall-run chinook salmon. We estimated capture efficiency of the traps by releasing 4 groups of marked hatchery chinook and 5 groups of marked natural chinook, about 1/4 mile upstream from the traps. Recovery rates of marked fish varied from 1.57% to 3.76%. A multiple-regression was developed to predict daily trap efficiency based on flow, turbidity, and fish size, and this predictive function was recalculated for 1996, 1997, and 1998 outmigration data.

The estimated number of juvenile chinook that migrated past the traps between January 18 and June 30, 1999 was 1,321,042 with an approximate 95% confidence interval of 1,007,443 to 1,634,642. The outmigration index by life stage was 1,155,424 fry, 92,615 parr, and 73,003 smolts. Emigration of fry was already underway when sampling began in January 1999. Daily fry indices exceeded 20,000 on 27 days in 1999, but only once in 1998. In contrast, parr and smolt outmigrants were significantly less abundant ($P < 0.05$) in 1999 than in 1998 as shown in the table that follows.

Caswell Outmigration Estimates by Life-Stage, 1996 through 1999

	1996 (Feb 5 - Jul 2)	**1997** (Mar 19 - Jun 27)	**1998** (Jan 29 - Jul 16)	**1999** (Jan 17 - Jun 30)
Fry	31,767	--	186,029	1,155,424
Parr	1,596	7,011	209,911	92,615
Smolts	81,896	60,333	197,884	73,003

Note that fry estimates represent only a portion of fry outmigration.

The mean lengths of juvenile chinook gradually increased over the course of sampling, ranging from about 35 mm at the start of sampling (mid-January) to about 90 mm in late June. The length increase was slower than in 1996-1998 and the threshold size for classifying smolts (80 mm) was not reached until May 10. This was 3 to 7 weeks later than other years. Mean lengths of fry captured at Caswell in January and February were similar from 1996 to 1999.

Mean lengths of natural chinook have been similar at Caswell and Oakdale in past years. In 1999 there was a noticeable difference in mean lengths between the sites beginning in March, once lengths began to increase above 40 mm. The difference was greatest in mid April, when fish reached approximately 75 mm at Caswell, but were still near 60 mm in length at Oakdale. The difference in lengths between the trap sites during 1999 may indicate that many parr paused to rear between Oakdale and Caswell. There was no sampling between the two sites to test this possibility, but data from our previous studies tend to support this hypothesis of rearing.

The smolt appearance index followed similar trends through time in 1998 and 1999. Fry (smolt index 1) were present through the end of April in both 1998 and 1999, with the exception of one fry captured in late May in 1999. Parr (smolt index 2) appeared later in 1999 (beginning of March) than in 1998 (late February), but in both years parr persisted until mid June.

During 1999, we captured 12 rainbow trout/steelhead at Caswell, ranging in size from 83 mm to 255 mm. Two distinct size classes were apparent (200-300 mm and <100mm), representing yearlings and young-of-the-year, respectively. More rainbow trout/steelhead were captured in 1999 than 1998, but 1999 counts were comparable to 1997.

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We thank the Tri-Dam Board of Directors, as well as Wayne Marcus, Manager of Oakdale Irrigation District, and Rick Martin, Manager of South San Joaquin Irrigation District, who provided equipment and personnel to facilitate this study.

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BACKGROUND

Juvenile salmonid sampling at the Caswell site is part of a coordinated monitoring effort on the Stanislaus River to better understand how salmonid populations respond to both habitat restoration measures and flow management actions currently underway. Monitoring of juvenile salmon outmigrants and estimates of their abundance at the Caswell site are conducted as part of two CVPIA programs. The Central Valley Project Improvement Act (CVPIA), enacted in 1992, directs the U.S. Fish and Wildlife Service to develop and implement a series of restoration programs for fish and wildlife purposes, with the goal of doubling the natural production of anadromous fish in Central Valley streams by the year 2002. The first is the Comprehensive Assessment and Monitoring Program (CAMP). The goal of the CAMP juvenile monitoring program is to assess the relative effectiveness of categories of fishery restoration actions recommended by the Anadromous Fish Restoration Program (AFRP). The AFRP, established by the CVPIA, set anadromous fish production targets and recommended fishery restoration actions for Central Valley streams. The water management program on the Stanislaus River, which is one component of the AFRP and authorized under sections 3406(b1-3) of the CVPIA, has identified the need for juvenile salmonid monitoring at the Caswell site to help understand the effects of water management on salmonid population dynamics. Finally, outmigrant sampling 31.5 miles upstream of the Caswell site near the town of Oakdale presents unique opportunities to compare outmigration characteristics of juvenile salmon between the two sampling sites. Sampling at Oakdale is funded by the Oakdale and South San Joaquin irrigation districts. The monitoring described here for the Caswell site will also provide information that will inform the adaptive management process.

STUDY OBJECTIVES FOR 1999

Sampling at the Caswell site in 1999 had four objectives:

- Ø Estimate the number of juvenile fall-run chinook salmon migrating out of the Stanislaus River in 1999,
- Ù Determine the size and smolting characteristics of juvenile chinook salmon and rainbow trout/steelhead migrating out of the Stanislaus River,
- Ú Identify factors that influence the timing, size and number of juvenile chinook salmon and rainbow trout/steelhead migrating out of the Stanislaus River.
- Û Estimate the survival of coded wire tag releases from Knights Ferry and Oakdale Recreation Area to Caswell State Park in 1999.

SUMMARY OF PREVIOUS MONITORING

Rotary screw traps have been used since 1993 to monitor timing and relative abundance of juvenile salmonids outmigrating from the Stanislaus River. Sampling has been conducted near Oakdale (RM 40.1) and near Caswell State Park (RM 8.6) by either California Department of Fish and Game (CDFG), US Fish and Wildlife Service (USFWS) or S.P. Cramer and Associates, Inc. (SPCA) (Table 1). Target species include fall-run chinook salmon and rainbow trout/steelhead. A summary of sampling in each past year follows.

1993 One trap was fished at the Oakdale site for a portion of the outmigration period in 1993, the first year of screw trap sampling in the Stanislaus River. The daily number of outmigrants was estimated from the results of two mark-recapture tests.

1994 One trap was operated at the Caswell site and no sampling occurred at the Oakdale site in 1994. Juvenile chinook catches were low in 1994, and no daily or seasonal abundance index was estimated.

Table 1. Date, location and number of rotary-screw traps operated in the Stanislaus River, 1993 - 1999.

Year	Trap Location	Number of Traps	Start Date	End Date	Flow-Year Type
1993	Oakdale	1	Apr 21	Jun 29	Low
1994	Caswell	1	Apr 23	May 26	Low
1995	Oakdale	1	Mar 18	Jul 1	Low
1995	Caswell	2	Mar 27	May 26	Low
1996	Oakdale	1	Feb 1	Jun 8	High
1996	Caswell	2	Feb 5	Jul 2	High
1997	Caswell	2	Mar 19	Jun 27	High
1998	Oakdale	1	Jan 26	Jul 15	High
1998	Caswell	2	Jan 8	Jul 16	High
1999	Oakdale	1	Jan 18	Jun 30	High
1999	Caswell	2	Jan 18	Jun 30	High

1995 Two traps were fished at the Caswell site in 1995. Catches of natural migrants were low, as were trap efficiencies estimated from recoveries of marked fish. However, since sampling was also conducted at Oakdale that year, it was possible to compare the size and timing of juvenile chinook between the upstream and downstream trapping locations. The abundance index of juvenile outmigrants was much higher at the Oakdale site. Screw trap efficiency was estimated at Oakdale with the release of 20 groups of marked natural or hatchery chinook.

1996 Two screw traps were fished at Caswell and one at Oakdale in 1996. Sampling began earlier in 1996 with the goal of estimating the total number of juvenile chinook outmigrants. However, we began sampling at Oakdale and Caswell in early

February and found that fry were already migrating. We modified the trap set-up at Caswell to increase capture rates and released 15 groups of marked fish to estimate trap efficiency. Recapture rates varied from 0 to 12.08%, and variation in capture efficiency was best accounted for by a logistic regression on turbidity.

1997 We fished two rotary screw traps at Caswell in 1997. No sampling occurred at Oakdale due to high flows. These high flows also delayed the initiation of sampling at Caswell until mid-March.

1998 Two rotary screw traps were fished at Caswell and one at Oakdale in 1998. Passage estimates at Oakdale were again higher than Caswell, however the ratio of Caswell to Oakdale was higher than seen in 1996.

DESCRIPTION OF STUDY AREA

The headwaters of the Stanislaus River originate on the western slope of the Sierra Nevada Mountains. The Stanislaus River and its tributaries flow southwest to the confluence with the San Joaquin River on the floor of the Central Valley (Figure 1). The San Joaquin River flows north and joins the Sacramento River in the Sacramento-San Joaquin Delta. There are several dams on the Stanislaus River that are used for flood control, power generation, and water supply. Water uses include irrigation and municipal needs, as well as recreational activities and water quality control.

Goodwin Dam, approximately 58.4 river miles (RM) upstream from the San Joaquin River confluence, blocks the upstream migration of anadromous fish. The lower river supports fall-run chinook salmon spawning between the town of Riverbank (RM 34) and Goodwin Dam (RM 58.4). Resident rainbow trout rear in 10-20 miles of the Stanislaus River below Goodwin Dam and adult steelhead are occasionally observed. However, it is not known whether a distinct anadromous population is present.

We reference river miles on the Stanislaus River throughout this report. River miles were determined with a map wheel and 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987). Trapping locations and key area landmarks are listed below along with the river mile location for each site:

Knights Ferry Bridge	RM 54.6
Orange Blossom Bridge (OBB)	RM 46.9
Highway 120/108 Bridge	RM 41.2
Oakdale Trapping Location	RM 40.1
Caswell Trapping Location	RM 8.6

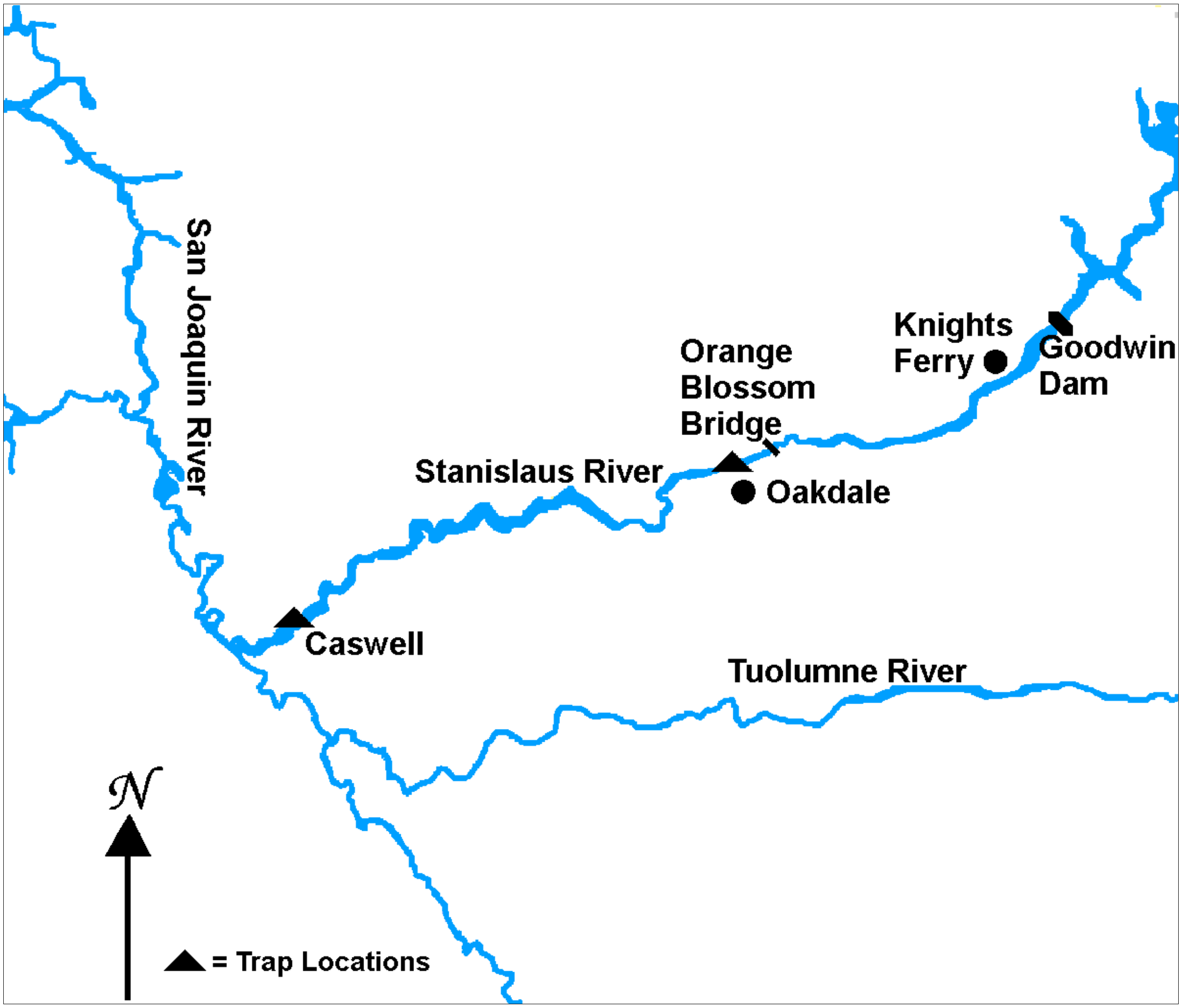

Figure 1. Location map of study area on the Stanislaus River.

METHODS

JUVENILE OUTMIGRANT MONITORING

Sampling Gear

We fished two rotary screw traps side-by-side in the mainstem of the lower Stanislaus River near Caswell State Park to sample juvenile salmonids as they migrated downstream. The screw traps, manufactured by E.G. Solutions in Eugene, Oregon, each consisted of a funnel shaped core suspended between two pontoons. Each trap was positioned in the current so that water entered the 8 ft wide funnel mouth and struck the internal screw core, causing the funnel to rotate. As the funnel rotated, fish were trapped in pockets of water and forced rearward into a livebox where captured fish could not escape.

Aluminum screen panels were placed in the rear of both liveboxes to provide fish with areas of refuge and to minimize stress and mortality. The screens caught wood and plant debris while allowing fish to pass through openings cut in the lower corners.

Each trap was held in place with 1/4 inch cable fastened to large trees upstream on the north bank. The downstream force of the water on the traps kept the cables taught and near the water surface. Buoys marked the location of the cables for human safety. Although there is some recreational use of the river near the traps by small boats, canoes, and anglers in float tubes, the majority of river use in the vicinity of the State Park occurs downstream from the trap site.

Trap Site Preparation

The Caswell trapping location was chosen by CDFG in 1994 since it was the farthest location downstream with adequate access to install and monitor the traps. In 1999, the traps fished in the same position as in 1996, 1997, and 1998, which was upstream approximately 100 yards from the site fished in 1994 and 1995. The trap nearest the left bank (looking upstream) was designated the north trap and the trap nearest the right bank was designated the south trap. These designations are the same as those used in the study since 1995. A sandbag wall extending approximately 5 ft out from the north bank was constructed in 1996 to divert flow into the traps and thereby increase trap efficiency. This wall remains at the site. The north trap fished about 10 ft downstream of this wall and approximately 8 - 12 ft from the bank in an area where the velocity was highest.

Safety Measures

Although recreational use of the river in this area was relatively light, we took precautions to warn park visitors and river users of the inherent dangers associated with the presence of rotary screw traps. One sign with large letters was placed upstream from the traps to warn river users traveling downstream towards the traps. The sign was approximately 4 ft x 4 ft with reflective red letters on a white background. A flashing light, similar to lights seen on roadside construction signs, was placed on the south trap to increase visibility at night. Reflective tape was applied to the A-frames of each trap to provide further warning.

To discourage people along the banks from swimming or floating towards the traps, numerous warning signs were placed at conspicuous places along the north bank and on the north trap facing the north bank. The signs warned of drowning danger near the traps and cautioned park visitors with messages such as "keep out" and "private property". The signs were in English and Spanish.

Trap Monitoring

We installed the rotary screw traps on January 13, and began monitoring catches the morning of January 18. Monitoring continued until June 30 and the traps were removed July 6.

The traps were fished 24 hours per day, 7 days per week from January 17 to May 28. Beginning on May 28, and continuing through the end of sampling, the traps were raised after every Friday morning check and lowered again Sunday evening due to heavy weekend recreational traffic on the river. An exception was made the first weekend in June to accommodate sampling through the weekend following survival releases from Knights Ferry and Oakdale.

At times of high turbid flows and when we had recently released marked fish, we retrieved trap catches both in the morning and during the day to document daytime catches of juvenile chinook. Following the release of marked hatchery fish, we monitored the traps frequently until we were no longer recapturing marked fish.

During each trap check, we removed the contents of the liveboxes and identified and counted all fish captured. Random samples of 50 chinook and 20 of each other species were measured and their lengths recorded in millimeters every morning. We also measured all rainbow trout/steelhead and yearling chinook. When evening checks were conducted, random samples of 20 chinook and 10 of each other species were measured.

The traps were cleaned after all fish were recorded. When the river was carrying a high debris load, it was often necessary to clean the traps again in the afternoon to clear away debris accumulated against the funnel walls and in the liveboxes. Debris levels varied with changes in flow and weather conditions.

Smolt Appearance Rating and Life Stage Classification

We recorded the external appearance of smolting characteristics for each chinook and rainbow trout/steelhead measured. Chinook smolting appearance was rated on a scale of 1 to 3, with 1 an obvious fry (no scales, highly visible parr marks), and 3 an obvious smolt (silvery appearance, easily shed scales, blackened fin tips). Rainbow trout/steelhead smolting appearance was rated according to the CDFG scale of 1 to 5 (1= yolk-sac fry, 2= fry, 3= parr, 4= silvery parr, and 5= smolt).

In past years we estimated total outmigration for each juvenile chinook life-stage according to the following scale: fry < 45 mm; parr 45 mm to 80 mm; smolt > 80mm. Cut-off dates were chosen for each life stage when daily mean lengths were larger than the previous stage for 3 consecutive days. However, the daily lengths of sampled fish over consecutive days can bounce above and below values we use to separate the different stages. Therefore, in 1999 we used an algorithm to establish dates that separate fry from parr, and parr from smolts. When the number of consecutive days that fish fall into the larger life-stage permanently exceeds the previous number of consecutive days when the fish fall into the smaller life-stage, we used the date between the two runs of days to separate the smaller and larger size classes.

Weight

A random sample of 50 chinook were weighed each week. If a sample of 50 could not be taken in a single day, weights were measured on consecutive days. In addition, weights were measured for all yearling chinook and rainbow trout/steelhead.

TRAP EFFICIENCY TESTS

Release Groups

Nine groups of marked chinook salmon (4 hatchery, 5 natural) were released to estimate trap efficiency (all releases made after dark). The CDFG supplied the hatchery fish from the Merced River Hatchery (MRH). All efficiency groups were released at the same site used in 1996, 1997, and 1998 (1/4 mile upstream of the traps). The number of fish in each group ranged from 671 to 2,550.

Holding Facility and Transport Method

Natural fish for mark-recapture experiments were marked and held at the Caswell site. Fish were held in net pens measuring 2 ft x 3 ft x 2 ft. The net pens consisted of 3/16 in. Delta mesh sewn onto frames constructed of ½ in. PVC pipe. The net pens were kept in an area of low water velocity off the south bank across from the traps. Fish were transported to the release site in coolers the morning of the release day. Towels were placed on top of the net pens when necessary to provide shade.

Hatchery fish were marked at MRH approximately one week prior to release. All hatchery groups were transported to the release site by CDFG the day of release. Fish were placed into net pens at the release site and allowed to recover prior to release.

Marking Procedure

Juvenile chinook were marked by cold-brand or dye inoculation. Before marking, fish were anesthetized with MS-222 (Schoettger and Steucke 1970). Once anesthetized, the appropriate mark was applied. Fish were cold-branded by freezing a branding stick in a thermos of liquid nitrogen. Fish were placed into a PVC slide and the freeze brand was applied by placing the tip of the branding tool against the body of the fish. Minimal pressure was applied for approximately 2 seconds. Each fish received only one mark. Fish were dye inoculated by placing the tip of a MadaJet or Pow'rject against the caudal (top or bottom lobe), dorsal, or anal fins (Hart and Pitcher 1969). Minimal pressure was applied as dye was injected into the fin rays. One mark was applied to each fish, and all fish in a group received the same mark. Location of the mark was varied between groups so that each group could be uniquely identified. The dyes used were photonic yellow and pink (NewWest Technologies, Santa Rosa, CA) and light green provided by CDFG. All were chosen because they were known to provide highly visible, long lasting marks.

Prerelease Sampling

Marked fish were sampled for mean length and mark retention. Fifty fish were randomly selected from each distinctly marked group and anesthetized. Mark retention was rated as present or absent. If any of these 50 were found to have no mark, an additional 50 fish were sampled. The proportion of fish found to have clear marks in each group was used to estimate the actual number of fish released using the following expression:

number released = proportion mark retention * number in group.

All groups of natural chinook were also counted prior to release in order to obtain a more accurate number released. Release numbers for hatchery groups were calculated by subtracting the number of mortalities from the total number marked.

Release Procedure

Fish were released directly from the net pens in which they were held. A dip net was used to remove and release about 50 fish per minute. The time required to release each marked group ranged from 15 to 60 minutes. This release procedure was similar to the procedure used in 1996, 1997, and 1998. The gradual release of fish was intended to prevent the fish from behaving as a single school by dispersing them in time and space, to mimic the distribution of natural migrants. In 1996, 1997, and 1999, release of each mark group was separated by 5 to 15 minutes. In 1998, some mark groups (May 10, May 18) were released simultaneously.

SURVIVAL TESTS

Release Groups

Marked juvenile chinook salmon were released at five locations and recaptured at two locations for the purpose of determining the feasibility of estimating survival in different river reaches with CWT's. Five groups of marked hatchery reared chinook salmon were released in the Stanislaus River to estimate survival. The CDFG supplied the hatchery fish from the Merced River Hatchery (MRH). All groups were marked and held at MRH approximately one week prior to release and transported to the release sites by CDFG the day of release. One group of 25,536 coded wire tagged (CWT) fish were released from Knights Ferry (RM 54.6) the night of June1. Two groups of approximately 5,000 CWT/dye inoculated fish were released just below the Oakdale screw trap (RM 40) the nights of June 1 and June 2. Another two groups of approximately 5,000 CWT/dye inoculated fish were released just below the Oakdale Recreation Area at the Gambini Ranch (RM 38) the nights of June 1 and June 2. All survival test fish captured in the screw traps were given a secondary dye mark and released the morning following capture. The results of this evaluation are presented in Appendix D.

Holding Facility and Transport Method

Fish for survival experiments were marked and held at MRH in outdoor troughs covered with 1" nylon mesh. Fish were transported to the release sites by CDFG the morning of the release day. All were held in 4 ft x 4 ft x 4 ft net pens until release, with the exception of the Knights Ferry group which were pumped directly from the 450 gallon hauling tank into the river.

Marking Procedure

Juvenile chinook for survival tests were marked by coded wire tag (CWT) and dye inoculation. CWT insertion and adipose fin clips were done by Big Eagle and Associates prior to dye inoculation. One dye mark was applied to each fish, and all fish in a group received the same mark. Location of the mark was varied between groups so that each group could be uniquely identified. The dyes used were black waterproof engrossing, calligraphy, and India inks (Higgins) and photonic pink (Oakdale re-mark only) and yellow (Caswell re-mark only).

MONITORING OF ENVIRONMENTAL FACTORS

Flow Measurements

Daily flow in the Stanislaus River was obtained from the California Data Exchange Center (CDEC). All flows cited in this report were measured at the Orange Blossom Bridge gage by the US Geological Survey (USGS). The flow data are daily means; instantaneous flows during freshets were higher. Depth-velocity profiles were taken in front of the traps once per week.

Water velocity entering the traps was measured each day with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA). Daily average trap rotation speed for each trap was also recorded by measuring the time, in seconds, for three contiguous revolutions every morning. The average time per revolution for each trap was then calculated.

Water Temperature and Turbidity

Daily water temperature was measured with a mercury thermometer at the trap site. An Onset StowAway recording thermograph was also installed to record water temperature once per hour throughout the sampling season. Recording thermographs maintained by SPCA are also stationed at Goodwin, Knights Ferry, Orange Blossom Bridge, Oakdale, and McHenry. Daily mean temperature was derived by averaging the hourly measurements. Temperature data is also available from stations maintained by USGS at Goodwin, Oakdale, and Ripon.

Turbidity was measured each day with a LaMotte turbidity meter, Model 2008. A water sample was collected each morning and later tested at the field station. Turbidity was recorded in Nephelometric Turbidity Units (NTU's).

OAKDALE TRAPPING SITE

Rotary-screw trap sampling was conducted by S.P. Cramer and Associates under a separate contract at an upstream site near the Oakdale site (RM 40.1) between January 18 and June 30.

STATISTICAL ANALYSIS

The outmigration estimates (Caswell and Oakdale) in this report were prepared by Dr. Doug Neeley (IntSTATS 712 12th Street, Oregon City, OR 97045). Dr. Neeley's complete methodology is presented as a complete report in Appendix A.

As part of this effort the AFRP had two independent statisticians review the statistical methods used for this and previous year's analyses. Comments by each reviewer and a response to comments from Dr. Doug Neeley are presented in the appendices B and C.

RESULTS

OBJECTIVE 1: ESTIMATE THE NUMBER OF CHINOOK SALMON MIGRATING OUT OF THE STANISLAUS RIVER IN 1999

Trap Catches of Chinook Salmon

From January 17 to June 30, 1999, we captured a total of 41,234 juvenile chinook salmon in the Caswell screw traps (Table 2). This compared to 19,903 in 1998, 2,357 in 1997, and 2,468 in 1996. Peak catch of 2,322 chinook fry during the outmigration occurred on February 10, 1999 (see Appendix A). With the exception of 3 days in March (trap repairs) and weekends from Memorial Day through June (high river traffic), the traps were fished everyday. It is uncertain whether or not a significant number of fish outmigrated prior to trap installation; however, degree day analysis suggests outmigration started only 10 days prior to the onset of sampling. This would indicate that only a small portion of the run was missed (discussed under Objective 3).

Table 2. Summary of 1996-1999 trapping seasons at Caswell.

	Period	Number of	Trap Catch				Total
Year	Sampled	Days Sampled	North	%	South	%	Catch
1996	Feb 6 - Jul 2	142	795	32.2%	1,673	67.8%	2,468
1997	Mar 19 - Jun 27	98	408	17.3%	1,949	82.7%	2,357
1998	Jan 8 - Jul 16	154	3,053	15.3%	16,850	84.7%	19,903
1999	Jan 18 to Jun 30	152	31,949	77.5%	9,285	22.5%	41,234

North and South Trap Catches

As in past years, during 1999 there were differences in the numbers of fish caught in the north and south traps. Also similar to past years, daily catch data were partitioned according to size class, where:

fry:	length <= 45 mm
parr:	45 mm < length <= 80 mm
smolt:	length> 80 mm.

The daily mean number of fry sampled from the north trap was significantly greater than that from the south trap ($P < 0.0001$), but the mean number of parr and smolt sampled from the north trap was significantly less than that from the south trap ($P = 0.0045$ for parr and $P = 0.0003$ for smolt).

Mean lengths of each life-stage captured were compared in the north and south traps during 1999. North-trapped fry were significantly smaller (more than 1 mm on the average) than south-trapped fry ($P < 0.0001$), but the differences between the lengths of north-trapped and south-trapped parr and smolt were less than 0.04 mm and not significantly different from 0 ($P > 0.9$). In 1998 the north trap also caught smaller fry (and parr); however, the north trap caught larger smolts than the south trap. (No such comparison was made for 1996.)

Prior to 1999 the south trap consistently captured more fish than the north trap (see Table 2). In 1999, the north trap captured 77.5% of the total number of chinook captured at Caswell (Figure 2). In 1999 the traps were positioned using the same methods and hardware in near identical positions as in past years. In contrast to 1998 sampling, a large tree was lodged on the cables that position the traps during the 1999 fry outmigration period. The large size of the tree prevented removal, and it remained in the cables from the second week of sampling to the end of fry outmigration.

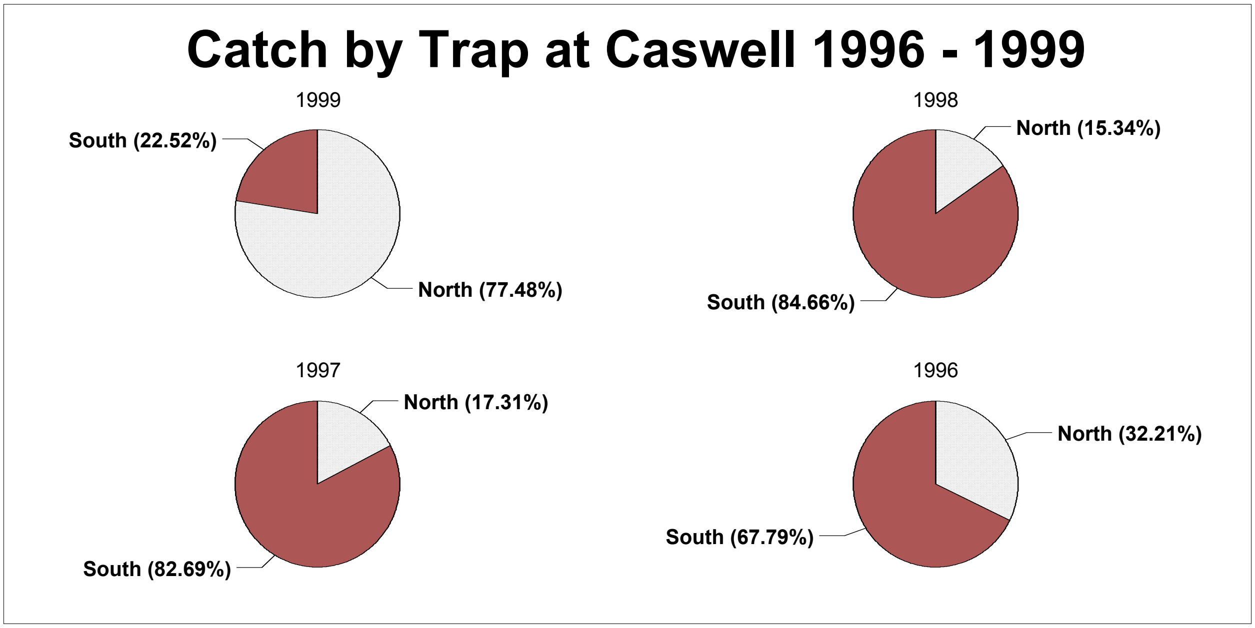

Figure 2. Catch percentage for north and south traps 1996-1999.

The tree, present during February and March, pushed the trap approximately 6 feet closer to the north bank than it had been in previous years. The entrance velocities at the north trap (3.2 ft/s) were higher than at the south trap (2.9 ft/s) during the period the tree was caught in the cable (Figure 3). However, when the log was not present entrance velocities were consistently higher at the south trap. The presence of the tree during the fry outmigration might explain the changes in catch rates or size differences of fry; however, since it was gone during the majority of the parr and smolt outmigration, they were likely unaffected.

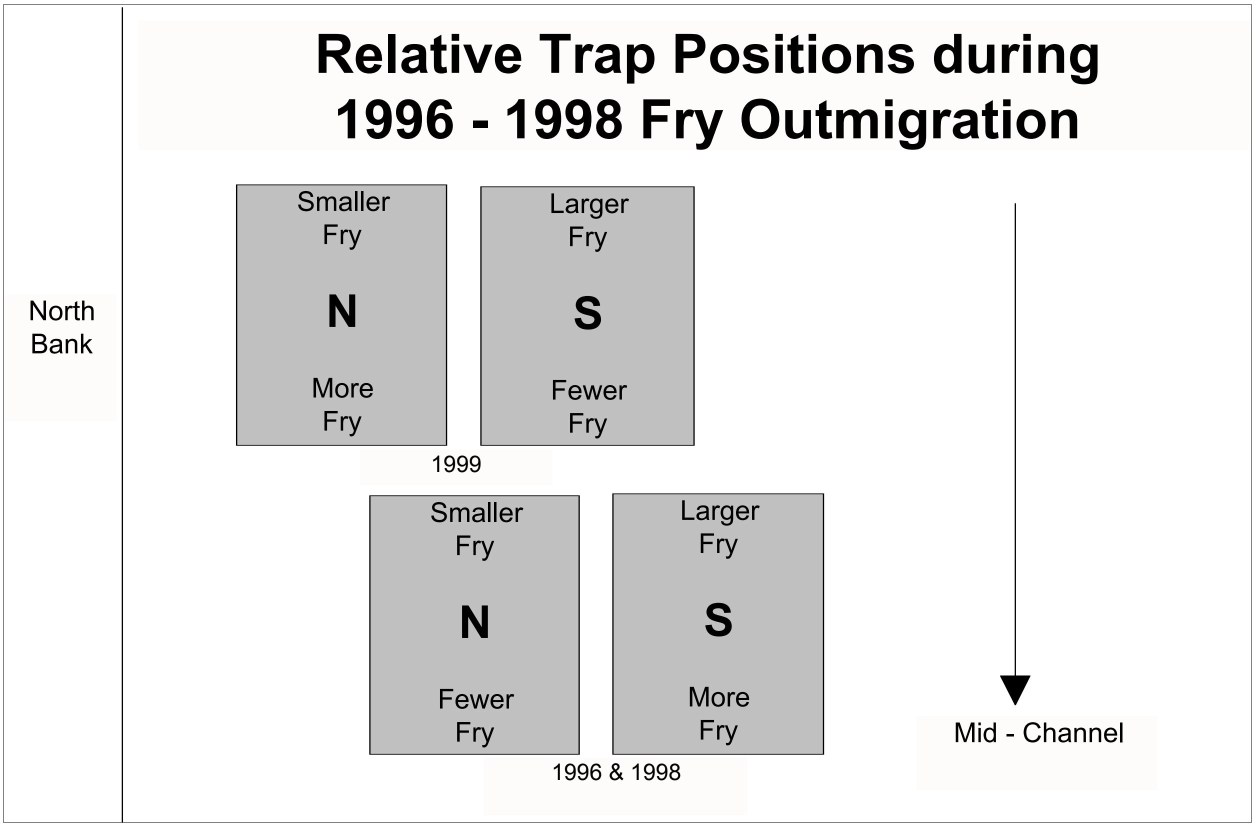

Figure 3. Schematic of trap positions in 1998 and in 1999 with tree lodged in cables.

The north trap may have captured more chinook this year because of the higher velocities through the trap when the majority of fish (fry) were migrating, and because the trap fished closer to the bank during fry migration, where fry probably prefer to migrate. The change in velocity pattern upstream from trap as a result of the tree may also have “guided” more fish into the trap, such that the higher catch is not solely a function of the increased entrance velocity or location.

We reviewed stream cross-sectional measurements taken directly in front of the traps to determine if changes in the stream channel may have influenced 1999 trap catch rates. The stream channel morphology did not appear to change significantly between any of the years measurements were taken.

Differences in the numbers of parr and smolts captured between traps during 1999 are likely a function of spatial abundance, not size bias. We found no significant difference in the mean lengths of parr and smolts captured in the north and south traps. Therefore, higher catches of parr and smolts in the south trap may indicate that more fish tend to migrate near the middle of the river channel, rather than near the bank.

Trap Efficiency Estimates

Nine trap efficiency tests were made on 8 days during the months of February, March, and June (Table 3). A total of 4 marked hatchery groups and 5 marked natural groups were released about 1/4 mile upstream of the traps at night. Capture efficiency ranged from 1.57% to 3.76%.

Table 3. Release data for all chinook used for trap efficiency tests in 1999.

Release Code	Release Date	Mark Type	Fish Stock	Release Time	Adjusted # Released	Number Recaptured	% Recaptured	Mean Length at Release (mm)
C1	20-Feb-99	Brand	Natural	Night	2550	96	3.76%	33.2
C2	27-Feb-99	Brand	Natural	Night	1672	43	2.57%	35.6
C3	02-Mar-99	Brand	Natural	Night	830	29	3.49%	34.1
C4	09-Mar-99	Brand	Natural	Night	962	20	2.08%	36.1
C5	17-Mar-99	Photonic	Natural	Night	671	15	2.24%	42.8
C6	02-Jun-99	Panjet	Hatchery	Night	2500	63	2.52%	83.6
C7	03-Jun-99	Panjet	Hatchery	Night	2487	39	1.57%	84.2
C8	04-Jun-99	Photonic	Hatchery	Night	2039	68	3.33%	82.5
C9	04-Jun-99	Photonic	Hatchery	Night	2002	35	1.75%	83.3

The number of naturally migrating fry early in the season was such that we could have made additional releases with fry. However, at the direction of the CDFG we limited the releases to approximately once per week.

We were unable to make releases of naturally migrating parr and smolts during April through June due to low catches in the Caswell traps. In order to conduct a trap efficiency release, we needed approximately 500 marked fish. This would have given only 10 recaptured fish at an estimated 2% efficiency. Although we can save trap catches for several days to accumulate 500 fish, at the rate we were catching parr and smolts it would have taken well over one week. Saving natural fish for more than about 5 days results in stressed fish that are unhealthy at release, and therefore not representative of the natural population.

Due to the few fish available for trap efficiency releases, we did not release special groups to test differences between day and night releases or release location. Results in previous years indicated that the release location in the channel did not play a significant role in determining trap efficiency, and due to extremely low recapture rates day releases were determined to be ineffective in accurately determining trap efficiency.

Effect of Mean Length on Trap Efficiency

To determine the effect of fish length on trapping efficiency, we compared the mean lengths of fish released to the mean lengths of fish recaptured for groups of marked fish used to test trapping efficiency. An indicator of possible sampling bias is whether or not the size of recaptured fish differed substantially from the mean of all released fish. Normally, there was less than twenty-four hours between release and recapture, so any detected difference in mean lengths would be associated with either a size-dependent sampling rate, or a size-dependent pre-recapture mortality rate. There would be insufficient time between release and recapture to result in any substantial change in the size of the fish.

There were not enough releases in a given size category in 1999, or within any of the years sampled at Caswell, to permit powerful comparisons of lengths; therefore, the

1996 through 1999 releases were pooled within size category. We found no substantial or significant difference between the lengths of released and recovered fry (P = 0.54). The recovered parr and smolts averaged more than 1 mm smaller than the released fish (P = 0.0178 for parr and P = 0.0651 for smolt). However, there were no parr releases in 1999, and the recovered smolts were actually larger than released smolts for all four smolt releases made in 1999. There may well be a size bias, but the nature of the size bias may differ over different years' river conditions. Such a size bias would bias the expansion of the catch if the size distribution of the released fish differed from that of the river-run passage. If there were such a difference, it would be difficult, if not impossible, to adjust for potential bias.

1999 Capture Efficiency Model

The daily outmigration index was calculated by dividing the number of chinook captured at Caswell each day by the predicted daily trap efficiency (proportion of released fish that were later recaptured):

$$Outmigration\ \ Index = \frac{Count}{Efficiency}$$

Daily counts from the two screw traps were available from February 6 through July 1, 1996[1], from March 19 through June 27, 1997, from January 29 (although the trap was installed January 8) to July 16, 1998 (hereafter referred to as passage days), and from January 18 to June 30, 1999. On 25 dates during these monitoring periods for the 4 years combined, a total of 43 uniquely marked releases[1] were made at a fixed distance upstream

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[1] The number of efficiency releases were: In 1996, 1 on Feb 14, 1 on Feb 19, 1 on March 22, 4 on April 6, 2 on May 2, 2 on May 10, 2 on May 26, and 2 on June 10; in 1997, 1 over a period from April 7 through 11 (denoted as April 9, mid-point day) and 4 releases on the night of May 28/29; and in 1998, 3 on March 14, 3 on March 25, 4 on April 18, 3 on May 10, 2 on May 18, 2 on June 4, and 2 on June 12. Of the 39 releases, 5 were day-time and 34 were night-time releases.

from the Caswell screw traps for the purpose of estimating trap efficiency.

Trap efficiency releases were made in the same location, using the same release procedures, and within similar flow ranges in all years. Among-year differences in the variation in trap efficiency adjusted for fish size, flow, and turbidity did not differ substantially or significantly, allowing a combined analysis to estimate deviance (a measure of variability, see Appendix A). Combining data from all years enabled more precise estimation of efficiency rates for time periods when tests were not conducted.

Developing the 1999 Model

In order to predict the efficiency for each passage day, the efficiency estimates were related as a response (dependent variable) to predictor variables (independent variables) that were measured on every day that the screw traps were operating. The predictor variables explored were flow (f) (in cubic feet per second, cfs) measured at OBB, fish size (s) (in millimeters, mm), and turbidity (t) (in nephelometric turbidity units, NTU). Efficiency (e), the proportion of released fish trapped per release, was related to the predictor variables using the logistic relation:

$$\textit{efficiency}\ (e) = \frac{1}{1 + \exp^{[-b(0)-b(f)\times f-b(s)\times s-b(t)\times t]}}$$

or, using the "logit" linear transform,

$$\textit{logit}\ (e) = \ln\left[\frac{e}{1-e}\right] = b(0) + b(f)\times f + b(s)\times s + b(t)\times t + b(s)\times s$$

In the above equations "exp" is the exponential function, "ln" is the natural log, "b(0)" is a coefficient associated with the intercept[2], and b(f), b(s), and b(t) are partial logistic regression coefficients relating the logit transform of efficiency to the indicated predictor variables. A major reason for choosing the logistic model is that the predicted efficiency can never be less than 0 or greater than 1 (100%), but the logit transform is continuous from negative to positive infinity.

Model Selection

A detailed description of the regression model fitting procedure is given in Appendix A, and a summary is presented here. Separate multiple regressions were calculated to predict trap efficiency in each year (1996-1997, 1998, 1999). A regression coefficient to account for the effect of turbidity could only be calculated with 1996 data, because that was the only year in which efficiency tests were completed on dates when turbidity exceeded 10 NTU (Appendix A). A strong effect of turbidity on trap efficiency was only apparent when turbidity exceeded 10 NTU. Although turbidity showed a significant influence on trapping efficiency in 1996, that influence was not measurable in other years due to relatively low turbidities (<10 NTU) for the dates on which efficiency was tested by releases of marked fish. However, turbidities did exceed 10 NTU for some days during the outmigration in all years. Therefore, the regression coefficient estimated for turbidity in 1996 was retained in the multiple regressions for other years, but it was only applied on days when turbidity exceeded 10 NTU.

The best fitting multiple regression on trap efficiency (logit transformed) was estimated separately for each year by a back-step procedure. Initially the predictor variables of turbidity, flow, and fish length were all included in the regressions for each year. Each regression was then reduced by dropping the predictor variables that did not contribute significantly (P > 0.2) to the regression fit. The reason for choosing such a high

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2 Intercept value = $1/\{1+\exp^{-b(0)}\}$ when f = s = t = 0.

significance level was to reduce the chance of omitting a coefficient when it should be included (Type 2 error). During the back-step procedure, the turbidity regression coefficient estimated from 1996 data was retained in the regression for each year. The final regression model for 1999 differed from previous years in that it included only the intercept and turbidity (Table 4). The net result was that trap efficiency was estimated to be 2.6% on all days with turbidity < 10 NTU, and was estimated to increase at turbidities > 10 NTU. The final regression model for 1996-1997 included all three predictor variables, and the model for 1998 included turbidity and fish length (Table 4).

The 1999 analysis and model selection differed from previous years. Previously flow, fish size, and turbidity were all included in the regression for each year, whether or not the coefficients differed significantly from 0 in any given year. Previously, if a predictor variable was significant in at least one year, it was included in the regressions for all years. The reason for the inclusion of non-significant coefficients was that flow and turbidity coefficients had the same sign each year, but were only significant in 1996 and 1997. Conversely, fish length was a significant predictor variable in 1998, but not in 1996 or 1997 (although the coefficients had the same sign as the 1998 coefficient). Because of the sign consistency, the non-significant coefficients were retained to avoid the bias that could have resulted from statistically declaring the coefficient to be 0, when in fact it was not (Type 2 error). In 1999, however, signs differed from the previous year's coefficients (Appendix 2.a). This finding prompted us to drop non-significant coefficients from all years. However, to reduce the chance of omitting a coefficient when it should be included, the significance level chosen was high (P = 0.2).

Table 4. Coefficient estimates and associated statistics for the regressions on trap efficiency.

1996-1997

Efficiency Predictor: er = 1/{1+exp[-b(0)-b(f)*f-b(s)*s-b(t')*t']}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-1.423720	0.476060	-2.99	0.0050
Flow (f)	-0.000829	0.000167	-4.97	0.0000
Recovery Size (s)	-0.010380	0.005237	-1.98	0.0551
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	**D.F.**	**Deviance/D.F.**	
	163.47	36	4.54	

			Variance-Covariance	
Predictor	**Intercept**	**Flow**	**Recovery Size**	**Turbidity > 10**
Intercept	2.2663E-01			
Flow	-4.3819E-05	2.7835E-08		
Recovery Size	-2.1342E-03	6.5842E-08	2.7427E-05	
Turbidity > 10	-3.4783E-03	-3.7326E-07	4.6771E-05	2.0479E-04

1998

Efficiency Predictor: er = 1/{1+exp[-b(0)-b(s)*s-b(t)*t]}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-2.251260	0.301509	-7.47	0.0000
Recovery Size (s)	-0.022160	0.004855	-4.56	0.0001
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	**D.F.**	**Deviance/D.F.**	
	163.47	36	4.54	

		Variance-Covariance	
Predictor	**Intercept**	**Recovery Size**	**Turbidity > 10**
Intercept	9.0907E-02		
Recovery Size	-1.3759E-03	2.3567E-05	
Turbidity > 10	0.0000E+00	0.0000E+00	2.0479E-04

1999

Efficiency Predictor: er = 1/{1+exp[-b(0)-b(t')*t']}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-3.624670	0.106971	-33.88	0.0000
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	**D.F.**	**Deviance/D.F.**	
	163.47	36	4.54	

	Variance-Covariance	
Predictor	**Intercept**	**Turbidity > 10**
Intercept	1.1443E-02	
Turbidity > 10	0.0000E+00	2.0479E-04

Outmigration Indices

The predicted daily efficiency was used to expand the daily count to estimate a daily passage index. Daily passage indices were substantially greater during late January through February than for the remainder of the outmigration season (Figure 4). The fish migrating at that time were fry. Indices reached a daily peak of over 85,000 fry on February 12 (Figure 4). Outmigrant abundance during February was more than 10-times greater than during March through June. The daily indices were summed over the dates when fry, parr, and smolt were passing (Table 5), to obtain the season's outmigration index estimates for each of these life stages.

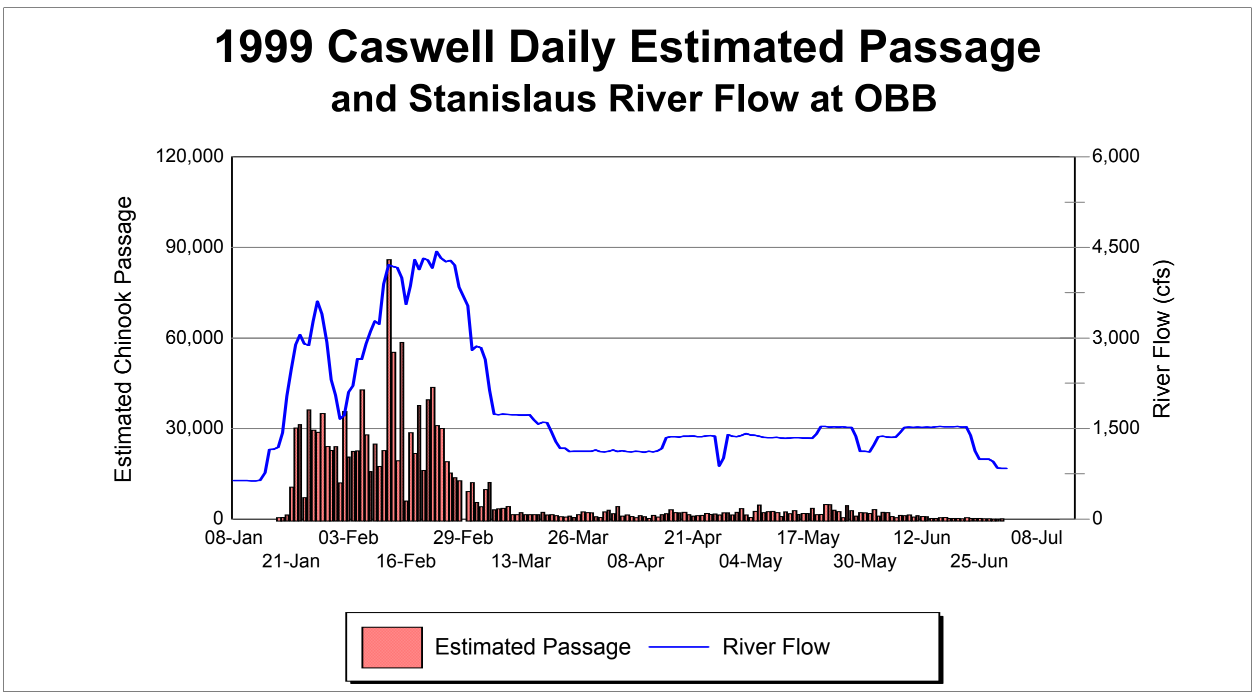


Figure 4. Daily outmigration index of juvenile chinook and flow of the Stanislaus River for 1999.

Table 5. Estimates of outmigration indices for fry, parr, and smolts, 1996 through 1999, based on efficiency estimates from regressions in Table 4. Daily catches and abundance indices are presented in Appendix A.

1996 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry	02/06	03/20	31,767	10,320	11,540	51,994	02/07	03/20	28,653
Parr	03/21	03/31	1,596	470	675	2,516	03/22	03/31	1,465
Smolt	04/01	07/01	81,896	11,065	60,209	103,582	04/02	07/01	65,083
All	02/06	07/01	115,258	15,051	85,759	144,757	02/07	07/01	95,201

1997 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry									
Parr	03/19	04/05	7,011	1,037	4,979	9,043	03/20	04/01	4,724
Smolt	04/06	06/27	60,333	7,478	45,676	74,990	04/03	06/27	48,861
All	03/19	06/27	67,344	8,000	51,663	83,024	03/20	06/27	53,585

1998 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry	01/29	03/07	186,029	44,908	98,009	274,049	01/30	03/07	287,801
Parr	03/08	04/23	209,911	31,238	148,685	271,137	03/09	04/21	179,448
Smolt	04/24	07/16	197,884	37,348	124,682	271,087	04/23	07/16	183,935
All	01/29	07/16	593,825	76,373	444,133	743,516	01/30	07/16	651,184

1999 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits	
	Date Domain		Estimate	S.E.	Lower	Upper
Fry	01/18	03/15	1,155,424	145,284	870,668	1,440,181
Parr	03/16	05/09	92,615	11,169	70,723	114,506
Smolt	05/10	06/30	73,003	9,679	54,031	91,975
All	01/18	06/30	1,321,042	160,000	1,007,443	1,634,642

Note that the estimates for past years (Table 5) differ from those presented in the 1998 report. These differences resulted from the revised regressions on efficiency and some data corrections (see Appendix A). The previous estimates fall within the new confidence limits, which are generally narrower than in previous reports. This is because the variance estimate has been improved as described in Appendix A.

The estimated fry (< 45mm) outmigration in 1999 was substantially greater than in 1998 (the previous greatest estimate) (Table 5 and Figure 5). The season totals for fry are not directly comparable between any years because sampling started on different dates and fry were already migrating when sampling began. Sampling began earlier in 1999 and fry passage continued until a later date in 1999 than in 1998 (1999 fry outmigration: January 18 - March 15; 1998 fry outmigration: Jan 29 - March 7), so the contrast in fry outmigration between years in Table 5 is exaggerated. However, daily fry indices exceeded 20,000 on 28 days in 1999, but only once in 1998. Clearly, substantially more chinook migrated as fry in 1999 than during the previous 2 years when fry were sampled (1996, 1998).

Unlike fry, the 1999 parr and smolt outmigrants were less abundant than in 1998. In fact, 1999 parr and smolt confidence intervals do not overlap those of 1998, indicating that the 1999 parr and smolt outmigration is truly less than that of 1998 (Table 5). Direct comparison of parr and smolt abundance are appropriate between years (excluding 1997 for parr) because the full outmigration period was sampled in each year from 1996 to 1999.

The parr outmigration of 1999 was substantially greater than in 1996 and 1997 and less than that of 1998. However, the differences were not as marked for smolts. In 1999, there was a 2 week period when the mean length was very near 80 mm, and the 80 mm demarcation between parr and smolt might be somewhat artificial, especially for the 1999 outmigration (see Appendix Table A.5.d). Because of the indistinct separation of parr and smolts in some years, there may be some benefit to combining the estimates of parr and smolts to compare abundance among years.

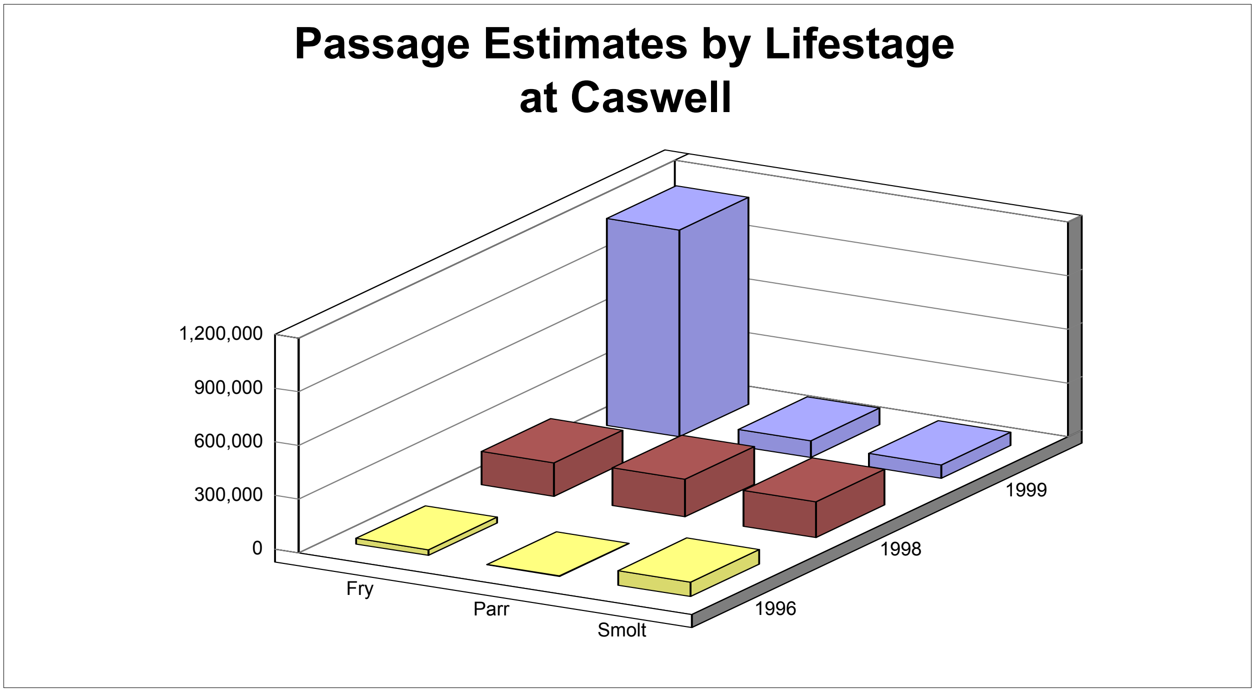
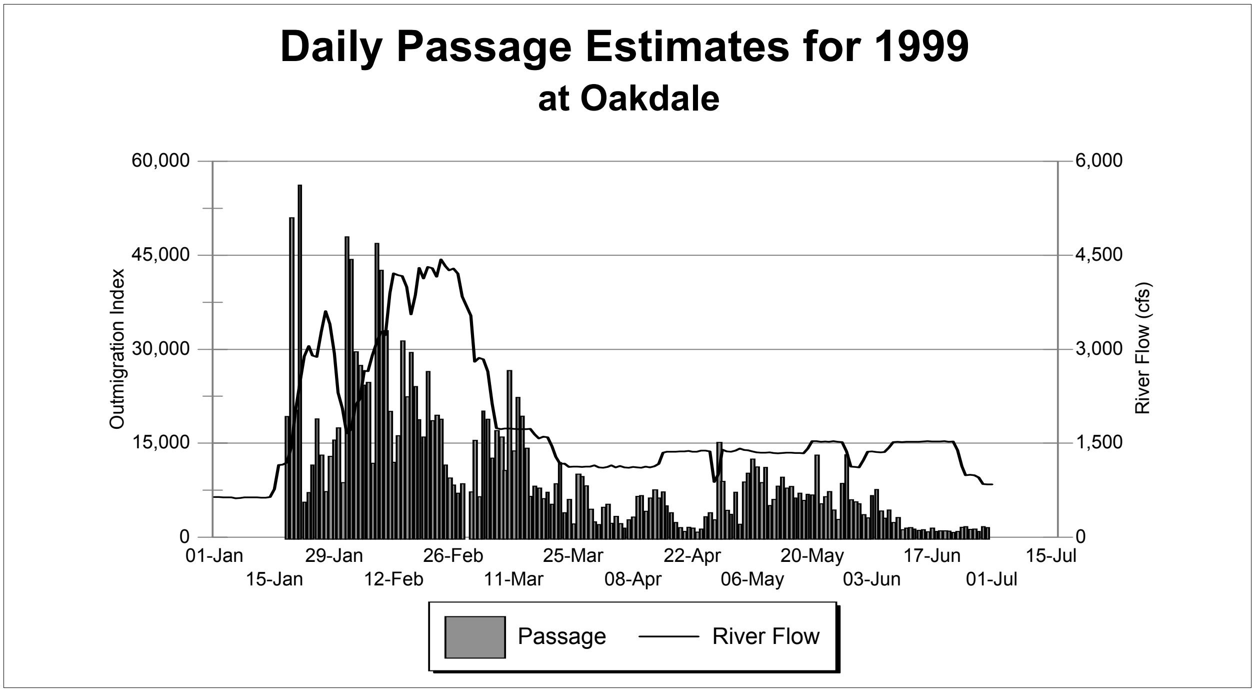


Figure 5. Estimates of total outmigration index by life stage classification from the Stanislaus River, 1996-1999.

Oakdale and Caswell Passage Estimates

Outmigration indices from the Oakdale and Caswell sites were compared to evaluate differences in passage estimates and migration timing for different life stages of chinook (Figure 6). Sampling at the two locations in 1999 covered the same dates, so direct comparisons between the sites may reflect 1) additions or losses that occurred between the sites, 2) rearing between the sites, or 3) lack of precision in passage estimates. Overall, more fish were estimated to have passed the Oakdale trap (1,669,000) than the Caswell trap (1,321,042) (Table 6). Most of the difference in passage between the two sites was in parr (275,748 less parr at Caswell) (Figure 7).



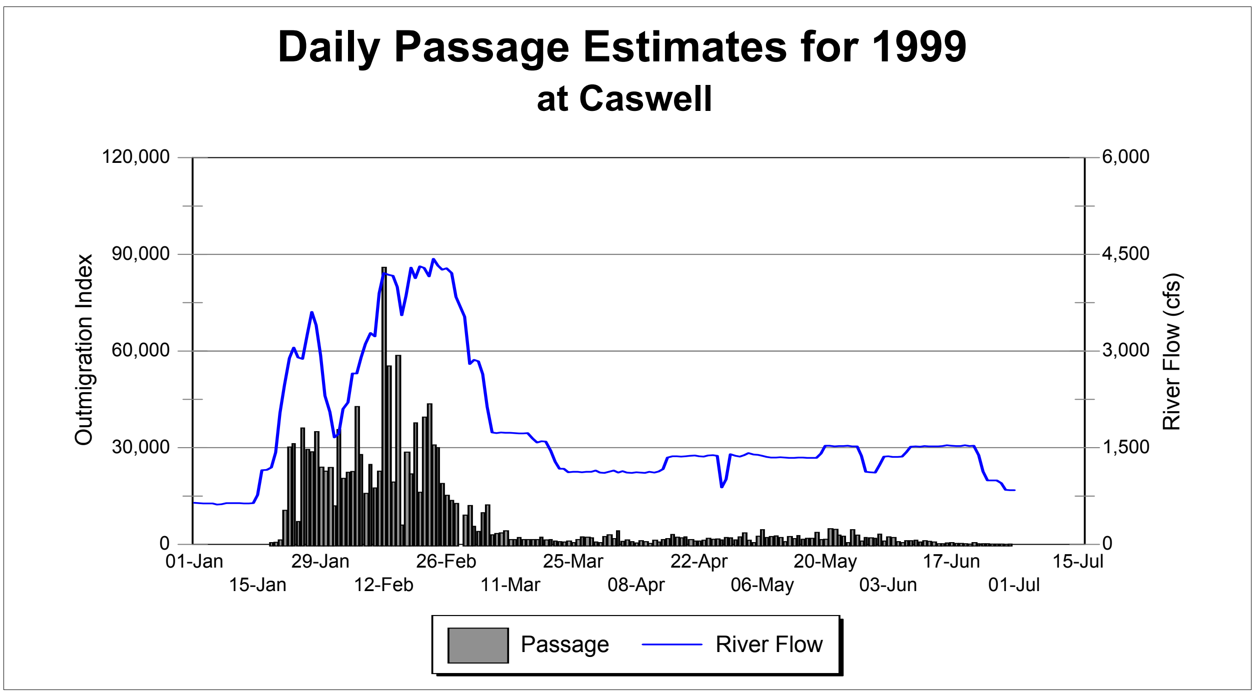


Figure 6. Estimates of the daily passage index for juvenile chinook at Oakdale and Caswell in 1999. Data for Oakdale from Demko et al. (2000).

Table 6. Estimates for the outmigration index of fry, parr and smolts at Oakdale and Caswell in 1999. Oakdale data from Demko et al. (2000).

	Caswell 1999			**Oakdale 1999**		
	Date Domain		**Estimate**	**Date Domain**		**Estimate**
Fry	1/18/99	3/15/99	1,155,424	01/18/99	03/22/99	1,198,144
Parr	3/16/99	5/9/99	92,615	03/23/99	05/26/99	368,363
Smolt	5/10/99	6/30/99	73,003	05/27/99	06/30/99	102,493
All	**1/18/99**	**6/30/99**	**1,321,042**	**01/18/99**	**06/30/99**	**1,669,000**

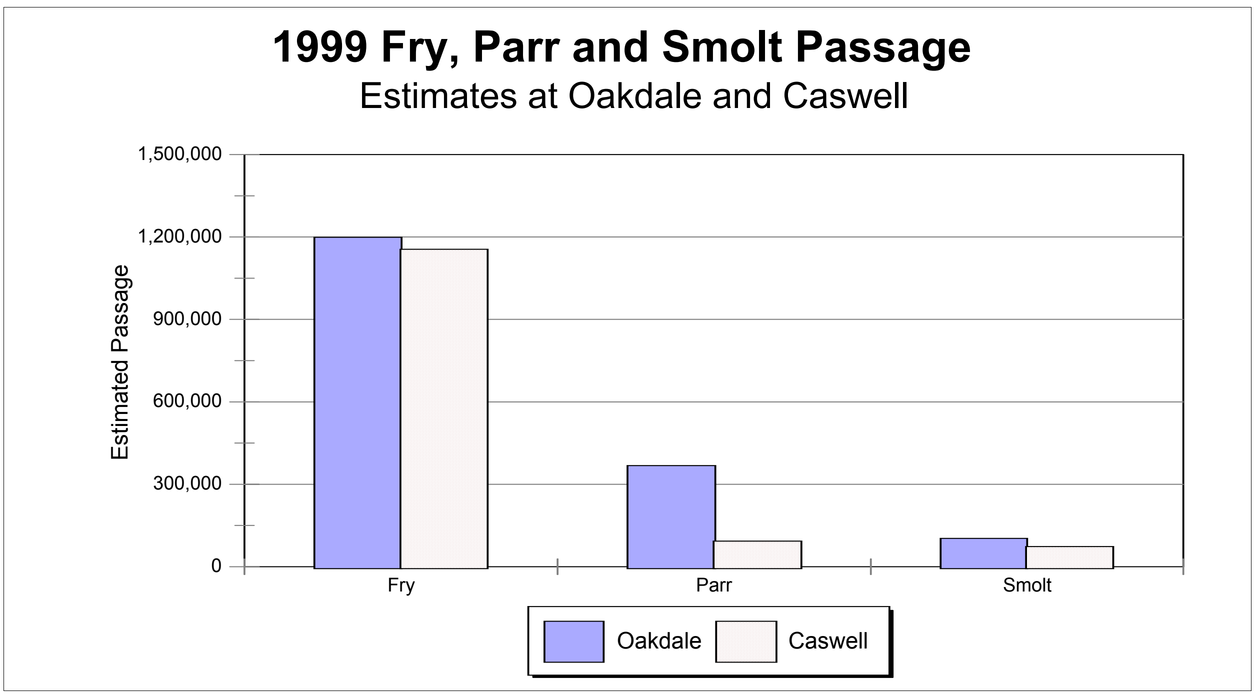


Figure 7. Comparison between Caswell and Oakdale of fry, parr, and smolt passage indices during 1999.

OBJECTIVE 2: DETERMINE THE SIZE AND SMOLTING CHARACTERISTICS OF JUVENILE CHINOOK SALMON AND RAINBOW TROUT/STEELHEAD MIGRATING OUT OF THE STANISLAUS RIVER

Length at Outmigration

The mean lengths of juvenile chinook gradually increased over the course of sampling, ranging from about 35 mm at the start of sampling (mid-January) to about 90 mm in late June (Figure 8). The gradual increase in mean lengths over time in 1999 was similar to the pattern seen in 1996, 1997, and 1998; however, the length increase was slower than other years and the threshold size for classifying smolts (80 mm) was not reached until May 10 (Figure 9). This was 3 to 7 weeks later than other years. Environmental factors such as water temperature, turbidity, and habitat availability, as well as fish abundance, may have played roles in determining growth rates and the lengths of migrating juvenile chinook. Late spawners could have contributed to smaller fish seen later in the season. The above factors will be addressed in the following section.

Comparison of Mean Lengths of Natural Migrants Between Years

Mean lengths of fry captured at Caswell in January and February were similar for all years sampled (1996 - 1999). However, at the onset of capturing parr in March, the mean lengths diverge between the years.

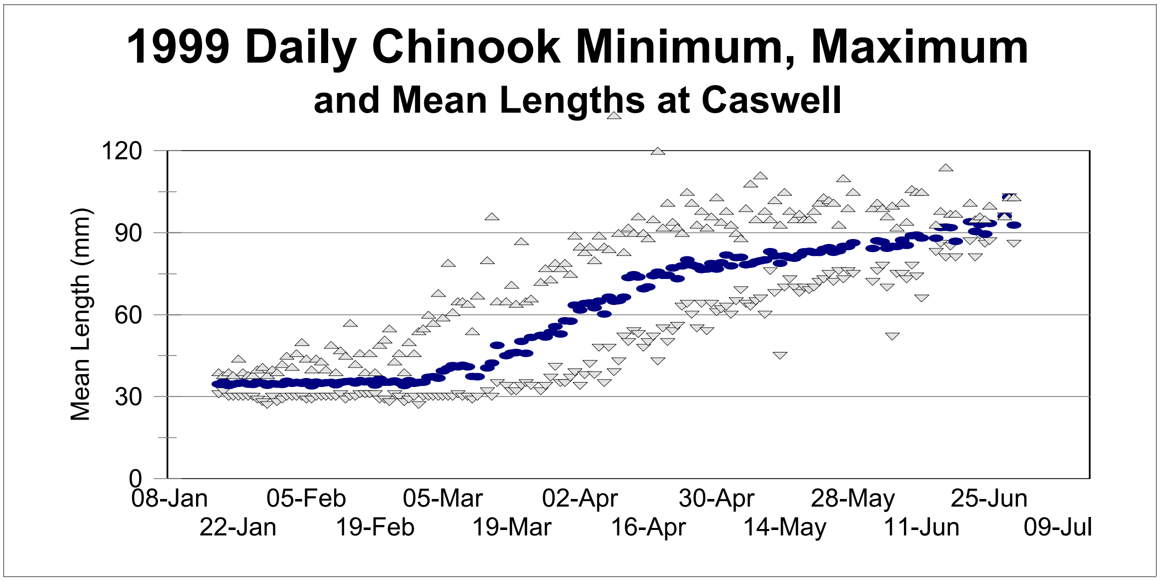


Figure 8. Maximum, minimum, and mean lengths of chinook captured daily at the Caswell trap in 1999.

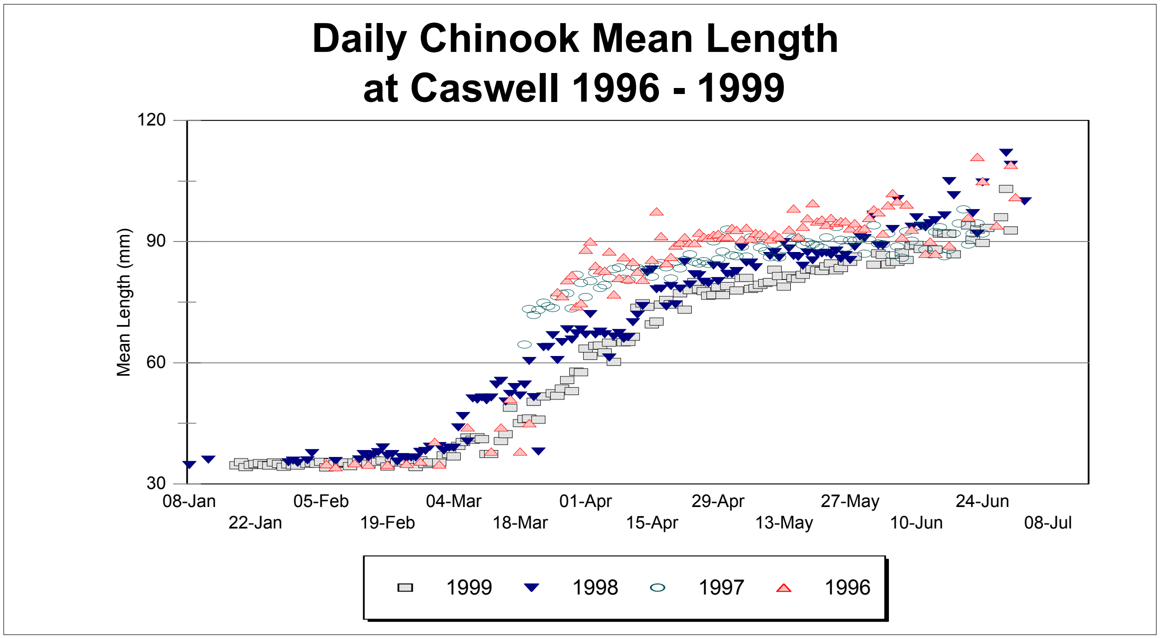


Figure 9. Mean lengths of chinook captured daily at the Caswell trap 1996-1999

Comparison of rearing temperature data at Goodwin Dam for 1998 and 1999 revealed that slightly cooler temperatures prevailed during January, February, and March of 1999 (Figure 10). This may have contributed to the delayed emergence and slower growth of juvenile chinook. However, temperatures in 1996 were similar to those in 1998 while 1996 fish were larger than 1998 fish (Figure 10). Thus, temperature alone does not explain the differences in length between years.

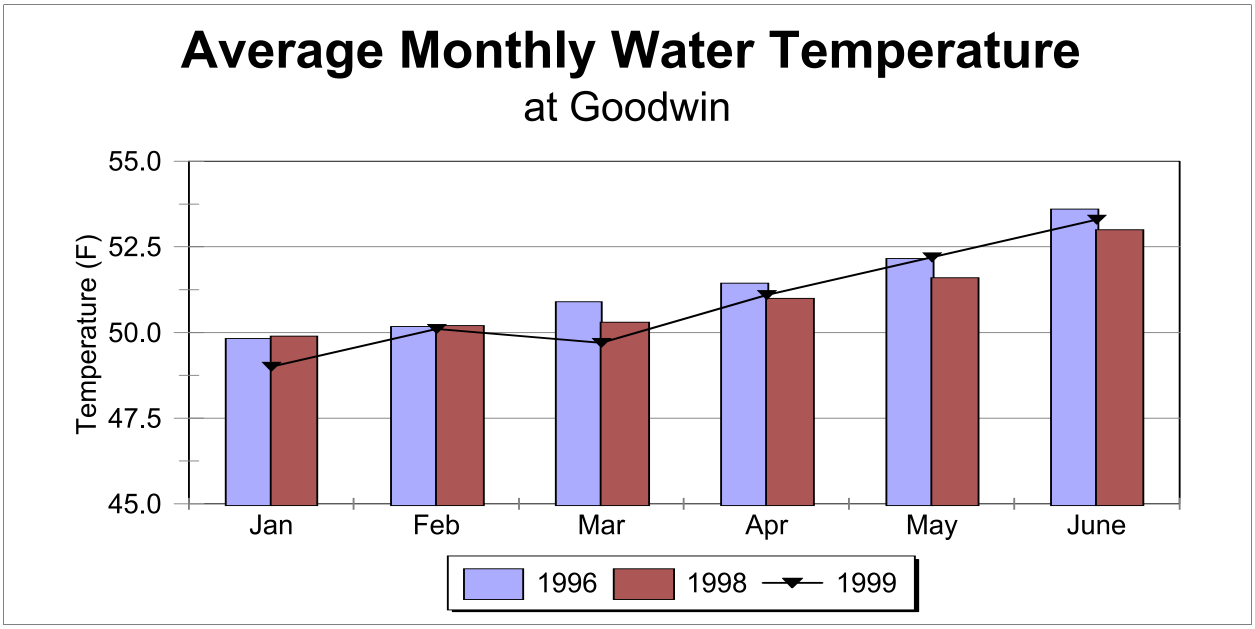


Figure 10. Average monthly temperatures of the Stanislaus River at Goodwin Dam 1996 thru 1999.

The combination of temperature and juvenile chinook abundance may account for a large share of the variation in juvenile growth between years, but a longer time series of data will be necessary to confirm this. Chinook, like many salmonids, are highly territorial (Chapman 1966, Elliot 1990) and as they grow their territory expands (Elliot 1990). With their growth and subsequent expansion of territories, fish would inevitably continue to be displaced downstream in search of unoccupied habitats. In spite of the early exit of a majority of the population (fry migrants), the remaining fish would still compete for resources. The largest mean lengths at Caswell by the first week of May were collected in 1996. The year of lowest fish abundance and the smallest mean lengths the first week of May was 1999, also the year of lowest temperatures. Cramer et al. (1985) found after 10 years of study in the Rogue River that 85% of variation between years in mean lengths of juvenile chinook could be accounted for by regression on juvenile abundance and river temperature. In that study, juveniles grew faster when spring river temperatures were high and when juvenile chinook abundance was lower.

Flow may also influence growth indirectly through its influence on habitat availability or capacity. As flow increases, new areas could be inundated. At bankfull stages fish would have access to productive rearing habitats in the flood plain, more cover, and more total area for rearing (Yoshiyama et al. 1998). However, there is no indication in our years of data that lengths are larger in higher flow years. Further, there is generally a negative correlation between flow and river temperature during spring. Higher water years result in cooler river temperatures, which in turn can slow growth rates. This was the finding after 10 years of study on the Rogue River where growth rates of juvenile chinook tended to be highest in years of lowest flow (Cramer et al. 1985). However, Cramer et al. (1985) concluded from a variety of growth measures that warmer temperatures, rather than lower flows, were driving growth of juvenile chinook.

Spawner timing and abundance could affect the lengths of fish observed in the spring. Eggs spawned early would accumulate temperature units quickly while temperatures were still warm in the fall. Eggs from later spawners would be subject to a cooler temperature regime from the start. Fish exposed to cooler temperatures would incubate slower and emerge later, thus elongating the fry portion (and possibly parr and smolt stages) of the outmigration. This might result in the more gradual increase in lengths observed in 1998 and 1999. At this point spawner data has not been incorporated into this report, but should be considered in future studies.

Turbidity can play a role in growth of juvenile chinook (Gregory and Northcote 1993). It has been suggested that predation is reduced under turbid conditions (Gradall and Swenson 1982, Cezilly 1992, Gregory 1993 cited from Gregory and Levings 1998) and juvenile fish may engage in activities such as increased feeding activity that would otherwise be risky (Ginetz and Larkin 1976). Turbidity levels in 1996, 1998, and 1999 (turbidity was excluded for 1997 due to the relatively short sampling period) differed slightly between years, but generally only varied within a range of 3 to 10 NTU (Figure 11). Gregory and Northcote (1993) found highest foraging rates of juvenile chinook when they were in water with turbidities ranging form 35 to 150 NTU. We found no indication from available studies that the low range of turbidities we observed would have a detectable effect on chinook growth.

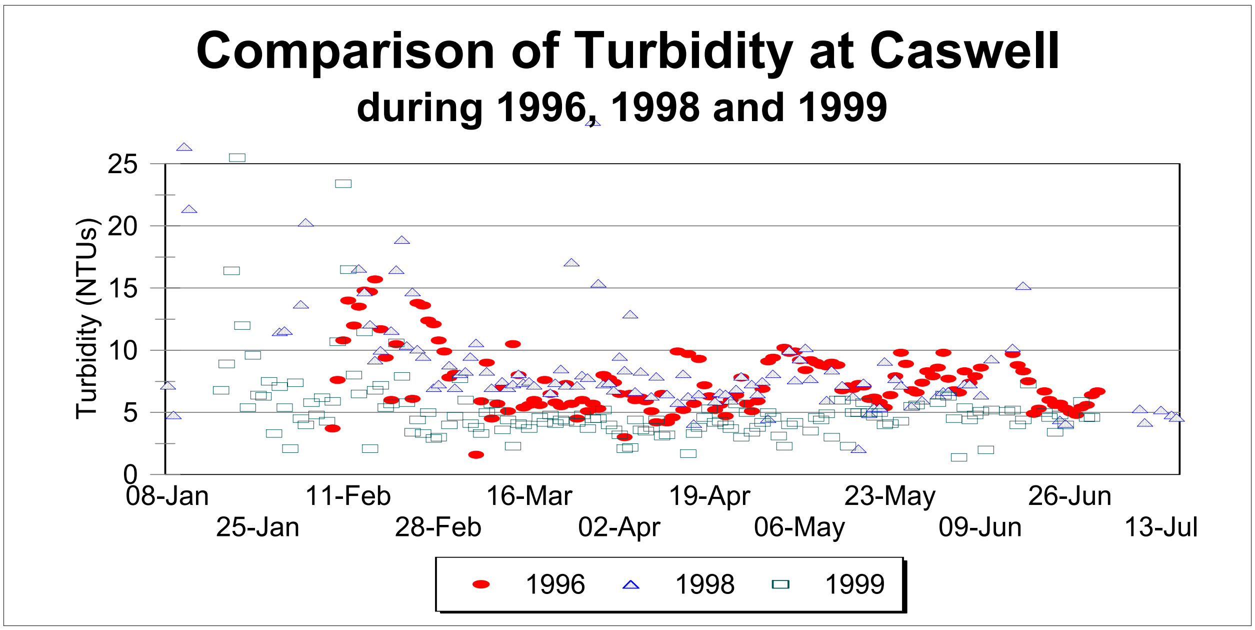


Figure 11. Daily turbidity of the Stanislaus River at Caswell for 1996, 1998, and 1999.

Comparison of Mean Lengths at Oakdale and Caswell in 1999

Mean lengths of natural chinook captured at Caswell and Oakdale have been similar throughout the trapping season in past years. In 1999 there was a noticeable difference in mean lengths between the sites beginning in March, once fish reached the parr stage (Figure 12). The difference was greatest in mid April, when fish reached approximately 75 mm at Caswell, but were still near 60 mm in length at Oakdale.

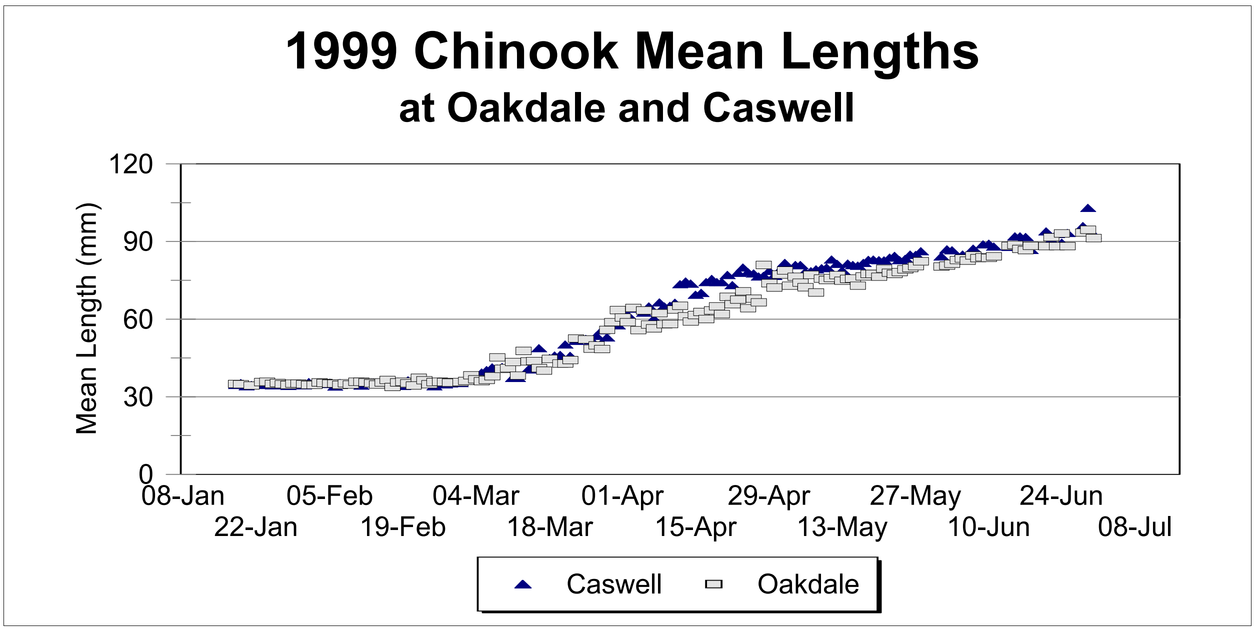
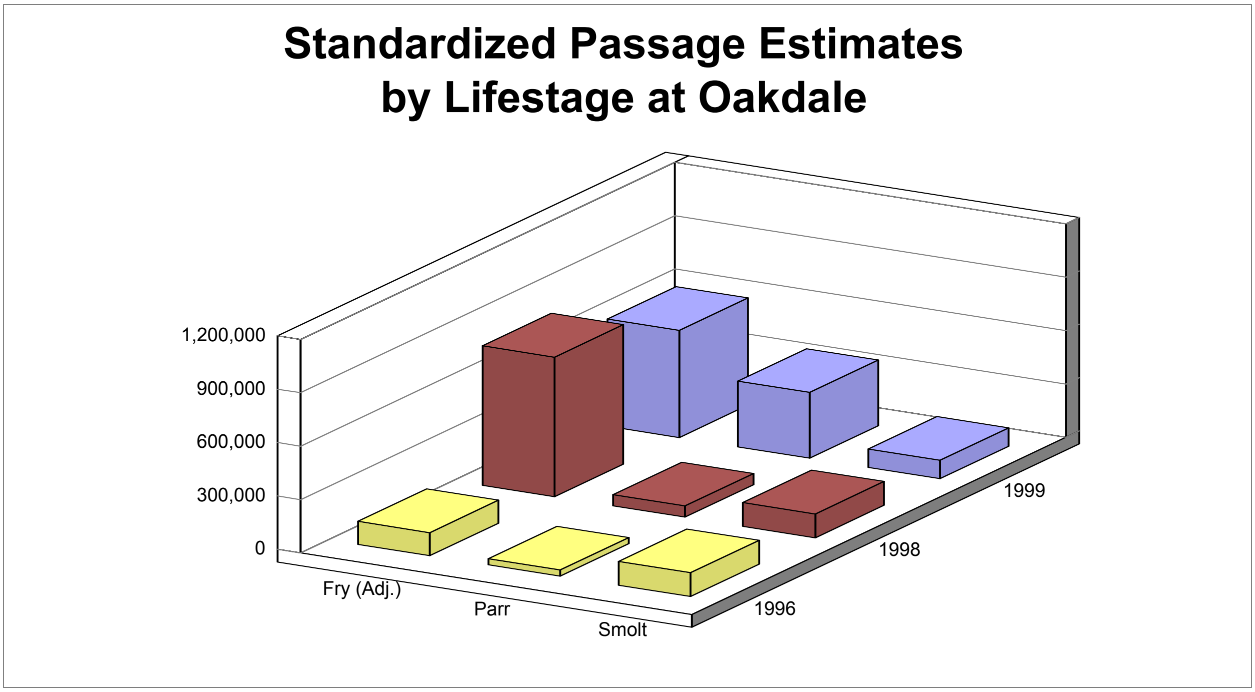


Figure 12. Comparison of daily mean lengths for juvenile chinook at Oakdale and Caswell in 1999.

The difference in lengths between the trap sites during 1999 may indicate that many parr paused to rear between Oakdale and Caswell. There was no sampling between the two sites to test this possibility, but data from our previous studies tend to support the rearing hypothesis.

Although mean lengths were nearly the same between the two sites in previous years, the relative abundance of migrants that were either fry, parr, or smolts differed between the trap sites. Most notably, the abundance of both parr and smolts was greater at Caswell than at Oakdale in 1998 (Figure 13). Because only a small percentage of spawning occurs below Oakdale (roughly 20%), the higher number of parr and smolts passing Caswell in 1998 would most likely have resulted from fry that migrated past Oakdale and then stopped to rear between Oakdale and Caswell. In order to make comparisons of relative fry abundance between stations and between years, we used the index of daily fry passage summed for the last 40 days of fry passage at each station (because we had at least 40 days of fry sampling at each station in each year). This 40 day index of fry abundance is the quantity shown in Figure 13. Data shown in Figure 13 indicates that the excess fry passing Oakdale compared to Caswell in 1998 must have then reared below Oakdale and later migrated to produce the excess parr and smolts at Caswell compared to Oakdale. Our finding that mean lengths of juvenile chinook on any given date in 1998 were similar between the two stations indicates that growth rates must have been similar between the two areas of the river.



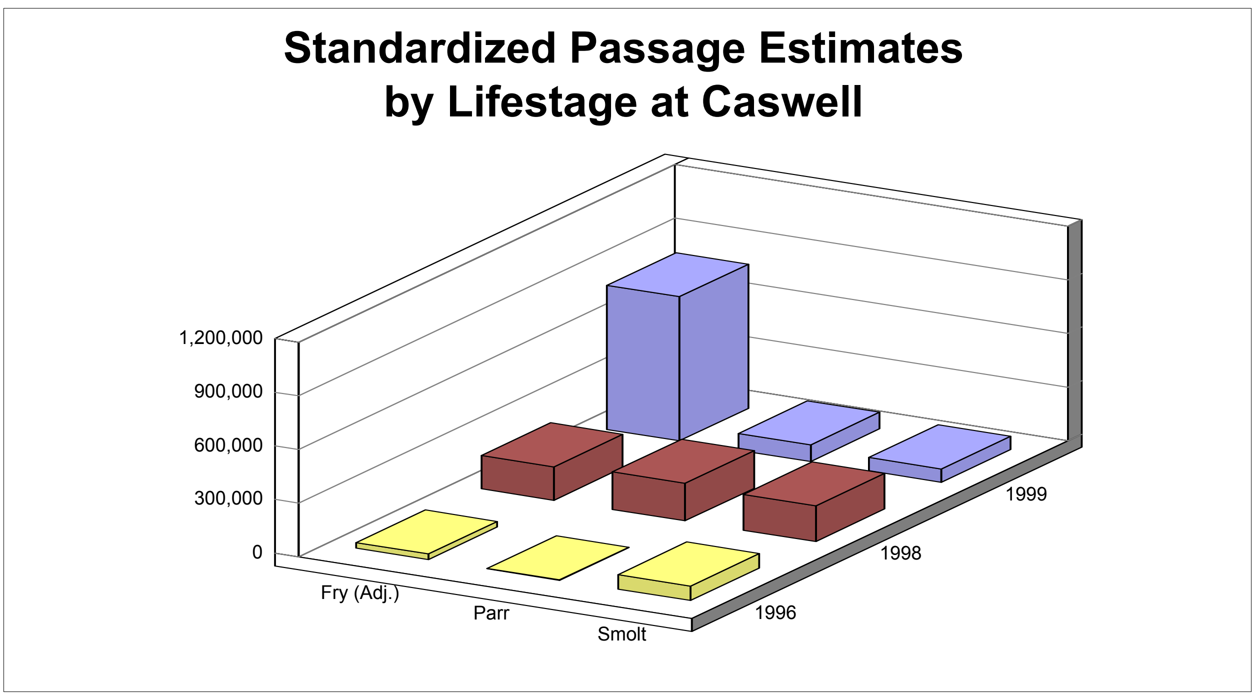


Figure 13. Comparison of passage indices between Oakdale and Caswell for fry, parr, and smolts during 1996, 1998, and 1999. Fry index is standardized for the last 40 days of fry passage in each year.

Chinook parr show habitat preferences for low velocities, small substrate particle size, and abundant cover (when available) (Chapman and Bjorrn 1969, Everest and Chapman 1972, Murphy et al. 1989 cited from Healey 1991). Such cover is frequently found in back eddies, behind fallen trees, and near undercut tree roots and other areas of bank cover (Healey 1991). These habitat characteristics are plentiful in the lower Stanislaus River during the spring. Relative to the river above Oakdale, the river downstream has temperatures during spring that may be more optimal for growth of juvenile chinook in some years, and higher turbidities that provide some cover from predation. However, warm water piscivores such as largemouth bass, smallmouth bass, and striped bass are more abundant below Oakdale. Overall, there may be survival advantages to juvenile chinook rearing between Oakdale and Caswell, but this is uncertain.

Smolt Appearance Index

The external appearance of smolt characteristics among chinook captured in the traps started to increase at the beginning of March (Figure 14), when the daily mean smolt index gradually increased from 1 to 2. Individual fish with a score of 2 appeared through mid-June and their lengths ranged up to 90 mm (Figure 14). Fish that were distinctly smolts (index = 3) were at least 80 mm and began appearing in mid-April. (Figure 14).

The smolt appearance index followed similar trends through time in 1998 and 1999. Fry were present through the end of April in both 1998 and 1999, with the exception of 1 fry captured in late May in 1999. Parr appeared later in 1999 (beginning of March) than in 1998 (late February), but in both years parr persisted until mid June. The difference in the timing of parr could be attributed to a variety of factors affecting growth and development, as discussed previously. In both years smolts (smolt index 3) were observed around the 15th of April through the end of sampling at the end of June.

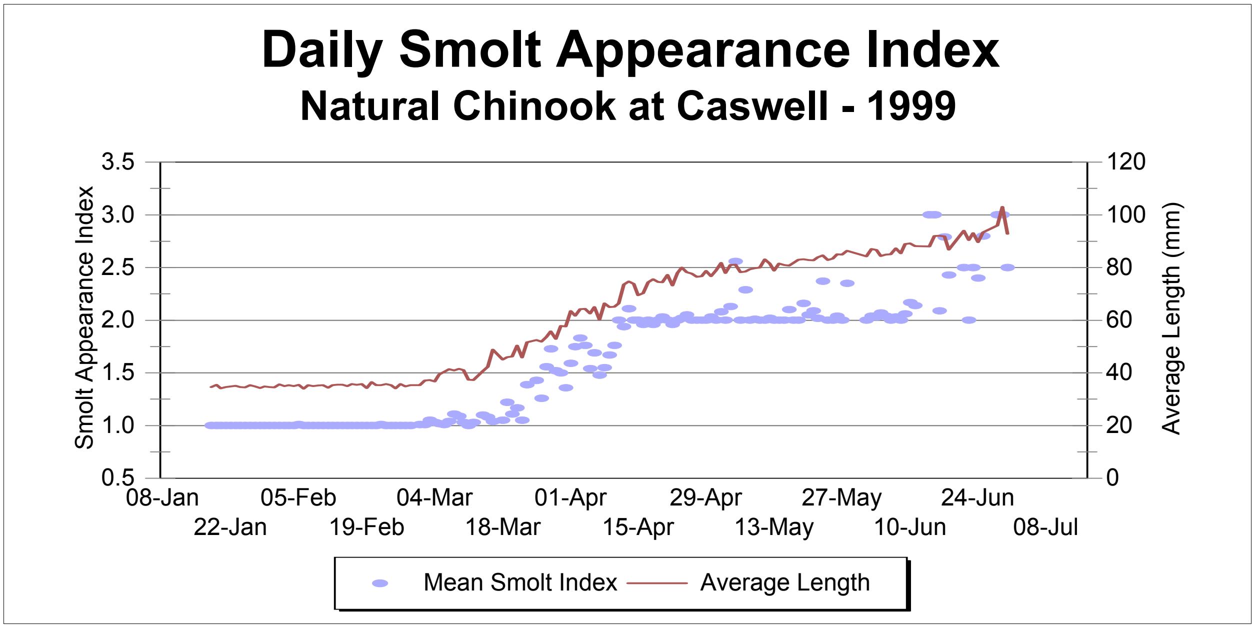


Figure 14. Mean daily smolt appearance index and mean length of natural chinook captured in the Caswell screw traps during 1999.

Rainbow Trout / Steelhead Lengths

During the sampling season, we captured 12 rainbow trout/steelhead at Caswell, ranging in size from 83 mm to 255 mm (Figure 15). Two distinct size classes were apparent (200-300 mm and <100mm), representing yearlings and young-of-the-year, respectively. More rainbow trout/steelhead were captured in 1999 than 1998, but 1999 counts were comparable to 1997.

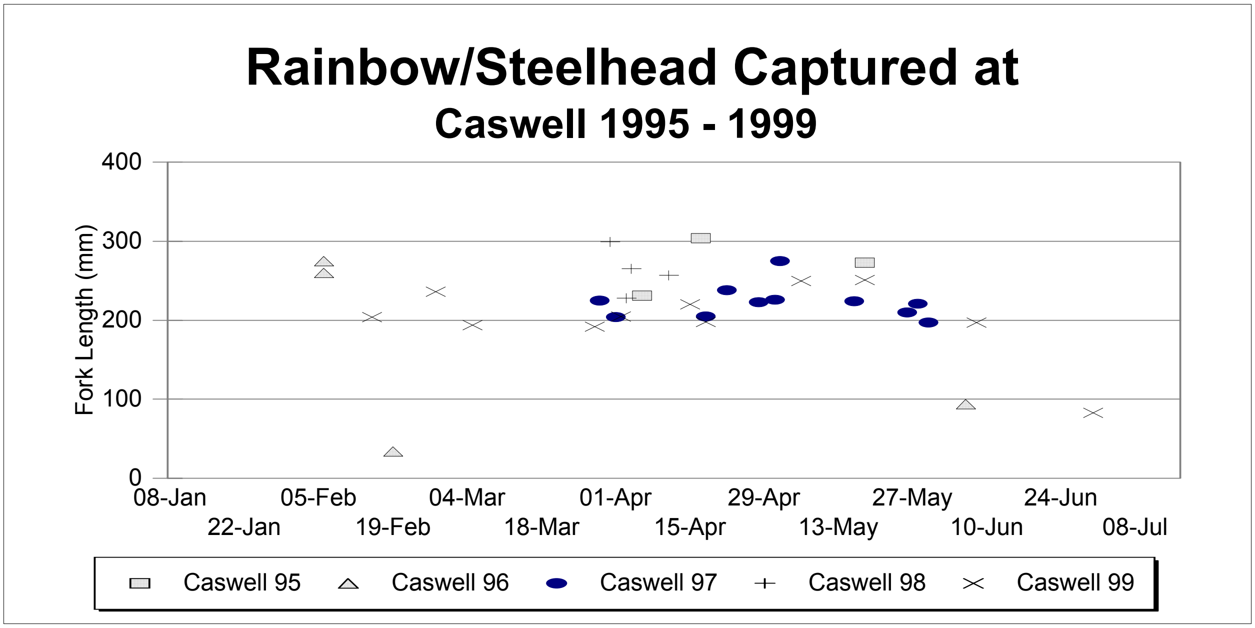


Figure 15. Lengths of all rainbow trout/steelhead captured at Caswell 1995 through 1999.

OBJECTIVE 3: IDENTIFY FACTORS THAT INFLUENCE THE TIMING, SIZE, AND NUMBER OF JUVENILE CHINOOK SALMON AND RAINBOW TROUT/STEELHEAD MIGRATING OUT OF THE STANISLAUS RIVER

Effects of Streamflow on Chinook Salmon Outmigration

There was no clear indication that variation in flow stimulated fry movement, but the magnitude of flow may have encouraged fry movement. Similar to 1998, the peak of chinook fry passage in 1999 corresponded with elevated flows (Figure 16). Heavy rains resulted in elevated flows for most of January and February, and fry migration peaked on February 12, when over 80,000 fry were estimated to pass Caswell in a single night. Fry passage estimates were high throughout late January and all February, while flows generally ranged between 3,000 - 4,000 cfs.

Streamflow has previously been correlated with peak fry catches. In the Sacramento-San Joaquin delta, Kjelson et al. (1981) found peak fry catches were often associated with flow increases caused by storm run-off. They speculated flow pulses stimulated fry migration out of the upper river spawning grounds. The correlation between flow and fry movement was also observed in the Nanaimo River (Healey 1980).

Migration peaked in mid-February during 1996, 1998, and 1999 (fry outmigration was not sampled in 1997). Each peak was also associated with an increase in daily average flow of 300 to 700 cfs. However, smaller peaks were not associated with flow increases. Flow may influence fry migration, but its affects are not consistent, indicating that flow is not the only factor driving outmigration timing.

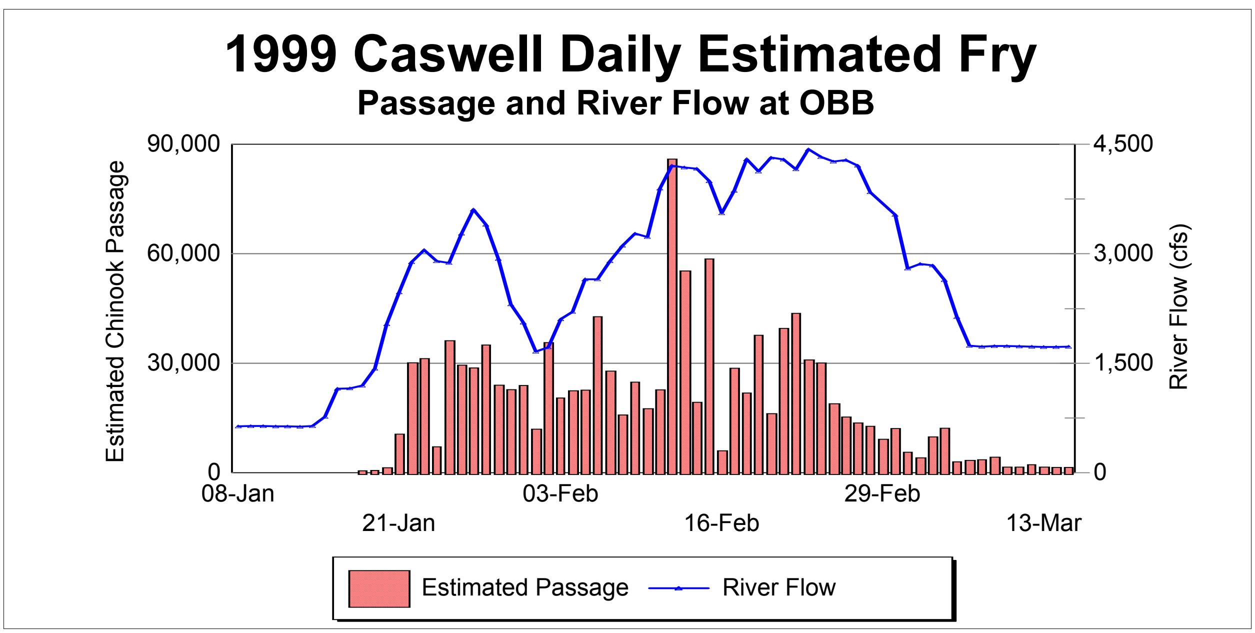


Figure 16. Daily index of fry passage at Caswell and flow for 1999.

It is possible that the magnitude of flows during the fry outmigration may play a role in determining the proportion of the total population that will migrate as fry. If flows during the onset of fry emergence are stable, more fry may establish feeding behavior and territories before they drift downstream with high flows. This may account for the low proportion of fry migrants in low flow years such as appeared to be the case in 1996. Other studies in the San Joaquin Delta tend to support the theory that a higher percentage of juvenile chinook migrate as fry in high flow years. For example, USFWS (1998) found that the abundance of chinook fry captured by seining in the northern Delta between 1985 and 1999 was positively correlated (r = 0.91) with the mean flow of the Sacramento River during February.

Between March and June, parr and smolt outmigrated without any dramatic peaks in migration, and flows were relatively stable between 1,200 cfs and 1,600 cfs (Figure 17). Unlike the fry outmigration, no relationship between outmigration and flow was observed for parr and smolts. Similar results were observed on the upper South Umpqua River basin, Oregon, where migration of 50-59 mm chinook (parr) was not cued by changes in discharge (Roper and Scarnecchia 1999). The relatively stable flows during the spring of 1999 provided little opportunity to observe the influence of flow variation on parr and smolt migration.

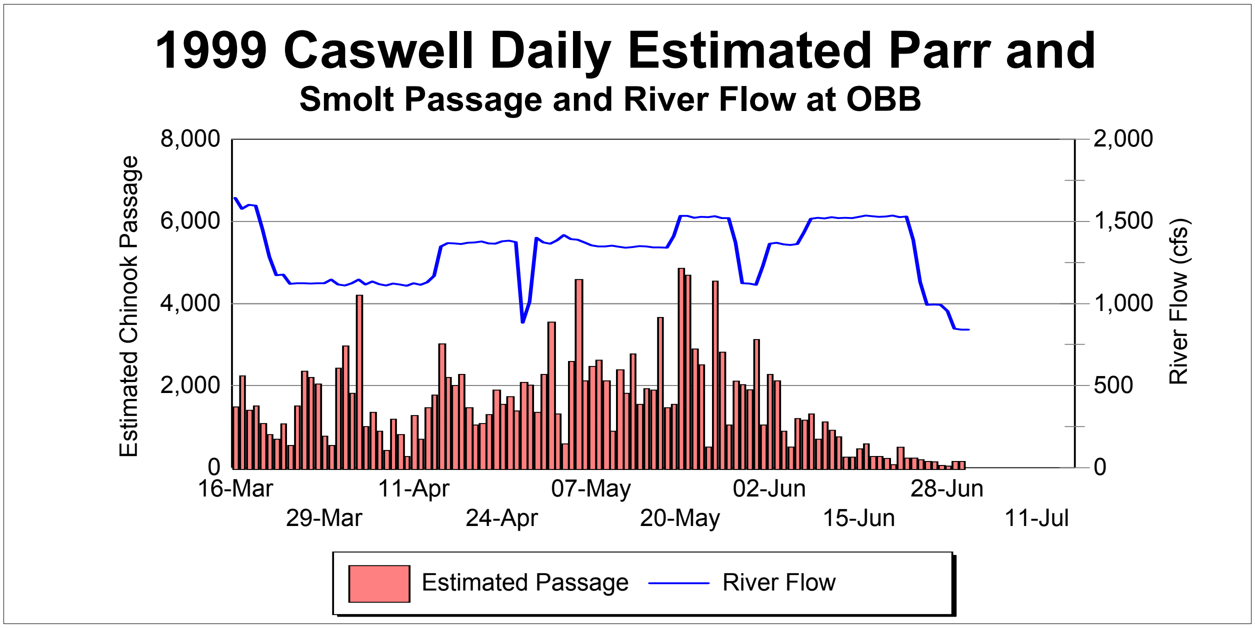


Figure 17. Daily index of parr and smolt passage at Caswell compared to flow for 1999.

Effects of Turbidity on Chinook Salmon Outmigration

Fry outmigrated during January and February when turbidity levels were high, ranging from approximately 4 to 24 NTU's. Although there were two dramatic spikes in turbidity lasting 1 day in both January and February, one slightly over and one slightly under 24 NTU's, daily turbidity generally ranged between 4 and 10 NTU's. The highest fry passage day did occur two days after the second turbidity spike (just under 24 NTU's on February 10), but there was no apparent migration change to the first spike. Turbidity ranged only from 2 to 7 NTU's during the parr and smolt outmigration, so there was little opportunity to observe the effect on parr and smolt migration. The limited variation in turbidity did not correspond with any peaks in passage of parr or smolt (Figure 18).

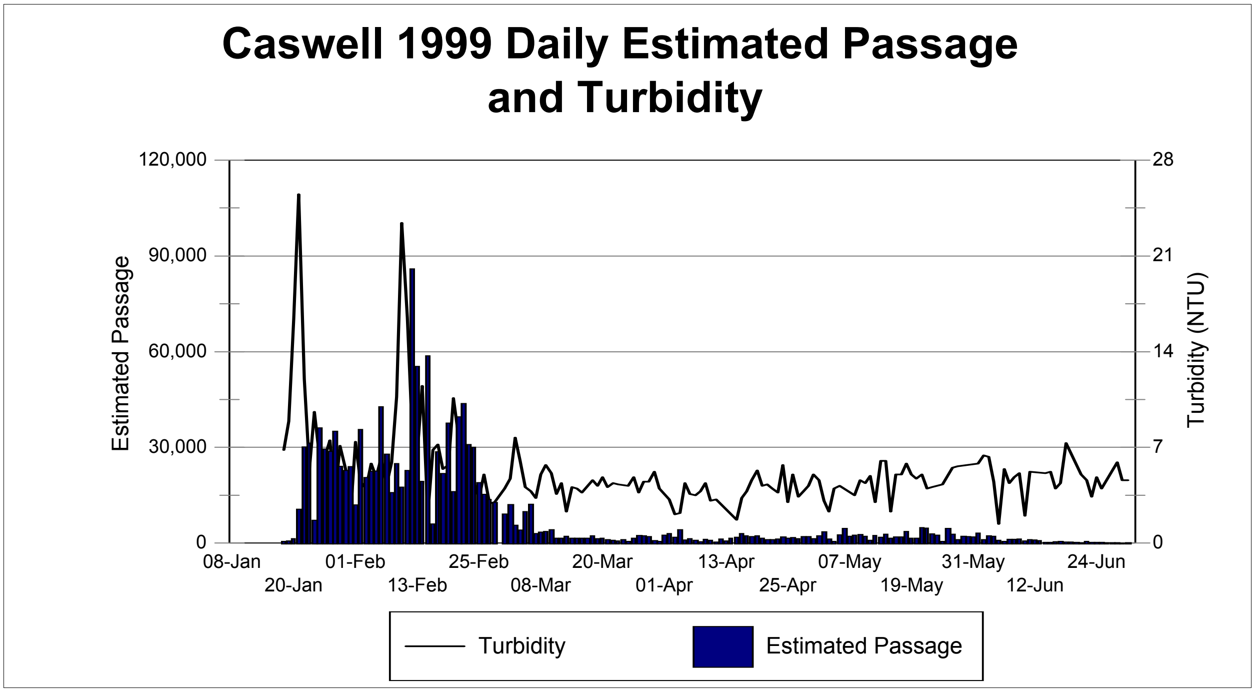


Figure 18. Daily chinook passage at Caswell compared to turbidity in 1999.

Little work has been done on the relationship between turbidity and fry outmigration timing; however, many studies have related turbid conditions to reduced fry predation. Predators, such a birds and fish, use vision to detect and attack prey. High turbidity can impair visual abilities, thus reducing the detection range of predators. A study by Gregory and Levings (1998) concluded predation did occur at lower rates in the Fraser River (27-108 NTU) compared to that of the clear water Harrison River. We might expect then that turbid water acts as cover for small fish, allowing more of them to outmigrate undetected. Previous studies have suggested juvenile fish engage in otherwise dangerous activities during turbid conditions, activities including feeding (Gregory and Northcote 1993, Gregory 1994), increased use of open water (Miner and Stein 1996), increased migration rate (Ginetz and Larkin 1976), and less cover seeking behavior (Gradall and Swenson 1982, Gregory 1993). These responses might encourage juvenile chinook to migrate during turbid conditions.

Effects of Lunar Phase on Chinook Salmon Migration

Lunar phase has been correlated to peaks in fry and smolt movement in some streams. Reimers (1971) observed that downstream movement of chinook was inhibited by bright moonlight (cited from Healey 1991). Grau et al. (1981) found that thyroxine levels, which are associated with smoltification, peaked during the new moon phase in anadromous salmonids. They postulated migration during nighttime hours and during the darkest nights of the month made detection by predators more difficult, thus increasing smolts chances for survival.

Caswell passage estimates did not consistently peak during the new moon phases (Table 7), but there was indication of an increase in passage at that time (Figure 19). Proximity to the spawning grounds can effect the patterns observed. For example, fish choosing to migrate from spawning grounds might not reach Caswell for 3 days to a week depending on flow conditions. Therefore, we might expect lunar phase patterns to be more evident at the Oakdale trap, which is closer to spawning grounds than the Caswell trap. Additionally, weather conditions may also play a role. Overcast or cloudy skies could filter or completely block moonlight, thus producing darkness such as experienced during a new moon.

Table 7. Dates each month for peak passage and new moon from January thru May in 1996-1999. Months in which peak passage and new moon occurred within 5 days of one another are highlighted.

	1996		1997		1998		1999	
Month	**Peak***	**New Moon**	**Peak***	**New Moon**	**Peak***	**New Moon**	**Peak***	**New Moon**
January	25	17	-	-	29	28	23	20
February	12	16	-	-	16	26	23	18
March	2	17	30	9	26	28	1	19
April	16	16	15	7	8	26	30	17
May	21	15	16	6	19	25	5	17

*Peak = peak passage of smolts from outmigration index estimates.

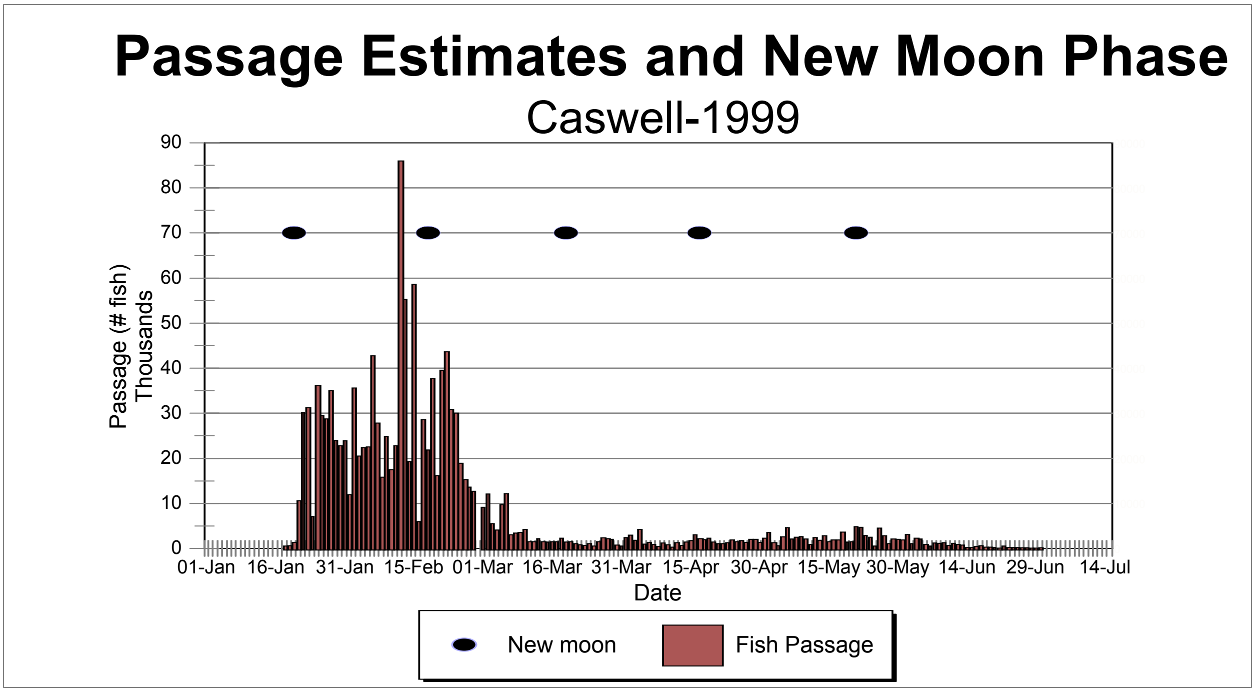


Figure 19. New moon phase and daily chinook passage estimates for 1999.

Effects of Temperature on Chinook Salmon Outmigration

Daily fluctuations in outmigration did not appear to correspond with changes in temperature. Temperature at Caswell gradually increased from around 10^{o} C at the beginning of sampling to 19EC at the end of June (Figure 20). It is likely that temperature does affect seasonal migration timing, because it strongly affects growth and development. The timing of chinook smolt migration was significantly related to temperature on the South Umpqua River (Roper and Scarnecchia 1999). Migration was later in cool years and earlier in warm years on the South Umpqua River. Cooler temperatures during winter slowed development resulting in later emergence dates whereas warmer temperatures accelerated growth and promoted earlier emigration (Roper and Scarnecchia 1999). Water temperature was also seen to coincide with fish movement in a study conducted by Bjornn (1971) but he did not find a consistent relationship and concluded photoperiod and growth were more likely initiating movement. Bjornn's results (1971) are consistent with those from the Stanislaus in that we found a coincidence of increases in outmigration and temperature change (up or down), but not consistently. Other studies have found that fish will migrate under constant temperature regimes (Bjornn et al. 1968 cited from Bjornn 1971).

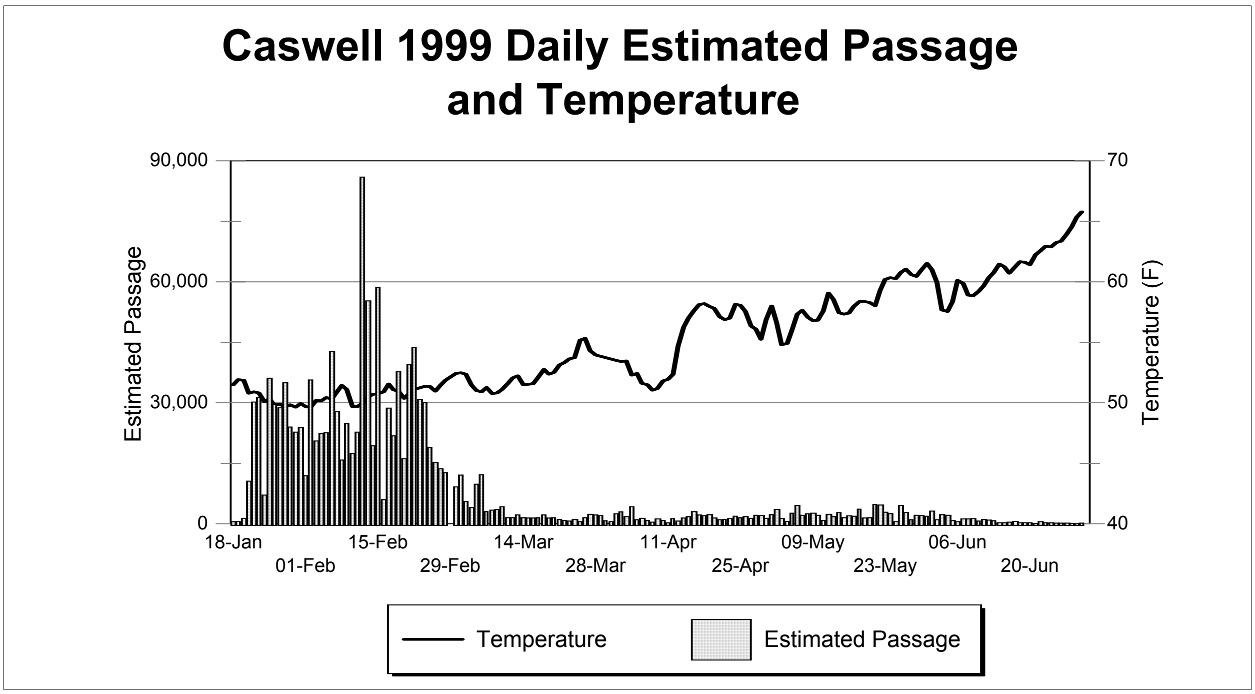


Figure 20. Daily chinook passage at Caswell, compared to river temperature during 1999.

Effects of Incubation Temperature on Fry Migration Timing

Incubation temperature during fall and early winter plays a key role in the development of chinook and their subsequent time of emergence. The warmer the water, the faster the development of eggs. Chinook eggs on average take 780-814 degree days

(EC) (Healey 1991) to incubate to hatching, and ~890 degree days (EC) to fry emergence from the gravel (USFWS 1998).

Water temperatures can be used to predict the start of chinook fry emergence. Temperatures at Goodwin Dam were recorded and used to perform a simple degree day analysis to estimate when fry first emerged. Degree days are the sum of the average degrees above freezing each day during incubation. Spawning was estimated to have begun at Knights Ferry around October 15, 1998 (personal communication, Duane Johnson, U.S. Army Corps of Engineers). Given this date, we summed average daily temperature until we achieved 888 degree days (CE) (literature value for emergence). The start of emergence was estimated to have begun on January 5th. This is consistent with trapping data. Traps were not fished until January 18th , at which time passage estimates already exceeded 10,000 fish/day. Therefore the start date of January 5th is not an unlikely estimate; however, it does suggest that traps should be installed at an earlier day if the entire run is to be sampled. Also, more detailed information on the temporal distribution of spawning would enable more accurate estimates of emergence timing.

Effects of Size on Timing of Migration

The variation in peak fry emergence among years did not appear to relate to fish size, as newly emerged fry were consistently 35-37 mm each year. This is at the low end of the ranges found for other populations (Mains and Smith 1964, Lister et al. 1971, Healey et al.1977 cited from Healey 1991).

No relationship of parr/smolt lengths to migration timing could be discerned in the 1999 data (Figure 21).

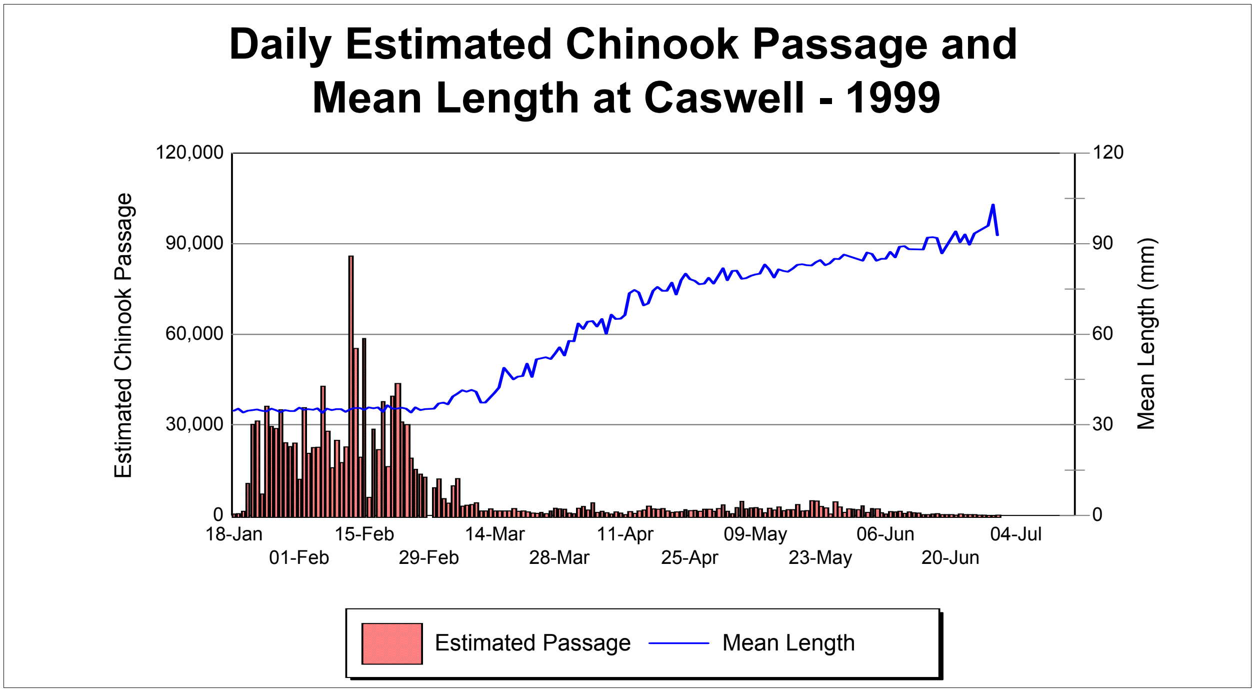


Figure 21. Daily mean length and chinook passage estimate at Caswell for 1999.

OBJECTIVE 4: ESTIMATE THE SURVIVAL OF CODED WIRE TAG RELEASES FROM KNIGHTS FERRY AND OAKDALE RECREATION AREA TO CASWELL STATE PARK IN 1999

Coded Wire Tagged Chinook Released in 1999

In 1999, we cooperated with California Department of Fish and Game to mark and release approximately 45,000 CWT hatchery chinook near Oakdale and Knights Ferry in an attempt to evaluate their survival rates through different segments of the river. Oakdale releases were divided equally between one release point above and one below the Oakdale Recreation Area (RM 38 and 40) to determine if mortality was disproportionately high as fish passed through the recreation area ponds. Previous radio tracking studies suggested that predation of chinook was high in the ponds (Demko et. al 1998). The Knights Ferry release was conducted to estimate survival for both the upper river (Knights Ferry to Oakdale) and the mid-section of the Stanislaus (Oakdale to Caswell). Results and survival estimates from this experiment are presented in Appendix D.

Migration Rates

Average migration rates through the Stanislaus River were estimated for marked fish released at Knights Ferry and Oakdale that were subsequently recovered in the Caswell trap. Average migration rates for groups with multiple recoveries varied from 3.9 to 13.8 miles/night among the different release groups (maximum= 23.0 miles/night, minimum=1.3 miles/night) (Table 8). Most recoveries from the CWT groups released at Oakdale arrived at Caswell 2 nights later, while the greatest number of recoveries from the Knights Ferry release came 3 nights later. Thus, most fish migrated roughly 15 miles per night, while a few moved much slower. Of the 40 fish recaptured at Caswell from the upstream releases, 15% took more than two weeks to travel from Oakdale to Caswell. This supports the hypothesis that many juveniles reared between Oakdale and Caswell.

We found no obvious relationship of migration rate to either flow or fish size. One might expect fish to migrate faster during high flows or at larger sizes. In all probability, these relationships do exist but are obscured by data collected from fish opting to rear and extend their residence in the river.

Table 8. Recapture data at the Caswell trap used to calculate migration rate of juvenile chinook from Oakdale Recreation, and from Oakdale or above down to Caswell, 1999. The groups titled "Oakx" were released at Oakdale to evaluate trapping efficiency and individual fish recaptured at Caswell.

Night	KF-CDFG	RM38-1	RM38-2	RM40-1	RM40-2	Oak1	Oak2	Oak3	Oak4	Oak9
1										
2	1	7	6	7	6	1				
3	16	1	1	1						
4	8									
5									1	
6	5									
7	1									
8							3			
9	1									
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14										1
15										
16										
17				1						
18										
19										
20										
21	1									
22			1							
23					1					
24				1				1		
Total Fish	35	8	8	10	7	1	3	1	1	1
avg. days	4.8	2.1	4.6	5.8	5.0	2.0	8.0	24.0	5.0	14.0
miles/day	9.5	13.8	6.4	5.4	6.3	15.8	3.9	1.3	6.3	2.3
flow	1,229	1,229	1,365	1,229	1,365	4,129	4,158	3,535	2,641	1,146
mean rec. LN	89.2	85.4	86	87.3	85.7	34.2	35.8	35.2	35.8	49.6

Mean Lengths at Release and Recapture

There was little change in mean lengths between all fish released and those that were recaptured (Figure 22). For both RM 40 releases, mean length was smaller at release than recapture; however, three fish from the two groups were recaptured 17-24 days after release and most likely grew during that period, contributing to the higher mean lengths observed at recapture. Currently, we have too little evidence to determine whether vulnerability to predation is size dependent.

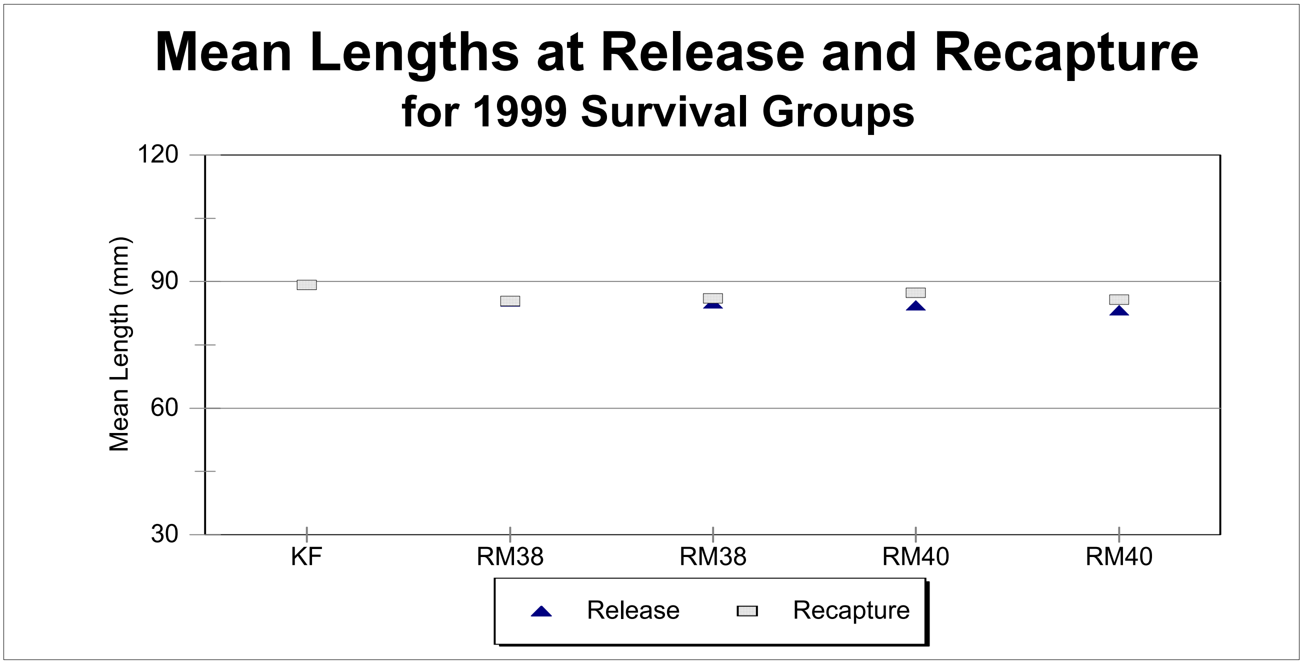

Figure 22. Mean lengths at release and recapture for 1999 test groups released to estimate survival.

CONCLUSIONS

1. The estimated number of juvenile chinook that passed Caswell between January 18 and June 30, 1999 was 1,321,042 with an approximate 95% confidence interval of 1,007,443 to 1,634,642.

2. The majority of chinook captured in 1999 were fry. Peak catch of 2,322 chinook fry occurred on February 10, 1999. Indices of daily fry passage exceeded 20,000 on 27 days in 1999. It is uncertain whether or not a significant number of fish outmigrated prior to trap installation; however, degree day analysis suggests outmigration started only 10 days prior to the onset of sampling.

3. In 1999 sampling began earlier than in 1998 (the only other year when sampling began in January), fry were already migrating when sampling began, and fry passage continued until a later date than in 1998. In contrast, parr and smolt outmigrants were less abundant in 1999 than in 1998.

4. During the sampling season, we captured 12 rainbow trout/steelhead at Caswell, ranging in size from 83 mm to 255 mm. Two distinct size classes were apparent (200-300 mm and <100mm), representing yearlings and young-of-the-year, respectively. More rainbow trout/steelhead were captured in 1999 than 1998, but 1999 counts were comparable to 1997.

5. There was no clear indication that variation in flow stimulated fry movement, but the magnitude of flow may have encouraged fry movement. Similar to 1998, the peak of chinook fry passage in 1999 corresponded with elevated flows. Heavy rains resulted in elevated flows for most of January and February, and fry migration peaked on February 12, when over 80,000 fry were estimated to pass Caswell in a single night. Fry passage estimates were high throughout late January and all

February, while flows generally ranged between 3,000 - 4,000 cfs.

6. The mean lengths of juvenile chinook gradually increased over the course of sampling, ranging from about 35 mm at the start of sampling (mid-January) to about 90 mm in late June. The rate of length increase was slower than other years and the threshold size for classifying smolts (80 mm) was not reached until May 10, which was 3 to 7 weeks later than other years.

RECOMMENDATIONS

1. More releases of marked fish should be made over different environmental and biological conditions including flow, turbidity, and fish size. It is especially important that releases be conducted at turbidities exceeding 10 NTU, since there appears to be a strong relationship between trapping efficiency and turbidity above 10 NTU, but turbidity exceeding 10 NTU's was only tested in 1996.

2. Chinook spawner data should be obtained from CDFG and included in future analyses. Since multiple years of outmigration data are now available, spawner data can now be used to develop correlations between spawn timing, river temperature, emergence and migration timing, and size at outmigration. The percentage of the population that spawns below Oakdale and their relative timing may also help understand differences in chinook life stage abundance between years, and the extent to which different life stages may rear between Oakdale and Caswell.

3. To accurately estimate total outmigrant abundance the traps should be installed early enough to determine the start of migration each year. This will also allow emergence and migration timing to be correlated to spawn timing, and to environmental factors. Both the Caswell and Oakdale traps should begin sampling on the same dates, sometime in mid-December. In each year sampled at Caswell, catches of chinook were high immediately after the traps were installed.

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Appendix A. Estimated 1999 Trapping Efficiency and Fish Outmigration Index at Caswell (with updated 1996 through 1998 estimates)

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The daily screw-trap count on day i at Caswell was expanded by dividing it by the predicted daily trapping efficiency (e_i, predicted proportion of fish trapped) to estimate the daily outmigration index (o_i):

$$o_i = \frac{c_i}{e_i} = c_i \left\{ \frac{1}{e_i} \right\}$$

Daily Counts (c_i)

Daily counts from two screw traps, referred to as the north and south traps, were available from February 6 through July 1, 1996; from March 19 through June 27, 1997; from January 29 to July 16, 1998[3]; and from January 18 through June 30, 1999 (hereafter referred to as passage days). The combined count over the two traps was the count that was expanded.

Correction for Missing Counts

There were days when counts were not made. If no counts were made on a given day, the combined count over traps was estimated using combined counts from the previous five and subsequent five days. The estimation procedure involved the following steps:

1. Adding one to the combined counts from the five previous and five subsequent days,
2. Taking the natural logs of the resulting values,
3. Computing the weighted mean of those natural logs, and
4. Retransforming the resulting mean

[3] In 1998, there were counts made on January 9, 11, and 12 ; however, the period to the next count (January 29) was so long that the counts could not be used to estimating the intervening cumulative count and its standard error. Leaving these early assessment day counts out would have had minimal effect on cumulative estimates since the total count from these three early assessment days were small: 0 on January 9, 0 on January 11, and 3 on January 12.

The computation is summarized in the following equation:

$$\bar{c}(i) = \exp\left\{ \frac{\sum_{j=1}^{5} w(i+j) * \ln[c(i+j)+1] + \sum_{j=1}^{5} w(i-j) * \ln[c(i-j)+1]}{\sum_{j=1}^{5} w(i+j) + \sum_{j=1}^{5} w(i-j)} \right\} - 1$$

wherein, ln[] represents natural log function, exp{} represents the exponential function, and w() represents a weighting variable. The weights are greater for more proximal days, specifically,

w(i+1) = 5, w(i+2) = 4, w(i+3) = 3, w(i+4) = 2, w(i+5) = 1,
w(i-1) = 5, w(i-2) = 4, w(i-3) = 3, w(i-4) = 2, w(i-5) = 1,

unless the count on the day associated with the weight is also missing or is associated with a stopped trap in which case the associated weight is 0.

Adjusting Counts on Days when the Trap has Stopped

In previous reports, no adjustments were made for trap stoppages. Occasionally, the trap stopped prior to being checked. Under trap stoppage, an expanded unadjusted count would tend to under-estimate outmigration since only a portion of the outmigration would have passed while the trap was operating. Adjustments were made to the 1996 though 1999 counts made from stopped traps. If the adjusted count was greater than the actual count from the stopped trap, then the adjusted count was used; otherwise, the actual count was used . The adjustments depended on whether only one trap or both traps were stopped. If both traps were stopped, the combined trap count was treated as a missing value and was estimated in the same manner given in the previous section, **Correction for Missing Counts**. If only one of the two traps had stopped, then the count from the stopped trap was adjusted using the north-to-south trap count ratio, r[(north-trap count)/(south-trap count)].

Specifically, if the north trap but not the south trap were stopped on day i, the north-trap count was estimated by

count (i, north trap) = count(i, south trap) r[(north-trap count)/(south-trap count)],*

and, if the south trap but not the north trap were stopped on day i, the south-trap count was estimated by

count (i, south trap) = count(i, north trap)/ r[(north-trap count)/(south-trap count)]

The north-to-south trap count ratio was computed from the total counts from the two traps over days when neither trap experienced stoppages and neither trap experienced missing values.

The degree of difference between north trap and south trap counts varied over years and over life stages within year; therefore different ratios were estimated for each life stage within each year. The 1999 north-trap and south-trap count and mean fish size are given in Tables A.1.a, A.1.b, and A.1.c respectively for fry-, parr-, and smolt-cohort segments of the run. The counts given in the table are for only those days on which there were no missing values or trap stoppages. The life-stage cohorts are defined by fish length:

fry:	length <= 45 mm
fingerling:	45 mm < length <= 80 mm
smolt:	size > 80 mm.

The partitioning of the outmigration period into three life-stage segments of contiguous days was complicated by size fluctuation of the sampled fish over the outmigration . Although fish size showed a strong tendency to increase with time, fluctuations did result in the lengths of sampled fish on one day sometimes being larger than those on a subsequent day. Therefore, the following algorithm was followed to identify a point to separate fry from parr and a point to separate parr from smolt: When the number of continuous days (run of days) that fish fell into the larger size category permanently exceeds the previous number of continuous days when the fish fell into the smaller size category, the point between these two runs of days was used to separate the smaller and larger size cohorts. This was the method used to establish the dates of cohort outmigration given in Tables A.1.a through A.1.c and elsewhere in this appendix. There was no such algorithm applied in the earlier reports; therefore the cohort outmigration periods presented in this report sometimes differ slightly from those presented in the 1998 report.

Referring to Tables A.1.a through A.1.c, the daily fry number sampled by the north trap was significantly greater than that by the south trap, but the number of parr and smolt sampled by the north trap was significantly less ($P < 0.0001$, Tables A.1.a. through A.1.c). A larger number of fry in the north trap relative to the south trap was not observed in previous years. In 1997 and 1998, the north-trap counts were less than the south-trap counts throughout the run[4]. There were also fish-size differences between the north- and south-trap that were inconsistent over cohorts and years. The length of fry sampled from the north trap in 1999 was significantly smaller than from the south trap ($P < 0.0001$, Table A.1.a), but the lengths of sampled north- and south-trapped parr and smolt did not significantly differ ($P > 0.5$ from Tables A.1.b and A.1.c). In 1998, early-run north-trapped fish were significantly smaller than south-trapped fish but late-run north-trapped fish were significantly larger; whereas, 1997 north-trapped fish tended be larger throughout the run. The variation between north and south count differences are not clearly associated with the changing size differences. The extent to which changing count differences are associated with changing fish morphology/physiology or changing river conditions is unknown.

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[4] Refer to previous reports: Outmigration Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1997 (June, 1998) and Outmigration Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site (June, 1999).

Because of the changing differences between the north-trapped and south-trapped fish, the north-to-south-trap count ratio was computed separately for each age-cohort run segment for each year. These ratios are presented in Table A.2. The application of the 1999 fry ratio to the stopped trap counts may result in biases for part of the fry outmigration. The north trap counts exceed the south trap counts for all recoveries up to March 2 but are less than the south counts beginning on March 9 (Table A.1.a). The intervening days involve trap stoppages and the application of the ratio to the counts could either overestimate or underestimate the counts, depending on whether the catch was more similar to the majority of the fry outmigration (up to March 2) or to the later part of the outmigration (March 9 through March 15). The adjusted values given in Appendix A.4.d.

Table A.1.a. Comparisons between Caswell north- and south-trap spring Chinook <u>fry</u> counts and sizes in 1999

	Number Caught				Mean Lengths of Fish					
	North	South	Difference		North Trap		South Trap		Difference	Weight for
	Trap	Trap	in Counts	{ln[c(N)+1]-	Mean	(sample)	Mean	(sample)	in means	mean
Date	c(N)	c(S)	c(N)-c(S)	ln{c(S)+1]}	{m(N)}	size)	{m(N)}	size)	{m(N)-m(S)}	Difference1
01/18/99	13	0	13	2.639	34.62	13				
01/19/99	10	6	4	0.452	35.00	10	36.00	6	-1.00	7.5
01/20/99	111	1	110	4.025	34.08	50	37.00	1	-2.92	2.0
01/21/99										
01/22/99	1,738	111	1,627	2.743	34.38	50	35.38	50	-1.00	50.0
01/23/99	793	19	774	3.681	35.06	50	35.21	19	-0.15	27.5
01/24/99	185	0	185	5.226	34.64	50				
01/25/99	938	0	938	6.845	34.48	50				
01/26/99	688	78	610	2.166	35.14	50	35.52	50	-0.38	50.0
01/27/99	590	156	434	1.326	33.96	50	35.82	50	-1.86	50.0
01/28/99	909	0	909	6.813	34.24	50				
01/29/99	578	45	533	2.533	34.44	50	35.53	30	-1.09	37.5
01/30/99	486	105	381	1.525	34.48	50	34.68	50	-0.20	50.0
01/31/99	395	226	169	0.556	34.32	50	34.65	51	-0.33	50.5
02/01/99	187	123	64	0.416	35.04	50	36.26	50	-1.22	50.0
02/02/99	569	356	213	0.468	35.26	50	34.68	50	0.58	50.0
02/03/99	330	203	127	0.484	35.12	69	35.39	64	-0.27	66.4
02/04/99	392	190	202	0.722	34.80	70	35.18	60	-0.38	64.6
02/05/99	358	228	130	0.450	35.00	59	35.84	63	-0.84	60.9
02/06/99	798	312	486	0.937	34.24	50	33.80	50	0.44	50.0
02/07/99	535	188	347	1.042	35.46	50	35.14	50	0.32	50.0
02/08/99	379	32	347	2.444	34.48	50	35.59	32	-1.11	39.0
02/09/99	1,382	8	1,374	5.035	34.72	50	38.00	8	-3.28	13.8
02/10/99	1,921	401	1,520	1.565	34.53	70	35.99	70	-1.46	70.0
02/11/99	1,903	0	1,903	7.552	34.36	50				
02/12/99	1,326	906	420	0.381	35.10	50	35.44	50	-0.34	50.0
02/13/99	1,261	175	1,086	1.970	34.76	50	36.38	50	-1.62	50.0
02/14/99	855	288	567	1.086	35.55	51	35.66	50	-0.11	50.5
02/15/99	1,520	2	1,518	6.229	34.90	50	37.50	2	-2.60	3.8
02/16/99	42	114	(72)	-0.984	36.17	42	35.53	51	0.64	46.1
02/17/99	613	130	483	1.545	35.34	50	35.60	50	-0.26	50.0
02/18/99	527	40	487	2.556	35.06	50	36.68	40	-1.61	44.4
02/19/99	978	0	978	6.887	34.30	50				
02/20/99	761	136	625	1.716	35.98	51	36.92	50	-0.94	50.5
02/21/99	740	287	453	0.945	34.90	50	35.71	51	-0.81	50.5
02/22/99	799	335	464	0.868	34.92	50	35.69	52	-0.77	51.0
02/23/99	767	35	732	3.060	35.48	50	36.06	35	-0.58	41.2

Date	Number Caught North Trap c(N)	Number Caught South Trap c(S)	Difference in Counts c(N)-c(S)	Difference {ln[c(N)+1]-ln{c(S)+1]}	Mean Lengths of Fish North Trap Mean {m(N)}	North Trap (sample) size)	South Trap Mean {m(N)}	South Trap (sample) size)	Difference in means {m(N)-m(S)}	Weight for mean Difference1
02/24/99	503	277	226	0.595	35.26	50	35.30	50	-0.04	50.0
02/25/99	353	138	215	0.935	33.56	50	34.66	50	-1.10	50.0
02/26/99	242	154	88	0.450	35.48	50	36.16	51	-0.68	50.5
02/27/99	268	86	182	1.129	34.34	50	35.42	50	-1.08	50.0
02/28/99	213	116	97	0.604	35.20	76	35.35	68	-0.16	71.8
03/01/99	162	75	87	0.763	35.12	50	35.54	50	-0.42	50.0
03/02/99	208	106	102	0.670	37.06	51	37.10	51	-0.04	51.0
03/03/99										
03/04/99										
03/05/99										
03/06/99										
03/07/99										
03/08/99										
03/09/99	43	50	(7)	-0.148	40.56	43	42.32	50	-1.76	46.2
03/10/99	31	78	(47)	-0.904	39.71	31	41.67	63	-1.96	41.6
03/11/99	19	20	(1)	-0.049	37.11	19	37.65	20	-0.54	19.5
03/12/99										
03/13/99										
03/14/99										
03/15/99	14	24	(10)	-0.511	44.79	14	40.83	24	3.95	17.7
Mean	605	135	470	1.945					-0.618	
Standard Error (SE)				0.317					0.132	
Degrees of Freedom				46					40	
t-ratio [(Mean-0)/SE]				6.14					-4.67	
P (Type I Error)				0.0000					0.0000	

Table A.1.b. Comparisons between Caswell north- and south-trap spring Chinook <u>parr</u> counts and sizes in 1999

Date	Number Caught North Trap c(N)	Number Caught South Trap c(S)	Difference in Counts c(N)-c(S)	Difference {ln[c(N)+1]-ln{c(S)+1]}	Mean Lengths of Fish North Trap Mean {m(N)}	North Trap (sample) size)	South Trap Mean {m(N)}	South Trap (sample) size)	Difference in means {m(N)-m(S)}	Weight for mean Difference1
03/20/99	15	24	-9	-0.446	48.31	13	45.04	24	3.27	16.9
03/21/99										
03/22/99	9	12	-3	-0.262	43.78	9	47.42	12	-3.64	10.3
03/23/99	8	10	-2	-0.201	49.75	8	53.20	10	-3.45	8.9
03/24/99										
03/25/99	2	12	-10	-1.466	50.50	2	52.75	12	-2.25	3.4
03/26/99	19	20	-1	-0.049	52.16	19	51.50	20	0.66	19.5
03/27/99	20	41	-21	-0.693	52.50	20	54.10	41	-1.60	26.9
03/28/99	22	35	-13	-0.448	55.73	22	55.71	35	0.02	27.0
03/29/99	23	30	-7	-0.256	50.78	23	54.69	30	-3.91	26.0
03/30/99	5	15	-10	-0.981	56.20	5	58.33	15	-2.13	7.5
03/31/99	4	10	-6	-0.788	58.75	4	57.20	10	1.55	5.7
04/01/99	14	49	-35	-1.204	60.82	11	64.16	45	-3.34	17.7
04/02/99	13	64	-51	-1.535	59.46	13	62.28	50	-2.82	20.6
04/03/99	9	38	-29	-1.361	69.33	9	62.92	38	6.41	14.6
04/04/99										
04/05/99	10	16	-6	-0.435	63.75	8	61.94	16	1.81	10.7
04/06/99	10	25	-15	-0.860	62.50	10	65.96	25	-3.46	14.3

Date	Number Caught: North Trap c(N)	South Trap c(S)	Difference in Counts c(N)-c(S)	Difference {ln[c(N)+1]-ln{c(S)+1]}	Mean Lengths of Fish: North Trap Mean {m(N)}	North Trap (sample) size)	South Trap Mean {m(N)}	South Trap (sample) size)	Difference in means {m(N)-m(S)}	Weight for mean Difference1
04/07/99	8	15	-7	-0.575	58.50	8	61.13	15	-2.63	10.4
04/08/99	6	5	1	0.154	67.50	6	65.20	5	2.30	5.5
04/09/99										
04/10/99	10	11	-1	-0.087	59.90	10	69.91	11	-10.01	10.5
04/11/99	3	4	-1	-0.223	62.67	3	69.25	4	-6.58	3.4
04/12/99	10	23	-13	-0.780	70.70	10	74.83	23	-4.13	13.9
04/13/99	8	10	-2	-0.201	74.50	8	74.80	10	-0.30	8.9
04/14/99	20	18	2	0.100	72.40	20	75.44	18	-3.04	18.9
04/15/99	23	23	0	0.000	71.57	23	67.32	23	4.25	23.0
04/16/99										
04/17/99	12	45	-33	-1.264	75.75	12	74.02	45	1.73	18.9
04/18/99	21	31	-10	-0.375	77.14	21	74.52	31	2.63	25.0
04/19/99	16	43	-27	-0.951	76.19	16	73.76	43	2.43	23.3
04/20/99	27	11	16	0.847	76.22	27	69.91	11	6.31	15.6
04/21/99	19	8	11	0.799	78.58	19	73.75	8	4.83	11.3
04/22/99	15	13	2	0.134	74.53	15	71.54	13	2.99	13.9
04/23/99										
04/24/99	27	22	5	0.197	81.30	27	78.45	22	2.84	24.2
04/25/99	15	25	-10	-0.486	82.33	15	75.76	25	6.57	18.8
04/26/99	10	35	-25	-1.186	77.40	10	77.80	35	-0.40	15.6
04/27/99										
04/28/99	20	34	-14	-0.511	76.85	20	76.65	34	0.20	25.2
04/29/99										
04/30/99										
05/01/99										
05/02/99	24	68	-44	-1.015	82.63	24	81.40	50	1.22	32.4
05/03/99	9	25	-16	-0.956	80.44	9	76.92	25	3.52	13.2
05/04/99										
05/05/99										
05/06/99	45	74	-29	-0.489	77.09	45	79.38	50	-2.29	47.4
05/07/99	16	39	-23	-0.856	78.44	16	78.56	39	-0.13	22.7
05/08/99	24	40	-16	-0.495	80.13	24	78.83	40	1.30	30.0
05/09/99	23	45	-22	-0.651	80.43	23	79.44	45	0.99	30.4
Mean	15.2	27.4	-12.2	-0.509					0.302	
Standard Error (SE)				0.0895					0.520	
Degrees of Freedom				39					38	
t-ratio [(Mean-0)/SE]				-5.686					0.58	
P (Type I Error)				0.0000					0.5645	

Table A.1.c. Comparisons between Caswell north- and south-trap spring Chinook smolt counts and sizes in 1998

Date	Number Caught: North Trap c(N)	South Trap c(S)	Difference in Counts c(N)-c(S)	Difference {ln[c(N)+1]-ln{c(S)+1]}	Mean Lengths of Fish: North Trap Mean {m(N)}	North Trap (sample) size)	South Trap Mean {m(N)}	South Trap (sample) size)	Difference in means {m(N)-m(S)}	Weight for mean Difference1
05/10/99	16	39	-23	-0.856	78.00	16	80.85	39	-2.85	22.7
05/11/99										
05/12/99	15	47	-32	-1.099	81.20	15	81.57	47	-0.37	22.7
05/13/99	10	37	-27	-1.240	77.50	10	79.19	37	-1.69	15.7
05/14/99	24	48	-24	-0.673	82.92	24	80.83	48	2.08	32.0

	Number Caught				Mean Lengths of Fish					
	North	South	Difference		North Trap		South Trap		Difference	Weight for
Date	Trap c(N)	Trap c(S)	in Counts c(N)-c(S)	{ln[c(N)+1]- ln{c(S)+1]}	Mean {m(N)}	(sample) size)	Mean {m(N)}	(sample) size)	in means {m(N)-m(S)}	mean Difference1
05/15/99	25	15	10	0.486	81.48	25	80.00	15	1.48	18.8
05/16/99	19	31	-12	-0.470	81.11	19	80.52	31	0.59	23.6
05/17/99	15	34	-19	-0.783	82.87	15	81.29	34	1.57	20.8
05/18/99	34	61	-27	-0.572	81.85	34	83.76	50	-1.91	40.5
05/19/99	18	20	-2	-0.100	82.56	18	83.70	20	-1.14	18.9
05/20/99	11	29	-18	-0.916	85.27	11	81.90	29	3.38	16.0
05/21/99	42	84	-42	-0.681	81.62	39	83.62	50	-2.00	43.8
05/22/99										
05/23/99	15	60	-45	-1.338	81.80	15	85.36	50	-3.56	23.1
05/24/99	11	54	-43	-1.522	83.55	11	82.70	50	0.85	18.0
05/25/99										
05/26/99	18	100	-82	-1.671	84.67	18	85.14	50	-0.47	26.5
05/27/99	19	54	-35	-1.012	83.58	19	85.44	50	-1.86	27.5
05/28/99	5	22	-17	-1.344	87.40	5	86.05	22	1.35	8.1
05/29/99										
05/30/99										
05/31/99										
06/01/99	32	49	-17	-0.416	85.81	32	83.29	49	2.53	38.7
06/02/99	14	13	1	0.069	88.21	14	85.85	13	2.37	13.5
06/03/99	22	37	-15	-0.502	87.32	22	86.24	37	1.07	27.6
06/04/99	18	37	-19	-0.693	83.83	18	84.57	37	-0.73	24.2
06/05/99	5	18	-13	-1.153	87.20	5	84.33	18	2.87	7.8
06/06/99										
06/07/99	5	26	-21	-1.504	83.40	5	88.04	26	-4.64	8.4
06/08/99	7	23	-16	-1.099	86.29	7	85.17	23	1.11	10.7
06/09/99	17	17	0	0.000	89.06	17	88.82	17	0.24	17.0
06/10/99	6	12	-6	-0.619	91.00	6	88.25	12	2.75	8.0
06/11/99	4	25	-21	-1.649	89.75	4	87.88	25	1.87	6.9
06/12/99										
06/13/99										
06/14/99										
06/15/99										
06/16/99	3	9	-6	-0.916	97.33	3	90.33	9	7.00	4.5
06/17/99	8	7	1	0.118	93.57	8	90.14	7	3.43	7.5
06/18/99	3	4	-1	-0.223	84.00	3	89.00	4	-5.00	3.4
06/19/99										
06/20/99										
06/21/99	0	2	-2	-1.099	0.00	0	94.00	2	-94.00	0.0
06/22/99										
06/23/99	2	4	-2	-0.511	93.50	2	92.75	4	0.75	2.7
06/24/99	2	4	-2	-0.511	89.50	2	89.67	4	-0.17	2.7
06/25/99	2	3	-1	-0.288	98.00	2	90.33	3	7.67	2.4
06/26/99										
06/27/99										
06/28/99										
06/29/99	0	1	-1	-0.693	0.00	0	103.00	1	-103.00	0.0
06/30/99	2	2	0	0.000	88.50	2	97.00	2	-8.50	2.0
Mean	12.8	29.4	-16.5	-0.728					0.0136	
Standard Error (SE)				0.0909					0.394	
Degrees of Freedom				33					32	
t-ratio [(Mean-0)/SE]				-8.01					0.03	
P (Type I Error)				0.0000					0.9727	

Table A.2. Caswell north-trap to south-trap count ratios for 1996-1999 fry, parr, and smolt.

Year of Outmigration	Life Stage	Used in this Report Beginning	Ending	Counts North	South	North/South Count Ratio
1996	Fry	02/06/96	03/20/96	48	385	0.1247
	Parr	03/21/96	03/31/96	7	19	0.3684
	Smolt	04/01/96	07/01/96	478	767	0.6232
1997	Fry					
	Parr	03/19/97	04/05/97	48	456	0.1053
	Smolt	04/06/97	06/27/97	222	999	0.2222
1998	Fry	01/29/98	03/07/98	1,201	6,922	0.1735
	Parr	03/08/98	04/23/98	594	3,748	0.1585
	Smolt	04/24/98	07/16/98	406	1,664	0.2440
1999	Fry	01/18/99	03/15/99	28,433	6,360	4.4706
	Parr	03/16/99	05/09/99	594	1,068	0.5562
	Smolt	05/10/99	06/30/99	449	1,028	0.4368

Daily Efficiency (e_i)

On 25 days during the 1996 though 1999 outmigration periods, a total of 43 uniquely marked night-time releases[5] were made at a fixed distance upriver from Caswell screw traps for the purpose of estimating trapping efficiency. Estimated efficiencies were simply the proportions of the released fish that were later trapped. In order to predict the efficiency for each passage day, the efficiency estimates had to be related as a response or "dependent" variable to predictor or "independent" variables that were measured every day that the screw traps were operating. Substituting a given day's values of the predictor variables into the predictive relation would then provide an estimate of that day's efficiency.

The predictor variables explored were flow (f in cubic feet per second, cfs) measured at Orange Blossom Bridge (OBB), size of recovered fish (s as length in millimeters, mm), and turbidity (t in nephelometric turbidity units, ntu) when turbidity reached 10. Efficiency (e), the proportion

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5 The number of standard efficiency night-time releases:
- In 1996, 1 on Feb 14, 1 on Feb 19, 1 on Mar 22, 4 on Apr 6, 2 on May 2, 2 on May 10, 2 on May 26, and 2 on Jun 10;
- In 1997, 1 over a period from Apr 7 through 11 (denoted as Apr 9, mid-point day) and 4 releases on the night of May 28/29 (designated as a May 28th release) ;
- In 1998, 3 on Mar 14, 3 on Mar 25, 2 on Apr 18, 2 on May 10, 2 on May 18, 2 on Jun 4, and 2 on June 2;
- In 1999, 1 each on Feb 20 and 27, Mar 2, 9 and 17, Jun 2 and 3; and 2 on Jun 4

Day-time releases were omitted for reasons given in the 1998 report (June 1999) of released fish trapped per release, was related to the predictor variables using the following logistic function:

$$e_i = \frac{1}{1 + \exp\left[-b(0) - b(f) * f - b(s) * s - b(t') * t'\right]}$$

or, in the form of the "logit" linear transform,

$$\log it(e_i) = \ln\left[\frac{e_i}{1 - e_i}\right] = b(0) + b(f) * f + b(s) * s + b(t') * t'$$

In the above equations, "b(0)" is a coefficient associated with the intercept[6], and b(f), b(s), and b(t') are partial logistic regression coefficients relating the logit transform of efficiency predictor respectively to flow, size, and turbidity when turbidity is at least 10 . A major reason for choosing the logistic model is that the predicted efficiency can never be less than 0 and can never exceed 1 (100%). The logistic regression used assumes that the underlying distribution of the number of captured fish is binomial when the model is accurate. Adjustments to the standard errors, variances, and covariances of the estimated coefficients for failure of the residuals to be binomially distributed had to be made, the adjustment procedures being discussed in Appendix A.1.

Predictor Variables

The predictor variables evaluated in this 1999 analysis were the same as in previous years; however, many of the 1996 through 1998 values differed from those used in the 1998 report:

1. Flow: In the current analysis I used the mean of release-day and recovery-day flows. In last year's analysis I used release-day flows. The reason for using the mean of release-day and recovery-day flows is that releases were made in the evening of the release day and almost all were recovered by the following morning (recovery day). Therefore the mean of the two days' flows was considered to be a better indicator of the flow during the recovery period then was the release-day flow. In general, the predictor variable is the mean of the flows from the day of recovery and from the day prior to recovery.

2. Fish size: The fish length used in the 1998 report was not consistent over years. The

[6] Intercept value = $1/\{1+\exp^{-b(0)}\}$ when f = s = t = 0.

lengths of a sample of released fish was used for the 1996-1997[7] data set; whereas, the lengths of a sample of recovered fish was used for the 1998 data set. In the current analysis, recovered fish length was used for all three data sets--1996-97, 1998, and 1999. The use of release size in previous reports could have contributed to a bias. Tables A.3.a though A.3.c present comparison between the size of fish sampled prior to release and the size of a sample of those same fish after recovery for all efficiency releases. While the mean release-recovery size difference is small and not significant for fry (P = 0.5385 in Table A.3.a), the mean sizes of sampled released parr and smolt exceeded those of sampled recovered parr and smolt by more than 1 mm (P = 0.0178 for parr in Table A.3.b and P = 0.0637 for smolt in Table A.3.c). Whether the sizes of released parr and smolt actually exceeded that of recovered parr and smolt in 1999 is unclear since no efficiency releases were made during the parr outmigration period in 1999 (Table A.3.b) and since the mean sizes of sampled recovered smolt were somewhat larger than those of sampled released smolt for the four 1999 efficiency releases (Table A.3.c).

3. Turbidity: Turbidity was never used in the prediction unless it was at least 10 because a threshold of 10 resulted in the greatest precision of the estimated coefficients in the model. For 1996 releases, I used release-day turbidities; whereas for 1997 and 1998 releases, I used recovery-day turbidities. Since turbidities were checked and recorded in the morning when the recovered fish are enumerated, I used recovery-day turbidities in the current analysis for all three data sets--1996-97, 1998, and 1999. The turbidity can change dramatically from one day to another. For the 1996 fit, the recovery-day turbidity had a dramatic affect on the fit when the turbidity reaches 10, but the effect was substantially reduced if the release-day turbidity was used. It should be noted that the only efficiency releases experiencing turbidities of at least 10 were those made in 1996. However, turbidities did exceed 10 for some days (release or non-release days) during the outmigration in all years.

Linear interpolation was used to estimate missing predictor variable values from the nearest straddling days' values. For example, if there was a flow of 1000 cfs on Day 4 (Day j) and there was a flow of 1200 cfs on Day 9 (Day j') and if there were no intervening flow measures, then the missing values for Day 5 through Day 8 (Day i) would be computed as follows:

[7] The 1997 and 1996 efficiency-release data sets were combined to obtained 1996-1997 coefficient estimates because there were only two release days in 1997 and because, for the flows on those two days, the efficiency estimates seemed more comparable to those in 1996 than they did to those in 1998 and 1999 (refer to Table A.4).

Day 4: 1000 (actual value)

Missing Value for day i =
[Day j' - Day i)(Day j value)+(Day i - Day j)*(Day j' value)]/(Day j' - Day i)*

Day 5: [(9-5)*1000 + (5-4)*1200]/(9-4) = [4*1000 + 1*1200]/(9-4) = 1040
Day 6: [(9-6)*1000 + (6-4)*1200]/(9-4) = [3*1000 + 2*1200]/(9-4) = 1080
Day 7: [(9-7)*1000 + (7-4)*1200]/(9-4) = [2*1000 + 3*1200]/(9-4) = 1120
Day 8: [(9-8)*1000 + (8-4)*1200]/(9-4) = [1*1000 + 4*1200]/(9-4) = 1160

Day 9: 1200 (actual value)

Table A.3.a. Comparisons between released and recovered spring Chinook fry sizes from 1996-1999 efficiency tests.

				Released Fish		Recovered Fish		Released - Recovered Lengths	
Release Date	Mark Type	Fish Stock	Release Time	Length (mm)	Sample Size	Length (mm)	Sample Size	Difference	Weight1
14-Feb-96	Brand	Natural	Night	34.3	30	35.2	62	-0.9	40.4
19-Feb-96	Brand	Natural	Night	33.8	30	35.5	56	-1.7	39.1
22-Mar-96	Panjet	Hatchery	Night	42.7	30	41.8	15	0.9	20.0
14-Mar-98	Brand	Natural	Night	36.2	50	37.3	101	-1.1	66.9
25-Mar-98	Panjet	Hatchery	Night	41.2	50	42.1	34	-0.9	40.5
25-Mar-98	Panjet	Hatchery	Night	41.1	50	41.8	32	-0.7	39.0
20-Feb-99	Brand	Natural	Night	33.2	50	34.1	86	-0.9	63.2
27-Feb-99	Brand	Natural	Night	35.6	100	34.7	43	0.9	60.1
02-Mar-99	Brand	Natural	Night	34.1	50	34.7	29	-0.6	36.7
09-Mar-99	Brand	Natural	Night	36.1	50	34.7	20	1.4	28.6
17-Mar-99	Photonic	Natural	Night	42.8	50	39.0	15	3.8	23.1
Weighted[1] Mean								-0.26	
Standard Error (SE)								0.409	
Degrees of Freedom								10	
t-ratio [(Weighted Mean)/SE]								-0.64	
P(Type I Error)								0.5385	

[1] Weight is the harmonic mean of the release and recovery sample sizes to account for differences in sample sizes within and among pairs

Table A.3.b. Comparisons between released and recovered spring Chinook parr sizes from 1996-1999 efficiency tests.

				Released Fish		Recovered Fish		Released - Recovered Lengths	
Release Date	Mark Type	Fish Stock	Release Time	Length (mm)	Sample Size	Length (mm)	Sample Size	Difference	Weight1
06-Apr-96	Brand	Hatchery	Night	67.4	30	71.6	22	-4.2	25.4
06-Apr-96	Brand	Hatchery	Night	70.2	30	72.9	8	-2.7	12.6
02-May-96	Panjet	Hatchery	Night	75.5	30	75.9	30	-0.4	30.0

02-May-96	Panjet	Hatchery	Night	76.1	30	76.7	30	-0.6	30.0
10-May-96	Panjet	Hatchery	Night	74.2	30	73.4	50	0.8	37.5
10-May-96	Panjet	Hatchery	Night	76.1	30	72.9	55	3.2	38.8
26-May-96	Panjet	Hatchery	Night	72.7	30	68.2	65	4.5	41.1
26-May-96	Panjet	Hatchery	Night	71.7	30	69.9	60	1.8	40.0
28-May-97	Panjet	Hatchery	Night	71.9	30	71.5	35	0.4	32.3
28-May-97	Panjet	Hatchery	Night	72.5	30	71.9	30	0.6	30.0
28-May-97	Panjet	Hatchery	Night	71.3	30	71.9	52	-0.6	38.0
29-May-97	Panjet	Hatchery	Night	73.3	30	72	66	1.3	41.3
14-Mar-98	Panjet	Hatchery	Night	55.2	50	54.1	35	1.1	41.2
14-Mar-98	Panjet	Hatchery	Night	55.1	50	53.6	45	1.5	47.4
25-Mar-98	Panjet	Natural	Night	52.4	50	48.1	43	4.3	46.2
18-Apr-98	Panjet	Hatchery	Day	75.3	50	70.7	4	4.6	7.4
18-Apr-98	Panjet	Hatchery	Night	75.1	50	73.7	26	1.4	34.2
18-Apr-98	Panjet	Hatchery	Night	74.6	50	70.3	15	4.3	23.1
18-Apr-98	Panjet	Natural	Day	65.6	50	66	12	-0.4	19.4
Weighted1 Mean								1.28	
Standard Error (SE)								0.492	
Degrees of Freedom								18	
t-ratio [(Weighted Mean)/SE]								2.61	
P(Type I Error)								0.0178	

1 Weight is the harmonic mean of the release and recovery sample sizes to account for differences in sample sizes within and among pairs

Table A.3.c. Comparisons between released and recovered spring Chinook <u>smolt</u> sizes from 1996-1999 efficiency tests.

				Released Fish		Recovered Fish		Released - Recovered Lengths	
Release Date	Mark Type	Fish Stock	Release Time	Length (mm)	Sample Size	Length (mm)	Sample Size	Difference	Weight1
10-Jun-96	Panjet	Hatchery	Night	91.6	30	85.5	43	6.1	35.3
10-Jun-96	Panjet	Hatchery	Night	90.5	30	86.8	56	3.7	39.1
7-11-Apr-97	Panjet	Natural		82.5	30	81.7	3	0.8	5.5
10-May-98	Panjet	Hatchery	Day	87.7	50	83	1	4.7	2.0
10-May-98	Panjet	Hatchery	Night	86.4	50	86.3	8	0.1	13.8
10-May-98	Panjet	Hatchery	Night	87.4	50	84.5	4	2.9	7.4
18-May-98	Panjet	Natural	Night	88.8	50	83.6	16	5.2	24.2
18-May-98	Panjet	Hatchery	Night	88.2	50	86.9	31	1.3	38.3
04-Jun-98	Panjet	Hatchery	Night	100.5	50	98.4	16	2.1	24.2
04-Jun-98	Panjet	Hatchery	Night	98.6	50	97.7	15	0.9	23.1
12-Jun-98	Panjet	Hatchery	Night	102.8	50	104.8	6	-2.0	10.7
12-Jun-98	Panjet	Hatchery	Night	102.8	50	95.3	4	7.5	7.4
02-Jun-99	Panjet	Hatchery	Night	83.6	50	84.8	41	-1.2	45.1
03-Jun-99	Panjet	Hatchery	Night	84.2	50	84.4	39	-0.2	43.8
04-Jun-99	Photonic	Hatchery	Night	83.3	50	83.7	33	-0.4	39.8
04-Jun-99	Photonic	Hatchery	Night	82.5	50	83.6	53	-1.1	51.5
Weighted1 Mean								1.32	

Release Date	Mark Type	Fish Stock	Release Time	Released Fish Length (mm)	Released Fish Sample Size	Recovered Fish Length (mm)	Recovered Fish Sample Size	Released - Recovered Lengths Difference	Weight1
Standard Error (SE)								0.660	
Degrees of Freedom								15	
t-ratio [(mean)/SE]								2.00	
P(Type I Error)								0.0637	

1 Weight is the harmonic mean of the release and recovery sample sizes to account for differences in sample sizes within and among pairs

Model Selection

The data in Table A.4. were used to develop efficiency predictors. An analysis of variation procedure was undertaken to initially evaluate the effectiveness of each predictor variable. The residual deviances produced from logistic regression are analogous the residual sums of squares from least squares regression. Therefore, the logistic regression deviances were subjected to the same analytic partitioning that sums of squares are subjected to in an analysis of variance.

Analyses of variation were initially performed separately within each set of years (1996-1997, 1998, 1999). As indicated in Table A.5, insufficient numbers of releases were made to permit estimation of coefficients within each size cohort within each year. For example, within each year x size-cohort category having only 3 releases, up to 3 coefficients (e.g., intercept, flow, size) could be estimated, but there would be no true variation measure within these categories. Therefore, individual coefficients were not estimated within each year x size-cohort category. Instead, the following organized step-wise procedures were followed within each year and are presented in Appendix A.2.

1. Size: Size was assessed by

    1. using recovery length as a one predictor variable [for estimating b(s)],
    2. using separate size-cohort intercepts within each year (fry, fingerling, and smolt cohort indicator variables), and
    3. using both the size and size-cohort-indicator variables.

    Within each year, using just size (a. above) gave the best fit, and the further inclusion of size-cohort indicator variables did not substantially or significantly improve the fit. Size-cohort was dropped from the model. Size was dropped from the model if its contribution was not significant.

2. Flow was then added as a variable to previously retained variables and its effect assessed.

3. Recovery-day turbidity was then added to other retained variables when it exceeded 10 ntu

(which happened only in 1996). As mentioned earlier, the turbidity threshold that resulted in the best fit (the lowest deviance) was 10 ntu.

Table A.4. Predictor variables and efficiency response variable used to develop logistic efficiency predictor

Release Date	Flows: Release Day	Flows: Recovery Day	Flows: Average	Recovery Length	Recovery Day Turbidity: Value	Recovery Day Turbidity: Value >= 0	Efficiency (Proportion Recovered)	Adjusted Release Number
02/14/96	1179	1595	1387	35.2	14.7	14.7	0.1208	1324
02/19/96	2014	2841	2427.5	35.5	10.5	10.5	0.0566	1078
03/22/96	3413	3010	3211.5	41.8	7.3	0	0.0137	1097
04/06/96	1791	1780	1785.5	71.6	5.9	0	0.0295	746
04/06/96	1791	1780	1785.5	72.9	5.9	0	0.0107	748
05/02/96	1680	1659	1669.5	76.7	10.2	10.2	0.0763	1979
05/02/96	1680	1659	1669.5	75.9	10.2	10.2	0.0442	1990
05/10/96	1667	1653	1660	73.4	8.7	0	0.0223	2242
05/10/96	1667	1653	1660	72.9	8.7	0	0.0252	2341
05/26/96	921	955	938	69.9	6.8	0	0.067	2374
05/26/96	921	955	938	68.2	6.8	0	0.0544	2298
06/10/96	1279	1300	1289.5	85.5	9.0	0	0.0276	1559
06/10/96	1279	1300	1289.5	86.8	9.0	0	0.0298	1981
04/09/97	599	598	598.5	81.7	8.8	0	0.0165	182
05/28/97	1608	1615	1611.5	71.9	9.8	0	0.0273	1905
05/28/97	1608	1615	1611.5	71.5	9.8	0	0.0242	1444
05/28/97	1608	1615	1611.5	71.9	9.8	0	0.0209	1433
05/28/97	1608	1615	1611.5	72	9.8	0	0.0363	1817
03/14/98	1577	1574	1575.5	54.1	7.4	0	0.0339	1033
03/14/98	1577	1574	1575.5	37.3	7.4	0	0.047	2149
03/14/98	1577	1574	1575.5	53.6	7.4	0	0.0429	1049
03/25/98	2657	2351	2504	41.8	8	0	0.0284	1128
03/25/98	2657	2351	2504	48.1	8	0	0.049	877
03/25/98	2657	2351	2504	42.1	8	0	0.0271	1254
04/18/98	1996	1996	1996	70.3	6.1	0	0.0152	988
04/18/98	1996	1996	1996	73.7	6.1	0	0.0261	995
05/10/98	2005	2004	2004.5	84.5	6	0	0.0062	649
05/10/98	2005	2004	2004.5	86.3	6	0	0.0079	1009
05/18/98	2023	2016	2019.5	86.9	4.9	0	0.0304	1020
05/18/98	2023	2016	2019.5	83.6	4.9	0	0.0145	1102
06/04/98	1527	1537	1532	98.4	7.1	0	0.0148	1079
06/04/98	1527	1537	1532	97.7	7.1	0	0.0144	1044
06/12/98	1593	1564	1578.5	104.8	9.75	0	0.0076	791
06/12/98	1593	1564	1578.5	95.3	9.75	0	0.004	1000
02/20/99	4316	4291	4303.5	34.1	7.9	0	0.0376	2550
02/27/99	4207	3842	4024.5	34.7	3	0	0.0257	1672
03/02/99	2800	2861	2830.5	34.7	7.7	0	0.0349	830
03/09/99	1736	1734	1735	34.7	5.1	0	0.0208	962

Release Date	Flows: Release Day	Flows: Recovery Day	Flows: Average	Flows: Recovery Length	Recovery Day Turbidity: Value	Recovery Day Turbidity: Value >= 0	Efficiency (Proportion Recovered)	Adjusted Release Number
03/17/99	1577	1602	1589.5	39	4.6	0	0.0224	671
06/02/99	1365	1369	1367	84.8	6.3	0	0.0252	2500
06/03/99	1369	1360	1364.5	84.4	4.5	0	0.0157	2487
06/04/99	1360	1356	1358	83.6	1.4	0	0.0333	2039
06/04/99	1360	1356	1358	83.7	1.4	0	0.0175	2002

Table A.5. Number of releases within each year x cohort grouping

Size	Year Category: 1996-1997	Year Category: 1998	Year Category: 1999	TOTAL
Fry	3	3*	5	11
Fingerling	12	5	0	17
Smolt	3*	8	4	15
TOTAL	18	16	9	43
* 2 of the 3 releases made on same day				

The within-year mean deviances[8] from the models were found not to differ substantially or significantly based on paired f-tests (full-model mean deviances compared: 1996-1997 versus 1998, 1996-1997 versus 1999, and 1998 versus 1999). Therefore, a combined analysis was performed including all coefficients except the size-cohort indicators. The coefficients for this full model are presented in Appendix A.3. The model was then reduced by dropping the predictor variable associated with any given year's coefficients that did not differ significantly from 0 at the 20% significance level (P > 0.2). The reason for choosing such a high significance level was to reduce the chance of omitting a coefficient when it should be included (Type 2 error). The coefficients from this refit reduced model are presented in Table A.6.a.

The above procedure is different than that used in last year's analysis wherein the full model was retained; i.e., in last year's analysis, all years b(f), b(s), and b(t') coefficient estimates were included whether or not a coefficient differed significantly from 0 in any given year, as long as it significantly differed from 0 in at least one year. The reason for the inclusion of non-significant coefficients in last year's report was because of sign consistency: In the 1998 report, the 1996-1997 flow coefficient differed significantly from 0, and, although the 1998 flow coefficient did not differ significantly from 0, it had the same sign as the 1996-1997 coefficient. Conversely, the 1998 fish-size coefficient differed significantly from 0; whereas the 1996-1997 coefficient did not but had the same sign as the 1998 coefficient. This year, however, there were sign differences between the 1999 and the previous year's coefficients. Since non-significant 1999 coefficients had sign differences

[8] Mean Deviance = Deviance/(Degrees of Freedom), analogous to the Mean Square = (Sum of Squares)(Degrees of Freedom) from least squares' analysis of variance.

from previous years, non-significant coefficients were dropped from the model irrespective of the sign.

It turned out that flow did not make a significant contribution to the 1998 predictor, and neither size nor flow made a significant contribution to the 1999 predictor; therefore they were dropped from the model, and the data were refit to estimate the coefficients for the reduced model. The turbidity coefficient was used for all years because the turbidity reached or exceeded 10 ntu in each year for some days during the outmigration.

Table A.6.a. Coefficient estimates and associated statistics for the efficiency model with the data sets having 1996 turbidity > 10 included

1996-1997
Efficiency Predictor: er = 1/{1+exp[-b(0)-b(f)*f-b(s)*s-b(t')*t']}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-1.423720	0.476060	-2.99	0.0050
Flow (f)	-0.000829	0.000167	-4.97	0.0000
Recovery Size (s)	-0.010380	0.005237	-1.98	0.0551
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	D.F.	Deviance/D.F.	
	163.47	36	4.54	

Predictor	Intercept	Variance-Covariance Flow	Recovery Size	Turbidity > 10
Intercept	2.2663E-01			
Flow	-4.3819E-05	2.7835E-08		
Recovery Size	-2.1342E-03	6.5842E-08	2.7427E-05	
Turbidity > 10	-3.4783E-03	-3.7326E-07	4.6771E-05	2.0479E-04

1998
Efficiency Predictor: er = 1/{1+exp[-b(0)-b(s)*s-b(t)*t]}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-2.251260	0.301509	-7.47	0.0000
Recovery Size (s)	-0.022160	0.004855	-4.56	0.0001
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	D.F.	Deviance/D.F.	
	163.47	36	4.54	

Predictor	Intercept	Variance-Covariance Recovery Size	Turbidity > 10
Intercept	9.0907E-02		
Recovery Size	-1.3759E-03	2.3567E-05	
Turbidity > 10	0.0000E+00	0.0000E+00	2.0479E-04

1999
Efficiency Predictor: er = 1/{1+exp[-b(0)-b(t')*t']}

Predictor	Estimate (b)	Standard Error (SE)	t-ratio (b/SE)	P (Type I)
Intercept (0)	-3.624670	0.106971	-33.88	0.0000
Turbidity > 10 (t)	0.074650	0.014311	5.22	0.0000
	Deviance	D.F.	Deviance/D.F.	
	163.47	36	4.54	

	Variance-Covariance	
Predictor	Intercept	Turbidity > 10
Intercept	1.1443E-02	
Turbidity > 10	0.0000E+00	2.0479E-04

The data set used did not distinguish between releases made on the same day and those made on different days; i.e., the data from each release was treated as an independent set. This creates "pseudo-replication" as far as flow and turbidity are concerned. Releases made on the same day always experience the same measured flow and turbidity; they only differ in their fish size and recovery data. Since variation is expected to be less between releases made on the same day than between releases made on different days, the concern would be whether treating multiple releases on the same day as independent releases would result in the measured precision being greater than it should be. To test this, fish sizes, release numbers, and efficiency estimates were pooled over releases within day, and these pooled data were fit using the full model. The resulting residual mean deviance was compared to the simple among-release within-day mean deviance (a measure of within-day random variation). The results of this analysis of variation is summarized at the bottom of Appendix A.2. The residual mean deviance from the fit of the pooled data was 4.52 based on 15 degrees of freedom, and the among-release within-day mean deviance was 3.85 based on 18 degrees of freedom. The first mean deviance did not significantly exceed the second mean deviance based on an F-test (P=0.3684). This indicates that the model was effective in explaining most, if not all, of the among day variation in efficiencies. It also suggests that the model is a reasonably good predictor. Since the two mean deviances were nearly equal, the decision was made to use fit based on treating data from each release as an independent set (i.e., use the coefficients from Table A.6.) to boost the degrees of freedom and the power of the test used.

Since the turbidity never reached 10 for the efficiency releases in 1997, 1998, and 1999, it is possible that the turbidity did not have an effect in 1997, 1998, and 1999. An additional fit was made using all years' night-time, fixed-point efficiency releases except for the 1996 efficiency releases for which the recovery day's turbidity equaled or exceed 10 ntu. The coefficients and associated statistics from this fit are present in Table A.6.b. It should be noted that t-tests were used for testing the coefficients in Tables A.6.a and A.6.b. The t-test is not truly appropriate because the estimated efficiencies are not expected to be normally distributed, it was only used because the asymptotic z-test would have been too liberal.

Table A.6.b. Coefficient estimates and associated statistics for the efficiency model with the data sets having 1996 turbidity > 10 excluded

1996-1997

Efficiency Predictor: er = 1/{1+exp[-b(0)-b(f)*f-b(s)*s]}

Predictor	**Estimate (b)**	**Standard Error (SE)**	**t-ratio (b/SE)**	**P (Type I)**
Intercept (0)	0.126940	0.896938	0.14	0.8883
Flow (f)	-0.001050	0.000181	-5.81	0.0000
Recovery Size (s)	-0.027780	0.011010	-2.52	0.0166
	Deviance	D.F.	Deviance/D.F.	
	125.4	33	3.80	

Predictor	**Variance-Covariance Intercept**	**Flow**	**Recovery Size**
Intercept	8.0450E-01		
Flow	-8.2080E-05	3.2642E-08	
Recovery Size	-9.5000E-03	5.2440E-07	1.2122E-04

1998

Efficiency Predictor: er = 1/{1+exp[-b(0)-b(s)*s]}

Predictor	**Estimate (b)**	**Standard Error (SE)**	**t-ratio (b/SE)**	**P (Type I)**
Intercept (0)	-2.251260	0.275819	-8.16	0.0000
Recovery Size (s)	-0.022160	0.004441	-0.20	0.8424
	Deviance	D.F.	Deviance/D.F.	
	125.4	33	3.80	

Predictor	Variance-Covariance Intercept	Recovery Size
Intercept	7.6076E-02	
Recovery Size	-1.1514E-03	1.9722E-05

1999

Efficiency Predictor: er = 1/{1+exp[-b(0)]}

Predictor	**Estimate (b)**	**Standard Error (SE)**	**t-ratio (b/SE)**	**P (Type I)**
Intercept (0)	-3.624670	0.097857	-37.04	0.0000
	Deviance	D.F.	Deviance/D.F.	
	125.4	33	3.80	

Predictor	Variance-Covariance Intercept
Intercept	9.5760E-03

Estimated Outmigration ($o_i = c_i/e_i$)

The daily counts were expanded by dividing them by the predicted daily efficiencies (multiplying by the inverse of the efficiencies) to estimate daily outmigration:

$$o_i = \frac{c_i}{\left\{\dfrac{1}{1+\exp\left[-b(0)-b(f)*f_i-b(s)*s_i-b(t')*t'_i\right]}\right\}}$$

$$= c_i\left\{1+\exp\left[-b(0)-b(f)*f_i-b(s)*s_i-b(t')*t'_i\right]\right\}$$

These expansions were then accumulated over days to estimate the cumulative outmigration. The daily predictor variables used and the counts are given in Appendices A.4.a. through A.4.d. respectively for 1996 through 1999. The associated estimated daily and cumulative outmigration for those years are respectively given in Appendices A.5.a. through A.5.d. for the Table A.6.a. coefficients using the 1996 turbidity coefficient. Table A.7.a presents fry-, fingerling-, and smolt-cohort-period cumulative outmigration summaries from these appendices. Note that the 1996, 1997, and 1998 estimates are different than those presented in the 1998 report because of the data modifications. The confidence intervals presented are generally narrower than in previous reports. This is because the previous confidence interval estimate was based, in part, on the approximate variance of a ratio [$S^2(c_i/e_i)$] which turned out to be conservative (bigger than it should be). The variance estimate has improved by using instead an unbiased estimate of the variance of a product [$S^2(c_i*1/e_i)$]. The methodology is spelled out in Appendix A.1.a.

The estimated fry outmigration in 1999 was greater than in 1998 (the previous greatest estimate). It should be borne in mind that the fry enumeration began earlier in 1999 and fry passage continued until a later date in 1999 than in 1998 (1999 fry outmigration: January 18 - March 15; 1998 fry outmigration: January 29 - March 7). Unlike fry, the 1999 parr and smolt outmigration index estimates are smaller than in 1998. Parr and smolt estimates may be more reliable than the fry estimates because parr and smolt may well be more actively outmigrating than fry. The 1999 parr and smolt confidence intervals do not overlap those of 1998, indicating that the 1999 parr-smolt outmigration was truly less than that of 1998.

The 1999 parr outmigration index is substantially greater than the 1996 and 1997 indices. While the same is not true of the 1999 smolt index, it is true of the 1999 combined parr and smolt indices which exceeds those of 1996 and 1997. In 1999 there was an extended period when the mean length was very near 80 mm, and the 80 mm demarcation between parr and smolt might be somewhat artificial. The 1999 fry-outmigration index did exceed that of 1996; however, the fry-monitoring period started earlier in 1999. There was no monitoring of the fry segment of the outmigration in 1997.

Table A.7.a. Estimates of outmigration indices for fry, parr, and smolt based on the efficiency model with the data sets having 1996 turbidity > 10 included

1996 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry	02/06	03/20	31,767	10,320	11,540	51,994	35,101	03/20	28,653
Parr	03/21	03/31	1,596	470	675	2,516	35,145	03/31	1,465
Smolt	04/01	07/01	81,896	11,065	60,209	103,582	35,156	07/01	65,083
All	02/06	07/01	115,258	15,051	85,759	144,757	35,101	07/01	95,201

1997 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry									
Parr	03/19	04/05	7,011	1,037	4,979	9,043	35,508	04/01	4,724
Smolt	04/06	06/27	60,333	7,478	45,676	74,990	35,522	06/27	48,861
All	03/19	06/27	67,344	8,000	51,663	83,024	35,508	06/27	53,585

1998 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits		1998 Report Data Summary		
	Date Domain		Estimate	S.E.	Lower	Upper	Date Domain		Estimate
Fry	01/29	03/07	186,029	44,908	98,009	274,049	35,824	03/07	287,801
Parr	03/08	04/23	209,911	31,238	148,685	271,137	35,862	04/21	179,448
Smolt	04/24	07/16	197,884	37,348	124,682	271,087	35,907	07/16	183,935
All	01/29	07/16	593,825	76,373	444,133	743,516	35,824	07/16	651,184

1999 Cumulative Outmigration

	Current				Approximate 95% Confidence Limits	
	Date Domain		Estimate	S.E.	Lower	Upper
Fry	01/18	03/15	1,155,424	145,284	870,668	1,440,181
Parr	03/16	05/09	92,615	11,169	70,723	114,506
Smolt	05/10	06/30	73,003	9,679	54,031	91,975
All	01/18	06/30	1,321,042	160,000	1,007,443	1,634,642

As mentioned earlier, the 1996 turbidity-greater-than-10 coefficient is used for all years. It may well be that turbidity should not be included in years other than 1996, but there is no statistical basis for either excluding or including it in years other than 1996. Exclusion of the positive turbidity coefficient would lead to a greater estimated outmigration index in 1997, 1998, and 1999. The counts were reexpanded using the efficiencies based on the reestimated coefficients and standard errors in Table A.6.b. which resulted from dropping the 1996 turbidity-greater-than-10 data sets. These expansions are given in Appendices 6.a through 6.d for 1996 through 1999 respectively. The cohort-based cumulative outmigration summary from these appendices is given in Table A.7.b.

The exclusion of the turbidity coefficient increased the 1997 parr cumulative estimate by 83% (from 7 K to 13 K) and the 1997 smolt estimate by 71% (from 60 K to 103 K). The1998 fry outmigration index was increased by 146% (from 186 K to 458 K), the 1998 par outmigration index by 6% (from 210 K to 223 K), and the 1998 smolt outmigration index by 1% (from 197 K to 200 K). The 1999 fry outmigration index was increased by 25% (from 1,155 K to 1,445 K), there being no change in the 1999 parr and smolt outmigration indices because of the failure of the turbidity to reach 10 ntu during their portion of the outmigration.

Table A.7.b. Estimates of outmigration indices for fry, Smolt, and smolt within years based on efficiency model EXCLUDING TURBIDITY >=10 (1996) records

1996 Cumulative Outmigration

	Current Date Domain		146,271 Estimate	S.E.	Approximate 95% Confidence Limits Lower	Upper	Turbidity-Based Estimate
Fry	02/06	03/20	29,658	13,347	3,499	55,818	31,767
Parr	03/21	03/31	2,090	654	809	3,372	1,596
Smolt	04/01	07/01	124,279	29,943	65,590	182,968	81,896
All	02/06	07/01	156,028	26,758	103,582	208,474	115,258

1997 Cumulative Outmigration

	Date Domain		Current Estimate	S.E.	Approximate 95% Confidence Limits Lower	Upper	Turbidity-Based Estimate
Fry					0	0	
Parr	03/19	04/05	12,818	1,368	10,136	15,500	7,011
Smolt	04/06	06/27	103,436	19,540	65,137	141,735	60,333
All	03/19	06/27	116,254	20,006	77,042	155,466	67,344

1998 Cumulative Outmigration

	Date Domain		Current Estimate	S.E.	Approximate 95% Confidence Limits Lower	Upper	Turbidity-Based Estimate
Fry	01/29	03/07	458,377	77,283	306,902	609,851	186,029
Parr	03/08	04/23	223,489	31,521	161,708	285,270	209,911
Smolt	04/24	07/16	200,320	35,291	131,150	269,491	197,884
All	01/29	07/16	882,186	99,514	687,137	1,077,234	593,825

1999 Cumulative Outmigration

	Date Domain		Current Estimate	S.E.	Approximate 95% Confidence Limits Lower	Upper	Turbidity-Based Estimate
Fry	01/18	03/15	1,444,960	170,901	1,109,995	1,779,925	1,155,424
Parr	03/16	05/09	92,615	10,470	72,094	113,136	92,615
Smolt	05/10	06/30	73,003	9,182	55,006	91,001	73,003
All	01/18	06/30	1,610,578	184,044	1,249,852	1,971,305	1,321,042

Survival

I have taken the turbidity-based efficiencies from Table A.6.a and applied them to Caswell recoveries of survival releases in 1998 and 1999. These are summarized in Table A.8.

Table A. 8. Estimated survival rates of survival to Caswell of releases made some distance upstream of the Caswell traps based on expanded recoveries.

Year	1998			1999					
Release Site	Knight's Ferry (1)	Knight's Ferry (2)	Pooled Oakdale	Knight's Ferry	River Mile 38 (1)	River Mile 38 (2)	River Mile 40 (1)	River Mile 40 (2)	Pooled Oakdale
Number Released (N)	-	2763	26693	25536	4981	5007	4975	4403	6165
Caswell Recoveries (n)	1	6	4	35	8	8	10	7	0
Proprotion Recovered (n/N)	-	0.0022	0.0002	0.0014	0.0016	0.0016	0.0020	0.0016	0.0011
Expanded Recoveries (er)	60.9	365.1	86.4	1347.9	308.1	308.1	385.1	269.6	269.6
Survival (er/N)	-	0.1322	0.0032	0.0528	0.0619	0.0615	0.0774	0.0612	0.0437

What was surprising to me is the relative uniformity of the survival estimates in 1999. Even so, with the exception of the 1999 Knight's Ferry release, the estimates in both years are based on very few recoveries, and far larger release sizes would be needed to obtain estimates that even approach a reasonably precise estimate of survival.

None of the 1999 survival recoveries involved days when the turbidity was 10 or greater, so the issue of a possible turbidity bias does not apply. This, however, is not true of the 1999 recoveries, and survival estimates would be higher if turbidity were not included in the prediction.

The 1998 and 1999 pooled Oakdale survival estimates given in the Table A.8 have no inherent meaning since the Oakdale releases were released over an extended period of time over which survival conditions likely varied greatly. Individual Oakdale-release estimates would be meaningless because the number of recoveries from the individual releases is too small, usually 0.

Appendix A.1. Variance of the Estimated Outmigration Index

The method of approximating the standard error of the confidence interval of the outmigration passage index is different than that used in the past. The outmigration index for day i is estimated by Equation 1.

Equation 1. $$o_i = \frac{c_i}{e_i} = c_i \left\{ \frac{1}{e_i} \right\}$$

wherein c_i is the screw-trap count on day i and e_i is the predicted efficiency (Equation 2) based on the logistic model

Equation 2. $$e_i = \frac{1}{1 + \exp[-b(0) - b(1)x_i(1) - ... - b(q)x_i(q)]}$$

wherein $x_i(j)$ is the jth predictor variable (e.g., flow) measured on day i. In the past, the standard error was approximated by using the estimated variance (s^2) of the ratio: $s^2(o_i) = s^2(c_i/o_i)$; however, the estimate of the variance of a ratio was an approximation. In this report, the variance estimator used was the estimated variance of a product, which can be more accurately estimated that the variance of a ratio. Substituting Equation 2 into Equation 1, puts the equation into product form (Equation 3):

Equation 3. $$o_i = \frac{c_i}{\dfrac{1}{1 + \exp[-b(0) - b(1)x_i(1) - ... - b(q)x_i(q)]}}$$

$$= c_i \{1 + \exp[-b(0) - b(1)x_i(1) - ... - b(q)x_i(q)]\}$$

The cumulative outmigration index can be written

Equation 4. $$\sum_i o_i = \sum_i c_i \left\{ \frac{1}{e_i} \right\}$$

The variance of the cumulative outmigration index is of the form given in Equation 5:

Equation 5. $$s^2\left[\sum_i o_i\right] = s^2\left[\sum_i c_i \left\{\frac{1}{e_i}\right\}\right] = \sum_i s^2\left[c_i \left\{\frac{1}{e_i}\right\}\right] + \sum_i \sum_{i' \neq i} s\left[c_i \left\{\frac{1}{e_i}\right\}, c_{i'} \left\{\frac{1}{e_{i'}}\right\}\right]$$

The form $s^2(y)$ representing the estimated variance of y and s(x,y) representing the estimated covariance between x and y.

In the above equation, $s^2[c_i\{1/e_i\}]$, a variance of a product, can written in the form:

Equation 5.a. $$s^2\left[c_i\left\{\frac{1}{e_i}\right\}\right] = c_i^2 * s^2\left[\frac{1}{e_i}\right] + s^2\left[c_i\right] * \left[\frac{1}{e_i}\right]^2 - s^2\left[c_i\right] * s^2\left[\frac{1}{e_i}\right]$$

Which is unbiased if the count, c_i, and the expansion factor, $1/e_i$, are stochastically independent and as long as their variance and covariance estimates are unbiased.

Within Equation 5.a, the variance of the count on day i, $s^2[c_i]$, is estimated by Equation 5.a.1, the variance among the counts involving the count on day i, c_i, and involving the counts on the immediate preceding and following days[9], c_{i-1} and c_{i+1}, respectively

Equation 5.a.1. $$s^2\left[c_i\right] = \frac{\left[c_{i-1} - \overline{c(i)}\right]^2 + \left[c_i - \overline{c(i)}\right]^2 + \left[c_{i+1} - \overline{c(i)}\right]^2}{3-1}$$

$$\textit{wherein} \quad \overline{c(i)} = \frac{c_{i-1} + c_i + c_{i+1}}{3}$$

and, within Equation 5.a, the variance of the inverse of the efficiency, $s^2[1/e_i]$, is estimated by Equation 5.a.2 using the delta method

Equation 5.a.2.

$$s^2\left[\frac{1}{e_i}\right] = s^2\left[1 + \exp\left[-b(0) - b(1)x_i(1) - \ldots - b(q)x_i(q)\right]\right]$$
$$= \exp^2\left[-b(0) - b(1)x_i(1) - b(q)x_i(q)\right] * s^2\left[b(0) + b(1)x_i(1) + \ldots + b(q)x_i(q)\right]$$

The delta method is also used to estimate the covariance terms in equation 5.

Equation 5.b.

---

9 If the day is the first day of monitoring, then the variance is the variance between the counts on that day and the following day; if the day is the last day of monitoring, then the variance is the variance between the counts on that day and the preceding day.

$$s\left[\frac{1}{e_i},\frac{1}{e_i}\right]=$$

$$s\left\{c_i\left[1+\exp\left[-b(0)-b(1)x_i(1)-\ldots-b(q)x_i(q)\right]\right],c_{i'}\left[1+\exp\left[-b(0)-b(1)x_{'i}(1)-\ldots-b(q)x_{i'}(q)\right]\right]\right\}=$$

$$c\ c_{i'}\left\{\exp\left[-b(0)-b(1)x_i(1)-\ldots-b(q)x_i(q)\right]*\exp\left[-b(0)-b(1)x_{'i}(1)-\ldots-b(q)x_{'i}(q)\right]\right\}*$$
$$s\left\{\left[b(0)+b(1)x_i(1)+\ldots+b(q)x_i(q)\right],\left[b(0)+b(1)x_{i'}(1)+\ldots+b(q)x_{'i}(q)\right]\right\}$$

Within equation 5.a.2

$$s^2\left[b(0)+b(1)x_i(1)+\ldots+b(q)x_i(q)\right]=$$

$$\left\{s^2\left[b(0)\right]+x_i^2(1)\,s^2\left[b(1)\right]+\ldots+x_i(q)_i^2\,s^2\left[b(q)\right]\right\}+$$
$$\left\{x_i(1)*s[b(0),b(1)]+\ldots+x_i(q)*s[b(0),b(q)]\right\}+$$
$$\{[x_i(1)*x_i(2)]*s[b(1),b(2)]+\ \ldots[x_i(1)*x_i(q)]*s[b(1),b(q)]+$$
$$\ldots[x_i(2)*x_i(q)]*s[b(2),b(q)]+\ldots\}$$

and within Equation 5.b.

$$s\left\{\left[b(0)+b(1)x_i(1)+\ldots+b(q)x_i(q)\right],\left[b(0)+b(1)x_{i'}(1)+\ldots+b(q)x_{'i}(q)\right]\right\}=$$

$$\left\{s^2\left[b(0)\right]+x_i(1)x_{i'}(1)\,s^2\left[b(1)\right]+\ldots+x_i(q)x_{i'}(q)\,s^2\left[b(q)\right]\right\}+$$
$$\{[x_i(1)+x_{i'}(1)]*s[b(0),b(1)]+\ldots+[x_i(q)+x_{i'}(q)]*s[b(0),b(q)]\}+$$
$$\{[x_i(1)*x_{i'}(2)+x_i(2)*x_{i'}(1)]*s[b(1),b(2)]+\ldots[x_i(1)*x_{i'}(q)+x_i(q)*x_{i'}(1)]*s[b(1),b(q)]+$$
$$\ldots[x_i(2)*x_{i'}(q)+x_i(q)*x_{i'}(2)]*s[b(2),b(q)]+\ldots\}$$

The variances of and covariances among the logistic regression coefficient estimates {s^2[b(j)] and s[b(j),b(j')]}were obtained from the variance-covariance-matrix output from logistic regression software; however, the output matrix assumes that the distribution of the efficiencies around the true predictor is binomial. The residual deviances suggests this is not likely to be the case; therefore, the variance-covariance matrix was multiplied by the mean deviance and the standard errors were multiplied by the square root of the mean deviance to correct a greater-than-assumed variation due to contagious movement and possible lack of fit of the model.

Appendix A.2. Logistic Analysis of Variation used for Preliminary Selection of Model

MODEL	Residual Deviance (Dev)	Degrees of Freedom (DF)	Dev/DF	Compared to Model	Change Dev	DF	Dev/DF	F-ratio	Type I P
YEAR: 1996-1997									
1. Constant	400.02	17	23.53						
2.a. Age Cohort+Constant	329.46	15	21.96	1	70.56	2	35.28	1.61	0.2333
2.b. Recovery Size+Constant	320.52	16	20.03	1	79.50	1	79.50	3.97	0.0637
2.c. Age Cohort+Recovery Size+Constant	310.62	14	22.19	2.a.	18.84	1	18.84	0.85	0.3724
				2.b.	9.90	2	4.95	0.22	0.8028
3. Average Flow+Constant	350.76	16	21.92	1	49.26	1	49.26	2.25	0.1533
4. Average Flow+Recovery Size+Constant	185.39	15	12.36	2.b.	135.13	1	135.13	10.93	0.0048
				3	165.37	1	165.37	13.38	0.0023
5. Average Flow+Recovery Size+Turbidity > 10+Constant	68.92	14	4.92	4	116.47	1	116.47	23.66	0.0003
6. Drop Recovery Size from 5.	86.93	15	5.80	5	18.01	1	18.01	3.66	0.0765
7. Drop Average Flow from 5.	191.29	15	12.75	5	122.37	1	122.37	24.86	0.0001
YEAR: 1998									
1. Constant	159.21	15	10.61						
2.a. Age Cohort+Constant	69.02	13	5.31	1	90.19	2	45.10	8.49	0.0044
2.b. Recovery Size+Constant	55.98	14	4.00	1	103.23	1	103.23	25.82	0.0002
2.c. Age Cohort+Recovery Size+Constant	44.07	12	3.67	2.a.	24.95	1	24.95	6.79	0.0230
				2.b.	11.91	2	5.96	1.62	0.2380
3. Average Flow+Constant	158.32	14	11.31	1	0.89	1	0.89	0.08	0.7832
4. Average Flow+Recovery Size+Constant	51.99	13	4.00	2.b.	3.99	1	3.99	1.00	0.3361
				3	106.33	1	106.33	26.59	0.0002
YEAR: 1999									
1. Constant	38.57	8	4.82						
2.a. Age Cohort+Constant	29.75	7	4.25	1	8.82	1	8.82	2.08	0.1929
2.b. Recovery Size+Constant	29.25	7	4.18	1	9.32	1	9.32	2.23	0.1790
2.c. Age Cohort+Recovery Size+Constant	25.28	6	4.21	2.a.	4.47	1	4.47	1.06	0.3427
				2.b.	3.97	1	3.97	0.94	0.3692
3. Average Flow+Constant	24.35	7	3.48	1	14.22	1	14.22	4.09	0.0829
4. Average Flow+Recovery Size+Constant	24.32	6	4.05	2.b.	4.93	1	4.93	1.22	0.3124

RESIDUAL FROM FULL MODEL AMONG DAYS VERSUS WITHIN DAY VARIATION

	Residual Dev	DF	Dev/Df	F-Ratio Pooled Full Model to within Day	Type I P
Full Model Fit among days with recovery data and fish size pooled over releases within days					
1996-97: Cons, flow, size (pooled), turbidity >10	31	6	5.17		
1998: Cons, flow, size (pooled)	22.88	4	5.72		
1999: Cons, flow, size (pooled)	13.87	5	2.77		
Pooled Full Model mong Days	**67.75**	**15**	**4.52**	**1.17**	**0.3684**
Variation among releases within days					
among releases within day 1996-97	36.94	8	4.62		
among releases within day 1998	21.85	9	2.43		
among releases within day 1999	10.43	1	10.43		
Pooled within Day	**69.22**	**18**	**3.85**		

Appendix A.3. Coefficients from Full Model

Predictor	Estimate	Standard Error	t-ratio	Type I P
1997-97 Intercept	-1.423720	0.468668	-3.04	0.0046
1998 Intercept	-1.709590	0.633254	-2.70	0.0109
1999 Intercept	-4.041050	0.839527	-4.81	0.0000
1996 1997 Flow	-0.000829	0.000164	-5.05	0.0000
1998 Flow	-0.000254	0.000268	-0.95	0.3506
1999 Flow	0.000158	0.000154	1.03	0.3099
1996-97 size	-0.010380	0.005156	-2.01	0.0523
1998 size	-0.023080	0.004820	-4.79	0.0000
1999 size	0.000733	0.008152	0.09	0.9289
Turbidity > 10	0.074650	0.014088	5.30	0.0000

Deviance	145.23
P(Type 1)	0.0000
Degrees of Freedom	33
Dev/DF	4.40

Type 1 Probabilities for Comparing Coefficients among Years

Coefficient	Year	Intercept 1996-1997	Intercept 1998	Flow 1996-1997	Flow 1998	Size 1996-1997	Size 1998
Intercept	1998	0.7190					
	1999	0.0103	0.0336				
Flow	1998			0.0761			
	1999			0.0001	0.1912		
Size	1998					0.0024	
	1999					0.2575	0.0170

Appendix A.4.a. Variables used to estimate 1996 Outmigration

		COUNT						FLOW (cfs)			SIZE		TURBIDITY (NTU)		
Cohort	DATE	North Trap		South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day		Used for fit
Fry	02/06/96	21		68		89	1.4	355.0	642.0	498.5	34.92		3.70	4	
	02/07/96	11		88.229	1.2	99.229		320.0	355.0	337.5	34.51	3	3.70	4	
	02/08/96	5.486	1.1	44		49.486		306.0	320.0	313.0	34.10		3.70		
	02/09/96	0		13		13		300.0	306.0	303.0	34.37	3	7.60		
	02/10/96	1		1		2		516.0	300.0	408.0	34.64	3	10.80		10.80
	02/11/96	0		0		0		678.0	516.0	597.0	34.90	3	14.00		14.00
	02/12/96	2		4		6		681.0	678.0	679.5	35.17		12.00		12.00
	02/13/96	0		2		2		913.0	681.0	797.0	35.03	3	13.50		13.50
	02/14/96	2		26		28		1179.0	913.0	1046.0	34.90	3	14.80		14.80
	02/15/96	1		38		39		1595.0	1179.0	1387.0	34.76		14.70		14.70
	02/16/96	5		11		21.318	1.3.b.	1648.0	1595.0	1621.5	34.77	3	15.70		15.70
	02/17/96	11		33		44	1.4	1652.0	1648.0	1650.0	34.77	3	11.70		11.70
	02/18/96	4		53		57		1650.0	1652.0	1651.0	34.78	3	9.40		
	02/19/96	7		45		52		2014.0	1650.0	1832.0	34.78		6.00		
	02/20/96	9		28		37		2841.0	2014.0	2427.5	34.84	3	10.50		10.50
	02/21/96					48.449	1.3.a	3223.0	2841.0	3032.0	34.89	3	9.03	4	
	02/22/96					43.086	1.3.a	2797.0	3223.0	3010.0	34.95	3	7.57	4	
	02/23/96	16		97		113		3093.0	2797.0	2945.0	35.00		6.10		
	02/24/96	2		16.042	1.2	18.042		3245.0	3093.0	3169.0	35.18	3	13.80		13.80
	02/25/96	1		23		24		3232.0	3245.0	3238.5	35.37	3	13.60		13.60
	02/26/96	0		11		11		3271.0	3232.0	3251.5	35.55		12.40		12.40
	02/27/96	0		16		16		3341.0	3271.0	3306.0	37.17	3	12.10		12.10
	02/28/96	0		11		11		3481.0	3341.0	3411.0	38.78	3	10.80		10.80
	02/29/96	0		5		5		3894.0	3481.0	3687.5	40.40		9.90		
	03/01/96	0		6		6		3897.0	3894.0	3895.5	34.83		7.80		
	03/02/96	0		1		7.731	1.3.b.	3866.0	3897.0	3881.5	36.36	3	8.10		
	03/03/96					6.783	1.3.a.	3856.0	3866.0	3861.0	37.89	3	6.48	4	
	03/04/96					4.798	1.3.a.	3836.0	3856.0	3846.0	39.42	3	4.85	4	
	03/05/96					2.751	1.3.a.	3975.0	3836.0	3905.5	40.94	3	3.23	4	
	03/06/96	0		0.000	1.2	0.000		3850.0	3975.0	3912.5	42.47	3	1.60		
	03/07/96	0		4		4	1.4	3847.0	3850.0	3848.5	44.00		5.90		
	03/08/96	4		0		4		3842.0	3847.0	3844.5	42.80	3	9.00		
	03/09/96	0		1		1		3849.0	3842.0	3845.5	41.60	3	4.50		
	03/10/96	0		0		0		3782.0	3849.0	3815.5	40.40	3	5.70		
	03/11/96	0		0.000	1.2	0.000		3641.0	3782.0	3711.5	39.20	3	7.00		
	03/12/96	0		1		1		3584.0	3641.0	3612.5	38.00		5.10		
	03/13/96	0		0		0		3552.0	3584.0	3568.0	41.00	3	10.50		10.50
	03/14/96	1		0		1		3489.0	3552.0	3520.5	44.00		8.00		
	03/15/96	0		0		0		3529.0	3489.0	3509.0	47.50	3	5.40		
	03/16/96	0		1		1		3524.0	3529.0	3526.5	51.00		5.60		
	03/17/96	0		0		0		3519.0	3524.0	3521.5	44.50	3	6.00		
	03/18/96	0		2		2		3530.0	3519.0	3524.5	38.00		5.60		
	03/19/96	0		0		0		3522.0	3530.0	3526.0	41.50	3	7.60		
	03/20/96	0		1		1		3503.0	3522.0	3512.5	45.00		6.50		
Parr	03/21/96	0		0		0		3509.0	3503.0	3506.0	50.42	3	5.80		
	03/22/96	0		0		0		3413.0	3509.0	3461.0	55.83	3	5.50		
	03/23/96	0		0		0		3010.0	3413.0	3211.5	61.25	3	7.30		
	03/24/96	0		0		0		2761.0	3010.0	2885.5	66.67	3	5.70		
	03/25/96	0		0		0		2539.0	2761.0	2650.0	72.08	3	4.50		
	03/26/96	2		2		4		2226.0	2539.0	2382.5	77.50		6.00		
	03/27/96	0		2		2		2125.0	2226.0	2175.5	76.50		5.10		
	03/28/96	5		2		7		2024.0	2125.0	2074.5	80.43		5.70		
	03/29/96	0		10		10		1896.0	2024.0	1960.0	81.70		5.30		
	03/30/96	0		3		3		1790.0	1896.0	1843.0	74.00		8.00		
	03/31/96	0		5		5	1.4	1748.0	1790.0	1769.0	74.80		7.70		
Smolt	04/01/96	1		2		3		1794.0	1748.0	1771.0	88.00		7.40		
	04/02/96	0		3		3	1.4	1791.0	1794.0	1792.5	90.00		6.50		
	04/03/96	2		6		8		1794.0	1791.0	1792.5	84.00		3.00		
	04/04/96	4		14		18		1788.0	1794.0	1791.0	82.94		6.50		

		COUNT						FLOW (cfs)					SIZE		TURBIDITY (NTU)		
Cohort	DATE	North Trap		South Trap		Total		Current Day		Previous Day		Average	(Length, mm)		Current Day		Used for fit
	04/05/96	2		7		9	1.4	1809.0		1788.0		1798.5	82.78		6.00		
	04/06/96	5		9		14		1791.0		1809.0		1800.0	87.50		6.20		
	04/07/96	1		12		13		1780.0		1791.0		1785.5	76.92		5.90		
	04/08/96	1		0		1		1779.0		1780.0		1779.5	81.00		5.10		
	04/09/96	3		5		8		1775.0		1779.0		1777.0	86.17		4.20		
	04/10/96	0		4		4		1776.0		1775.0		1775.5	80.75		6.50		
	04/11/96	1		1		2		1791.0		1776.0		1783.5	85.00		4.20		
	04/12/96	2		7		9	1.4	1731.0		1791.0		1761.0	82.56		4.60		
	04/13/96	2		0		2		1598.0		1731.0		1664.5	80.50		9.90		
	04/14/96	0.000	1.1	0		0.000		1595.0		1598.0		1596.5	83.00	3	5.20		
	04/15/96	2.0		8		10		1599.0		1595.0		1597.0	85.50		9.70		
	04/16/96	0.0		2		2		1656.0		1599.0		1627.5	97.50		5.70		
	04/17/96	2.0		3.209	1.2	5.209		1706.0		1656.0		1681.0	91.33		9.30		
	04/18/96	3.0		3		6		1711.0		1706.0		1708.5	84.67		7.20		
	04/19/96	3.0		12		15	1.4	1679.0		1711.0		1695.0	86.20		6.30		
	04/20/96	0.0		1		1	1.4	1670.0		1679.0		1674.5	89.00		5.20		
	04/21/96	11.0		11		22		1675.0		1670.0		1672.5	89.77		5.60		
	04/22/96	15.0		21		36		1673.0		1675.0		1674.0	91.08		4.70		
	04/23/96	20.0		32.092	1.2	52.092		1668.0		1673.0		1670.5	89.65		6.00		
	04/24/96	17.0		21		38		1673.0		1668.0		1670.5	89.66		6.40		
	04/25/96	18.0		21		39		1676.0		1673.0		1674.5	92.23		7.80		
	04/26/96	12.0		26		38		1676.0		1676.0		1676.0	91.19		5.70		
	04/27/96	36.0		59		95		1662.0		1676.0		1669.0	90.97		5.10		
	04/28/96	34.0		75		109	1.4	1668.0		1662.0		1665.0	91.68		5.90		
	04/29/96	26.0		63		89		1684.0		1668.0		1676.0	91.89		6.90		
	04/30/96	47.987	1.1	77		124.987		1683.0		1684.0		1683.5	91.02		9.10		
	05/01/96	36		57.766	1.2	93.766		1684.0		1683.0		1683.5	91.21		9.40		
	05/02/96	25		59		84		1680.0		1684.0		1682.0	93.40		9.80	4	
	05/03/96	11		33		75.237	1.3.b.	1659.0		1680.0		1669.5	92.88		10.20		10.20
	05/04/96	21		46		67		1674.0		1659.0		1666.5	90.47		9.80		
	05/05/96	32		75		107		1662.0		1674.0		1668.0	93.48		9.90		
	05/06/96	35		38		73		1640.0		1662.0		1651.0	90.80		9.20		
	05/07/96	20		22		42		1664.0		1640.0		1652.0	92.10		8.40		
	05/08/96	25		22		47		1650.0		1664.0		1657.0	91.91		9.20		
	05/09/96	19		28		47		1663.0		1650.0		1656.5	91.36		9.00		
	05/10/96	20		32.092	1.2	52.092		1667.0		1663.0		1665.0	90.57		8.80		
	05/11/96	24		36		60		1653.0		1667.0		1660.0	91.84		8.70		
	05/12/96	8		12		20		1644.0		1653.0		1648.5	91.08		9.00		
	05/13/96	0		6		35.842	1.3.b	1654.8	2.1	1644.0		1649.4	92.02	3	8.80		
	05/14/96	13		20.860	1.2	33.860		1665.6	2.1	1654.8	2.2	1660.2	92.95		6.80		
	05/15/96	5		0		28.721	1.3.b	1676.4	2.1	1665.6	2.2	1671.0	98.20		7.10		
	05/16/96	3		16		19	1.4	1687.2	2.1	1676.4	2.2	1681.8	91.21		6.90		
	05/17/96	6		4		10	1.4	1698.0		1687.2	2.2	1692.6	93.70		7.30		
	05/18/96	0		14		14	1.4	1658.0		1698.0		1678.0	95.79		7.10		
	05/19/96	1		9		10	1.4	1693.0		1658.0		1675.5	99.50		6.10		
	05/20/96	6		13		19		1697.0		1693.0		1695.0	95.00		6.20		
	05/21/96	3		20		23		1670.0		1697.0		1683.5	95.45		5.80		
	05/22/96	4		6.418	1.2	10.418		1525.0		1670.0		1597.5	94.12		5.40		
	05/23/96	6		3		9		1151.0		1525.0		1338.0	95.89		6.40		
	05/24/96	6		12		18		936.0		1151.0		1043.5	94.61		7.90		
	05/25/96	12.464	1.1	20		32.464		901.0		936.0		918.5	95.10		9.80		
	05/26/96	28		24		52		921.0		901.0		911.0	95.02		8.90		
	05/27/96	13		17		30		955.0		921.0		938.0	93.26		6.80		
	05/28/96	10		5		15		958.0		955.0		956.5	94.57		6.60		
	05/29/96	10		12		22		935.0		958.0		946.5	92.95		7.40		
	05/30/96	3		6		9		935.0		935.0		935.0	93.33		8.30		
	05/31/96	5		5		10		939.0		935.0		937.0	95.90		7.90		
	06/01/96	7		3		10		945.0		939.0		942.0	98.00		8.60		
	06/02/96	5		6		11		939.0		945.0		942.0	97.27		9.80		
	06/03/96	1		1		2		933.0		939.0		936.0	92.00		7.70		
	06/04/96	2		3.209	1.2	5.209		936.0		933.0		934.5	99.00		6.80		
	06/05/96	3		4		7	1.4	933.0		936.0		934.5	102.00		6.60		

Cohort	DATE	COUNT North Trap		South Trap	Total		FLOW (cfs) Current Day	Previous Day	Average	SIZE (Length, mm)		TURBIDITY (NTU) Current Day		Used for fit
	06/06/96	2		1	3		929.0	933.0	931.0	100.00		8.30		
	06/07/96	1		0	1		976.0	929.0	952.5	91.00		7.40		
	06/08/96	2		2	4		1281.0	976.0	1128.5	99.25		7.90		
	06/09/96	1		1	2.000	1.4	1275.0	1281.0	1278.0	93.00		8.60		
	06/10/96	0		0	1.497	1.3.b.	1279.0	1275.0	1277.0	91.00	3	8.78	4	
	06/11/96	0		0	0		1300.0	1279.0	1289.5	89.00	3	8.97	4	
	06/12/96	0		3	3		1308.0	1300.0	1304.0	87.00		9.15	4	
	06/13/96	1		1	2		1292.0	1308.0	1300.0	90.00		9.33	4	
	06/14/96	1.246	1.1	2	3.246		1200.0	1292.0	1246.0	87.00		9.52	4	
	06/15/96	0		0	0		1077.0	1200.0	1138.5	87.67	3	9.70		
	06/16/96	0		0	0		928.0	1077.0	1002.5	88.33	3	8.80		
	06/17/96	0		1	1		848.0	928.0	888.0	89.00		8.30		
	06/18/96	0		0	0		850.0	848.0	849.0	90.75	3	7.50		
	06/19/96	0		0	0		844.0	850.0	847.0	92.50	3	4.90		
	06/20/96	0		0	0		829.0	844.0	836.5	94.25	3	5.30		
	06/21/96	0		1	1		821.0	829.0	825.0	96.00		6.70		
	06/22/96	0		0	0		833.0	821.0	827.0	103.50	3	6.00		
	06/23/96	0		1	1		811.0	833.0	822.0	111.00		5.60		
	06/24/96	0		1	1		825.0	811.0	818.0	105.00		5.70		
	06/25/96	0		0	0		842.0	825.0	833.5	101.33	3	5.30		
	06/26/96	0		0	0		852.0	842.0	847.0	97.67	3	5.00		
	06/27/96	0		1	1		831.0	852.0	841.5	94.00		4.80		
	06/28/96	0		0	0		815.0	831.0	823.0	99.00	3	5.40		
	06/29/96	0		0	0		776.0	815.0	795.5	104.00	3	5.60		
	06/30/96	0		1	1		757.0	776.0	766.5	109.00		6.40		
	07/01/96	0		1	1		753.0	757.0	755.0	101.00		6.70		

1.1 North Trap = South Trap*(North-to-South-Trap Ratio)
1.2 South Trap = North Trap/(North-to-South-Trap Ratio)
1.3.a Missing value estimate for count (see text)
1.3.b Missing value estimate for count because both traps stopped, total of north and south trap not the value used (see text)
1.4 Actual North + Actual South Trap even though there was trap stoppage (adjusted value for stoppage or missing value produced smaller count).
2.1 Missing value flow estimate for predictor variable (see text)
2.2 Missing value flow estimate for predictor variable (see text)
3. Missing value length estimate for predictor variable (see text)
4. Missing value turbidity estimate for predictor variable (see text)

Appendix A.4.b. Variables used to estimate 1997 Outmigration

COHORT	DATE	COUNT North Trap		South Trap		Total	FLOW (cfs) Current Day	Previous Day	Average	SIZE (Length, mm)	TURBIDITY (NTU) Current Day		Used for fit
Parr	03/19/97	0		15		15	1618.0	1647.0	1632.5	64.47	11.80		11.80
	03/20/97	2		15		17	1631.0	1618.0	1624.5	73.29	10.40		10.40
	03/21/97	0		35		35	1645.0	1631.0	1638.0	71.77	12.80		12.80
	03/22/97	0		36		36	1558.0	1645.0	1601.5	73.06	11.10		11.10
	03/23/97	2		46		48	1362.0	1558.0	1460.0	74.85	10.80		10.80
	03/24/97	3		39		42	1175.0	1362.0	1268.5	73.98	10.60		10.60
	03/25/97	1		31		32	876.0	1175.0	1025.5	73.53	10.20		10.20
	03/26/97	0		30		30	524.0	876.0	700.0	76.37	12.10		12.10
	03/27/97	0		22		22	621.0	524.0	572.5	77.05	14.00		14.00
	03/28/97	2		26		28	595.0	621.0	608.0	77.18	13.40		13.40
	03/29/97	1		20		21	601.0	595.0	598.0	73.43	10.70		10.70
	03/30/97	5		47.500	1.2	52.500	605.0	601.0	603.0	81.78	8.70		
	03/31/97	9		21		30	616.0	605.0	610.5	79.73	10.10		10.10
	04/01/97	6		39		45	618.0	616.0	617.0	76.27	10.80		10.80
	04/02/97	2.316	1.1	22		24.316	614.0	618.0	616.0	80.18	10.50	4	10.50
	04/03/97	5		22		27	597.0	614.0	605.5	82.26	10.20		10.20
	04/04/97	5		23		28	599.0	597.0	598.0	78.50	9.40		

	COUNT							FLOW (cfs)			SIZE		TURBIDITY (NTU)	
COHORT	DATE	North Trap		South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day	Used for fit
	04/05/97	12		36		48		602.0	599.0	600.5	79.19		8.70	
Smolt	04/06/97	12		39		51		597.0	602.0	599.5	81.02		9.30	
	04/07/97	11		28		39		590.0	597.0	593.5	83.18		6.30	
	04/08/97	2		24		26		602.0	590.0	596.0	83.54		7.80	
	04/09/97	8.444	1.1	38		46.444		599.0	602.0	600.5	80.76		8.40	
	04/10/97	21		39		60		598.0	599.0	598.5	80.42		8.80	
	04/11/97	8		36.000	1.2	44.000		589.0	598.0	593.5	83.84		8.40	
	04/12/97	11		38		49		730.0	589.0	659.5	83.37		7.80	
	04/13/97	11		34		45		1164.0	730.0	947.0	82.86		10.30	10.30
	04/14/97	17		51		68		1711.0	1164.0	1437.5	82.78		12.50	12.50
	04/15/97	23		103.500	1.2	126.500		1707.0	1711.0	1709.0	81.32		12.50	12.50
	04/16/97	19		85.500	1.2	104.500		1651.0	1707.0	1679.0	84.22		11.20	11.20
	04/17/97	11		70		81		1668.0	1651.0	1659.5	84.68		11.30	11.30
	04/18/97	3		40		43		1684.0	1668.0	1676.0	83.63		12.00	12.00
	04/19/97	2		20		22	1.4	1680.0	1684.0	1682.0	80.86		13.90	13.90
	04/20/97	4		47		51	1.4	1695.0	1680.0	1687.5	85.02		13.40	13.40
	04/21/97	3		25		28		1685.0	1695.0	1690.0	83.36		12.40	12.40
	04/22/97	8.000	1.1	36		44.000		1668.0	1685.0	1676.5	85.39		11.40	11.40
	04/23/97	2		8		10		1679.0	1668.0	1673.5	86.80		11.00	11.00
	04/24/97	0		9		9	1.4	1680.0	1679.0	1679.5	85.00		10.50	10.50
	04/25/97	3		23		26		1686.0	1680.0	1683.0	84.54		10.00	10.00
	04/26/97	3		29		32		1691.0	1686.0	1688.5	85.16		10.30	10.30
	04/27/97	2		13		15		1716.0	1691.0	1703.5	84.53		10.10	10.10
	04/28/97	3		13.500	1.2	16.500		1685.0	1716.0	1700.5	90.00		9.90	
	04/29/97	6		15		21		1686.0	1685.0	1685.5	85.57		9.20	
	04/30/97	6		21		27		1680.0	1686.0	1683.0	87.56		8.90	
	05/01/97	0		3		3		1682.0	1680.0	1681.0	93.00		9.40	
	05/02/97	2		13		15		1672.0	1682.0	1677.0	86.60		9.70	
	05/03/97	11		31		42		1653.0	1672.0	1662.5	86.33		9.50	
	05/04/97	5		23		28		1648.0	1653.0	1650.5	88.71		9.30	
	05/05/97	13		34		47		1659.0	1648.0	1653.5	86.26		9.40	
	05/06/97	1		8		9	1.4	1633.0	1659.0	1646.0	91.00		8.90	
	05/07/97	3		29		32		1653.0	1633.0	1643.0	90.53		9.00	
	05/08/97	5		24		29		1639.0	1653.0	1646.0	88.52		9.20	
	05/09/97	4		27		31		1662.0	1639.0	1650.5	87.65		8.80	
	05/10/97	3		20		23		1652.0	1662.0	1657.0	86.13		9.10	
	05/11/97	1		20		21	1.4	1639.0	1652.0	1645.5	89.33		8.90	
	05/12/97	7		31.500	1.2	38.500		1642.0	1639.0	1640.5	86.04		8.80	
	05/13/97	7		31.500	1.2	38.500		1581.0	1642.0	1611.5	88.14		8.60	
	05/14/97	8		23		31		1038.0	1581.0	1309.5	89.61		8.70	
	05/15/97	0		19		35.566	1.3.a.	1571.0	1038.0	1304.5	90.89		9.00	
	05/16/97	13		58.500	1.2	71.500		1613.0	1571.0	1592.0	90.73		9.40	
	05/17/97	5		22.500	1.2	27.500		1602.0	1613.0	1607.5	89.20		9.30	
	05/18/97	7		35		42	1.4	1616.0	1602.0	1609.0	89.78		8.90	
	05/19/97	7		55		62		1621.0	1616.0	1618.5	89.36		9.10	
	05/20/97	8		36.000	1.2	44.000		1598.0	1621.0	1609.5	88.95		9.20	
	05/21/97	0		23		23		1600.0	1598.0	1599.0	88.43		9.00	
	05/22/97	2		28		30		1607.0	1600.0	1603.5	91.07		8.90	
	05/23/97	0		0		33.785	1.3.a.	1506.0	1607.0	1556.5	92.33	3	8.60	
	05/24/97	3		9		34.612	1.3.a.	1218.0	1506.0	1362.0	93.58		9.10	
	05/25/97	6		25		31		1233.0	1218.0	1225.5	90.45		9.30	
	05/26/97	7		44		51		1224.0	1233.0	1228.5	88.58		9.40	
	05/27/97	1		10		11	1.4	1398.0	1224.0	1311.0	90.27		9.70	
	05/28/97	6		27.000	1.2	33.000		1608.0	1398.0	1503.0	90.17		9.60	
	05/29/97	6		36		42		1615.0	1608.0	1611.5	90.59		9.80	
	05/30/97	0		2		12.509	1.3.a.	1468.0	1615.0	1541.5	87.00		9.50	
	05/31/97	2		5		7		1395.0	1468.0	1431.5	90.43		9.40	
	06/01/97	0		3		3		1300.0	1395.0	1347.5	94.00		9.50	
	06/02/97	1		10		11		1300.0	1300.0	1300.0	89.45		9.30	
	06/03/97	0		7		7	1.4	1602.8	1300.0	1451.4	89.29		9.70	
	06/04/97	1		1		2		1610.5	1602.8	1606.7	92.00		10.20	10.20
	06/05/97	0		7		7		1609.3	1610.5	1609.9	86.57		10.50	10.50
	06/06/97	1.556	1.1	7		8.556		1546.6	1609.3	1577.9	88.75		10.30	10.30
	06/07/97	0		3		3	1.4	1193.7	1546.6	1370.2	86.00		11.10	11.10
	06/08/97	0		2		2	1.4	948.6	1193.7	1071.1	92.50		11.50	11.50
	06/09/97	4		18.000	1.2	22.000		906.6	948.6	927.6	90.17		12.60	12.60

		COUNT				FLOW (cfs)					SIZE		TURBIDITY (NTU)		
COHORT	DATE	North Trap		South Trap	Total	Current Day		Previous Day		Average	(Length, mm)		Current Day		Used for fit
	06/10/97	0.667	1.1	3	3.667	923.6		906.6		915.1	93.67		12.90		12.90
	06/11/97	1		6	7	916.7		923.6		920.2	93.86		12.50		12.50
	06/12/97	5		1	6	913.3		916.7		915.0	88.00		12.60		12.60
	06/13/97	3		2	5	914.7		913.3		914.0	86.80		12.30		12.30
	06/14/97	0		3	3	908.2		914.7		911.4	92.33		11.90		11.90
	06/15/97	1		1	2	905.4		908.2		906.8	93.50		12.10		12.10
	06/16/97	0		6	6	907.8		905.4		906.6	86.33		11.15	4	11.15
	06/17/97	0.222	1.1	1	1.222	903.4		907.8		905.6	88.00		10.20		10.20
	06/18/97	0		3	3	895.9		903.4		899.7	92.00		10.70		10.70
	06/19/97	0		4	4	897.9		895.9		896.9	94.50		11.00		11.00
	06/20/97	1		2	3	912.5		897.9		905.2	98.00		10.60		10.60
	06/21/97	1		3	4	921.1		912.5		916.8	89.25		10.50		10.50
	06/22/97	0		4	4	915.9		921.1		918.5	92.00		9.80		
	06/23/97	0		2	2	917.9		915.9		916.9	94.50		10.10		10.10
	06/24/97	0		1	1	924.6		917.9		921.3	92.00		9.60		
	06/25/97	0		0	0	916.8		924.6		920.7	92.00	3	10.30		10.30
	06/26/97	0		0	0	882.2	2.1	916.8	2.2	921.0	92.00	3	10.70		10.70
	06/27/97	0		0	0	792.3	2.1	882.2	2.2	921.0	92.00	3	11.40		11.40

1.1 North Trap = South Trap*(North-to-South-Trap Ratio)
1.2 South Trap = North Trap/(North-to-South-Trap Ratio)
1.3.a Missing value estimate for count (see text)
1.3.b Missing value estimate for count because both traps stopped, total of north and south trap not the value used (see text)
1.4 Actual North + Actual South Trap even though there was trap stoppage (adjusted value for stoppage produced smaller count).
2.1 Missing value flow estimate for predictor variable (see text)
2.2 Missing value flow estimate for predictor variable (see text)
3. Missing value length estimate for predictor variable (see text)
4. Missing value turbidity estimate for predictor variable (see text)

Appendix A.4.c. Variables used to estimate 1998 Outmigration

			COUNT				FLOW (cfs)			SIZE		TURBIDITY (NTU)		
COHORT	DATE	North Trap	South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day		Used for fit
Fry	01/29/98	186	616		802		1806.0	1365.0	1585.5	35.41		11.50		11.50
	01/30/98	32	254		286	1.4	2623.0	1806.0	2214.5	35.79		11.60		11.60
	01/31/98	193	2		703.916	1.3.b	2629.0	2623.0	2626.0	35.22		12.30	4	12.30
	02/01/98				678.083	1.3.a	2526.0	2629.0	2577.5	35.53	3	13.00	4	13.00
	02/02/98	37	1048		1085		2524.0	2526.0	2525.0	35.84		13.70		13.70
	02/03/98	259	73		332		3854.0	2524.0	3189.0	37.65		20.30		20.30
	02/04/98				643.310	1.3.a	3767.0	3854.0	3810.5	37.25	3	25.06	4	25.06
	02/05/98				693.067	1.3.a	5497.0	3767.0	4632.0	36.85	3	29.82	4	29.82
	02/06/98				759.130	1.3.a	4915.0	5497.0	5206.0	36.45	3	34.58	4	34.58
	02/07/98				850.620	1.3.a	4333.0	4915.0	4624.0	36.05	3	39.34	4	39.34
	02/08/98	138	1042		1180		5434.0	4333.0	4883.5	35.65		44.10		44.10
	02/09/98				1091.088	1.3.a	5460.0	5434.0	5447.0	35.74	3	38.60	4	38.60
	02/10/98				1045.738	1.3.a	5095.0	5460.0	5277.5	35.83	3	33.10	4	33.10
	02/11/98				1011.772	1.3.a	5004.0	5095.0	5049.5	35.91	3	27.60	4	27.60
	02/12/98				862.420	1.3.a	4850.0	5004.0	4927.0	36.00	3	22.10	4	22.10
	02/13/98	64	833		897		4772.0	4850.0	4811.0	36.09		16.60		16.60
	02/14/98	156	693		849	1.4	4508.0	4772.0	4640.0	37.40		14.70		14.70
	02/15/98	104	918		1022		4358.0	4508.0	4433.0	36.51		12.10		12.10
	02/16/98	158	2351		2509	1.4	5003.0	4358.0	4680.5	37.32		9.20		
	02/17/98	49	178		227		4468.0	5003.0	4735.5	37.86		10.00		10.00
	02/18/98	1	61		62	1.4	5064.0	4468.0	4766.0	39.05		10.80	4	10.80
	02/19/98	30	243		273		4481.0	5064.0	4772.5	37.04		11.60		11.60
	02/20/98	29	323		352		4530.0	4481.0	4505.5	37.41		16.50		16.50
	02/21/98	50	343		393		4566.0	4530.0	4548.0	35.55		18.90		18.90
	02/22/98	22	294		316		4571.0	4566.0	4568.5	36.59		10.40		10.40
	02/23/98	19	109.507	1.2	128.507		4201.0	4571.0	4386.0	36.33		14.70		14.70
	02/24/98	22	169		191		3746.0	4201.0	3973.5	36.51		10.10		10.10
	02/25/98	26	162		188		3746.0	3746.0	3746.0	36.53		9.50		
	02/26/98	32	127		159		3751.0	3746.0	3748.5	37.96		8.25	4	
	02/27/98	25	124		149		3700.0	3751.0	3725.5	38.17		7.00		
	02/28/98	23	139		162		3709.0	3700.0	3704.5	39.16		7.30		

COHORT	DATE	COUNT North Trap		COUNT South Trap		COUNT Total		FLOW (cfs) Current Day	FLOW (cfs) Previous Day	FLOW (cfs) Average	SIZE (Length, mm)	TURBIDITY (NTU) Current Day		TURBIDITY (NTU) Used for fit
	03/01/98	24		73		97		3713.0	3709.0	3711.0	39.38	8.80		
	03/02/98	21		102		123		3508.0	3713.0	3610.5	38.24	7.00		
	03/03/98	24		50		74		2967.0	3508.0	3237.5	38.95	8.10		
	03/04/98	12		69.162	1.2	81.162		2450.0	2967.0	2708.5	38.96	8.30		
	03/05/98	14		35		49		2048.0	2450.0	2249.0	43.98	9.50		
	03/06/98	22		30		52		2106.0	2048.0	2077.0	46.85	10.60		10.60
	03/07/98	21		121.034	1.2	142.034		2071.0	2106.0	2088.5	40.48	9.45	4	
Parr	03/08/98	27		97		124		2059.0	2071.0	2065.0	51.18	8.30		
	03/09/98	55		347.037	1.2	402.037		2089.0	2059.0	2074.0	50.89	7.00		
	03/10/98	58		336		394		2098.0	2089.0	2093.5	51.40	7.25	4	
	03/11/98	40		202		242		1974.0	2098.0	2036.0	50.73	7.50		
	03/12/98	37		315		352		1721.0	1974.0	1847.5	51.43	7.00		
	03/13/98	14		54		68		1620.0	1721.0	1670.5	54.59	7.30		
	03/14/98	17		60		77		1577.0	1620.0	1598.5	55.56	8.10		
	03/15/98	23		55		78		1574.0	1577.0	1575.5	50.41	7.40		
	03/16/98	23		85		108		1570.0	1574.0	1572.0	52.25	7.50		
	03/17/98	32		206		238		1569.0	1570.0	1569.5	54.01	7.20		
	03/18/98	5		15		20		1768.0	1569.0	1668.5	51.85	7.00	4	
	03/19/98	8		21		29		2798.0	1768.0	2283.0	54.62	6.80	4	
	03/20/98	6		37.859	1.2	43.859		3413.0	2798.0	3105.5	60.44	6.60		
	03/21/98	3		4		55	1.3.b	3365.0	3413.0	3389.0	51.50	7.40		
	03/22/98	1		6.310	1.2	7.310		2744.0	3365.0	3054.5	38.00	8.50		
	03/23/98	8		50.478	1.2	58.478		2499.0	2744.0	2621.5	63.89	7.20		
	03/24/98	4		50		54		2491.0	2499.0	2495.0	63.98	17.10		17.10
	03/25/98	5		43		48		2657.0	2491.0	2574.0	66.83	7.20		
	03/26/98	68		436		504		2351.0	2657.0	2504.0	60.71	8.00		
	03/27/98	38.195	1.1	241		279.195		1883.0	2351.0	2117.0	65.09	7.80		
	03/28/98	7		78		85		1728.0	1883.0	1805.5	68.32	28.40		28.40
	03/29/98	14		88.337	1.2	102.337		1593.0	1728.0	1660.5	65.71	15.40		15.40
	03/30/98	16		107		123		1561.0	1593.0	1577.0	67.30	7.30		
	03/31/98	9.351	1.1	59		68.351		1582.0	1561.0	1571.5	68.24	7.40		
	04/01/98	16		55		71		1645.0	1582.0	1613.5	67.00	6.80		
	04/02/98	10		52		62		1580.0	1645.0	1612.5	72.02	9.50		
	04/03/98	10		95		105		1758.0	1580.0	1669.0	66.97	8.40		
	04/04/98	18		209		227		1649.0	1758.0	1703.5	67.67	12.90		12.90
	04/05/98	22		280		302		1580.0	1649.0	1614.5	67.04	6.70		
	04/06/98	8		29		194.683	1.3.b	1561.0	1580.0	1570.5	61.30	8.30		
	04/07/98	28		226		254		1822.0	1561.0	1691.5	66.54	7.30	4	
	04/08/98	29		283		312		2080.0	1822.0	1951.0	67.35	6.30		
	04/09/98	6		33		133.332	1.3.b	2065.0	2080.0	2072.5	65.95	7.90		
	04/10/98	11		69.407	1.2	80.407		2062.0	2065.0	2063.5	66.36	7.20	4	
	04/11/98	12		67		79		2066.0	2062.0	2064.0	70.02	6.50		
	04/12/98	2		69		71		2069.0	2066.0	2067.5	71.92	6.15	4	
	04/13/98	1		23		24		2206.0	2069.0	2137.5	74.04	5.80		
	04/14/98	1		24		25		2182.0	2206.0	2194.0	82.40	8.10		
	04/15/98	5		34		39		2066.0	2182.0	2124.0	83.08	6.30		
	04/16/98	5		22		27		2051.0	2066.0	2058.5	78.23	4.10		
	04/17/98	3		13		16		2035.0	2051.0	2043.0	78.38	6.50		
	04/18/98	5		31.549	1.2	36.549		1996.0	2035.0	2015.5	73.88	6.30	4	
	04/19/98	24		50		74		1996.0	1996.0	1996.0	78.97	6.10	4	
	04/20/98	3		20		23		2008.0	1996.0	2002.0	74.43	5.90		
	04/21/98	10		11		21		1979.0	2008.0	1993.5	78.38	6.60		
	04/22/98	3		24		27		1982.0	1979.0	1980.5	84.93	6.50		
	04/23/98	8		31		39		2009.0	1982.0	1995.5	79.36	6.00		
Smolt	04/24/98	10		40.985	1.2	50.985		2057.0	2009.0	2033.0	81.92	6.90		
	04/25/98	11		45.084	1.2	56.084		2016.0	2057.0	2036.5	81.68	7.90		
	04/26/98	5		37		42	1.4	1992.0	2016.0	2004.0	80.07	7.60	4	
	04/27/98	11		33		44		2005.0	1992.0	1998.5	79.68	7.30		
	04/28/98	17		58		75		1998.0	2005.0	2001.5	84.12	6.50		
	04/29/98	12		55		67		2004.0	1998.0	2001.0	80.19	7.50		
	04/30/98	17		55		72		2014.0	2004.0	2009.0	83.70	4.50		
	05/01/98	15		86		101		2019.0	2014.0	2016.5	82.00	8.10		

COHORT	DATE	North Trap		COUNT South Trap		Total		FLOW (cfs) Current Day		Previous Day		Average	SIZE (Length, mm)		TURBIDITY (NTU) Current Day		Used for fit
	05/02/98	14		43		57		1972.0		2019.0		1995.5	81.98		8.73	4	
	05/03/98	7		38		45		2008.0		1972.0		1990.0	82.71		9.37	4	
	05/04/98	6		33		39		2049.0		2008.0		2028.5	88.72		10.00		10.00
	05/05/98	20.007	1.1	82		102.007		2063.0		2049.0		2056.0	84.84		7.60		
	05/06/98	19		46		65		2011.0		2063.0		2037.0	84.83		9.30		
	05/07/98	15		0		15		-	2.1	2011.0	2.2	2013.3	83.67		10.20		10.20
	05/08/98	0.000	1.1	0		0.000		-	2.1	-	2.2	2018.0	84.59	3	7.70		
	05/09/98					52.160	1.3.a	2025.0	2.1	-	2.2	2022.7	85.51	3	7.13	4	
	05/10/98	13		82		95	1.4	2005.0		2025.0		2015.0	86.43		6.57	4	
	05/11/98	33		55		88		2004.0		2005.0		2004.5	87.35		6.00		
	05/12/98	21		73		94		2033.0		2004.0		2018.5	86.04		8.40		
	05/13/98	4		41		45		2088.0		2033.0		2060.5	89.84		7.80	4	
	05/14/98	10		123		133		2027.0		2088.0		2057.5	88.35		7.20		
	05/15/98	20		138		158		2017.0		2027.0		2022.0	86.46		6.75	4	
	05/16/98	26		106		132		2019.0		2017.0		2018.0	86.21		6.30		
	05/17/98	19		94		113		2028.0		2019.0		2023.5	84.03		2.10		
	05/18/98	16		73		89		2023.0		2028.0		2025.5	87.32		7.40		
	05/19/98	45		184.433	1.2	229.433		2016.0		2023.0		2019.5	85.33		4.90		
	05/20/98	15		65		80		2027.0		2016.0		2021.5	87.00		5.40		
	05/21/98	10		27		37		2010.0		2027.0		2018.5	87.08		5.40		
	05/22/98	10		49		59	1.4	2036.0		2010.0		2023.0	87.19		9.10		
	05/23/98	23		94.266	1.2	117.266		2033.0		2036.0		2034.5	86.68		8.40	4	
	05/24/98	11		42		53		2061.0		2033.0		2047.0	87.75		7.70		
	05/25/98	6		34		40		2077.0		2061.0		2069.0	85.72		7.20		
	05/26/98	14		57		71		2067.0		2077.0		2072.0	86.70		6.35	4	
	05/27/98	0		5		5	1.4	2060.0		2067.0		2063.5	85.40		5.50		
	05/28/98	4		37		41		2086.0		2060.0		2073.0	88.73		5.75	4	
	05/29/98	12		39		51		2035.0		2086.0		2060.5	91.31		6.00		
	05/30/98	6		33		39		2034.0		2035.0		2034.5	90.92		6.13	4	
	05/31/98	0		0		29.817	1.3.b	2053.0		2034.0		2043.5	93.80	3	6.27	4	
	06/01/98	6		0		6		1929.0		2053.0		1991.0	96.67		6.40		
	06/02/98	4		50		54		1671.0		1929.0		1800.0	89.07		6.70		
	06/03/98	0		29		29		1551.0		1671.0		1611.0	89.00		6.70		
	06/04/98	0.000	1.1	0		0.000		1527.0		1551.0		1539.0	91.06	3	6.90	4	
	06/05/98	10		66		76	1.4	1537.0		1527.0		1532.0	93.12		7.10	4	
	06/06/98	1		4.099	1.2	5.099		1531.0		1537.0		1534.0	100.50		7.30		
	06/07/98	0		0		17.874	1.3.b	1536.0		1531.0		1533.5	98.23	3	7.30		
	06/08/98	0		0.000	1.2	0.000		1539.0		1536.0		1537.5	95.95	3	6.85	4	
	06/09/98	9		57		66		1515.0		1539.0		1527.0	93.68		6.40		
	06/10/98	1		0		1		1528.0		1515.0		1521.5	96.00		7.85	4	
	06/11/98	4		11		15		1557.0		1528.0		1542.5	93.93		9.30		
	06/12/98	3.904	1.1	16		19.904		1593.0		1557.0		1575.0	93.50		9.53	4	
	06/13/98	16		9		25		1564.0		1593.0		1578.5	94.54		9.75	4	
	06/14/98	1		9		10		1565.0		1564.0		1564.5	95.30		9.98	4	
	06/15/98	0		0		0		1621.0		1565.0		1593.0	95.90	3	10.20		10.20
	06/16/98	2		4		6		1697.0		1621.0		1659.0	96.50		12.70	4	12.70
	06/17/98	1		0		1		1947.0		1697.0		1822.0	105.00		15.20		15.20
	06/18/98	0		2		2		2082.0		1947.0		2014.5	101.50		13.66	4	13.66
	06/19/98	0.000	1.1	0		0.000		2146.0		2082.0		2114.0	100.38	3	12.11	4	12.11
	06/20/98					1.748	1.3.a	2154.0		2146.0		2150.0	99.25	3	10.57	4	10.57
	06/21/98					1.818	1.3.a	2132.0		2154.0		2143.0	98.13	3	9.03	4	
	06/22/98	0		1		1		2127.0		2132.0		2129.5	97.00		7.49	4	
	06/23/98	1		1		2		2119.0		2127.0		2123.0	92.00		5.94	4	
	06/24/98	0		3		3		2130.0		2119.0		2124.5	104.67		4.40		
	06/25/98	0		0.000	1.2	0.000		2155.0		2130.0		2142.5	106.14	3	4.10		
	06/26/98	0		0		1.630	1.3.b	2105.0		2155.0		2130.0	107.60	3	4.19	4	
	06/27/98					1.398	1.3.a	2094.0		2105.0		2099.5	109.07	3	4.27	4	
	06/28/98					1.230	1.3.a	2110.0		2094.0		2102.0	110.53	3	4.36	4	
	06/29/98	0		1		1		2120.0		2110.0		2115.0	112.00		4.44	4	
	06/30/98	1		1		2		2120.0		2120.0		2120.0	109.00		4.53	4	
	07/01/98	0		0		0		2112.0		2120.0		2116.0	106.00	3	4.61	4	
	07/02/98	0		0.000	1.2	0.000		2112.0		2112.0		2112.0	103.00	3	4.70	4	

		COUNT					FLOW (cfs)			SIZE		TURBIDITY (NTU)		
COHORT	DATE	North Trap	South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day		Used for fit
	07/03/98	0	2		2		2116.0	2112.0	2114.0	100.00		4.79	4	
	07/04/98				0.749	1.3.a	2115.0	2116.0	2115.5	100.00	3	4.87	4	
	07/05/98				0.526	1.3.a	2125.0	2115.0	2120.0	100.00	3	4.96	4	
	07/06/98				0.316	1.3.a	2097.0	2125.0	2111.0	100.00	3	5.04	4	
	07/07/98	0	0		0		2077.0	2097.0	2087.0	100.00	3	5.13	4	
	07/08/98	0	0.000	1.2	0.000		2110.0	2077.0	2093.5	100.00	3	5.21	4	
	07/09/98	0	0		0		2009.0	2110.0	2059.5	100.00	3	5.30		
	07/10/98	0	0.000	1.2	0.000		1861.0	2009.0	1935.0	100.00	3	4.20		
	07/11/98				0.000	1.3.a	1830.0	1861.0	1845.5	100.00	3	4.53	4	
	07/12/98				0.000	1.3.a	1828.0	1830.0	1829.0	100.00	3	4.87	4	
	07/13/98	0	0		0		1810.0	1828.0	1819.0	100.00	3	5.20		
	07/14/98	0	0		0		1799.0	1810.0	1804.5	100.00	3	5.00	4	
	07/15/98				0.000	1.3.a	1808.0	1799.0	1803.5	100.00	3	4.80		
	07/16/98	0	0		0		1805.0	1808.0	1806.5	100.00	3	4.60		

1.1 North Trap = South Trap*(North-to-South-Trap Ratio)
1.2 South Trap = North Trap/(North-to-South-Trap Ratio)
1.3.a Missing value estimate for count (see text)
1.3.b Missing value estimate for count because both traps stopped, total of north and south trap not the value used (see text)
1.4 Actual North + Actual South Trap even though there was trap stoppage (adjusted value for stoppage produced smaller count).
2.1 Missing value flow estimate for predictor variable (see text)
2.2 Missing value flow estimate for predictor variable (see text)
3. Missing value length estimate for predictor variable (see text)
4. Missing value turbidity estimate for predictor variable (see text)

Appendix A.4.d. Variables used to estimate 1999 Outmigration

		COUNT				FLOW (cfs)			SIZE	TURBIDITY (NTU)	
COHORT	DATE	North Trap	South Trap	Total		Current Day	Previous Day	Average	(Length, mm)	Current Day	Used for fit
Fry	01/18/99	13.0	0.0	13.0		1192.0	1157.0	1174.5	34.62	6.80	
	01/19/99	10.0	6.0	16.0		1428.0	1192.0	1310.0	35.38	8.90	
	01/20/99	111.0	1.0	112.0		2037.0	1428.0	1732.5	34.14	16.40	16.40
	01/21/99	1535.0	71.0	1606.0	1.4	2471.0	2037.0	2254.0	34.65	25.50	25.50
	01/22/99	1738.0	111.0	1849.0		2888.0	2471.0	2679.5	34.88	12.00	12.00
	01/23/99	793.0	19.0	812.0		3052.0	2888.0	2970.0	35.10	5.40	
	01/24/99	185.0	0.0	185.0		2901.0	3052.0	2976.5	34.64	9.60	
	01/25/99	938.0	0.0	938.0		2876.0	2901.0	2888.5	34.48	6.40	
	01/26/99	688.0	78.0	766.0		3276.0	2876.0	3076.0	35.33	6.30	
	01/27/99	590.0	156.0	746.0		3607.0	3276.0	3441.5	34.89	7.50	
	01/28/99	909.0	0.0	909.0		3399.0	3607.0	3503.0	34.24	3.30	
	01/29/99	578.0	45.0	623.0		2930.0	3399.0	3164.5	34.85	7.10	
	01/30/99	486.0	105.0	591.0		2308.0	2930.0	2619.0	34.58	5.40	
	01/31/99	395.0	226.0	621.0		2057.0	2308.0	2182.5	34.49	2.10	
	02/01/99	187.0	123.0	310.0		1658.0	2057.0	1857.5	35.65	7.40	
	02/02/99	569.0	356.0	925.0		1719.0	1658.0	1688.5	34.97	4.50	
	02/03/99	330.0	203.0	533.0		2104.0	1719.0	1911.5	35.25	4.00	
	02/04/99	392.0	190.0	582.0		2205.0	2104.0	2154.5	34.98	5.80	
	02/05/99	358.0	228.0	586.0		2652.0	2205.0	2428.5	35.43	4.80	
	02/06/99	798.0	312.0	1110.0		2649.0	2652.0	2650.5	34.02	6.20	
	02/07/99	535.0	188.0	723.0		2901.0	2649.0	2775.0	35.30	4.30	
	02/08/99	379.0	32.0	411.0		3110.0	2901.0	3005.5	34.91	5.90	
	02/09/99	1382.0	8.0	1390.0		3278.0	3110.0	3194.0	35.17	10.70	10.70
	02/10/99	1921.0	401.0	2322.0		3228.0	3278.0	3253.0	35.26	23.40	23.40
	02/11/99	1903.0	0.0	1903.0		3896.0	3228.0	3562.0	34.36	16.50	16.50
	02/12/99	1326.0	906.0	2232.0		4209.0	3896.0	4052.5	35.27	8.00	
	02/13/99	1261.0	175.0	1436.0		4183.0	4209.0	4196.0	35.57	6.50	
	02/14/99	855.0	288.0	1143.0		4166.0	4183.0	4174.5	35.60	11.50	11.50
	02/15/99	1520.0	2.0	1522.0		3995.0	4166.0	4080.5	35.00	2.10	
	02/16/99	42.0	114.0	156.0		3557.0	3995.0	3776.0	35.82	6.80	
	02/17/99	613.0	130.0	743.0		3863.0	3557.0	3710.0	35.47	7.20	
	02/18/99	527.0	40.0	567.0		4296.0	3863.0	4079.5	35.78	5.40	
	02/19/99	978.0	0.0	978.0		4129.0	4296.0	4212.5	34.30	5.70	
	02/20/99	761.0	136.0	897.0		4316.0	4129.0	4222.5	36.45	10.60	10.60

		COUNT					FLOW (cfs)			SIZE		TURBIDITY (NTU)	
COHORT	DATE	North Trap	South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day	Used for fit
	02/21/99	740.0	287.0		1027.0		4291.0	4316.0	4303.5	35.31		7.90	
	02/22/99	799.0	335.0		1134.0		4158.0	4291.0	4224.5	35.31		5.80	
	02/23/99	767.0	35.0		802.0		4432.0	4158.0	4295.0	35.72		3.40	
	02/24/99	503.0	277.0		780.0		4325.0	4432.0	4378.5	35.28		4.40	
	02/25/99	353.0	138.0		491.0		4261.0	4325.0	4293.0	34.11		3.30	
	02/26/99	242.0	154.0		396.0		4284.0	4261.0	4272.5	35.82		5.00	
	02/27/99	268.0	86.0		354.0		4207.0	4284.0	4245.5	34.88		2.90	
	02/28/99	213.0	116.0		329.0		3842.0	4207.0	4024.5	35.27		3.00	
	03/01/99	162.0	75.0		237.0		3535.0	3842.0	3688.5	35.33		4.00	
	03/02/99	208.0	106.0		314.0		2800.0	3535.0	3167.5	37.08		4.70	
	03/03/99	113.0	31.0		144.0	1.4	2861.0	2800.0	2830.5	37.36		7.70	
	03/04/99	86.0	19.2	1.2	105.2		2840.0	2861.0	2850.5	36.76		6.00	
	03/05/99	179.0	75.0	1.2	254.0	1.4	2641.0	2840.0	2740.5	39.45		4.10	
	03/06/99	158.0	159.0	1.2	317.0	1.4	2135.0	2641.0	2388.0	40.33		3.80	
	03/07/99	54.0	24.0	1.2	78.0	1.4	1738.0	2135.0	1936.5	41.41		3.30	
	03/08/99	66.0	22.0	1.2	88.0	1.4	1727.0	1738.0	1732.5	40.93		5.00	
	03/09/99	43.0	50.0		93.0		1736.0	1727.0	1731.5	41.51		5.70	
	03/10/99	31.0	78.0		109.0		1734.0	1736.0	1735.0	41.02		5.10	
	03/11/99	19.0	20.0		39.0		1730.0	1734.0	1732.0	37.38		3.60	
	03/12/99	12.0	27.0		39.0	1.4	1727.0	1730.0	1728.5	37.36		4.40	
	03/13/99				56.2	1.3.a	1724.0	1727.0	1725.5	38.98	3	2.30	
	03/14/99	16.0	23.0		39.0	1.4	1722.0	1724.0	1723.0	40.59		4.10	
	03/15/99	14.0	24.0		38.0		1729.0	1722.0	1725.5	42.29		4.00	
Parr	03/16/99	11	14		38.4	1.3.b	1643.0	1729.0	1686.0	48.84		3.70	
	03/17/99				38.4	1.3.a	1577.0	1643.0	1610.0	46.95	3	4.15	4
	03/18/99	28.0	30.0		58.0	1.4	1602.0	1577.0	1589.5	45.05		4.60	
	03/19/99	13.0	23.4	1.2	36.4		1595.0	1602.0	1598.5	46.00		4.20	
	03/20/99	15.0	24.0		39.0		1450.0	1595.0	1522.5	46.19		4.80	
	03/21/99	10.0	18.0	1.2	28.0		1283.0	1450.0	1366.5	50.29		4.10	
	03/22/99	9.0	12.0		21.0		1172.0	1283.0	1227.5	45.86		4.40	
	03/23/99	8.0	10.0		18.0		1175.0	1172.0	1173.5	51.67		4.30	
	03/24/99				27.7	1.3.a	1119.0	1175.0	1147.0	52.05	3	4.25	4
	03/25/99	2.0	12.0		14.0		1124.0	1119.0	1121.5	52.43		4.20	
	03/26/99	19.0	20.0		39.0		1124.0	1124.0	1124.0	51.82		4.80	
	03/27/99	20.0	41.0		61.0		1121.0	1124.0	1122.5	53.57		3.70	
	03/28/99	22.0	35.0		57.0		1124.0	1121.0	1122.5	55.71		4.50	
	03/29/99	23.0	30.0		53.0		1124.0	1124.0	1124.0	52.96		4.50	
	03/30/99	5.0	15.0		20.0		1146.0	1124.0	1135.0	57.80		5.20	
	03/31/99	4.0	10.0		14.0		1116.0	1146.0	1131.0	57.64		4.00	
	04/01/99	14.0	49.0		63.0		1111.0	1116.0	1113.5	63.50		3.60	
	04/02/99	13.0	64.0		77.0		1123.0	1111.0	1117.0	61.70		3.20	
	04/03/99	9.0	38.0		47.0		1146.0	1123.0	1134.5	64.15		2.10	
	04/04/99	27.0	82.0		109.0	1.4	1116.0	1146.0	1131.0	64.29		2.20	
	04/05/99	10.0	16.0		26.0		1135.0	1116.0	1125.5	62.54		4.40	
	04/06/99	10.0	25.0		35.0		1117.0	1135.0	1126.0	64.97		3.60	
	04/07/99	8.0	15.0		23.0		1111.0	1117.0	1114.0	60.22		3.50	
	04/08/99	6.0	5.0		11.0		1121.0	1111.0	1116.0	66.45		3.80	
	04/09/99	11.0	19.8	1.2	30.8		1115.0	1121.0	1118.0	65.00		4.40	
	04/10/99	10.0	11.0		21.0		1108.0	1115.0	1111.5	65.14		3.10	
	04/11/99	3.0	4.0		7.0		1124.0	1108.0	1116.0	66.43		3.20	
	04/12/99	10.0	23.0		33.0		1113.0	1124.0	1118.5	73.58		2.83	4
	04/13/99	8.0	10.0		18.0		1129.0	1113.0	1121.0	74.67		2.45	4
	04/14/99	20.0	18.0		38.0		1169.0	1129.0	1149.0	73.84		2.08	4
	04/15/99	23.0	23.0		46.0		1348.0	1169.0	1258.5	69.49		1.70	
	04/16/99	28.0	50.3	1.2	78.3		1368.0	1348.0	1358.0	70.21		3.30	
	04/17/99	12.0	45.0		57.0		1366.0	1368.0	1367.0	74.39		3.80	
	04/18/99	21.0	31.0		52.0		1363.0	1366.0	1364.5	75.58		4.60	
	04/19/99	16.0	43.0		59.0		1369.0	1363.0	1366.0	74.43		5.30	
	04/20/99	27.0	11.0		38.0		1372.0	1369.0	1370.5	74.39		4.20	
	04/21/99	19.0	8.0		27.0		1377.0	1372.0	1374.5	77.15		4.30	
	04/22/99	15.0	13.0		28.0		1366.0	1377.0	1371.5	73.14		4.00	
	04/23/99	12.0	21.6	1.2	33.6		1364.0	1366.0	1365.0	77.92		3.70	
	04/24/99	27.0	22.0		49.0		1380.0	1364.0	1372.0	80.02		5.70	

		COUNT						FLOW (cfs)			SIZE		TURBIDITY (NTU)	
COHORT	DATE	North Trap		South Trap		Total		Current Day	Previous Day	Average	(Length, mm)		Current Day	Used for fit
	04/25/99	15.0		25.0		40.0		1382.0	1380.0	1381.0	78.22		3.00	
	04/26/99	10.0		35.0		45.0		1373.0	1382.0	1377.5	77.71		5.00	
	04/27/99	12.0		24.0		36.0	1.4	883.0	1373.0	1128.0	76.53		3.40	
	04/28/99	20.0		34.0		54.0		1010.0	883.0	946.5	76.72		3.80	
	04/29/99	5		30		52.2	1.3.b	1399.0	1010.0	1204.5	78.69		4.20	
	04/30/99	12.0		23.0		35.0	1.4	1372.0	1399.0	1385.5	76.74		5.00	
	05/01/99	17.0		42.0		59.0	1.4	1364.0	1372.0	1368.0	78.98		4.60	
	05/02/99	24.0		68.0		92.0		1384.0	1364.0	1374.0	81.80		3.10	
	05/03/99	9.0		25.0		34.0		1416.0	1384.0	1400.0	77.85		2.30	
	05/04/99	0.0		15.0		15.0	1.4	1392.0	1416.0	1404.0	80.93		4.00	
	05/05/99	5		4		67.1	1.3.b	1389.0	1392.0	1390.5	81.00		4.20	
	05/06/99	45.0		74.0		119.0		1372.0	1389.0	1380.5	78.29		3.97	4
	05/07/99	16.0		39.0		55.0		1355.0	1372.0	1363.5	78.53		3.73	4
	05/08/99	24.0		40.0		64.0		1348.0	1355.0	1351.5	79.31		3.50	
	05/09/99	23.0		45.0		68.0		1348.0	1348.0	1348.0	79.78		4.60	
Smolt	05/10/99	16.0		39.0		55.0		1352.0	1348.0	1350.0	80.02		4.40	
	05/11/99	5.0		18.0		23.0	1.4	1345.0	1352.0	1348.5	83.05		4.90	
	05/12/99	15.0		47.0		62.0		1339.0	1345.0	1342.0	81.48		3.00	
	05/13/99	10.0		37.0		47.0		1344.0	1339.0	1341.5	78.83		6.00	
	05/14/99	24.0		48.0		72.0		1349.0	1344.0	1346.5	81.53		6.00	
	05/15/99	25.0		15.0		40.0		1347.0	1349.0	1348.0	80.92		2.30	
	05/16/99	19.0		31.0		50.0		1342.0	1347.0	1344.5	80.74		5.00	
	05/17/99	15.0		34.0		49.0		1341.0	1342.0	1341.5	81.78		5.00	
	05/18/99	34.0		61.0		95.0		1339.0	1341.0	1340.0	82.99		5.80	
	05/19/99	18.0		20.0		38.0		1412.0	1339.0	1375.5	83.16		5.00	
	05/20/99	11.0		29.0		40.0		1534.0	1412.0	1473.0	82.83		4.70	
	05/21/99	42.0		84.0		126.0		1533.0	1534.0	1533.5	82.74		5.00	
	05/22/99	37.0		84.7	1.2	121.7		1523.0	1533.0	1528.0	83.88		4.00	
	05/23/99	15.0		60.0		75.0		1527.0	1523.0	1525.0	84.54		4.10	
	05/24/99	11.0		54.0		65.0		1525.0	1527.0	1526.0	82.85		4.20	4
	05/25/99	13.0		0.0		13.0	1.4	1532.0	1525.0	1528.5	83.38		4.30	
	05/26/99	18.0		100.0		118.0		1521.0	1532.0	1526.5	85.01		0.00	
	05/27/99	19.0		54.0		73.0		1520.0	1521.0	1520.5	84.93		5.50	
	05/28/99	5.0		22.0		27.0		1371.0	1520.0	1445.5	86.31		5.60	
	05/29/99					54.7	1.3.a	1124.0	1371.0	1247.5	85.80	3	5.65	4
	05/30/99					52.6	1.3.a	1122.0	1124.0	1123.0	85.30	3	5.70	4
	05/31/99					49.3	1.3.a	1114.0	1122.0	1118.0	84.79	3	5.75	4
	06/01/99	32.0		49.0		81.0		1229.0	1114.0	1171.5	84.28		5.80	
	06/02/99	14.0		13.0		27.0		1365.0	1229.0	1297.0	87.07		6.40	
	06/03/99	22.0		37.0		59.0		1369.0	1365.0	1367.0	86.64		6.30	
	06/04/99	18.0		37.0		55.0		1360.0	1369.0	1364.5	84.33		4.50	
	06/05/99	5.0		18.0		23.0		1356.0	1360.0	1358.0	84.96		1.40	
	06/06/99	4.0		9.2	1.2	13.2		1362.0	1356.0	1359.0	85.00		5.40	
	06/07/99	5.0		26.0		31.0		1433.0	1362.0	1397.5	87.29		4.40	
	06/08/99	7.0		23.0		30.0		1516.0	1433.0	1474.5	85.43		4.80	
	06/09/99	17.0		17.0		34.0		1522.0	1516.0	1519.0	88.94		5.10	
	06/10/99	6.0		12.0		18.0		1518.0	1522.0	1520.0	89.17		2.00	
	06/11/99	4.0		25.0		29.0		1525.0	1518.0	1521.5	88.14		5.20	
	06/12/99					23.7	1.3.a	1521.0	1525.0	1523.0	88.09	3	5.17	4
	06/13/99					19.5	1.3.a	1522.0	1521.0	1521.5	88.05	3	5.13	4
	06/14/99	2.0		4.6	1.2	6.6		1521.0	1522.0	1521.5	88.00		5.10	
	06/15/99	2.0		4.6	1.2	6.6		1527.0	1521.0	1524.0	92.00		5.20	
	06/16/99	3.0		9.0		12.0		1535.0	1527.0	1531.0	92.08		4.00	
	06/17/99	8.0		7.0		15.0		1531.0	1535.0	1533.0	91.86		4.40	
	06/18/99	3.0		4.0		7.0		1528.0	1531.0	1529.5	86.86		7.30	
	06/19/99					7.0	1.3.a	1529.0	1528.0	1528.5	89.24	3	6.53	4
	06/20/99					6.0	1.3.a	1535.0	1529.0	1532.0	91.62	3	5.77	4
	06/21/99	0.0		2.0		2.0		1525.0	1535.0	1530.0	94.00		5.00	
	06/22/99	3.9	1.1	9.0		12.9		1530.0	1525.0	1527.5	90.44		4.60	
	06/23/99	2.0		4.0		6.0		1386.0	1530.0	1458.0	93.00		3.40	
	06/24/99	2.0		4.0		6.0		1130.0	1386.0	1258.0	89.60		4.80	
	06/25/99	2.0		3.0		5.0		992.0	1130.0	1061.0	93.40		4.00	
	06/26/99					4.0	1.3.a	994.0	992.0	993.0	94.27	3	4.63	4

		COUNT					FLOW (cfs)			SIZE		TURBIDITY (NTU)	
COHORT	DATE	North Trap		South Trap	Total		Current Day	Previous Day	Average	(Length, mm)		Current Day	Used for fit
	06/27/99				3.6	1.3.a	992.0	994.0	993.0	95.13	3	5.27	4
	06/28/99	0.4	1.1	1.0	1.4		953.0	992.0	972.5	96.00		5.90	
	06/29/99	0.0		1.0	1.0		846.0	953.0	899.5	103.00		4.60	
	06/30/99	2.0		2.0	4.0		841.0	846.0	843.5	92.75		4.60	

1.1 North Trap = South Trap*(North-to-South-Trap Ratio)
1.2 South Trap = North Trap/(North-to-South-Trap Ratio)
1.3.a Missing value estimate for count (see text)
1.3.b Missing value estimate for count because both traps stopped, total of north and south trap not the value used (see text)
1.4 Actual North + Actual South Trap even though there was trap stoppage (adjusted value for stoppage produced smaller count).
2.1 Missing value flow estimate for predictor variable (see text)
2.2 Missing value flow estimate for predictor variable (see text)
3. Missing value length estimate for predictor variable (see text)
4. Missing value turbidity estimate for predictor variable (see text)

Appendix A.5.a. 1996 Outmigration index estimates based on efficiency predictor that included turbidity > 10

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
02/06/96	89.0	0.0998	892	233	892	233	Fry	892	233
02/07/96	99.2	0.1129	879	322	1,771	510		1,771	510
02/08/96	49.5	0.1154	429	379	2,200	711		2,200	711
02/09/96	13.0	0.1159	112	209	2,312	764		2,312	764
02/10/96	2.0	0.2116	10	33	2,321	766		2,321	766
02/11/96	0.0	0.2252	0	13	2,321	766		2,321	766
02/12/96	6.0	0.1890	32	17	2,353	770		2,353	770
02/13/96	2.0	0.1915	10	72	2,364	774		2,364	774
02/14/96	28.0	0.1754	160	110	2,523	793		2,523	793
02/15/96	39.0	0.1374	284	75	2,807	813		2,807	813
02/16/96	21.3	0.1238	172	98	2,979	826		2,979	826
02/17/96	44.0	0.0929	474	202	3,453	878		3,453	878
02/18/96	57.0	0.0410	1,391	337	4,844	1,083		4,844	1,083
02/19/96	52.0	0.0355	1,467	433	6,311	1,350		6,311	1,350
02/20/96	37.0	0.0468	790	221	7,101	1,420		7,101	1,420
02/21/96	48.4	0.0134	3,616	1,276	10,717	2,286		10,717	2,286
02/22/96	43.1	0.0136	3,160	2,889	13,877	4,183		13,877	4,183
02/23/96	113.0	0.0144	7,864	4,120	21,741	7,031		21,741	7,031
02/24/96	18.0	0.0328	551	1,568	22,292	7,290		22,292	7,290
02/25/96	24.0	0.0305	788	306	23,079	7,429		23,079	7,429
02/26/96	11.0	0.0276	399	255	23,478	7,506		23,478	7,506
02/27/96	16.0	0.0254	630	218	24,107	7,628		24,107	7,628
02/28/96	11.0	0.0209	527	301	24,634	7,743		24,634	7,743
02/29/96	5.0	0.0074	676	485	25,310	7,966		25,310	7,966
03/01/96	6.0	0.0066	909	454	26,219	8,292		26,219	8,292
03/02/96	7.7	0.0066	1,177	543	27,396	8,717		27,396	8,717
03/03/96	6.8	0.0066	1,031	502	28,427	9,094		28,427	9,094
03/04/96	4.8	0.0066	732	424	29,159	9,364		29,159	9,364
03/05/96	2.8	0.0061	448	404	29,607	9,536		29,607	9,536
03/06/96	0.0	0.0060	0	305	29,607	9,541		29,607	9,541

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
03/07/96	4.0	0.0062	641	434	30,248	9,776		30,248	9,776
03/08/96	4.0	0.0063	631	368	30,879	10,009		30,879	10,009
03/09/96	1.0	0.0064	156	300	31,035	10,071		31,035	10,071
03/10/96	0.0	0.0067	0	78	31,035	10,071		31,035	10,071
03/11/96	0.0	0.0073	0	71	31,035	10,072		31,035	10,072
03/12/96	1.0	0.0081	124	83	31,159	10,116		31,159	10,116
03/13/96	0.0	0.0176	0	31	31,159	10,116		31,159	10,116
03/14/96	1.0	0.0082	122	80	31,281	10,156		31,281	10,156
03/15/96	0.0	0.0080	0	67	31,281	10,156		31,281	10,156
03/16/96	1.0	0.0076	132	86	31,413	10,198		31,413	10,198
03/17/96	0.0	0.0081	0	114	31,413	10,198		31,413	10,198
03/18/96	2.0	0.0087	231	153	31,644	10,279		31,644	10,279
03/19/96	0.0	0.0083	0	110	31,644	10,279		31,644	10,279
03/20/96	1.0	0.0081	123	81	31,767	10,320		31,767	10,320
03/21/96	0.0	0.0077	0	69	31,767	10,320	Parr	0	0
03/22/96	0.0	0.0076	0	0	31,767	10,320		0	0
03/23/96	0.0	0.0088	0	0	31,767	10,320		0	0
03/24/96	0.0	0.0109	0	0	31,767	10,320		0	0
03/25/96	0.0	0.0125	0	180	31,767	10,322		0	180
03/26/96	4.0	0.0147	272	142	32,038	10,354		272	230
03/27/96	2.0	0.0176	114	142	32,152	10,366		385	273
03/28/96	7.0	0.0184	381	224	32,533	10,397		766	363
03/29/96	10.0	0.0199	502	187	33,035	10,429		1,268	426
03/30/96	3.0	0.0237	127	152	33,162	10,439		1,395	458
03/31/96	5.0	0.0249	201	50	33,362	10,450		1,596	470
04/01/96	3.0	0.0218	138	55	33,500	10,454	Smolt	138	17
04/02/96	3.0	0.0210	143	138	33,643	10,458		281	141
04/03/96	8.0	0.0223	359	343	34,002	10,477		640	375
04/04/96	18.0	0.0226	798	259	34,800	10,512		1,438	470
04/05/96	9.0	0.0225	401	205	35,201	10,530		1,839	527
04/06/96	14.0	0.0214	655	148	35,856	10,552		2,494	578
04/07/96	13.0	0.0241	540	304	36,396	10,586		3,034	676
04/08/96	1.0	0.0232	43	258	36,439	10,591		3,077	726
04/09/96	8.0	0.0221	362	164	36,802	10,604		3,440	764
04/10/96	4.0	0.0233	171	131	36,973	10,613		3,611	784
04/11/96	2.0	0.0222	90	162	37,063	10,618		3,701	806
04/12/96	9.0	0.0232	388	178	37,451	10,635		4,089	846
04/13/96	2.0	0.0256	78	184	37,529	10,639		4,167	870
04/14/96	0.0	0.0264	0	200	37,529	10,641		4,167	893
04/15/96	10.0	0.0257	389	209	37,918	10,649		4,556	936
04/16/96	2.0	0.0222	90	180	38,008	10,650		4,646	960
04/17/96	5.2	0.0226	230	97	38,238	10,653		4,876	980
04/18/96	6.0	0.0237	253	230	38,492	10,663		5,129	1,021
04/19/96	15.0	0.0236	636	307	39,128	10,684		5,766	1,104
04/20/96	1.0	0.0233	43	456	39,171	10,695		5,808	1,197
04/21/96	22.0	0.0232	950	764	40,121	10,737		6,758	1,471
04/22/96	36.0	0.0228	1,577	684	41,698	10,782		8,335	1,711
04/23/96	52.1	0.0232	2,243	463	43,940	10,835		10,578	1,913

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
04/24/96	38.0	0.0232	1,636	390	45,577	10,879		12,214	2,073
04/25/96	39.0	0.0226	1,729	228	47,306	10,915		13,944	2,233
04/26/96	38.0	0.0228	1,669	1,437	48,975	11,050		15,613	2,783
04/27/96	95.0	0.0229	4,140	1,707	53,115	11,289		19,753	3,548
04/28/96	109.0	0.0229	4,769	756	57,885	11,456		24,522	4,007
04/29/96	89.0	0.0226	3,937	941	61,822	11,640		28,460	4,470
04/30/96	125.0	0.0227	5,514	1,105	67,336	11,934		33,974	5,108
05/01/96	93.8	0.0226	4,145	1,077	71,481	12,190		38,119	5,630
05/02/96	84.0	0.0222	3,792	661	75,273	12,408		41,911	6,080
05/03/96	75.2	0.0470	1,602	368	76,875	12,411		43,513	6,279
05/04/96	67.0	0.0231	2,899	975	79,774	12,621		46,412	6,656
05/05/96	107.0	0.0224	4,780	1,153	84,554	12,964		51,192	7,289
05/06/96	73.0	0.0233	3,130	1,437	87,684	13,244		54,322	7,760
05/07/96	42.0	0.0230	1,826	755	89,510	13,388		56,148	8,000
05/08/96	47.0	0.0229	2,048	291	91,558	13,532		58,196	8,235
05/09/96	47.0	0.0231	2,036	287	93,594	13,679		60,232	8,466
05/10/96	52.1	0.0231	2,254	397	95,848	13,850		62,485	8,723
05/11/96	60.0	0.0229	2,619	977	98,467	14,079		65,104	9,074
05/12/96	20.0	0.0233	858	864	99,325	14,170		65,963	9,212
05/13/96	35.8	0.0231	1,554	421	100,879	14,293		67,516	9,399
05/14/96	33.9	0.0227	1,495	255	102,374	14,413		69,011	9,581
05/15/96	28.7	0.0213	1,349	407	103,723	14,531		70,361	9,775
05/16/96	19.0	0.0227	839	424	104,562	14,606		71,199	9,881
05/17/96	10.0	0.0219	457	213	105,018	14,647		71,656	9,941
05/18/96	14.0	0.0217	645	141	105,664	14,703		72,301	10,027
05/19/96	10.0	0.0209	478	226	106,141	14,747		72,779	10,098
05/20/96	19.0	0.0216	881	330	107,022	14,828		73,660	10,218
05/21/96	23.0	0.0217	1,061	331	108,084	14,925		74,722	10,362
05/22/96	10.4	0.0235	442	330	108,526	14,963		75,164	10,421
05/23/96	9.0	0.0285	316	173	108,842	14,979		75,480	10,458
05/24/96	18.0	0.0366	492	328	109,334	14,989		75,971	10,507
05/25/96	32.5	0.0402	807	436	110,141	14,994		76,779	10,583
05/26/96	52.0	0.0405	1,284	349	111,425	14,997		78,063	10,697
05/27/96	30.0	0.0403	744	468	112,168	15,006		78,806	10,767
05/28/96	15.0	0.0392	382	197	112,551	15,010		79,189	10,803
05/29/96	22.0	0.0402	547	177	113,098	15,014		79,736	10,849
05/30/96	9.0	0.0404	223	180	113,321	15,016		79,959	10,869
05/31/96	10.0	0.0393	254	40	113,575	15,018		80,213	10,893
06/01/96	10.0	0.0384	261	43	113,836	15,021		80,474	10,919
06/02/96	11.0	0.0386	285	133	114,121	15,024		80,758	10,947
06/03/96	2.0	0.0409	49	111	114,170	15,025		80,807	10,952
06/04/96	5.2	0.0382	136	69	114,306	15,026		80,944	10,966
06/05/96	7.0	0.0371	189	62	114,495	15,029		81,133	10,988
06/06/96	3.0	0.0379	79	81	114,574	15,030		81,212	10,997
06/07/96	1.0	0.0408	25	37	114,598	15,030		81,236	10,999
06/08/96	4.0	0.0326	123	50	114,721	15,034		81,359	11,013
06/09/96	2.0	0.0308	65	43	114,786	15,037		81,424	11,020
06/10/96	1.5	0.0315	48	33	114,833	15,040		81,471	11,025

Date	Count	Efficiency	Outmigration Daily Estimate	S.E.	Outmigration Cumulative Estimate	S.E.	Life-Stage Cohort	Cohort Cumulative Outmigration Estimate	S.E.
06/11/96	0.0	0.0318	0	47	114,833	15,040		81,471	11,025
06/12/96	3.0	0.0321	94	48	114,927	15,044		81,565	11,033
06/13/96	2.0	0.0312	64	22	114,991	15,047		81,629	11,039
06/14/96	3.2	0.0336	97	50	115,088	15,050		81,726	11,046
06/15/96	0.0	0.0364	0	51	115,088	15,050		81,726	11,047
06/16/96	0.0	0.0402	0	14	115,088	15,050		81,726	11,047
06/17/96	1.0	0.0438	23	13	115,111	15,050		81,748	11,048
06/18/96	0.0	0.0444	0	13	115,111	15,050		81,748	11,048
06/19/96	0.0	0.0437	0	0	115,111	15,050		81,748	11,048
06/20/96	0.0	0.0433	0	13	115,111	15,050		81,748	11,048
06/21/96	1.0	0.0429	23	14	115,134	15,050		81,772	11,050
06/22/96	0.0	0.0398	0	14	115,134	15,050		81,772	11,050
06/23/96	1.0	0.0371	27	16	115,161	15,051		81,799	11,054
06/24/96	1.0	0.0395	25	15	115,186	15,051		81,824	11,057
06/25/96	0.0	0.0404	0	14	115,186	15,051		81,824	11,057
06/26/96	0.0	0.0415	0	14	115,186	15,051		81,824	11,057
06/27/96	1.0	0.0432	23	14	115,209	15,051		81,847	11,059
06/28/96	0.0	0.0417	0	14	115,209	15,051		81,847	11,059
06/29/96	0.0	0.0406	0	14	115,209	15,051		81,847	11,059
06/30/96	1.0	0.0395	25	15	115,235	15,051		81,872	11,062
07/01/96	1.0	0.0432	23	4	115,258	15,051		81,896	11,065

Appendix A.5.b. 1997 Outmigration index estimates based on efficiency predictor that <u>included</u> turbidity > 10

Date	Count	Efficiency	Outmigration Daily Estimate	S.E.	Outmigration Cumulative Estimate	S.E.	Life-Stage Cohort	Cohort Cumulative Outmigration Estimate	S.E.
03/19/97	15.0	0.0714	210	30	210	30	Parr	210	30
03/20/97	17.0	0.0598	284	186	494	192		494	192
03/21/97	35.0	0.0710	493	164	987	268		987	268
03/22/97	36.0	0.0641	562	133	1,549	327		1,549	327
03/23/97	48.0	0.0688	697	125	2,246	397		2,246	397
03/24/97	42.0	0.0793	530	122	2,775	457		2,775	457
03/25/97	32.0	0.0932	344	83	3,119	494		3,119	494
03/26/97	30.0	0.1309	229	58	3,348	524		3,348	524
03/27/97	22.0	0.1607	137	38	3,485	544		3,485	544
03/28/97	28.0	0.1508	186	45	3,671	572		3,671	572
03/29/97	21.0	0.1321	159	127	3,830	605		3,830	605
03/30/97	52.5	0.0588	892	303	4,722	716		4,722	716
03/31/97	30.0	0.1188	252	106	4,975	758		4,975	758
04/01/97	45.0	0.1278	352	105	5,327	813		5,327	813
04/02/97	24.3	0.1210	201	99	5,528	849		5,528	849
04/03/97	27.0	0.1173	230	48	5,758	886		5,758	886
04/04/97	28.0	0.0610	459	204	6,217	941		6,217	941
04/05/97	48.0	0.0605	794	235	7,011	1,031		7,011	1,037

			Outmigration					Cohort Cumulative Outmigration	
			Daily		Cumulative		Life-Stage		
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
04/06/97	51.0	0.0594	858	164	7,869	1,122	Smolt	858	190
04/07/97	39.0	0.0585	667	234	8,536	1,215		1,525	341
04/08/97	26.0	0.0581	447	188	8,983	1,279		1,972	427
04/09/97	46.4	0.0595	780	307	9,763	1,396		2,752	587
04/10/97	60.0	0.0598	1,003	205	10,766	1,519		3,755	712
04/11/97	44.0	0.0581	758	181	11,524	1,621		4,513	817
04/12/97	49.0	0.0554	884	135	12,408	1,729		5,397	925
04/13/97	45.0	0.0911	494	158	12,901	1,802		5,891	983
04/14/97	68.0	0.0730	931	590	13,833	1,983		6,822	1,190
04/15/97	126.5	0.0600	2,108	610	15,941	2,226		8,930	1,417
04/16/97	104.5	0.0545	1,918	529	17,858	2,467		10,847	1,658
04/17/97	81.0	0.0555	1,460	608	19,318	2,701		12,308	1,911
04/18/97	43.0	0.0581	740	523	20,058	2,841		13,047	2,066
04/19/97	22.0	0.0679	324	225	20,382	2,892		13,371	2,118
04/20/97	51.0	0.0627	813	289	21,196	3,020		14,185	2,247
04/21/97	28.0	0.0593	472	214	21,668	3,090		14,657	2,319
04/22/97	44.0	0.0547	804	338	22,471	3,215		15,461	2,448
04/23/97	10.0	0.0526	190	374	22,662	3,263		15,651	2,502
04/24/97	9.0	0.0514	175	185	22,836	3,290		15,826	2,531
04/25/97	26.0	0.0497	523	251	23,359	3,364		16,348	2,607
04/26/97	32.0	0.0503	636	200	23,995	3,451		16,985	2,696
04/27/97	15.0	0.0493	304	195	24,300	3,495		17,289	2,742
04/28/97	16.5	0.0226	731	165	25,030	3,538		18,019	2,790
04/29/97	21.0	0.0239	878	239	25,908	3,583		18,898	2,842
04/30/97	27.0	0.0235	1,150	545	27,058	3,683		20,047	2,958
05/01/97	3.0	0.0223	135	535	27,193	3,731		20,182	3,016
05/02/97	15.0	0.0238	630	836	27,822	3,855		20,811	3,164
05/03/97	42.0	0.0242	1,737	587	29,559	3,986		22,549	3,312
05/04/97	28.0	0.0238	1,175	433	30,734	4,083		23,724	3,418
05/05/97	47.0	0.0244	1,929	803	32,663	4,268		25,652	3,626
05/06/97	9.0	0.0234	385	814	33,048	4,374		26,037	3,746
05/07/97	32.0	0.0235	1,360	553	34,407	4,509		27,397	3,891
05/08/97	29.0	0.0240	1,210	154	35,618	4,595		28,607	3,983
05/09/97	31.0	0.0241	1,287	225	36,904	4,689		29,894	4,082
05/10/97	23.0	0.0243	945	239	37,850	4,756		30,839	4,155
05/11/97	21.0	0.0238	883	413	38,733	4,843		31,722	4,248
05/12/97	38.5	0.0247	1,560	440	40,292	4,968		33,282	4,382
05/13/97	38.5	0.0247	1,556	247	41,849	5,093		34,838	4,513
05/14/97	31.0	0.0311	997	163	42,846	5,181		35,835	4,599
05/15/97	35.6	0.0308	1,154	727	44,000	5,336		36,989	4,757
05/16/97	71.5	0.0245	2,921	1,013	46,921	5,684		39,910	5,123
05/17/97	27.5	0.0246	1,120	916	48,041	5,852		41,030	5,302
05/18/97	42.0	0.0244	1,723	734	49,764	6,048		42,753	5,507
05/19/97	62.0	0.0243	2,552	540	52,316	6,292		45,305	5,760
05/20/97	44.0	0.0246	1,790	815	54,106	6,500		47,095	5,977
05/21/97	23.0	0.0249	923	439	55,029	6,595		48,018	6,076
05/22/97	30.0	0.0242	1,241	271	56,270	6,721		49,260	6,204
05/23/97	33.8	0.0248	1,363	196	57,633	6,863		50,622	6,348

			Outmigration					Cohort Cumulative	
			Daily		Cumulative			Outmigration	
Date	**Count**	**Efficiency**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Life-Stage Cohort**	**Estimate**	**S.E.**
05/24/97	34.6	0.0286	1,209	164	58,842	6,992		51,831	6,476
05/25/97	31.0	0.0330	940	339	59,782	7,088		52,771	6,569
05/26/97	51.0	0.0335	1,521	615	61,303	7,247		54,293	6,726
05/27/97	11.0	0.0308	357	647	61,660	7,309		54,649	6,790
05/28/97	33.0	0.0265	1,247	616	62,907	7,454		55,897	6,938
05/29/97	42.0	0.0241	1,741	656	64,648	7,653		57,637	7,142
05/30/97	12.5	0.0265	472	709	65,120	7,726		58,109	7,218
05/31/97	7.0	0.0280	250	172	65,371	7,752		58,360	7,244
06/01/97	3.0	0.0288	104	138	65,475	7,765		58,464	7,257
06/02/97	11.0	0.0314	351	132	65,825	7,798		58,814	7,290
06/03/97	7.0	0.0278	252	163	66,077	7,823		59,066	7,315
06/04/97	2.0	0.0498	40	57	66,117	7,830		59,106	7,321
06/05/97	7.0	0.0535	131	67	66,248	7,847		59,237	7,338
06/06/97	8.6	0.0529	162	61	66,409	7,870		59,399	7,359
06/07/97	3.0	0.0676	44	52	66,454	7,875		59,443	7,365
06/08/97	2.0	0.0822	24	134	66,478	7,880		59,467	7,370
06/09/97	22.0	0.1008	218	118	66,696	7,912		59,685	7,398
06/10/97	3.7	0.1005	37	95	66,733	7,918		59,722	7,404
06/11/97	7.0	0.0973	72	24	66,805	7,929		59,794	7,414
06/12/97	6.0	0.1039	58	16	66,862	7,937		59,852	7,421
06/13/97	5.0	0.1030	49	18	66,911	7,943		59,900	7,426
06/14/97	3.0	0.0954	31	17	66,942	7,948		59,932	7,431
06/15/97	2.0	0.0960	21	22	66,963	7,951		59,952	7,434
06/16/97	6.0	0.0963	62	29	67,026	7,959		60,015	7,441
06/17/97	1.2	0.0890	14	27	67,039	7,961		60,029	7,442
06/18/97	3.0	0.0890	34	17	67,073	7,966		60,062	7,447
06/19/97	4.0	0.0889	45	12	67,118	7,973		60,107	7,453
06/20/97	3.0	0.0832	36	11	67,154	7,979		60,143	7,458
06/21/97	4.0	0.0890	45	11	67,199	7,985		60,188	7,464
06/22/97	4.0	0.0415	96	31	67,295	7,994		60,285	7,473
06/23/97	2.0	0.0824	24	19	67,320	7,998		60,309	7,476
06/24/97	1.0	0.0414	24	24	67,344	8,000		60,333	7,478
06/25/97	0.0	0.0853	0	7	67,344	8,000		60,333	7,478
06/26/97	0.0	0.0876	0	0	67,344	8,000		60,333	7,478
06/27/97	0.0	0.0919	0	0	67,344	8,000		60,333	7,478

Appendix A.5.c. 1998 Outmigration index estimates based on efficiency predictor that included turbidity > 10

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
01/29/98	802.0	0.1018	7,879	3,852	7,879	3,852	Fry	7,879	3,852
01/30/98	286.0	0.1017	2,812	2,699	10,691	4,890		10,691	4,890
01/31/98	703.9	0.1078	6,531	2,521	17,222	6,009		17,222	6,009
02/01/98	678.1	0.1122	6,042	2,364	23,263	7,120		23,263	7,120
02/02/98	1085.0	0.1168	9,287	3,744	32,550	9,170		32,550	9,170
02/03/98	332.0	0.1722	1,928	2,179	34,478	9,782		34,478	9,782
02/04/98	643.3	0.2304	2,792	1,161	37,270	10,424		37,270	10,424
02/05/98	693.1	0.3012	2,301	749	39,572	10,973		39,572	10,973
02/06/98	759.1	0.3828	1,983	662	41,555	11,461		41,555	11,461
02/07/98	850.6	0.4717	1,803	712	43,358	11,903		43,358	11,903
02/08/98	1180.0	0.5624	2,098	663	45,456	12,379		45,456	12,379
02/09/98	1091.1	0.4597	2,374	748	47,830	12,982		47,830	12,982
02/10/98	1045.7	0.3603	2,903	929	50,733	13,764		50,733	13,764
02/11/98	1011.8	0.2715	3,726	1,197	54,459	14,773		54,459	14,773
02/12/98	862.4	0.1979	4,357	1,280	58,816	15,879		58,816	15,879
02/13/98	897.0	0.1404	6,388	1,550	65,204	17,292		65,204	17,292
02/14/98	849.0	0.1210	7,015	1,731	72,219	18,765		72,219	18,765
02/15/98	1022.0	0.1037	9,858	8,849	82,076	22,357		82,076	22,357
02/16/98	2509.0	0.0440	57,012	27,239	139,088	37,423		139,088	37,423
02/17/98	227.0	0.0876	2,592	15,356	141,680	40,741		141,680	40,741
02/18/98	62.0	0.0903	687	1,214	142,367	40,838		142,367	40,838
02/19/98	273.0	0.0992	2,752	1,579	145,119	41,203		145,119	41,203
02/20/98	352.0	0.1360	2,587	757	147,706	41,581		147,706	41,581
02/21/98	393.0	0.1641	2,395	661	150,102	41,959		150,102	41,959
02/22/98	316.0	0.0923	3,423	1,587	153,525	42,404		153,525	42,404
02/23/98	128.5	0.1236	1,040	788	154,565	42,561		154,565	42,561
02/24/98	191.0	0.0906	2,108	551	156,673	42,823		156,673	42,823
02/25/98	188.0	0.0448	4,201	710	160,873	43,108		160,873	43,108
02/26/98	159.0	0.0434	3,662	681	164,535	43,354		164,535	43,354
02/27/98	149.0	0.0432	3,447	494	167,982	43,587		167,982	43,587
02/28/98	162.0	0.0423	3,827	953	171,810	43,851		171,810	43,851
03/01/98	97.0	0.0421	2,302	828	174,112	44,013		174,112	44,013
03/02/98	123.0	0.0432	2,850	683	176,962	44,216		176,962	44,216
03/03/98	74.0	0.0425	1,741	659	178,702	44,342		178,702	44,342
03/04/98	81.2	0.0425	1,909	469	180,611	44,478		180,611	44,478
03/05/98	49.0	0.0382	1,283	487	181,894	44,560		181,894	44,560
03/06/98	52.0	0.0760	684	695	182,578	44,645		182,578	44,645
03/07/98	142.0	0.0412	3,451	1,231	186,029	44,897		186,029	44,908
03/08/98	124.0	0.0328	3,786	4,740	189,815	45,337	Parr	3,786	5,982
03/09/98	402.0	0.0330	12,198	4,945	202,013	46,227		15,984	7,827
03/10/98	394.0	0.0326	12,086	3,028	214,099	46,956		28,070	8,643
03/11/98	242.0	0.0331	7,317	2,484	221,416	47,428		35,387	9,243
03/12/98	352.0	0.0326	10,804	4,515	232,221	48,238		46,191	10,689

			Outmigration					Cohort Cumulative Outmigration	
			Daily		Cumulative				
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Life-Stage Cohort	Estimate	S.E.
03/13/98	68.0	0.0304	2,234	5,280	234,454	48,641		48,425	12,013
03/14/98	77.0	0.0298	2,583	318	237,037	48,770		51,008	12,125
03/15/98	78.0	0.0333	2,342	582	239,379	48,913		53,350	12,247
03/16/98	108.0	0.0320	3,374	2,666	242,753	49,176		56,724	12,689
03/17/98	238.0	0.0308	7,721	3,626	250,474	49,722		64,445	13,543
03/18/98	20.0	0.0323	619	3,800	251,093	49,904		65,064	14,097
03/19/98	29.0	0.0304	953	406	252,047	49,957		66,017	14,149
03/20/98	43.9	0.0268	1,634	511	253,681	50,030		67,651	14,232
03/21/98	55.0	0.0325	1,692	783	255,372	50,137		69,343	14,340
03/22/98	7.3	0.0434	169	653	255,541	50,155		69,511	14,365
03/23/98	58.5	0.0249	2,347	1,157	257,888	50,258		71,859	14,516
03/24/98	54.0	0.0837	645	169	258,532	50,338		72,503	14,544
03/25/98	48.0	0.0234	2,053	11,124	260,586	51,619		74,556	18,383
03/26/98	504.0	0.0267	18,887	8,711	279,472	53,150		93,443	21,002
03/27/98	279.2	0.0243	11,500	8,674	290,973	54,288		104,944	23,164
03/28/98	85.0	0.1618	526	649	291,498	54,373		105,469	23,194
03/29/98	102.3	0.0719	1,423	414	292,921	54,534		106,892	23,260
03/30/98	123.0	0.0231	5,315	1,319	298,236	54,745		112,207	23,528
03/31/98	68.4	0.0227	3,014	1,391	301,250	54,872		115,221	23,706
04/01/98	71.0	0.0233	3,048	385	304,298	54,991		118,269	23,853
04/02/98	62.0	0.0209	2,968	1,135	307,266	55,097		121,236	24,020
04/03/98	105.0	0.0233	4,505	3,683	311,770	55,399		125,741	24,521
04/04/98	227.0	0.0580	3,915	1,858	315,685	55,828		129,656	24,798
04/05/98	302.0	0.0233	12,976	2,741	328,661	56,426		142,632	25,610
04/06/98	194.7	0.0263	7,389	2,163	336,050	56,845		150,021	26,109
04/07/98	254.0	0.0235	10,796	2,738	346,846	57,396		160,817	26,870
04/08/98	312.0	0.0231	13,496	4,187	360,342	58,162		174,312	27,999
04/09/98	133.3	0.0238	5,595	5,099	365,937	58,662		179,908	28,811
04/10/98	80.4	0.0236	3,404	1,354	369,341	58,847		183,312	29,062
04/11/98	79.0	0.0218	3,621	476	372,962	59,015		186,933	29,306
04/12/98	71.0	0.0209	3,391	1,466	376,353	59,183		190,324	29,574
04/13/98	24.0	0.0200	1,200	1,341	377,553	59,249		191,524	29,688
04/14/98	25.0	0.0167	1,500	548	379,052	59,301		193,023	29,804
04/15/98	39.0	0.0164	2,374	586	381,427	59,382		195,398	29,987
04/16/98	27.0	0.0183	1,479	657	382,906	59,443		196,877	30,103
04/17/98	16.0	0.0182	879	573	383,785	59,480		197,756	30,175
04/18/98	36.5	0.0201	1,821	1,472	385,606	59,580		199,577	30,343
04/19/98	74.0	0.0180	4,119	1,567	389,726	59,763		203,696	30,696
04/20/98	23.0	0.0198	1,160	1,510	390,886	59,835		204,856	30,820
04/21/98	21.0	0.0182	1,154	231	392,040	59,883		206,011	30,911
04/22/98	27.0	0.0158	1,711	637	393,751	59,947		207,722	31,058
04/23/98	39.0	0.0178	2,190	736	395,940	60,042		209,911	31,238
04/24/98	51.0	0.0168	3,026	689	398,967	60,166	Smolt	3,026	504
04/25/98	56.1	0.0169	3,312	649	402,279	60,305		6,338	1,063
04/26/98	42.0	0.0175	2,395	552	404,673	60,411		8,733	1,448
04/27/98	44.0	0.0177	2,487	1,095	407,161	60,532		11,220	2,055
04/28/98	75.0	0.0161	4,671	1,238	411,831	60,738		15,891	2,866
04/29/98	67.0	0.0175	3,830	601	415,661	60,919		19,721	3,353

			Outmigration					Cohort Cumulative Outmigration	
			Daily		Cumulative		Life-Stage		
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
04/30/98	72.0	0.0162	4,443	1,320	420,104	61,133		24,164	4,138
05/01/98	101.0	0.0168	6,006	1,599	426,110	61,440		30,169	5,131
05/02/98	57.0	0.0168	3,388	1,807	429,498	61,636		33,557	5,854
05/03/98	45.0	0.0166	2,718	689	432,215	61,777		36,275	6,245
05/04/98	39.0	0.0302	1,293	1,161	433,508	61,909		37,568	6,542
05/05/98	102.0	0.0158	6,453	2,236	439,961	62,274		44,021	7,729
05/06/98	65.0	0.0158	4,111	2,805	444,072	62,553		48,132	8,753
05/07/98	15.0	0.0341	440	981	444,512	62,606		48,572	8,866
05/08/98	0.0	0.0159	0	1,667	444,512	62,628		48,572	9,021
05/09/98	52.2	0.0156	3,348	3,062	447,861	62,884		51,920	9,950
05/10/98	95.0	0.0153	6,222	1,815	454,082	63,250		58,142	10,913
05/11/98	88.0	0.0150	5,880	1,040	459,963	63,592		64,022	11,768
05/12/98	94.0	0.0154	6,104	1,991	466,067	63,988		70,126	12,765
05/13/98	45.0	0.0142	3,175	3,113	469,242	64,256		73,301	13,616
05/14/98	133.0	0.0146	9,083	4,298	478,325	64,965		82,385	15,526
05/15/98	158.0	0.0153	10,355	1,984	488,680	65,682		92,739	17,064
05/16/98	132.0	0.0153	8,604	2,044	497,283	66,316		101,343	18,400
05/17/98	113.0	0.0161	7,023	1,730	504,306	66,852		108,366	19,450
05/18/98	89.0	0.0150	5,943	5,046	510,250	67,489		114,309	20,965
05/19/98	229.4	0.0156	14,670	5,806	524,919	68,858		128,979	23,719
05/20/98	80.0	0.0151	5,305	6,662	530,224	69,610		134,284	25,395
05/21/98	37.0	0.0151	2,458	1,469	532,682	69,830		136,742	25,795
05/22/98	59.0	0.0150	3,929	2,803	536,611	70,215		140,670	26,518
05/23/98	117.3	0.0152	7,722	2,648	544,333	70,918		148,392	27,753
05/24/98	53.0	0.0148	3,573	2,815	547,905	71,287		151,965	28,429
05/25/98	40.0	0.0155	2,579	1,078	550,485	71,521		154,544	28,820
05/26/98	71.0	0.0152	4,677	2,285	555,162	71,972		159,222	29,595
05/27/98	5.0	0.0156	320	2,088	555,483	72,031		159,542	29,715
05/28/98	41.0	0.0145	2,824	1,714	558,306	72,309		162,366	30,200
05/29/98	51.0	0.0137	3,716	835	562,022	72,662		166,081	30,818
05/30/98	39.0	0.0138	2,817	918	564,839	72,934		168,899	31,292
05/31/98	29.8	0.0130	2,294	1,362	567,133	73,171		171,192	31,720
06/01/98	6.0	0.0122	492	1,925	567,624	73,245		171,684	31,869
06/02/98	54.0	0.0144	3,746	1,770	571,371	73,624		175,430	32,508
06/03/98	29.0	0.0144	2,009	1,877	573,380	73,842		177,439	32,880
06/04/98	0.0	0.0138	0	2,730	573,380	73,892		177,439	32,993
06/05/98	76.0	0.0132	5,761	3,352	579,140	74,542		183,200	34,141
06/06/98	5.1	0.0112	454	3,281	579,595	74,663		183,654	34,388
06/07/98	17.9	0.0118	1,515	830	581,109	74,829		185,169	34,686
06/08/98	0.0	0.0124	0	2,693	581,109	74,877		185,169	34,790
06/09/98	66.0	0.0130	5,064	3,015	586,174	75,459		190,233	35,792
06/10/98	1.0	0.0124	81	2,702	586,255	75,516		190,314	35,908
06/11/98	15.0	0.0130	1,157	777	587,412	75,641		191,471	36,119
06/12/98	19.9	0.0131	1,521	479	588,933	75,803		192,993	36,387
06/13/98	25.0	0.0128	1,955	704	590,888	76,015		194,947	36,741
06/14/98	10.0	0.0126	795	993	591,683	76,107		195,742	36,899
06/15/98	0.0	0.0262	0	186	591,683	76,107		195,742	36,899
06/16/98	6.0	0.0310	193	113	591,876	76,138		195,936	36,935

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
06/17/98	1.0	0.0310	32	82	591,909	76,143		195,968	36,942
06/18/98	2.0	0.0299	67	38	591,976	76,154		196,035	36,955
06/19/98	0.0	0.0274	0	38	591,976	76,154		196,035	36,955
06/20/98	1.7	0.0251	70	44	592,045	76,165		196,105	36,969
06/21/98	1.8	0.0118	154	50	592,199	76,182		196,259	36,998
06/22/98	1.0	0.0121	83	46	592,282	76,191		196,341	37,014
06/23/98	2.0	0.0135	148	78	592,430	76,207		196,489	37,039
06/24/98	3.0	0.0102	293	161	592,722	76,241		196,782	37,102
06/25/98	0.0	0.0099	0	147	592,722	76,241		196,782	37,103
06/26/98	1.6	0.0096	170	99	592,892	76,262		196,952	37,141
06/27/98	1.4	0.0093	150	45	593,042	76,280		197,102	37,175
06/28/98	1.2	0.0090	137	43	593,179	76,297		197,238	37,208
06/29/98	1.0	0.0087	115	66	593,294	76,311		197,353	37,235
06/30/98	2.0	0.0093	215	118	593,508	76,337		197,568	37,285
07/01/98	0.0	0.0099	0	112	593,508	76,337		197,568	37,285
07/02/98	0.0	0.0106	0	106	593,508	76,337		197,568	37,285
07/03/98	2.0	0.0113	176	95	593,684	76,357		197,744	37,320
07/04/98	0.7	0.0113	66	70	593,750	76,365		197,810	37,333
07/05/98	0.5	0.0113	46	21	593,797	76,370		197,856	37,343
07/06/98	0.3	0.0113	28	24	593,825	76,373		197,884	37,348
07/07/98	0.0	0.0113	0	16	593,825	76,373		197,884	37,348
07/08/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/09/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/10/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/11/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/12/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/13/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/14/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/15/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348
07/16/98	0.0	0.0113	0	0	593,825	76,373		197,884	37,348

Appendix A.5.d. 1999 Outmigration index estimates based on efficiency predictor that included turbidity > 10

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
01/18/99	13	0.0260	501	97	501	97	Fry	501	97
01/19/99	16	0.0260	616	2,158	1,117	2,162		1,117	2,162
01/20/99	112	0.0831	1,347	10,424	2,464	10,647		2,464	10,647
01/21/99	1,606	0.1517	10,585	6,789	13,049	12,721		13,049	12,721
01/22/99	1,849	0.0613	30,168	10,407	43,216	17,668		43,216	17,668
01/23/99	812	0.0260	31,272	32,353	74,488	37,236		74,488	37,236
01/24/99	185	0.0260	7,125	15,466	81,613	40,458		81,613	40,458
01/25/99	938	0.0260	36,125	15,575	117,737	44,062		117,737	44,062
01/26/99	766	0.0260	29,501	5,079	147,238	45,178		147,238	45,178
01/27/99	746	0.0260	28,730	4,534	175,968	46,388		175,968	46,388
01/28/99	909	0.0260	35,008	6,596	210,976	48,241		210,976	48,241

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	**Count**	**Efficiency**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Cohort**	**Estimate**	**S.E.**
01/29/99	623	0.0260	23,993	7,157	234,969	49,870		234,969	49,870
01/30/99	591	0.0260	22,761	2,469	257,730	51,068		257,730	51,068
01/31/99	621	0.0260	23,916	7,028	281,646	52,819		281,646	52,819
02/01/99	310	0.0260	11,939	11,844	293,585	54,795		293,585	54,795
02/02/99	925	0.0260	35,624	12,490	329,209	58,169		329,209	58,169
02/03/99	533	0.0260	20,527	8,456	349,736	60,006		349,736	60,006
02/04/99	582	0.0260	22,414	2,595	372,150	61,452		372,150	61,452
02/05/99	586	0.0260	22,568	11,868	394,718	64,018		394,718	64,018
02/06/99	1,110	0.0260	42,749	11,322	437,467	67,754		437,467	67,754
02/07/99	723	0.0260	27,844	13,723	465,311	71,006		465,311	71,006
02/08/99	411	0.0260	15,829	19,227	481,140	74,636		481,140	74,636
02/09/99	1,390	0.0559	24,848	17,376	505,988	78,634		505,988	78,634
02/10/99	2,322	0.1326	17,507	6,303	523,495	80,718		523,495	80,718
02/11/99	1,903	0.0837	22,733	5,975	546,227	83,427		546,227	83,427
02/12/99	2,232	0.0260	85,960	17,747	632,187	91,007		632,187	91,007
02/13/99	1,436	0.0260	55,304	22,341	687,491	97,635		687,491	97,635
02/14/99	1,143	0.0592	19,314	4,859	706,805	99,818		706,805	99,818
02/15/99	1,522	0.0260	58,616	27,693	765,421	107,800		765,421	107,800
02/16/99	156	0.0260	6,008	26,254	771,429	111,396		771,429	111,396
02/17/99	743	0.0260	28,615	11,917	800,044	114,131		800,044	114,131
02/18/99	567	0.0260	21,837	8,219	821,880	116,058		821,880	116,058
02/19/99	978	0.0260	37,665	9,216	859,545	119,250		859,545	119,250
02/20/99	897	0.0555	16,149	3,061	875,694	120,977		875,694	120,977
02/21/99	1,027	0.0260	39,552	6,136	915,246	124,171		915,246	124,171
02/22/99	1,134	0.0260	43,673	7,927	958,919	127,836		958,919	127,836
02/23/99	802	0.0260	30,887	8,250	989,806	130,568		989,806	130,568
02/24/99	780	0.0260	30,040	7,348	1,019,845	133,201		1,019,845	133,201
02/25/99	491	0.0260	18,910	7,910	1,038,755	134,984		1,038,755	134,984
02/26/99	396	0.0260	15,251	3,123	1,054,006	136,278		1,054,006	136,278
02/27/99	354	0.0260	13,633	1,923	1,067,639	137,423		1,067,639	137,423
02/28/99	329	0.0260	12,671	2,704	1,080,310	138,507		1,080,310	138,507
03/01/99	237	0.0260	9,127	2,116	1,089,437	139,288		1,089,437	139,288
03/02/99	314	0.0260	12,093	3,496	1,101,530	140,347		1,101,530	140,347
03/03/99	144	0.0260	5,546	4,292	1,107,076	140,881		1,107,076	140,881
03/04/99	105	0.0260	4,053	2,986	1,111,129	141,256		1,111,129	141,256
03/05/99	254	0.0260	9,782	4,288	1,120,911	142,148		1,120,911	142,148
03/06/99	317	0.0260	12,208	4,912	1,133,119	143,266		1,133,119	143,266
03/07/99	78	0.0260	3,004	5,188	1,136,123	143,616		1,136,123	143,616
03/08/99	88	0.0260	3,389	459	1,139,512	143,905		1,139,512	143,905
03/09/99	93	0.0260	3,582	562	1,143,094	144,212		1,143,094	144,212
03/10/99	109	0.0260	4,198	1,471	1,147,292	144,578		1,147,292	144,578
03/11/99	39	0.0260	1,502	1,556	1,148,794	144,714		1,148,794	144,714
03/12/99	39	0.0260	1,502	411	1,150,296	144,843		1,150,296	144,843
03/13/99	56	0.0260	2,163	442	1,152,459	145,029		1,152,459	145,029
03/14/99	39	0.0260	1,502	421	1,153,961	145,159		1,153,961	145,159
03/15/99	38	0.0260	1,464	154	1,155,424	145,284		1,155,424	145,284
03/16/99	38	0.0260	1,478	154	1,156,902	145,411	Parr	1,478	154
03/17/99	38	0.0260	1,480	460	1,158,382	145,538		2,958	532
03/18/99	58	0.0260	2,234	513	1,160,616	145,731		5,191	830
03/19/99	36	0.0260	1,401	475	1,162,017	145,852		6,592	1,036
03/20/99	39	0.0260	1,502	270	1,163,519	145,981		8,094	1,167
03/21/99	28	0.0260	1,078	365	1,164,596	146,074		9,172	1,298
03/22/99	21	0.0260	809	214	1,165,405	146,144		9,981	1,375
03/23/99	18	0.0260	693	203	1,166,098	146,204		10,674	1,443
03/24/99	28	0.0260	1,066	291	1,167,164	146,296		11,739	1,554
03/25/99	14	0.0260	539	483	1,167,703	146,343		12,279	1,669
03/26/99	39	0.0260	1,502	914	1,169,205	146,475		13,781	2,005
03/27/99	61	0.0260	2,349	511	1,171,554	146,678		16,130	2,233
03/28/99	57	0.0260	2,195	275	1,173,749	146,867		18,325	2,414
03/29/99	53	0.0260	2,041	806	1,175,790	147,045		20,366	2,700
03/30/99	20	0.0260	770	808	1,176,561	147,114		21,136	2,879

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	**Count**	**Efficiency**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Cohort**	**Estimate**	**S.E.**
03/31/99	14	0.0260	539	1,025	1,177,100	147,164		21,676	3,096
04/01/99	63	0.0260	2,426	1,292	1,179,526	147,379		24,102	3,521
04/02/99	77	0.0260	2,966	653	1,182,492	147,636		27,067	3,791
04/03/99	47	0.0260	1,810	1,203	1,184,302	147,797		28,877	4,109
04/04/99	109	0.0260	4,198	1,710	1,188,500	148,169		33,075	4,737
04/05/99	26	0.0260	1,001	1,748	1,189,501	148,266		34,077	5,120
04/06/99	35	0.0260	1,348	277	1,190,849	148,383		35,424	5,224
04/07/99	23	0.0260	886	469	1,191,735	148,460		36,310	5,309
04/08/99	11	0.0260	424	384	1,192,158	148,498		36,734	5,354
04/09/99	31	0.0260	1,185	398	1,193,344	148,601		37,919	5,457
04/10/99	21	0.0260	809	466	1,194,152	148,671		38,728	5,537
04/11/99	7	0.0260	270	499	1,194,422	148,696		38,998	5,580
04/12/99	33	0.0260	1,271	517	1,195,693	148,807		40,268	5,699
04/13/99	18	0.0260	693	405	1,196,386	148,867		40,962	5,766
04/14/99	38	0.0260	1,464	573	1,197,849	148,995		42,425	5,906
04/15/99	46	0.0260	1,772	839	1,199,621	149,151		44,197	6,100
04/16/99	78	0.0260	3,017	704	1,202,638	149,414		47,214	6,372
04/17/99	57	0.0260	2,195	583	1,204,833	149,606		49,409	6,572
04/18/99	52	0.0260	2,003	250	1,206,836	149,780		51,412	6,738
04/19/99	59	0.0260	2,272	473	1,209,108	149,978		53,684	6,940
04/20/99	38	0.0260	1,464	641	1,210,572	150,107		55,147	7,091
04/21/99	27	0.0260	1,040	257	1,211,612	150,197		56,187	7,183
04/22/99	28	0.0260	1,078	176	1,212,690	150,291		57,266	7,276
04/23/99	34	0.0260	1,293	438	1,213,983	150,404		58,559	7,399
04/24/99	49	0.0260	1,887	356	1,215,870	150,569		60,446	7,567
04/25/99	40	0.0260	1,541	236	1,217,411	150,703		61,986	7,703
04/26/99	45	0.0260	1,733	250	1,219,144	150,854		63,719	7,857
04/27/99	36	0.0260	1,386	374	1,220,530	150,976		65,106	7,987
04/28/99	54	0.0260	2,080	437	1,222,610	151,158		67,185	8,181
04/29/99	52	0.0260	2,009	453	1,224,618	151,333		69,194	8,370
04/30/99	35	0.0260	1,348	494	1,225,966	151,452		70,542	8,505
05/01/99	59	0.0260	2,272	1,121	1,228,238	151,654		72,814	8,779
05/02/99	92	0.0260	3,543	1,174	1,231,782	151,968		76,357	9,168
05/03/99	34	0.0260	1,309	1,543	1,233,091	152,090		77,667	9,413
05/04/99	15	0.0260	578	1,013	1,233,669	152,144		78,244	9,518
05/05/99	67	0.0260	2,586	2,010	1,236,254	152,384		80,830	9,951
05/06/99	119	0.0260	4,583	1,387	1,240,837	152,790		85,413	10,440
05/07/99	55	0.0260	2,118	1,345	1,242,956	152,982		87,531	10,711
05/08/99	64	0.0260	2,465	362	1,245,420	153,198		89,996	10,934
05/09/99	68	0.0260	2,619	374	1,248,039	153,428		92,615	11,169
05/10/99	55	0.0260	2,118	914	1,250,157	153,617	Smolt	2,118	894
05/11/99	23	0.0260	886	802	1,251,043	153,697		3,004	1,218
05/12/99	62	0.0260	2,388	794	1,253,431	153,908		5,392	1,506
05/13/99	47	0.0260	1,810	518	1,255,241	154,068		7,202	1,658
05/14/99	72	0.0260	2,773	706	1,258,014	154,313		9,975	1,919
05/15/99	40	0.0260	1,541	647	1,259,554	154,450		11,515	2,106
05/16/99	50	0.0260	1,926	291	1,261,480	154,620		13,441	2,236
05/17/99	49	0.0260	1,887	1,025	1,263,367	154,789		15,328	2,569
05/18/99	95	0.0260	3,659	1,219	1,267,026	155,116		18,987	3,051
05/19/99	38	0.0260	1,464	1,248	1,268,489	155,250		20,450	3,386
05/20/99	40	0.0260	1,541	1,931	1,270,030	155,397		21,991	3,985
05/21/99	126	0.0260	4,853	1,924	1,274,882	155,837		26,843	4,680
05/22/99	122	0.0260	4,687	1,189	1,279,570	156,254		31,531	5,103
05/23/99	75	0.0260	2,888	1,198	1,282,458	156,514		34,419	5,427
05/24/99	65	0.0260	2,503	1,301	1,284,961	156,741		36,922	5,746
05/25/99	13	0.0260	501	2,012	1,285,462	156,798		37,423	6,121
05/26/99	118	0.0260	4,545	2,073	1,290,007	157,213		41,967	6,742
05/27/99	73	0.0260	2,811	1,767	1,292,818	157,472		44,779	7,151
05/28/99	27	0.0260	1,040	894	1,293,858	157,566		45,819	7,277
05/29/99	55	0.0260	2,107	630	1,295,965	157,754		47,926	7,446
05/30/99	53	0.0260	2,024	236	1,297,989	157,934		49,950	7,590

			Outmigration						
			Daily		Cumulative		Life-Stage	Cohort Cumulative Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
05/31/99	49	0.0260	1,897	697	1,299,886	158,103		51,847	7,756
06/01/99	81	0.0260	3,120	1,089	1,303,006	158,384		54,966	8,053
06/02/99	27	0.0260	1,040	1,046	1,304,045	158,479		56,006	8,196
06/03/99	59	0.0260	2,272	709	1,306,318	158,683		58,278	8,393
06/04/99	55	0.0260	2,118	787	1,308,436	158,873		60,397	8,588
06/05/99	23	0.0260	886	843	1,309,322	158,954		61,282	8,696
06/06/99	13	0.0260	507	346	1,309,828	158,999		61,789	8,742
06/07/99	31	0.0260	1,194	404	1,311,022	159,106		62,983	8,842
06/08/99	30	0.0260	1,155	144	1,312,178	159,208		64,138	8,932
06/09/99	34	0.0260	1,309	347	1,313,487	159,325		65,448	9,040
06/10/99	18	0.0260	693	322	1,314,180	159,387		66,141	9,100
06/11/99	29	0.0260	1,117	241	1,315,297	159,487		67,258	9,191
06/12/99	24	0.0260	911	206	1,316,208	159,568		68,169	9,265
06/13/99	20	0.0260	750	350	1,316,958	159,635		68,919	9,332
06/14/99	7	0.0260	253	286	1,317,211	159,658		69,172	9,356
06/15/99	7	0.0260	253	123	1,317,464	159,680		69,425	9,377
06/16/99	12	0.0260	462	170	1,317,927	159,722		69,887	9,416
06/17/99	15	0.0260	578	166	1,318,504	159,773		70,465	9,464
06/18/99	7	0.0260	270	180	1,318,774	159,797		70,735	9,487
06/19/99	7	0.0260	268	36	1,319,042	159,821		71,003	9,509
06/20/99	6	0.0260	229	103	1,319,271	159,842		71,232	9,528
06/21/99	2	0.0260	77	212	1,319,348	159,849		71,309	9,537
06/22/99	13	0.0260	498	218	1,319,846	159,893		71,807	9,580
06/23/99	6	0.0260	231	155	1,320,077	159,914		72,038	9,600
06/24/99	6	0.0260	231	33	1,320,308	159,934		72,269	9,619
06/25/99	5	0.0260	193	43	1,320,501	159,952		72,462	9,634
06/26/99	4	0.0260	154	32	1,320,655	159,965		72,616	9,647
06/27/99	4	0.0260	140	55	1,320,794	159,978		72,755	9,659
06/28/99	1	0.0260	55	54	1,320,850	159,983		72,811	9,663
06/29/99	1	0.0260	39	62	1,320,888	159,986		72,849	9,667
06/30/99	4	0.0260	154	83	1,321,042	160,000		73,003	9,680

Appendix A.6.a. **1996 Outmigration index estimates based on efficiency predictor that excluded turbidity > 10**

			Outmigration						
			Daily		Cumulative		Life-Stage	Cohort Cumulative Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
02/06/96	89.0	0.2032	438	172	438	172	Fry	438	172
02/07/96	99.2	0.2340	424	194	862	350		862	350
02/08/96	49.5	0.2407	206	184	1,068	457		1,068	457
02/09/96	13.0	0.2412	54	97	1,122	485		1,122	485
02/10/96	2.0	0.2204	9	30	1,131	489		1,131	489
02/11/96	0.0	0.1870	0	15	1,131	490		1,131	490
02/12/96	6.0	0.1731	35	21	1,165	502		1,165	502
02/13/96	2.0	0.1567	13	83	1,178	513		1,178	513
02/14/96	28.0	0.1256	223	164	1,401	604		1,401	604
02/15/96	39.0	0.0915	426	186	1,827	752		1,827	752
02/16/96	21.3	0.0730	292	188	2,119	864		2,119	864
02/17/96	44.0	0.0710	620	333	2,739	1,103		2,739	1,103
02/18/96	57.0	0.0709	804	318	3,543	1,389		3,543	1,389

			Outmigration				Life-	Cohort Cumulative	
			Daily		Cumulative		Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
02/19/96	52.0	0.0594	876	373	4,419	1,711		4,419	1,711
02/20/96	37.0	0.0326	1,134	506	5,553	2,127		5,553	2,127
02/21/96	48.4	0.0175	2,763	1,256	8,316	3,199		8,316	3,199
02/22/96	43.1	0.0179	2,406	2,220	10,722	4,620		10,722	4,620
02/23/96	113.0	0.0191	5,909	3,457	16,631	7,337		16,631	7,337
02/24/96	18.0	0.0151	1,195	3,188	17,826	8,425		17,826	8,425
02/25/96	24.0	0.0140	1,717	887	19,543	9,092		19,543	9,092
02/26/96	11.0	0.0137	802	561	20,344	9,415		20,344	9,415
02/27/96	16.0	0.0124	1,289	618	21,634	9,916		21,634	9,916
02/28/96	11.0	0.0106	1,033	657	22,667	10,325		22,667	10,325
02/29/96	5.0	0.0076	655	484	23,322	10,590		23,322	10,590
03/01/96	6.0	0.0072	837	475	24,159	10,972		24,159	10,972
03/02/96	7.7	0.0070	1,109	589	25,267	11,470		25,267	11,470
03/03/96	6.8	0.0068	993	541	26,261	11,910		26,261	11,910
03/04/96	4.8	0.0067	721	447	26,982	12,226		26,982	12,226
03/05/96	2.8	0.0060	459	417	27,441	12,428		27,441	12,428
03/06/96	0.0	0.0057	0	312	27,441	12,432		27,441	12,432
03/07/96	4.0	0.0058	684	477	28,125	12,714		28,125	12,714
03/08/96	4.0	0.0061	659	405	28,785	12,991		28,785	12,991
03/09/96	1.0	0.0063	160	300	28,944	13,062		28,944	13,062
03/10/96	0.0	0.0067	0	75	28,944	13,062		28,944	13,062
03/11/96	0.0	0.0077	0	66	28,944	13,062		28,944	13,062
03/12/96	1.0	0.0088	113	79	29,058	13,112		29,058	13,112
03/13/96	0.0	0.0085	0	60	29,058	13,112		29,058	13,112
03/14/96	1.0	0.0082	122	82	29,179	13,159		29,179	13,159
03/15/96	0.0	0.0076	0	69	29,179	13,159		29,179	13,159
03/16/96	1.0	0.0067	148	99	29,328	13,209		29,328	13,209
03/17/96	0.0	0.0081	0	111	29,328	13,210		29,328	13,210
03/18/96	2.0	0.0097	207	143	29,534	13,299		29,534	13,299
03/19/96	0.0	0.0088	0	102	29,534	13,300		29,534	13,300
03/20/96	1.0	0.0081	124	84	29,658	13,347		29,658	13,347
03/21/96	0.0	0.0070	0	75	29,658	13,347	Parr	0	0
03/22/96	0.0	0.0063	0	0	29,658	13,347		0	0
03/23/96	0.0	0.0071	0	0	29,658	13,347		0	0
03/24/96	0.0	0.0085	0	0	29,658	13,347		0	0
03/25/96	0.0	0.0094	0	239	29,658	13,349		0	239
03/26/96	4.0	0.0107	374	200	30,032	13,369		374	311
03/27/96	2.0	0.0136	147	184	30,179	13,377		521	367
03/28/96	7.0	0.0136	516	308	30,695	13,383		1,037	499
03/29/96	10.0	0.0148	677	264	31,372	13,378		1,714	605
03/30/96	3.0	0.0206	146	175	31,518	13,385		1,860	638
03/31/96	5.0	0.0217	230	58	31,749	13,391		2,090	654
04/01/96	3.0	0.0151	199	86	31,947	13,378	Smolt	199	42
04/02/96	3.0	0.0140	215	207	32,162	13,362		413	221
04/03/96	8.0	0.0165	485	464	32,647	13,352		898	529
04/04/96	18.0	0.0170	1,059	365	33,706	13,326		1,957	690
04/05/96	9.0	0.0169	531	277	34,237	13,316		2,489	784
04/06/96	14.0	0.0149	942	264	35,179	13,265		3,431	927

			Outmigration				Life-	Cohort Cumulative	
			Daily		Cumulative		Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
04/07/96	13.0	0.0201	646	365	35,825	13,281		4,076	1,042
04/08/96	1.0	0.0181	55	329	35,880	13,285		4,131	1,098
04/09/96	8.0	0.0158	507	240	36,387	13,264		4,638	1,185
04/10/96	4.0	0.0183	218	168	36,605	13,264		4,856	1,218
04/11/96	2.0	0.0162	124	220	36,728	13,261		4,980	1,254
04/12/96	9.0	0.0177	508	240	37,236	13,253		5,488	1,331
04/13/96	2.0	0.0207	97	227	37,333	13,254		5,585	1,359
04/14/96	0.0	0.0207	0	252	37,333	13,256		5,585	1,382
04/15/96	10.0	0.0194	517	284	37,850	13,232		6,101	1,469
04/16/96	2.0	0.0135	148	288	37,998	13,216		6,249	1,526
04/17/96	5.2	0.0151	344	159	38,342	13,188		6,593	1,590
04/18/96	6.0	0.0177	340	309	38,682	13,180		6,933	1,662
04/19/96	15.0	0.0172	874	438	39,555	13,147		7,807	1,832
04/20/96	1.0	0.0162	62	643	39,617	13,159		7,868	1,951
04/21/96	22.0	0.0159	1,380	1,120	40,997	13,113		9,249	2,430
04/22/96	36.0	0.0154	2,345	1,100	43,342	12,991		11,594	2,994
04/23/96	52.1	0.0160	3,251	889	46,593	12,844		14,845	3,597
04/24/96	38.0	0.0160	2,372	706	48,965	12,762		17,217	4,062
04/25/96	39.0	0.0149	2,623	644	51,588	12,656		19,840	4,622
04/26/96	38.0	0.0153	2,488	2,157	54,076	12,765		22,327	5,551
04/27/96	95.0	0.0155	6,137	2,758	60,213	12,948		28,465	7,195
04/28/96	109.0	0.0152	7,150	1,827	67,363	13,108		35,615	8,715
04/29/96	89.0	0.0150	5,939	1,850	73,302	13,453		41,554	10,091
04/30/96	125.0	0.0152	8,208	2,287	81,510	14,146		49,761	11,939
05/01/96	93.8	0.0151	6,190	2,003	87,699	14,839		55,951	13,384
05/02/96	84.0	0.0143	5,878	1,640	93,578	15,584		61,829	14,833
05/03/96	75.2	0.0147	5,124	1,404	98,702	16,302		66,953	16,075
05/04/96	67.0	0.0157	4,259	1,625	102,960	16,949		71,212	17,053
05/05/96	107.0	0.0145	7,396	2,387	110,357	18,222		78,608	18,943
05/06/96	73.0	0.0158	4,608	2,258	114,964	19,064		83,216	20,061
05/07/96	42.0	0.0153	2,750	1,249	117,714	19,564		85,965	20,730
05/08/96	47.0	0.0153	3,077	762	120,791	20,102		89,042	21,445
05/09/96	47.0	0.0155	3,030	734	123,820	20,635		92,072	22,135
05/10/96	52.1	0.0157	3,315	856	127,135	21,221		95,387	22,870
05/11/96	60.0	0.0153	3,933	1,645	131,068	21,995		99,320	23,825
05/12/96	20.0	0.0158	1,269	1,277	132,337	22,261		100,588	24,142
05/13/96	35.8	0.0154	2,335	783	134,672	22,711		102,923	24,694
05/14/96	33.9	0.0148	2,288	623	136,960	23,168		105,212	25,255
05/15/96	28.7	0.0127	2,267	897	139,226	23,715		107,478	25,936
05/16/96	19.0	0.0152	1,252	668	140,478	23,967		108,730	26,230
05/17/96	10.0	0.0140	713	362	141,192	24,121		109,443	26,414
05/18/96	14.0	0.0134	1,042	337	142,233	24,358		110,485	26,700
05/19/96	10.0	0.0122	822	439	143,055	24,569		111,307	26,959
05/20/96	19.0	0.0135	1,408	613	144,463	24,893		112,715	27,341
05/21/96	23.0	0.0135	1,705	660	146,168	25,288		114,420	27,809
05/22/96	10.4	0.0153	681	518	146,850	25,436		115,101	27,985
05/23/96	9.0	0.0190	473	275	147,322	25,525		115,574	28,103
05/24/96	18.0	0.0267	675	460	147,997	25,624		116,249	28,247

			Outmigration				Life-	Cohort Cumulative	
			Daily		Cumulative		Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
05/25/96	32.5	0.0299	1,086	613	149,083	25,769		117,334	28,473
05/26/96	52.0	0.0302	1,722	568	150,804	25,994		119,056	28,825
05/27/96	30.0	0.0308	974	628	151,778	26,119		120,030	29,014
05/28/96	15.0	0.0292	514	278	152,292	26,190		120,544	29,120
05/29/96	22.0	0.0308	714	260	153,007	26,278		121,258	29,254
05/30/96	9.0	0.0308	292	238	153,298	26,315		121,550	29,310
05/31/96	10.0	0.0287	348	89	153,647	26,366		121,898	29,385
06/01/96	10.0	0.0270	370	103	154,017	26,425		122,268	29,473
06/02/96	11.0	0.0275	400	202	154,416	26,488		122,668	29,566
06/03/96	2.0	0.0319	63	140	154,479	26,496		122,731	29,577
06/04/96	5.2	0.0265	197	107	154,676	26,529		122,927	29,626
06/05/96	7.0	0.0244	287	119	154,963	26,584		123,214	29,705
06/06/96	3.0	0.0259	116	118	155,078	26,605		123,330	29,735
06/07/96	1.0	0.0323	31	47	155,109	26,608		123,361	29,741
06/08/96	4.0	0.0216	186	86	155,295	26,645		123,547	29,790
06/09/96	2.0	0.0219	91	62	155,386	26,660		123,638	29,810
06/10/96	1.5	0.0232	65	46	155,451	26,670		123,702	29,823
06/11/96	0.0	0.0241	0	61	155,451	26,671		123,702	29,823
06/12/96	3.0	0.0251	120	63	155,570	26,686		123,822	29,841
06/13/96	2.0	0.0232	86	33	155,656	26,699		123,908	29,858
06/14/96	3.2	0.0266	122	64	155,778	26,713		124,030	29,876
06/15/96	0.0	0.0292	0	63	155,778	26,714		124,030	29,876
06/16/96	0.0	0.0329	0	17	155,778	26,714		124,030	29,876
06/17/96	1.0	0.0363	28	16	155,806	26,716		124,057	29,880
06/18/96	0.0	0.0361	0	16	155,806	26,716		124,057	29,880
06/19/96	0.0	0.0345	0	0	155,806	26,716		124,057	29,880
06/20/96	0.0	0.0333	0	17	155,806	26,716		124,057	29,880
06/21/96	1.0	0.0321	31	19	155,837	26,720		124,088	29,887
06/22/96	0.0	0.0262	0	21	155,837	26,720		124,088	29,887
06/23/96	1.0	0.0215	47	31	155,884	26,732		124,135	29,904
06/24/96	1.0	0.0254	39	25	155,923	26,740		124,175	29,915
06/25/96	0.0	0.0276	0	20	155,923	26,740		124,175	29,915
06/26/96	0.0	0.0300	0	19	155,923	26,740		124,175	29,915
06/27/96	1.0	0.0333	30	18	155,953	26,743		124,205	29,921
06/28/96	0.0	0.0297	0	19	155,953	26,743		124,205	29,921
06/29/96	0.0	0.0267	0	20	155,953	26,743		124,205	29,921
06/30/96	1.0	0.0240	42	27	155,995	26,753		124,246	29,935
07/01/96	1.0	0.0301	33	10	156,028	26,758		124,279	29,943

Appendix A.6.b. 1997 Outmigration index estimates based on efficiency predictor that excluded turbidity > 10

			Outmigration					Cohort Cumulative Outmigration	
			Daily		Cumulative				
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Life-Stage Cohort	Estimate	S.E.
03/19/97	15.0	0.0330	455	66	455	66	Parr	455	66
03/20/97	17.0	0.0262	648	422	1,103	431		1,103	431
03/21/97	35.0	0.0269	1,299	410	2,402	610		2,402	610
03/22/97	36.0	0.0270	1,333	288	3,735	705		3,735	705
03/23/97	48.0	0.0297	1,615	235	5,350	785		5,350	785
03/24/97	42.0	0.0370	1,136	232	6,486	848		6,486	848
03/25/97	32.0	0.0478	670	146	7,156	874		7,156	874
03/26/97	30.0	0.0612	490	105	7,646	889		7,646	889
03/27/97	22.0	0.0682	323	76	7,968	899		7,968	899
03/28/97	28.0	0.0656	427	82	8,395	916		8,395	916
03/29/97	21.0	0.0730	288	228	8,682	954		8,682	954
03/30/97	52.5	0.0585	897	306	9,579	1,041		9,579	1,041
03/31/97	30.0	0.0613	490	198	10,069	1,088		10,069	1,088
04/01/97	45.0	0.0666	675	183	10,744	1,144		10,744	1,144
04/02/97	24.3	0.0602	404	194	11,148	1,189		11,148	1,189
04/03/97	27.0	0.0576	468	79	11,616	1,230		11,616	1,230
04/04/97	28.0	0.0641	437	193	12,053	1,280		12,053	1,280
04/05/97	48.0	0.0628	765	225	12,818	1,364		12,818	1,368
04/06/97	51.0	0.0599	851	163	13,669	1,454	Smolt	851	189
04/07/97	39.0	0.0569	685	243	14,354	1,546		1,536	349
04/08/97	26.0	0.0563	462	196	14,816	1,610		1,998	442
04/09/97	46.4	0.0603	771	303	15,587	1,720		2,769	598
04/10/97	60.0	0.0609	985	201	16,572	1,838		3,754	721
04/11/97	44.0	0.0560	786	193	17,358	1,944		4,540	838
04/12/97	49.0	0.0531	923	151	18,282	2,061		5,464	960
04/13/97	45.0	0.0403	1,116	335	19,397	2,200		6,579	1,122
04/14/97	68.0	0.0246	2,770	1,736	22,167	2,943		9,349	2,159
04/15/97	126.5	0.0193	6,544	1,783	28,711	3,692		15,893	2,993
04/16/97	104.5	0.0184	5,673	1,542	34,384	4,443		21,566	3,791
04/17/97	81.0	0.0186	4,364	1,806	38,748	5,231		25,930	4,629
04/18/97	43.0	0.0188	2,290	1,614	41,038	5,715		28,219	5,144
04/19/97	22.0	0.0201	1,093	752	42,131	5,867		29,313	5,301
04/20/97	51.0	0.0179	2,855	980	44,985	6,288		32,167	5,733
04/21/97	28.0	0.0186	1,502	669	46,487	6,498		33,669	5,948
04/22/97	44.0	0.0179	2,460	1,033	48,946	6,898		36,128	6,357
04/23/97	10.0	0.0173	579	1,138	49,526	7,076		36,708	6,543
04/24/97	9.0	0.0180	499	528	50,025	7,162		37,207	6,632
04/25/97	26.0	0.0182	1,430	691	51,455	7,380		38,636	6,854
04/26/97	32.0	0.0178	1,800	573	53,254	7,646		40,436	7,124
04/27/97	15.0	0.0178	842	540	54,096	7,779		41,278	7,259
04/28/97	16.5	0.0154	1,072	312	55,169	7,975		42,351	7,458
04/29/97	21.0	0.0176	1,191	364	56,360	8,156		43,541	7,641
04/30/97	27.0	0.0167	1,612	798	57,972	8,453		45,154	7,943
05/01/97	3.0	0.0145	207	804	58,179	8,534		45,361	8,027
05/02/97	15.0	0.0173	867	1,146	59,046	8,744		46,228	8,243
05/03/97	42.0	0.0177	2,374	869	61,421	9,143		48,603	8,646
05/04/97	28.0	0.0168	1,668	670	63,089	9,453		50,271	8,960
05/05/97	47.0	0.0179	2,627	1,150	65,716	9,923		52,898	9,434

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
05/06/97	9.0	0.0158	568	1,183	66,284	10,103		53,466	9,619
05/07/97	32.0	0.0161	1,988	879	68,273	10,515		55,455	10,034
05/08/97	29.0	0.0169	1,711	362	69,984	10,820		57,166	10,341
05/09/97	31.0	0.0173	1,794	425	71,778	11,133		58,960	10,656
05/10/97	23.0	0.0179	1,286	374	73,064	11,344		60,246	10,868
05/11/97	21.0	0.0166	1,266	625	74,330	11,597		61,512	11,123
05/12/97	38.5	0.0182	2,111	665	76,441	11,950		63,623	11,478
05/13/97	38.5	0.0177	2,169	492	78,610	12,339		65,792	11,869
05/14/97	31.0	0.0233	1,333	304	79,943	12,570		67,125	12,096
05/15/97	35.6	0.0226	1,575	1,015	81,518	12,895		68,700	12,420
05/16/97	71.5	0.0169	4,238	1,651	85,756	13,821		72,938	13,353
05/17/97	27.5	0.0173	1,589	1,309	87,345	14,182		74,527	13,716
05/18/97	42.0	0.0170	2,469	1,127	89,813	14,701		76,995	14,238
05/19/97	62.0	0.0170	3,638	995	93,451	15,421		80,633	14,961
05/20/97	44.0	0.0174	2,530	1,216	95,981	15,943		83,163	15,485
05/21/97	23.0	0.0178	1,290	642	97,271	16,194		84,452	15,737
05/22/97	30.0	0.0165	1,816	524	99,087	16,580		86,269	16,124
05/23/97	33.8	0.0168	2,016	498	101,103	17,024		88,285	16,569
05/24/97	34.6	0.0198	1,749	426	102,852	17,406		90,034	16,950
05/25/97	31.0	0.0248	1,251	490	104,103	17,637		91,285	17,179
05/26/97	51.0	0.0260	1,962	836	106,066	17,976		93,248	17,514
05/27/97	11.0	0.0228	482	866	106,548	18,086		93,730	17,624
05/28/97	33.0	0.0188	1,757	909	108,305	18,453		95,487	17,992
05/29/97	42.0	0.0166	2,530	1,052	110,836	19,005		98,018	18,546
05/30/97	12.5	0.0197	636	948	111,471	19,137		98,653	18,679
05/31/97	7.0	0.0201	349	244	111,820	19,207		99,002	18,749
06/01/97	3.0	0.0199	151	199	111,971	19,242		99,153	18,784
06/02/97	11.0	0.0236	466	189	112,438	19,325		99,620	18,867
06/03/97	7.0	0.0203	345	228	112,783	19,391		99,965	18,932
06/04/97	2.0	0.0161	125	177	112,907	19,420		100,089	18,961
06/05/97	7.0	0.0186	377	194	113,285	19,486		100,467	19,027
06/06/97	8.6	0.0181	474	182	113,758	19,577		100,940	19,118
06/07/97	3.0	0.0241	124	146	113,883	19,596		101,065	19,138
06/08/97	2.0	0.0275	73	401	113,955	19,614		101,137	19,156
06/09/97	22.0	0.0338	650	346	114,606	19,720		101,788	19,260
06/10/97	3.7	0.0312	118	306	114,723	19,745		101,905	19,284
06/11/97	7.0	0.0309	227	75	114,950	19,789		102,132	19,328
06/12/97	6.0	0.0363	165	40	115,115	19,812		102,297	19,350
06/13/97	5.0	0.0375	133	46	115,248	19,829		102,430	19,367
06/14/97	3.0	0.0325	92	50	115,341	19,846		102,523	19,383
06/15/97	2.0	0.0316	63	66	115,404	19,858		102,586	19,395
06/16/97	6.0	0.0383	157	71	115,561	19,877		102,743	19,414
06/17/97	1.2	0.0367	33	65	115,594	19,882		102,776	19,418
06/18/97	3.0	0.0331	91	46	115,685	19,898		102,867	19,434
06/19/97	4.0	0.0311	129	35	115,813	19,924		102,995	19,459
06/20/97	3.0	0.0280	107	35	115,920	19,948		103,102	19,484
06/21/97	4.0	0.0351	114	27	116,035	19,966		103,217	19,501
06/22/97	4.0	0.0325	123	43	116,158	19,987		103,340	19,522
06/23/97	2.0	0.0304	66	51	116,223	20,001		103,405	19,535
06/24/97	1.0	0.0324	31	31	116,254	20,006		103,436	19,540
06/25/97	0.0	0.0324	0	17	116,254	20,006		103,436	19,540
06/26/97	0.0	0.0324	0	0	116,254	20,006		103,436	19,540
06/27/97	0.0	0.0324	0	0	116,254	20,006		103,436	19,540

Appendix A.6.c. 1998 Outmigration index estimates based on efficiency predictor that <u>excluded</u> turbidity > 10

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
01/29/98	802.0	0.0458	17,500	8,225	17,500	8,225	Fry	17,500	8,225
01/30/98	286.0	0.0455	6,291	6,032	23,791	10,386		23,791	10,386
01/31/98	703.9	0.0460	15,298	5,439	39,090	12,257		39,090	12,257
02/01/98	678.1	0.0457	14,834	5,315	53,923	14,099		53,923	14,099
02/02/98	1085.0	0.0454	23,892	8,804	77,815	17,917		77,815	17,917
02/03/98	332.0	0.0437	7,596	8,642	85,411	20,379		85,411	20,379
02/04/98	643.3	0.0441	14,595	4,778	100,006	21,903		100,006	21,903
02/05/98	693.1	0.0445	15,591	2,382	115,597	23,188		115,597	23,188
02/06/98	759.1	0.0448	16,933	2,804	132,531	24,731		132,531	24,731
02/07/98	850.6	0.0452	18,814	5,440	151,345	26,945		151,345	26,945
02/08/98	1180.0	0.0456	25,879	5,034	177,224	29,763		177,224	29,763
02/09/98	1091.1	0.0455	23,974	3,485	201,198	32,307		201,198	32,307
02/10/98	1045.7	0.0454	23,020	3,143	224,218	34,820		224,218	34,820
02/11/98	1011.8	0.0453	22,314	3,617	246,532	37,373		246,532	37,373
02/12/98	862.4	0.0453	19,056	3,022	265,588	39,577		265,588	39,577
02/13/98	897.0	0.0452	19,857	2,646	285,445	41,871		285,445	41,871
02/14/98	849.0	0.0439	19,323	3,170	304,767	44,109		304,767	44,109
02/15/98	1022.0	0.0448	22,826	20,425	327,593	50,963		327,593	50,963
02/16/98	2509.0	0.0440	57,012	27,091	384,605	62,836		384,605	62,836
02/17/98	227.0	0.0435	5,217	31,188	389,821	70,614		389,821	70,614
02/18/98	62.0	0.0424	1,461	2,602	391,283	70,789		391,283	70,789
02/19/98	273.0	0.0443	6,166	3,450	397,449	71,435		397,449	71,435
02/20/98	352.0	0.0439	8,013	1,711	405,462	72,183		405,462	72,183
02/21/98	393.0	0.0457	8,601	1,410	414,063	73,019		414,063	73,019
02/22/98	316.0	0.0447	7,070	3,153	421,132	73,753		421,132	73,753
02/23/98	128.5	0.0449	2,859	2,139	423,992	74,058		423,992	74,058
02/24/98	191.0	0.0448	4,266	956	428,258	74,472		428,258	74,472
02/25/98	188.0	0.0448	4,201	669	432,458	74,879		432,458	74,879
02/26/98	159.0	0.0434	3,662	651	436,120	75,223		436,120	75,223
02/27/98	149.0	0.0432	3,447	457	439,567	75,546		439,567	75,546
02/28/98	162.0	0.0423	3,827	931	443,394	75,901		443,394	75,901
03/01/98	97.0	0.0421	2,302	820	445,697	76,116		445,697	76,116
03/02/98	123.0	0.0432	2,850	666	448,546	76,386		448,546	76,386
03/03/98	74.0	0.0425	1,741	653	450,287	76,550		450,287	76,550
03/04/98	81.2	0.0425	1,909	458	452,196	76,729		452,196	76,729
03/05/98	49.0	0.0382	1,283	483	453,479	76,835		453,479	76,835
03/06/98	52.0	0.0359	1,447	1,471	454,926	76,958		454,926	76,958
03/07/98	142.0	0.0412	3,451	1,219	458,377	77,276		458,377	77,283
03/08/98	124.0	0.0328	3,786	4,742	462,162	77,669	Parr	3,786	5,986
03/09/98	402.0	0.0330	12,198	4,922	474,361	78,628		15,984	7,805
03/10/98	394.0	0.0326	12,086	2,987	486,446	79,475		28,070	8,568
03/11/98	242.0	0.0331	7,317	2,466	493,764	80,010		35,387	9,127
03/12/98	352.0	0.0326	10,804	4,496	504,568	80,854		46,191	10,515
03/13/98	68.0	0.0304	2,234	5,284	506,802	81,160		48,425	11,845
03/14/98	77.0	0.0298	2,583	301	509,384	81,310		51,008	11,940
03/15/98	78.0	0.0333	2,342	574	511,727	81,475		53,350	12,047
03/16/98	108.0	0.0320	3,374	2,664	515,100	81,740		56,724	12,469

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	**Count**	**Efficiency**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Cohort**	**Estimate**	**S.E.**
03/17/98	238.0	0.0308	7,721	3,615	522,821	82,296		64,445	13,278
03/18/98	20.0	0.0323	619	3,803	523,441	82,425		65,064	13,838
03/19/98	29.0	0.0304	953	404	524,394	82,484		66,017	13,884
03/20/98	43.9	0.0268	1,634	507	526,028	82,564		67,651	13,955
03/21/98	55.0	0.0325	1,692	781	527,719	82,683		69,343	14,052
03/22/98	7.3	0.0434	169	654	527,888	82,702		69,511	14,076
03/23/98	58.5	0.0249	2,347	1,154	530,235	82,804		71,859	14,212
03/24/98	54.0	0.0249	2,172	295	532,407	82,891		74,030	14,299
03/25/98	48.0	0.0234	2,053	11,134	534,460	83,703		76,083	18,186
03/26/98	504.0	0.0267	18,887	8,684	553,346	85,038		94,970	20,724
03/27/98	279.2	0.0243	11,500	8,668	564,847	85,921		106,470	22,845
03/28/98	85.0	0.0226	3,755	4,738	568,602	86,174		110,225	23,466
03/29/98	102.3	0.0240	4,272	893	572,874	86,343		114,497	23,645
03/30/98	123.0	0.0231	5,315	1,299	578,189	86,542		119,812	23,887
03/31/98	68.4	0.0227	3,014	1,386	581,203	86,656		122,826	24,050
04/01/98	71.0	0.0233	3,048	361	584,251	86,769		125,874	24,181
04/02/98	62.0	0.0209	2,968	1,127	587,218	86,855		128,842	24,333
04/03/98	105.0	0.0233	4,505	3,681	591,723	87,103		133,346	24,806
04/04/98	227.0	0.0230	9,887	4,422	601,610	87,576		143,234	25,631
04/05/98	302.0	0.0233	12,976	2,683	614,586	88,121		156,209	26,376
04/06/98	194.7	0.0263	7,389	2,143	621,975	88,528		163,598	26,829
04/07/98	254.0	0.0235	10,796	2,699	632,771	89,018		174,394	27,522
04/08/98	312.0	0.0231	13,496	4,148	646,267	89,666		187,890	28,558
04/09/98	133.3	0.0238	5,595	5,098	651,862	90,061		193,485	29,324
04/10/98	80.4	0.0236	3,404	1,347	655,266	90,223		196,890	29,551
04/11/98	79.0	0.0218	3,621	445	658,887	90,360		200,510	29,770
04/12/98	71.0	0.0209	3,391	1,459	662,278	90,489		203,901	30,013
04/13/98	24.0	0.0200	1,200	1,341	663,478	90,536		205,101	30,118
04/14/98	25.0	0.0167	1,500	541	664,977	90,560		206,601	30,222
04/15/98	39.0	0.0164	2,374	568	667,352	90,596		208,975	30,388
04/16/98	27.0	0.0183	1,479	653	668,831	90,633		210,454	30,493
04/17/98	16.0	0.0182	879	572	669,710	90,656		211,333	30,558
04/18/98	36.5	0.0201	1,821	1,471	671,531	90,727		213,155	30,712
04/19/98	74.0	0.0180	4,119	1,552	675,651	90,835		217,274	31,031
04/20/98	23.0	0.0198	1,160	1,511	676,811	90,885		218,434	31,146
04/21/98	21.0	0.0182	1,154	222	677,965	90,914		219,588	31,227
04/22/98	27.0	0.0158	1,711	628	679,676	90,939		221,299	31,360
04/23/98	39.0	0.0178	2,190	726	681,866	90,994		223,489	31,521
04/24/98	51.0	0.0168	3,026	664	684,892	91,055	Smolt	3,026	469
04/25/98	56.1	0.0169	3,312	618	688,204	91,125		6,338	991
04/26/98	42.0	0.0175	2,395	535	690,598	91,185		8,733	1,350
04/27/98	44.0	0.0177	2,487	1,087	693,086	91,254		11,220	1,944
04/28/98	75.0	0.0161	4,671	1,203	697,756	91,345		15,891	2,699
04/29/98	67.0	0.0175	3,830	557	701,586	91,446		19,721	3,134
04/30/98	72.0	0.0162	4,443	1,291	706,029	91,546		24,164	3,867
05/01/98	101.0	0.0168	6,006	1,558	712,035	91,705		30,169	4,790
05/02/98	57.0	0.0168	3,388	1,798	715,423	91,809		33,557	5,486
05/03/98	45.0	0.0166	2,718	669	718,140	91,880		36,275	5,840
05/04/98	39.0	0.0145	2,685	2,402	720,825	91,953		38,960	6,649
05/05/98	102.0	0.0158	6,453	2,200	727,278	92,127		45,413	7,712
05/06/98	65.0	0.0158	4,111	2,798	731,389	92,269		49,524	8,667
05/07/98	15.0	0.0162	925	2,081	732,314	92,318		50,449	9,018
05/08/98	0.0	0.0159	0	1,671	732,314	92,333		50,449	9,171
05/09/98	52.2	0.0156	3,348	3,061	735,662	92,465		53,797	10,034

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
05/10/98	95.0	0.0153	6,222	1,768	741,884	92,630		60,019	10,883
05/11/98	88.0	0.0150	5,880	956	747,764	92,776		65,899	11,629
05/12/98	94.0	0.0154	6,104	1,951	753,869	92,964		72,003	12,520
05/13/98	45.0	0.0142	3,175	3,113	757,043	93,090		75,178	13,320
05/14/98	133.0	0.0146	9,083	4,259	766,127	93,428		84,261	15,085
05/15/98	158.0	0.0153	10,355	1,857	776,481	93,771		94,616	16,451
05/16/98	132.0	0.0153	8,604	1,962	785,085	94,085		103,220	17,647
05/17/98	113.0	0.0161	7,023	1,673	792,108	94,373		110,243	18,589
05/18/98	89.0	0.0150	5,943	5,041	798,051	94,724		116,186	20,037
05/19/98	229.4	0.0156	14,670	5,736	812,721	95,483		130,856	22,594
05/20/98	80.0	0.0151	5,305	6,667	818,026	95,935		136,161	24,231
05/21/98	37.0	0.0151	2,458	1,462	820,484	96,051		138,619	24,594
05/22/98	59.0	0.0150	3,929	2,796	824,413	96,261		142,547	25,261
05/23/98	117.3	0.0152	7,722	2,600	832,135	96,638		150,269	26,378
05/24/98	53.0	0.0148	3,573	2,811	835,707	96,841		153,842	27,003
05/25/98	40.0	0.0155	2,579	1,066	838,287	96,970		156,421	27,356
05/26/98	71.0	0.0152	4,677	2,268	842,964	97,218		161,099	28,061
05/27/98	5.0	0.0156	320	2,093	843,284	97,257		161,419	28,181
05/28/98	41.0	0.0145	2,824	1,707	846,108	97,404		164,242	28,622
05/29/98	51.0	0.0137	3,716	787	849,824	97,576		167,958	29,175
05/30/98	39.0	0.0138	2,817	895	852,641	97,712		170,775	29,600
05/31/98	29.8	0.0130	2,294	1,354	854,935	97,825		173,069	29,988
06/01/98	6.0	0.0122	492	1,932	855,426	97,866		173,561	30,132
06/02/98	54.0	0.0144	3,746	1,753	859,173	98,068		177,307	30,711
06/03/98	29.0	0.0144	2,009	1,876	861,181	98,188		179,316	31,053
06/04/98	0.0	0.0138	0	2,738	861,181	98,226		179,316	31,173
06/05/98	76.0	0.0132	5,761	3,331	866,942	98,560		185,077	32,226
06/06/98	5.1	0.0112	454	3,295	867,396	98,636		185,531	32,475
06/07/98	17.9	0.0118	1,515	822	868,911	98,710		187,046	32,743
06/08/98	0.0	0.0124	0	2,703	868,911	98,747		187,046	32,855
06/09/98	66.0	0.0130	5,064	2,997	873,976	99,046		192,110	33,771
06/10/98	1.0	0.0124	81	2,712	874,056	99,087		192,191	33,893
06/11/98	15.0	0.0130	1,157	773	875,214	99,150		193,348	34,084
06/12/98	19.9	0.0131	1,521	465	876,735	99,230		194,870	34,324
06/13/98	25.0	0.0128	1,955	688	878,690	99,334		196,824	34,642
06/14/98	10.0	0.0126	795	994	879,485	99,380		197,619	34,785
06/15/98	0.0	0.0124	0	398	879,485	99,381		197,619	34,788
06/16/98	6.0	0.0123	490	274	879,974	99,407		198,109	34,870
06/17/98	1.0	0.0102	98	254	880,073	99,412		198,207	34,890
06/18/98	2.0	0.0110	182	97	880,255	99,421		198,389	34,924
06/19/98	0.0	0.0113	0	95	880,255	99,421		198,389	34,924
06/20/98	1.7	0.0115	152	93	880,406	99,428		198,541	34,950
06/21/98	1.8	0.0118	154	48	880,560	99,436		198,695	34,977
06/22/98	1.0	0.0121	83	46	880,643	99,441		198,777	34,991
06/23/98	2.0	0.0135	148	77	880,791	99,449		198,925	35,013
06/24/98	3.0	0.0102	293	159	881,083	99,463		199,218	35,070
06/25/98	0.0	0.0099	0	147	881,083	99,463		199,218	35,070
06/26/98	1.6	0.0096	170	98	881,253	99,471		199,388	35,105
06/27/98	1.4	0.0093	150	42	881,403	99,477		199,538	35,136
06/28/98	1.2	0.0090	137	40	881,540	99,484		199,674	35,165
06/29/98	1.0	0.0087	115	65	881,655	99,489		199,789	35,190
06/30/98	2.0	0.0093	215	116	881,869	99,498		200,004	35,234
07/01/98	0.0	0.0099	0	113	881,869	99,498		200,004	35,234
07/02/98	0.0	0.0106	0	106	881,869	99,498		200,004	35,235

			Outmigration						
			Daily		Cumulative			Cohort Cumulative Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Life-Stage Cohort	Estimate	S.E.
07/03/98	2.0	0.0113	176	94	882,045	99,507		200,180	35,266
07/04/98	0.7	0.0113	66	70	882,111	99,511		200,246	35,278
07/05/98	0.5	0.0113	46	21	882,158	99,513		200,292	35,286
07/06/98	0.3	0.0113	28	24	882,186	99,515		200,320	35,291
07/07/98	0.0	0.0113	0	16	882,186	99,515		200,320	35,291
07/08/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/09/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/10/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/11/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/12/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/13/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/14/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/15/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291
07/16/98	0.0	0.0113	0	0	882,186	99,515		200,320	35,291

Appendix A.6.d. 1999 Outmigration index estimates based on efficiency predictor that excluded turbidity > 10

			Outmigration						
			Daily		Cumulative			Cohort Cumulative Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Life-Stage Cohort	Estimate	S.E.
01/18/99	13.0	0.0260	501	94	501	94	Fry	501	94
01/19/99	16.0	0.0260	616	2,160	1,117	2,163		1,117	2,163
01/20/99	112.0	0.0260	4,313	34,183	5,430	34,252		5,430	34,252
01/21/99	1606.0	0.0260	61,851	36,538	67,281	50,143		67,281	50,143
01/22/99	1849.0	0.0260	71,209	21,872	138,490	55,496		138,490	55,496
01/23/99	812.0	0.0260	31,272	32,355	169,762	64,849		169,762	64,849
01/24/99	185.0	0.0260	7,125	15,477	176,887	66,834		176,887	66,834
01/25/99	938.0	0.0260	36,125	15,514	213,012	69,452		213,012	69,452
01/26/99	766.0	0.0260	29,501	4,928	242,512	70,442		242,512	70,442
01/27/99	746.0	0.0260	28,730	4,372	271,242	71,469		271,242	71,469
01/28/99	909.0	0.0260	35,008	6,433	306,250	72,950		306,250	72,950
01/29/99	623.0	0.0260	23,993	7,091	330,243	74,199		330,243	74,199
01/30/99	591.0	0.0260	22,761	2,276	353,004	75,148		353,004	75,148
01/31/99	621.0	0.0260	23,916	6,961	376,920	76,480		376,920	76,480
02/01/99	310.0	0.0260	11,939	11,844	388,859	77,918		388,859	77,918
02/02/99	925.0	0.0260	35,624	12,410	424,483	80,479		424,483	80,479
02/03/99	533.0	0.0260	20,527	8,419	445,010	81,891		445,010	81,891
02/04/99	582.0	0.0260	22,414	2,418	467,424	83,025		467,424	83,025
02/05/99	586.0	0.0260	22,568	11,840	489,993	85,000		489,993	85,000
02/06/99	1110.0	0.0260	42,749	11,187	532,741	87,925		532,741	87,925
02/07/99	723.0	0.0260	27,844	13,684	560,586	90,485		560,586	90,485
02/08/99	411.0	0.0260	15,829	19,232	576,414	93,374		576,414	93,374
02/09/99	1390.0	0.0260	53,532	36,988	629,946	103,187		629,946	103,187
02/10/99	2322.0	0.0260	89,426	19,822	719,372	109,836		719,372	109,836
02/11/99	1903.0	0.0260	73,289	10,968	792,661	114,640		792,661	114,640
02/12/99	2232.0	0.0260	85,960	17,386	878,621	121,172		878,621	121,172
02/13/99	1436.0	0.0260	55,304	22,238	933,924	126,728		933,924	126,728
02/14/99	1143.0	0.0260	44,020	8,697	977,944	129,933		977,944	129,933
02/15/99	1522.0	0.0260	58,616	27,606	1,036,560	136,698		1,036,560	136,698

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
02/16/99	156.0	0.0260	6,008	26,277	1,042,568	139,606		1,042,568	139,606
02/17/99	743.0	0.0260	28,615	11,866	1,071,182	142,031		1,071,182	142,031
02/18/99	567.0	0.0260	21,837	8,175	1,093,019	143,752		1,093,019	143,752
02/19/99	978.0	0.0260	37,665	9,086	1,130,684	146,613		1,130,684	146,613
02/20/99	897.0	0.0260	34,546	4,145	1,165,229	149,071		1,165,229	149,071
02/21/99	1027.0	0.0260	39,552	5,909	1,204,782	151,969		1,204,782	151,969
02/22/99	1134.0	0.0260	43,673	7,716	1,248,455	155,274		1,248,455	155,274
02/23/99	802.0	0.0260	30,887	8,154	1,279,342	157,725		1,279,342	157,725
02/24/99	780.0	0.0260	30,040	7,244	1,309,381	160,088		1,309,381	160,088
02/25/99	491.0	0.0260	18,910	7,876	1,328,291	161,679		1,328,291	161,679
02/26/99	396.0	0.0260	15,251	3,058	1,343,542	162,842		1,343,542	162,842
02/27/99	354.0	0.0260	13,633	1,837	1,357,175	163,871		1,357,175	163,871
02/28/99	329.0	0.0260	12,671	2,653	1,369,846	164,843		1,369,846	164,843
03/01/99	237.0	0.0260	9,127	2,083	1,378,973	165,543		1,378,973	165,543
03/02/99	314.0	0.0260	12,093	3,461	1,391,066	166,492		1,391,066	166,492
03/03/99	144.0	0.0260	5,546	4,290	1,396,612	166,968		1,396,612	166,968
03/04/99	105.2	0.0260	4,053	2,984	1,400,665	167,302		1,400,665	167,302
03/05/99	254.0	0.0260	9,782	4,272	1,410,447	168,099		1,410,447	168,099
03/06/99	317.0	0.0260	12,208	4,889	1,422,655	169,097		1,422,655	169,097
03/07/99	78.0	0.0260	3,004	5,191	1,425,659	169,406		1,425,659	169,406
03/08/99	88.0	0.0260	3,389	436	1,429,048	169,666		1,429,048	169,666
03/09/99	93.0	0.0260	3,582	542	1,432,630	169,941		1,432,630	169,941
03/10/99	109.0	0.0260	4,198	1,462	1,436,828	170,268		1,436,828	170,268
03/11/99	39.0	0.0260	1,502	1,556	1,438,330	170,390		1,438,330	170,390
03/12/99	39.0	0.0260	1,502	406	1,439,832	170,506		1,439,832	170,506
03/13/99	56.2	0.0260	2,163	432	1,441,995	170,672		1,441,995	170,672
03/14/99	39.0	0.0260	1,502	417	1,443,497	170,788		1,443,497	170,788
03/15/99	38.0	0.0260	1,464	141	1,444,960	170,901		1,444,960	170,901
03/16/99	38.4	0.0260	1,478	141	1,446,438	171,014	Parr	1,478	141
03/17/99	38.4	0.0260	1,480	456	1,447,918	171,128		2,958	517
03/18/99	58.0	0.0260	2,234	505	1,450,152	171,301		5,191	802
03/19/99	36.4	0.0260	1,401	472	1,451,552	171,409		6,592	999
03/20/99	39.0	0.0260	1,502	263	1,453,054	171,525		8,094	1,116
03/21/99	28.0	0.0260	1,078	363	1,454,132	171,608		9,172	1,240
03/22/99	21.0	0.0260	809	211	1,454,941	171,671		9,981	1,310
03/23/99	18.0	0.0260	693	201	1,455,634	171,724		10,674	1,372
03/24/99	27.7	0.0260	1,066	288	1,456,700	171,806		11,739	1,474
03/25/99	14.0	0.0260	539	483	1,457,239	171,848		12,279	1,587
03/26/99	39.0	0.0260	1,502	913	1,458,741	171,967		13,781	1,920
03/27/99	61.0	0.0260	2,349	502	1,461,090	172,148		16,130	2,128
03/28/99	57.0	0.0260	2,195	259	1,463,285	172,318		18,325	2,289
03/29/99	53.0	0.0260	2,041	802	1,465,326	172,477		20,366	2,562
03/30/99	20.0	0.0260	770	808	1,466,097	172,538		21,136	2,739
03/31/99	14.0	0.0260	539	1,026	1,466,636	172,583		21,676	2,960
04/01/99	63.0	0.0260	2,426	1,289	1,469,062	172,775		24,102	3,373
04/02/99	77.0	0.0260	2,966	641	1,472,027	173,005		27,067	3,618
04/03/99	47.0	0.0260	1,810	1,201	1,473,838	173,149		28,877	3,927
04/04/99	109.0	0.0260	4,198	1,702	1,478,035	173,482		33,075	4,530
04/05/99	26.0	0.0260	1,001	1,749	1,479,037	173,568		34,077	4,917
04/06/99	35.0	0.0260	1,348	272	1,480,385	173,673		35,424	5,009
04/07/99	23.0	0.0260	886	468	1,481,270	173,742		36,310	5,087
04/08/99	11.0	0.0260	424	384	1,481,694	173,775		36,734	5,129
04/09/99	30.8	0.0260	1,185	396	1,482,879	173,867		37,919	5,220
04/10/99	21.0	0.0260	809	465	1,483,688	173,931		38,728	5,294

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	**Count**	**Efficiency**	**Estimate**	**S.E.**	**Estimate**	**S.E.**	**Cohort**	**Estimate**	**S.E.**
04/11/99	7.0	0.0260	270	500	1,483,958	173,952		38,998	5,335
04/12/99	33.0	0.0260	1,271	515	1,485,229	174,051		40,268	5,443
04/13/99	18.0	0.0260	693	405	1,485,922	174,106		40,962	5,505
04/14/99	38.0	0.0260	1,464	570	1,487,385	174,220		42,425	5,632
04/15/99	46.0	0.0260	1,772	836	1,489,157	174,359		44,197	5,812
04/16/99	78.3	0.0260	3,017	693	1,492,174	174,595		47,214	6,057
04/17/99	57.0	0.0260	2,195	576	1,494,369	174,766		49,409	6,237
04/18/99	52.0	0.0260	2,003	236	1,496,372	174,922		51,412	6,384
04/19/99	59.0	0.0260	2,272	464	1,498,644	175,099		53,684	6,564
04/20/99	38.0	0.0260	1,464	639	1,500,108	175,214		55,147	6,703
04/21/99	27.0	0.0260	1,040	253	1,501,147	175,295		56,187	6,785
04/22/99	28.0	0.0260	1,078	170	1,502,226	175,379		57,266	6,867
04/23/99	33.6	0.0260	1,293	435	1,503,519	175,480		58,559	6,978
04/24/99	49.0	0.0260	1,887	347	1,505,406	175,627		60,446	7,129
04/25/99	40.0	0.0260	1,541	227	1,506,946	175,747		61,986	7,250
04/26/99	45.0	0.0260	1,733	239	1,508,680	175,882		63,719	7,388
04/27/99	36.0	0.0260	1,386	370	1,510,066	175,991		65,106	7,505
04/28/99	54.0	0.0260	2,080	428	1,512,146	176,153		67,185	7,679
04/29/99	52.2	0.0260	2,009	445	1,514,154	176,310		69,194	7,849
04/30/99	35.0	0.0260	1,348	491	1,515,502	176,416		70,542	7,972
05/01/99	59.0	0.0260	2,272	1,118	1,517,774	176,597		72,814	8,229
05/02/99	92.0	0.0260	3,543	1,165	1,521,317	176,877		76,357	8,588
05/03/99	34.0	0.0260	1,309	1,543	1,522,627	176,986		77,667	8,829
05/04/99	15.0	0.0260	578	1,013	1,523,204	177,034		78,244	8,933
05/05/99	67.1	0.0260	2,586	2,009	1,525,790	177,248		80,830	9,355
05/06/99	119.0	0.0260	4,583	1,374	1,530,373	177,611		85,413	9,804
05/07/99	55.0	0.0260	2,118	1,344	1,532,491	177,782		87,531	10,061
05/08/99	64.0	0.0260	2,465	347	1,534,956	177,975		89,996	10,260
05/09/99	68.0	0.0260	2,619	357	1,537,575	178,181		92,615	10,470
05/10/99	55.0	0.0260	2,118	911	1,539,693	178,349	Smolt	2,118	891
05/11/99	23.0	0.0260	886	802	1,540,579	178,420		3,004	1,212
05/12/99	62.0	0.0260	2,388	788	1,542,967	178,609		5,392	1,490
05/13/99	47.0	0.0260	1,810	512	1,544,777	178,752		7,202	1,631
05/14/99	72.0	0.0260	2,773	697	1,547,550	178,971		9,975	1,873
05/15/99	40.0	0.0260	1,541	645	1,549,090	179,093		11,515	2,050
05/16/99	50.0	0.0260	1,926	280	1,551,016	179,244		13,441	2,165
05/17/99	49.0	0.0260	1,887	1,023	1,552,903	179,396		15,328	2,489
05/18/99	95.0	0.0260	3,659	1,211	1,556,562	179,687		18,987	2,946
05/19/99	38.0	0.0260	1,464	1,248	1,558,025	179,807		20,450	3,277
05/20/99	40.0	0.0260	1,541	1,932	1,559,566	179,938		21,991	3,879
05/21/99	126.0	0.0260	4,853	1,915	1,564,418	180,330		26,843	4,544
05/22/99	121.7	0.0260	4,687	1,173	1,569,106	180,703		31,531	4,931
05/23/99	75.0	0.0260	2,888	1,193	1,571,994	180,935		34,419	5,233
05/24/99	65.0	0.0260	2,503	1,298	1,574,497	181,137		36,922	5,535
05/25/99	13.0	0.0260	501	2,013	1,574,998	181,187		37,423	5,918
05/26/99	118.0	0.0260	4,545	2,066	1,579,542	181,558		41,967	6,510
05/27/99	73.0	0.0260	2,811	1,765	1,582,354	181,788		44,779	6,902
05/28/99	27.0	0.0260	1,040	893	1,583,394	181,873		45,819	7,020
05/29/99	54.7	0.0260	2,107	624	1,585,501	182,040		47,926	7,172
05/30/99	52.6	0.0260	2,024	220	1,587,525	182,201		49,950	7,297
05/31/99	49.3	0.0260	1,897	693	1,589,422	182,352		51,847	7,446
06/01/99	81.0	0.0260	3,120	1,082	1,592,541	182,602		54,966	7,717
06/02/99	27.0	0.0260	1,040	1,046	1,593,581	182,688		56,006	7,854
06/03/99	59.0	0.0260	2,272	703	1,595,853	182,869		58,278	8,031

			Outmigration					Cohort Cumulative	
			Daily		Cumulative		Life-Stage	Outmigration	
Date	Count	Efficiency	Estimate	S.E.	Estimate	S.E.	Cohort	Estimate	S.E.
06/04/99	55.0	0.0260	2,118	783	1,597,972	183,038		60,397	8,207
06/05/99	23.0	0.0260	886	843	1,598,857	183,111		61,282	8,308
06/06/99	13.2	0.0260	507	346	1,599,364	183,151		61,789	8,350
06/07/99	31.0	0.0260	1,194	401	1,600,558	183,246		62,983	8,439
06/08/99	30.0	0.0260	1,155	136	1,601,713	183,338		64,138	8,518
06/09/99	34.0	0.0260	1,309	343	1,603,023	183,442		65,448	8,614
06/10/99	18.0	0.0260	693	321	1,603,716	183,498		66,141	8,668
06/11/99	29.0	0.0260	1,117	236	1,604,833	183,586		67,258	8,748
06/12/99	23.7	0.0260	911	203	1,605,744	183,659		68,169	8,814
06/13/99	19.5	0.0260	750	349	1,606,493	183,719		68,919	8,873
06/14/99	6.6	0.0260	253	286	1,606,747	183,739		69,172	8,895
06/15/99	6.6	0.0260	253	122	1,607,000	183,759		69,425	8,914
06/16/99	12.0	0.0260	462	170	1,607,462	183,796		69,887	8,948
06/17/99	15.0	0.0260	578	164	1,608,040	183,842		70,465	8,991
06/18/99	7.0	0.0260	270	179	1,608,310	183,863		70,735	9,012
06/19/99	7.0	0.0260	268	34	1,608,578	183,885		71,003	9,031
06/20/99	6.0	0.0260	229	103	1,608,807	183,903		71,232	9,048
06/21/99	2.0	0.0260	77	212	1,608,884	183,909		71,309	9,056
06/22/99	12.9	0.0260	498	217	1,609,382	183,949		71,807	9,094
06/23/99	6.0	0.0260	231	155	1,609,613	183,967		72,038	9,112
06/24/99	6.0	0.0260	231	31	1,609,844	183,986		72,269	9,129
06/25/99	5.0	0.0260	193	43	1,610,037	184,001		72,462	9,142
06/26/99	4.0	0.0260	154	31	1,610,191	184,013		72,616	9,154
06/27/99	3.6	0.0260	140	55	1,610,330	184,024		72,755	9,164
06/28/99	1.4	0.0260	55	54	1,610,386	184,029		72,811	9,168
06/29/99	1.0	0.0260	39	62	1,610,424	184,032		72,849	9,171
06/30/99	4.0	0.0260	154	83	1,610,578	184,044		73,003	9,182

Appendix B. Doug Neeley's response to statistical reviews by Skalski and McDonald and Howlin.

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From: Doug Neeley

Subject: Response to reviews of Appendix A. in Outmigrant Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1999

I am responding to the reviews of John R. Skalski (March 21, 2000) and Lyman L. McDonald and Shay Howlin (April 28, 2000) to the model used to estimate trapping efficiency and smolt outmigration at Caswell State Park. Their reviews seem to based on S. P. Cramer and Associations report on the 1997 outmigration[1] and on a draft report of the 1999 outmigration. Below, I respond to the reviews separately as they apply to my contribution (i.e., Appendix A). However, the reviewers may wish to read all of my comments because there are some related responses even though their reviews centered on different issues.

Response to Skalski's review.

While I was not responsible for the release schedule, it is important that the reader of the review be aware of the limitations imposed on the field team. As I understand it, the California

[1] D. B. Demko and S. P. Cramer. June 1998. Outmigrant Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1997.

Department of Fish and Game (CDFG) imposed the restriction that no more than one release of river-run fish could be made a week, and throughout a large portion of the outmigration, river-run fish were all that were available. More releases should have been made, but I believe that during periods of low recovery, the field team felt that there were too few fish available to make a release. They probably did not realize that the logistic regression effectively weights the efficiencies by the release size and that I could have easily accommodated small releases without their results having a disproportionate effect on the parameter estimates. I should note that a major benefit of Skalski's review was that CDFG has reversed its policy and that more frequent releases can now be made. The decision was probably too late for efficiency estimates during the "fry" portion of the 2000 outmigration.

Now to specific comments regarding the efficiency predictions and count expansions.

Page 3, Paragraph 3 of Skalski's Review

Skalski criticizes the use of only night-time releases in 1999 and the abundance of hatchery-fish fish (as opposed to river-run fish) in 1998.

Day-time releases: Regarding the lack of 1999 day-time releases. This lack was based on my recommendation which stemmed from the analysis done on the 1998 releases and presented in the report of 1998 outmigration[2] (which I assume that Skalski did not have for his review). I quote from my appendix. "… The decision was made to drop day releases because the day release efficiency would not have been representative of day passage."

There were three paired day-time and night-time releases made and discussed in the 1998 report. Out of the total of 9172 fish released in the day time, only 17 were recovered and 16 of those 17 were captured at night. For comparable night-time releases, out of a total of 5153 night-time releases, there was a total of 83 fish recovered, all at night. The day-release and night-release efficiency estimates, ignoring time of recovery, respectively were 0.0019 and 0.0162. Assuming that the night-time efficiency would be independent of whether a fish was released during the day or night, the much lower efficiency associated with the day-time releases and based predominantly on nighttime recoveries implies that many day-time released fish were passing during the day but were not being recovered. While it would be possible to partition the day-time release recoveries into day and night recoveries and use maximum-likelihood techniques to estimate day-time efficiency based on both day-time and night-time release estimates, the estimated day-time efficiency would be near 0 and would be based on only one day-time recovered fish. The result would be that the small day-time catches would be expanded by a huge number based on an estimate derived from one recovered fish.

[2] D.B. Demko, C. Gemperle, S.P. Cramer, and A. Phillips. June 1999. Outmigrant Trapping of Juvenile Salmonids in the Lower Stanislaus River Caswell State Park Site 1998.

The holding of fish may trigger a mass movement of fish when released which may not be representative of river-run fish movement. We hope that radio-telemetry studies can address the movement of fish during the day and night. Some consideration is being given to making paired day-time and night-time releases this year. But until issues are resolved regarding day-time and night-time movement, I would not use 1 unadjusted day-time recovery to estimate day-time efficiency when most of the day-time-released fish are recovered at night. The lack of separate day and night expansions is one reason that I state the outmigration estimates should only be regarded as an index, and I always tried to use the term "index" throughout my appendix. This issue needs a clearer presentation in future reports.

Hatchery releases: The frequency of hatchery and river-run fish is driven by the relative availability of those two sources of fish. With the changes in CDFG policy mentioned above, there should now be greater numbers of river-run-fish releases in 2000. There was a total of four paired releases of river-run ("natural") and hatchery fish in 1998 for the purpose of comparing trapping efficiency estimates. A logistic analysis of variance resulted in no statistically significant differences between the efficiency estimates (P = 0.5063 with a pooled river-run efficiency estimate of 0.0337 from 5100 released fish and a pooled hatchery efficiency estimate of 0.0197 from 11249 released fish.

The report on the 1998 outmigration did present the paired comparisons between hatchery and river-run fish and between day-time and the night-time releases.

Skalski suggests that I use a r^2 analog

$$r^2 = \text{(Model Deviance)}/\text{(Total Deviance)}$$

analogous to the sums-of-squares-based estimate from least squares analysis. The least squares estimate is the equivalent to the square of the correlation coefficient between the response variable values and the predictor estimates (thus the term r2). Such an equality does not exist for non-linear fits. I have no problem in presenting a "r2" measure, but I believe that an estimate based on the weighted estimate of the correlation coefficient would be more appropriate (the weight being the release number).

Page 4, Paragraph 2 of Skalski's Review

Skalski suggests that I use Anscombe's residuals instead of Pearson's residuals, and I will consider doing so in any future residual analysis. The reason that I used Pearson standardized residuals is that I felt that they would be more familiar to the fishery biologists and that the release sizes were sufficiently large for the Central Limit to hold.

Page 5, Paragraph 2 of Skalski's Review

It is unlikely that we will be able to adopt stratified sampling procedures with either 1) releases made each day or 2) release days randomly sampled within strata. Even with modifications in CDFG's policies, fish availability will dictate the number of releases we can make, but we will be striving for at least two releases per week. A model approach will still probably be necessary but it will be over a more representative distribution of the predictor variables, and I hope that post-data-collection stratification will be possible (e.g., according to cohort: fry, parr, smolt). Cross stratification of recovery and release days would probably not be necessary for us because, with rare exceptions, all fish are recovered within the night of the night release (or the night following the day release). However, the technique that Skalsi recommends may be beneficial for paired night and day releases, treating the day and night recoveries as strata. I appreciate the information on the availability of the SPAS program.

Variance estimate (Pages 6-10 Skalski's Review)

On page 10, Skalski states that my estimate of the variance is "largely" correct but that individual components need to be adjusted. He doesn't state at this point what the individual components should be, I list below what I think the components probably are:

Variance of efficiency estimate: I believe my estimate of the variance of the efficiency (e)

$$s^2\{e\} = s^2\{1/[\exp[-b(0)-b(1)*x(1)-\ldots]\}$$

is correct. But Skalski is correct in stating that I should be using

$$s^2(e^*) = s^2(1) + s^2\{1/[\exp[-b(0)-b(1)*x(1)-\ldots]\}$$

[my formulation, not Skalski's[3]] for the variance when performing the expansion.

The $s^2(1)$ term, which I didn't use but should have, can be estimated by

$$s^2(1) = \frac{\text{Residual Deviance}}{\text{Residual Degrees of Freedom}} * \frac{e(1-e)}{N}$$

wherein N is the number of outmigrating fish on the date of the expansion. N would then have to be the day's estimated expanded catch.

The over-dispersion correction [(Residual Deviance)/(Degrees of Freedom)] used above is necessary because the efficiency variance among releases made on the same day significantly differed from the binomial.

[3] Skalski's formulation was applicable to least squares linear regression

Variance of unexpanded catch estimate: Skalski suggests that I use an estimated variance based on the binomial. I believe the appropriate "binomially-based" variance estimate would be

$$s^2(catch) = \frac{\text{Residual Deviance}}{\text{Residual Degrees of Freedom}} * N * e * (1-e)$$

I, instead, used the variance among three days' catch (the day's catch, the previous day's catch, and the next day's catch) as an estimate of s^2(catch). Skalski correctly states that my estimate will be biased upwards (too big); however, I will still probably use my conservative estimate. If I use the above over-dispersion-adjusted binomially-based estimate of the catch variance, it will be based strictly on my efficiency predictor. Given the limited number of releases on which the efficiency estimates were based, I feel that it is better to base catch estimates on the catch data which are collected each day. As will be seen in my response to the review by McDonald and Howlin, my estimate of the variance will sometimes be too liberal.

I know of no other "components" that Skalski identified to adjust the variance for.

Error in Skalski's variance estimator

I do want to flag an error in Skalski's development. On page 6, ignoring his covariance terms, he uses the following form for the variance of a product.

$$\sigma^2(xy) = E^2(x) * \sigma^2(y) + \sigma^2(x) * E^2(y) + \sigma^2(x) * \sigma^2(y)$$

(My notation not his.) While this is correct when the expected values and variances are known, the unbiased estimate is of the form

$$s^2(xy) = x^2 * s^2(y) + s^2(x) * y^2 - s^2(x) * s^2(y)$$

Note the subtraction of the last term instead of the addition. This is because

$$E(x^2) = E^2(x) + \sigma^2(x)$$

(refer to Kendal and Stuart's The Advanced Theory of Statistics, Volume 1 under the variance of a product).

Response to McDonald and Howlin's review.

Missing Count Estimates (Page 2 of McDonald and Howlin's review)

I appreciate their considering my missing-value estimates (which were also applied to some counts when there were trap stoppages of both screw traps) as reasonable. The missing value estimates were of great concern to me since they were what to McDonald and Howlin referred to as "ad hoc" and were not statistically based. It should be noted that when the variance of counts was estimated, the procedure did not distinguish whether the counts were missing or not. If they were missing value estimates, then the counts from the evaluated day and from the previous day and the following day were not independent and would be positively correlated. Under these conditions, the estimated variance of the count could be too small rather than too large (as discussed earlier when responding to Skalski's comments).

Bootstrapping would be difficult for us because the dates on which releases were made did not represent a "random sampling" of the outmigration dates. Underlying bootstrapping procedures is the assumption that the sample is a random sample from the underlying population.

Daily Efficiency (Page 2 of McDonald and Howlin's review)

I mentioned in my comments to Skalski's review that the report on the 1998 outmigration (which the reviewers apparently didn't receive) compared various release strategies; i.e., day-time versus night-time releases and hatchery- versus river-run-fish releases referred to in my comments to Skalski's review. There were also comparisons of the effect of different release positions. There was a release set that involved the "standard" location and positions located upstream and downstream of the standard. The efficiency estimates were compared using a logistic analysis of variance. The estimates did not differ substantially or significantly ($P = 0.89$ for standard versus upstream and $P = 0.57$ for standard versus downstream; the efficiency estimates being 0.015 for standard, 0.016 for upstream, and 0.020 for downstream based on 2123, 826, and 1003 standard, upstream, and downstream released fish). In my opinion, an undo number of comparative releases within-day were being made at the expense of daily releases (there were only 8 release days in 1996 and 1997 combined and 7 release days in 1998). I felt resources could be better allocated by having more release days at the expense of multiple daily releases, and abandoning multiple daily releases was my idea. Unfortunately, only 8 release days were included in 1999.

I should note that, if multiple release sites/times are used, then they should all be used on every release day or the inclusion/exclusion of release sites should be based on a random process; otherwise, bias will result from associating different release-site/time effects with random "error" or residual variation when they are in fact biasing the coefficient estimates.

Logistic Regression (Page 2-3 of McDonald and Howlin's review)

More discussion of the logistic in future reports is clearly warranted.

The "sample size" when making comparisons in size of fish is the number of fish measured. When applied to logistic regression, sample size should refer to the number of releases. For the 1996-1997 releases it would have included 18 releases with multiple releases within days (8 release days), in 1998 it would have included 16 releases with multiple releases within days (7 release days), and in 1999 it would have included 9 releases with multiple releases within days (8 release days). Because of homogeneity in the residual mean deviance over years[4], the samples were combined to boost the degrees of freedom (18 + 16 + 9 = 43 releases with 7 parameters estimated[5] for 43 - 7 = 36 residual degrees of freedom).

McDonald and Howlin are correct in assuming that the fish size predictor was the size measured from a sample of recovered fish. I was inconsistent in previous years, inadvertently using size of released fish in some cases and size of recovered fish in others. In 1999 I went back through all previous years' data and corrected this inconsistency, and those 1999 revised estimates are based on recovered fish size.

The "adjustment to the binomial" was discussed. It was the multiplication of the variances of the coefficients by the mean deviance[6] (or the multiplying of the standard errors by the square root of the mean deviance). This was the adjustment for overdispersion mentioned in Skalski's review.

Regarding the 10 ntu turbidity "threshold". All integer threshold values were evaluated and 10 gave by far the smallest mean deviance. I am embarrassed to say that I found no reference to this evaluation in any of the reports (I think I must have left part of my discussion out of the report on the 1996 outmigration and will have to include this discussion in the 2000 outmigration report). For the estimation of the regression coefficients, if the turbidity was less than the threshold value, zero was substituted for turbidity, otherwise the actual turbidity value was used. Recovery-day (morning following release) turbidity was used as the predictor variable and gave a coefficient that substantially and significantly differed from 0 ($P < 0.0001$) when the threshold value of 10 was reached or exceeded. The turbidity values were equated to 0 for efficiency prediction whenever the value was less than the threshold.

Model Selection (Page 3 of McDonald and Howlin's review)

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4 It should be noted that the among-day model-based residual deviances was not significantly greater than the within-day deviance; therefore the among-day and within-day deviances were also pooled.

5 Four parameters in 1996-1997; two parameters in 1998 and 1 parameter in 1999 (the 1996-based turbidity coefficient estimate was used for all years)

6 Mean Deviance = (Residual Deviance)/(Residual Degrees of Freedom)

I understand the desire for models to be driven by biological considerations as well as by statistical significance. The question is how can this be assessed. For example, should efficiency increase as flow increases or decrease as flow increases? Arguments can be put forward for either case. If flow increases, the fish may have a more difficult time avoiding the trap in which case the efficiency-to-flow coefficient should be positive. However, as flow increases, the percent volume of water entering the trap decreases; therefore the proportion of fish trapped should drop and the efficiency-to-flow coefficient should be negative. I used a very liberal P for inclusion. If $P < 0.2$, then the coefficient would be included. It turned out that all of the included coefficients had significance levels of $P < 0.06$.

Estimated Outmigration and its Variance (Page 3-5 of McDonald and Howlin's review)

The estimate of the catch-to-efficiency ratio, Sci/Sei, given by the reviewers is only unbiased if there is truly a random sampling of days for release within reasonably homogeneous strata. This is not the case. Further, the counts are made every day ($n = N$) but the daily efficiency is predicted from estimates derived from "sampled" days on which releases are made (true n is a small fraction of N). Using the efficiency estimates in the reviewer's ratio estimate would be appropriate if each day's efficiency were independently estimated as the counts are (with the exception of missing value estimates). They are not; they are all predicted using the same coefficient estimates.

I believe that the estimator that I use is the appropriate one for our situation, and so we are stuck with the complicated variance estimate.

I believe that Monte Carlo simulation techniques would be take time to develop, and the resources devoted to this effort (even though they would be financially rewarding to me) would be better directed to more field releases and monitoring.

APPENDIX C. Statistical reviews by John Skalski and Lyman McDonald and Shay Howlin.

Appendix D. Stillwater analysis of data.

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M E M O R A N D U M

DATE: July 3, 2000

TO: Scott Spaulding and Craig Fleming USFWS–AFRP

FROM: Jennifer Vick, Stillwater Sciences

SUBJECT: Revised Preliminary Analysis of Data From 1999 Stanislaus River Rotary Screw Trap Experiments

This report has been revised to include additional recaputure information provided by S.P. Cramer and Associates following completion of the original report, dated March 17, 2000.

Background

Flows in the lower Stanislaus River are controlled by the New Melones Project. Under the authority of the Central Valley Improvement Act (CVPIA), the Bureau of Reclamation and the U.S. Fish and Wildlife Service are developing operating criteria for the New Melones Project to maximize production of fish resources in the lower Stanislaus River. With this in mind, the 1999 Annual Work Plan for the Stanislaus River Basin Water Needs, CVPIA Section 3406(c)(2), identified general objectives and actions to provide information useful to the overall planning efforts for the operation of the New Melones Project. A key objective in this plan was to evaluate elements of biological water needs and flow effects, including relationship of flow volume and patterns to biological processes.

In 1999, the U.S. Fish and Wildlife Service conducted releases of marked chinook salmon smolts to assess smolt survival in the Stanislaus River. Stillwater Sciences worked with the U.S. Fish and Wildlife Service to design the releases so that a multinomial mark-recapture model could be used to estimate survival in specific reaches of the river. Field implementation of the studies was conducted by S.P. Cramer and Associates. Marked salmon were captured in rotary screw traps at two locations – Oakdale (RM 40) and Caswell (RM 8). Salmon were released at five locations – Knights Ferry (RM 56.7), immediately upstream of the Oakdale trap (RM 40), immediately upstream of the Oakdale Recreational Area (RM 40), immediately downstream of the Oakdale Recreational Area (RM 38), and immediately upstream of the Caswell trap (RM 8)

(Figure 1). All marked fish captured in the traps were re-marked and re-released. Release and recovery data are shown in Table 1.

Stillwater Sciences developed a simple mark-recapture model to estimate survival in specific river reaches and in all reaches combined based on the releases described above. Typically, survival has been estimated by expanding the number of recaptured fish based on estimated trap efficiency. In this approach, trap efficiency is estimated by releasing marked fish immediately upstream of the trap, and efficiency is defined as the ratio of fish recaptured to fish released. This approach is vulnerable to problems of estimating trap efficiency, which may result in significant over- or under-estimation of survival. This was demonstrated on the Tuolumne River, where releases of marked fish immediately upstream of a rotary screw trap consistently and significantly underestimated trap efficiency (TID/MID 1998, 1999). The multinomial model does not rely on traditional estimates of trap efficiency but rather analyzes the data as an interlocking set of paired releases.

This study consisted of five smolt release groups totaling approximately 50,000 coded-wire tagged (CWT) fish (Figure 1). One group of approximately 25,000 CWT fish was released at Knights Ferry (RM 54.7); the second group of approximately 800 CWT fish (split into two sub-groups) was released upstream of the Oakdale rotary screw trap (RM 40); the third group of approximately 10,000 CWT fish (split into two sub-groups) was released just upstream of the Oakdale Recreation ponds; a fourth group of approximately 10,000 CWT fish (split into two subgroups) was released below the Oakdale Recreation ponds at about RM 39; and the final group of 5,000 CWT fish (also split into two separate groups) was released around RM 8 upstream of the Caswell rotary screw trapping (RST) site, which served as the efficiency release for the Caswell traps. The existing RST sites, one trap at RM 40 near Oakdale and two traps near Caswell State Park (RM 8), served as the primary recovery locations for the marked fish. All release groups bore unique marks, and any fish captured in the Oakdale rotary screw trap was given a new mark and re-released. The numbers of fish released and marks used are shown in Table 1. All fish released for this study were coded-wire tagged and adipose fin-clipped. Two CWT lots were used (one for the Knights Ferry release and one for the downstream release groups). The fish groups released at the lower four sites (constituting one tag lot) also had a secondary dye inoculation mark so that their release location could be identified without sacrificing the fish, which is necessary for recovering the CWT.

The fish were released over a three day period during flows of 1,230–1,370 cfs (Figure 1, Table 1). The first day included the release of 25,000 fish at Knights Ferry, 400 fish upstream of the Oakdale rotary screw trap, and one group each of 5,000 fish above Oakdale Recreation Area and below Oakdale Recreation Area, respectively. The second day included the release of the remaining 400 fish upstream of the Oakdale rotary screw trap and the remaining 5,000 fish groups at the two Oakdale sites downstream of the trap and 2,500 fish at the Caswell site. On the final day, the remaining group of 2,500 fish was released at the Caswell site. This release strategy was intended to allow the fish to disperse in as natural a pattern as possible and to maximize the likelihood that the fish would move through the same segments of river under the same environmental conditions.

Table 1. Fish release groups used for 1999 smolt survey evaluations and recaptures at the Oakdale and Caswell Traps.

Release Location	Release Date	Mark[1]	Number Released	Mean Length (mm)	# Recaptured at Oakdale	% Recaptured at Oakdale	# Recaptured at Caswell	% Recaptured at Caswell
Knights Ferry	1 June	Ad-clip	25,536	ND	156	0.6	35	0.1
Oakdale Eff.	1 June	BCG + Ad-clip	367	82.9	1	0.3	0	0.0
Oakdale Eff.	2 June	AFG + Ad-clip	394	86.3	5	1.3	0	0.0
RM 40	1 June	DFK + Ad-clip	4,975	84.4	N/A	N/A	10	0.2
RM 40	2 June	TCK + Ad-clip	4,403	83.2	N/A	N/A	7	0.2
RM 38	1 June	BCK + Ad-clip	4,981	85.3	N/A	N/A	8	0.2
RM 38	2 June	AFK + Ad-clip	5,007	84.8	N/A	N/A	8	0.2
Caswell Eff.	2 June	DFG + Ad-clip	2,500	83.6	N/A	N/A	63	2.5
Caswell Eff.	3 June	TCG + Ad-clip	2,487	84.2	N/A	N/A	39	1.6
Oakdale re-mark	3–6 June	DFP	146	ND	N/A	N/A	0	0.0

[1] Mark Abbreviations:

Fin	Color
TC– top caudal	K– black
BC– bottom caudal	G– green
AF– anal	
DF– dorsal	

Analysis Methods

The tasks, as defined in the scope of work are as follows:

Task 1: Estimate survival (with confidence intervals) in the upper and middle reaches (Knights Ferry–RM 40 and RM 40–RM 38, respectively) using a multinomial model. This model treats the Knights Ferry, RM 40, and RM 38 releases as an interlocking set of three paired-release experiments with recoveries at the Caswell trap. The model does not rely on estimated trap efficiency at Caswell.

Task 2a: Estimate survival (with confidence intervals) in all three reaches (Knights Ferry–RM 40, RM 40–RM 38, and RM 38–Caswell) and river-wide using the traditional approach, which expands recovery based on estimated trap efficiency. This task relies on recaptures at Caswell and estimated daily trap efficiency (based on the efficiency relationships developed by S.P. Cramer and Associates). For reaches Knights Ferry–RM 40 and RM 40–RM 38, compare the results of the more traditional estimates to the results of the multinomial modeling completed in Task 1.

Task 2b: Estimate survival (with confidence intervals) between Knights Ferry–RM 40 using Oakdale recovery data and the Oakdale efficiency experiment (conducted during the survival releases). Compare this with the reach Knights Ferry–RM 40 survival estimate from Tasks 1 and 2a.

The methods used to complete these analyses are described in Appendix A.

Results

Results of the survival analyses are shown in Table 2 and Figures 2, 3 and 4.

Table 2. Estimated smolt survival in the Stanislaus River, 1999.

Reach	Estimated Survival and 95 % confidence intervals (%)		
	Multinomial Model (Task 1)	Traditional based on Caswell recoveries (Task 2a)	Traditional based on Oakdale recoveries (Task 2b)
Knights Ferry–RM 40	80 (51–100)	77 (44–100)	77 (40–100)
RM 40–RM 38	100 (57–100)	100 (55–100)	
RM 38–Caswell	8.2 (6.3–13)[1]	7.8 (4.2–12)[1]	
River-wide	6.6 (4.5–8.5)[1]	6.7 (4.4–9.6)[1]	

[1] These estimates rely on traditional estimates of trap efficiency at Caswell. The estimate used is 2.1%.

The benefits of the multinomial approach are limited because only two recovery locations (i.e., trap locations) were available in the design. As such, the multinomial model (Task 1) and the traditional method using Caswell recoveries (Task 2a) use exactly the same data and the same assumptions about survival and recovery of each group individually. (Superficially, the traditional method for estimating survival in the Knights Ferry–RM 40 and the RM 40–RM 38 reaches uses an efficiency estimate at the Caswell trap, but this term cancels out algebraically, contributing nothing to the final estimator). The only differences between the two approaches are that the multinomial model is constrained by the requirement that all survival parameters in the model must be #100%, and that the multinomial model is able to form slightly smaller confidence intervals because it treats all three releases as a single experiment, rather than three separate experiments. Neither method provides any check on the validity of the efficiency assumption at the Caswell trap.

The multinomial model and the traditional method using Oakdale recoveries (Task 2b) use different data sets and different assumptions. In particular, the former makes no assumption about efficiency at either trap, whereas the latter depends on an efficiency-release for the Oakdale trap. In this reach, the general agreement of the estimates indicates that, at least for this particular experiment, the assumptions of the trap efficiency releases were met. It is not known whether this would be the case under other flow conditions or for other releases.

APPENDIX A. DESCRIPTION OF MODELS USED FOR SURVIVAL ANALYSIS

TASK 1. MULTINOMIAL MODEL

Assumptions:

- All smolts released at Knights Ferry have the same probability $\mathbf{n}_1$ of surviving to RM 40.
- All smolts released at RM 40, and all smolts from Knights Ferry reaching RM 40, have the same probability $\mathbf{n}_2$ of surviving to RM 38.
- All smolts released at RM 38, and all smolts from Knights Ferry or RM 40 reaching RM 38, have the same probability σ of appearing in the Caswell traps.

Let $\mathbf{n} = (\mathbf{n}_1, \mathbf{n}_2, \sigma)$.

Under these assumptions, the probability of recovering $\boldsymbol{m} = \{m_1, m_2, m_3\}$ smolts from the Knights Ferry, RM 40, and RM 38 releases, respectively, out of releases of $\boldsymbol{n} = \{n_1, n_2, n_3\}$ smolts at these locations, is

$$p(\boldsymbol{m} \mid \mathbf{n}, \boldsymbol{n}) = \binom{n_1}{m_1} (\mathbf{n}_1 \mathbf{n}_2 \sigma)^{m_1} (1 - \mathbf{n}_1 \mathbf{n}_2 \sigma)^{n_1 - m_1} \times \binom{n_2}{m_2} (\mathbf{n}_2 \sigma)^{m_2} (1 - \mathbf{n}_2 \sigma)^{n_2 - m_2} \times \binom{n_3}{m_3} \sigma^{m_3} (1 - \sigma)^{n_3 - m_3}$$

The likelihood, $L(\mathbf{n} \mid \boldsymbol{m}, \boldsymbol{n})$, is any function proportional to this, considered as a function of $\mathbf{n}$.

Temporarily ignoring the requirement that $\mathbf{n} \in [0,1]^3$, the maximum value of L is easily found to occur at

(2a) $$\hat{\mathbf{n}}_1 = \frac{m_1}{n_1} / \frac{m_2}{n_2}, \quad \hat{\mathbf{n}}_2 = \frac{m_2}{n_2} / \frac{m_3}{n_3}, \quad \hat{\sigma} = \frac{m_3}{n_3}.$$

This will be the maximum likelihood estimate when it is in the parameter space.

If the point (2a) does *not* lie in the parameter space, the maximum likelihood is attained somewhere on the boundary, and the estimator should be modified accordingly. The following cases can arise:

- If $\frac{m_1}{n_1} > \frac{m_2}{n_2}$ and $\frac{m_1 + m_2}{n_1 + n_2} \le \frac{m_3}{n_3}$, the estimator is

(2b) $$\hat{\mathbf{n}}_1 = 1, \quad \hat{\mathbf{n}}_2 = \frac{m_1 + m_2}{n_1 + n_2} / \frac{m_3}{n_3}, \quad \hat{\sigma} = \frac{m_3}{n_3}.$$

• If $\frac{m_2}{n_2} > \frac{m_3}{n_3}$ and $\frac{m_1}{n_1} \le \frac{m_2+m_3}{n_2+n_3}$, the estimator is

(2c) $$\hat{\mathbf{n}}_1 = \frac{m_1}{n_1} / \frac{m_2+m_3}{n_2+n_3}, \quad \hat{\mathbf{n}}_2 = 1, \quad \hat{\sigma} = \frac{m_2+m_3}{n_2+n_3}.$$

• Finally, if $\frac{m_1}{n_1} > \frac{m_2}{n_2}$ and $\frac{m_1+m_2}{n_1+n_2} > \frac{m_3}{n_3}$, or if $\frac{m_2}{n_2} > \frac{m_3}{n_3}$ and $\frac{m_1}{n_1} > \frac{m_2+m_3}{n_2+n_3}$, the estimator is

(2d) $$\hat{\mathbf{n}}_1 = 1, \quad \hat{\mathbf{n}}_2 = 1, \quad \hat{\sigma} = \frac{m_1+m_2+m_3}{n_1+n_2+n_3}.$$

For the Stanislaus River data, $\boldsymbol{n} = (25536, 9378, 9988)$, $\boldsymbol{m} = (35, 17, 16)$, the estimator (2c) applies, and the fitted model is

$$\hat{\mathbf{n}}_1 = 0.80, \quad \hat{\mathbf{n}}_2 = 1.00, \quad \hat{\sigma} = 0.0017.$$

Classical Confidence Regions

By definition, confidence intervals for model parameters arise from the distribution of the parameters re-estimated from samples drawn from the fitted model. These distributions can be derived analytically in some cases, but when the model is non-standard, or the estimators are complicated (as here), we may as well just calculate them via simulation.

Using parametric bootstrapping (B=10,000) with the 1999 Stanislaus River data, and applying the routine `sm.density` from the smoothing library of Bowman and Azzalini (1997), ten smoothed density curves were generated for each of the three parameters. These curves are shown in Figure 2, along with the consensus curve obtained by averaging.

The 95% confidence intervals associated with these marginal densities were

$$0.51 \le \mathbf{n}_1 \le 1.00, \quad 0.57 \le \mathbf{n}_2 \le 1.00, \quad 0.0013 \le \sigma \le 0.0026.$$

Problems With Confidence Regions

When the form of the estimator can vary from sample to sample, as in (2a–d) above, the distribution of re-estimated parameters, on which the classical confidence intervals are based, can look very strange. Indeed, this was the case in Figure 2.

The problem here goes beyond aesthetics, however. Because the classical intervals are based on samples from the fitted model, “accidental” features of the basic estimate carry over to these intervals. This is particularly troublesome when, as here, the general behavior of the model is very sensitive to the parameter values. For example, if a basic estimate of survival or capture probability is exactly zero, all the re-estimated values will be also, so that the confidence intervals will have width zero. Although technically correct, such a result is not easy to explain to non-statistical readers, nor particularly useful once explained.

This has been a problem for us in the past and has prompted us to explore other ways of quantifying parameter uncertainty. The only methods which seem applicable here are those which rely on the shape of the likelihood, regarded as a function of the possible states of nature $\mathbf{n}$ when the data $\boldsymbol{m}$ are held fixed.

Marginal Likelihood

The likelihood is a joint function of all three parameters. It is hard to visualize a four-dimensional object such as the graph of this likelihood, or even three-dimensional objects such as its contour surfaces. Ordinarily, we want to consider parameters one or two at a time.

A very simple way to reduce the dimensionality is to consider cross-sections of the likelihood hypersurface along planes (or hyperplanes) perpendicular to the parameter space and passing through the maximum-likelihood estimate. Such cross-sections are shown in Figure 3.

The right way to do things, however, is to integrate out some parameters, and obtain marginal likelihoods on those remaining.

As it turns out, none of the desired integrals can be written in terms of standard functions (or at least in terms of built-in functions of S-Plus). With an eye toward generalization to a greater number of reaches (and consequently higher-dimensional integrals), and the possible introduction of Bayesian methods at some point, we chose to use a form of Monte-Carlo integration. Our algorithm is equivalent to sampling from the joint distribution proportional to the likelihood. The marginal distributions of the components of these samples are then proportional to the marginal likelihoods.

To sample from this joint distribution, consider the change of variables

$$\theta_1 = \mathbf{n}_1\mathbf{n}_2\sigma, \quad \theta_2 = \mathbf{n}_2\sigma, \quad \theta_3 = \sigma.$$

Sampling from the distribution

$$P_{\mathbf{n}} \propto L(\mathbf{n})\,d\mathbf{n},$$

supported on the unit $\mathbf{n}$-cube, is equivalent to sampling from the distribution

$$P^S_{\boldsymbol{\theta}} \propto L(\mathbf{n}(\boldsymbol{\theta}))\left|\frac{\partial \mathbf{n}}{\partial \boldsymbol{\theta}}\right| d\boldsymbol{\theta},$$

supported on the simplex $S = \{\boldsymbol{\theta} \mid 0 \le \theta_1 \le \theta_2 \le \theta_3 \le 1\}$.

Interpret $P^S_{\boldsymbol{\theta}}$ as the conditional distribution $P_{\boldsymbol{\theta}|S}$, where $P_{\boldsymbol{\theta}}$ is proportional to the extension of $L|\partial\mathbf{n}/\partial\boldsymbol{\theta}|d\boldsymbol{\theta}$ to the entire unit $\boldsymbol{\theta}$-cube. Then

$$P_{\boldsymbol{\theta}} \propto \theta_1^{m_1}(1-\theta_1)^{n_1-m_1}d\theta_1 \times \theta_2^{m_2-1}(1-\theta_2)^{n_2-m_2}d\theta_2 \times \theta_3^{m_3-1}(1-\theta_3)^{n_3-m_3}d\theta_3,$$

which is just the product of three independent beta distributions (but notice the subtle effect of the Jacobian $|\partial \mathbf{n} / \partial \boldsymbol{\theta}| = \theta_2^{-1} \theta_3^{-1}$ on the parameters of these distributions).

We sample from $P_{\boldsymbol{\theta}|S}$ by simply drawing random samples from $P_{\boldsymbol{\theta}}$ and rejecting those which are not in S.

This worked well for the 1999 Stanislaus River data. The marginal likelihood curves shown in Figure 4 were drawn by the method described in Section 2, using a total of 100,000 samples.

Bayesian HPD Regions

The likelihood function is proportional to the Bayesian posterior distribution for the prior consisting of the product of independent uniform distributions on $\mathbf{n}_1$, $\mathbf{n}_2$, and σ. The marginal posterior distributions are simply the normalizations of the marginal likelihoods. This interpretation allows us to use the Bayesian concept of HPD (highest posterior density) regions in place of classical confidence regions.

For the 1999 Stanislaus River data, the marginal posterior distributions are just the normalizations of the marginal likelihoods, presented in Figure 4.

The 95% HPD intervals associated with these were:

$$0.54 \leq \mathbf{n}_1 \leq 0.99, \quad 0.58 \leq \mathbf{n}_2 \leq 0.99, \quad 0.0014 \leq \sigma \leq 0.0028$$

Survival in the Lowermost Reach

It is impossible to separate survival in the RM 38–Caswell reach from capture efficiency at the Caswell traps without additional data. If the capture efficiency at Caswell, p, were known, survival in this lowermost reach could be estimated by simply dividing the estimate for σ by p. The confidence and HPD intervals would scale in the same way.

The 1999 Stanislaus River Rotary Screw Trap Program included experiments designed to estimate this efficiency. In these experiments, a total of 4,987 marked smolts were released a short distance upstream of the Caswell traps, of which 103 were subsequently recovered. This yields the efficiency $p = 0.0207$; treating this as if it were an exact value yields an estimate of 0.082 for survival in the RM 38-to-Caswell reach, with 95% confidence and HPD intervals (0.063–0.13) and (0.068–0.14) respectively.

Of course, this value of p is only an estimate, whose uncertainty should be taken into account. This would yield broader intervals for the survival, and shift the survival estimate itself slightly to the right. There are several ways this could be done; the tidiest would be to modify the basic model to have three release locations and four reaches, the last representing the segment between the efficiency release location and the trap, and setting survival in this reach to 1. Alternatively, one could simply treat the recovery of efficiency fish as a separate binomial or Poisson experiment to get estimates the mean and variance of p, use the delta method to approximate the mean and variance of σ/p, and inflate the intervals calculated above accordingly.

We do neither of these here, however, because our experience with similar experiments on the Tuolumne River has led us to suspect that conventional trap efficiency experiments like these, in which smolts are released closely enough to the trap that mortality between release and recovery can be safely neglected, may be badly biased as estimators of the efficiency appropriate to groups released much further upstream. We believe that the effect of such bias on the accuracy of the survival estimate are potentially more important than the effect of sampling error on the precision of the estimate.

TASKS 2 AND 3. TRADITIONAL APPROACH

Survival from Knights Ferry to RM 40, Using Data from Oakdale Trap

Survival in the Knights Ferry–RM 40 reach can be estimated using recovery of the Knights Ferry release group at the Oakdale Trap (at RM 40), together with data from the Oakdale Trap efficiency experiments.

Usually, this survival estimate is described as a two-stage process: First, capture efficiency at the trap is estimated as $\hat{p} = m_e/n_e$, where n_e is the number released in the efficiency experiment and m_e is the number of these recovered at the trap. Second, survival from the upstream site is estimated as $\hat{\mathbf{n}}_1 = m_s/(\hat{p}(n_s)$, where n_s is the number released in the survival experiment and m_s is the number of these recovered at the trap.

This is equivalent to treating the survival and efficiency releases together as a paired-release experiment (note that this would not be the case if the capture efficiency were estimated separately, e.g., by using the logistic model described in (Demko and Cramer 1998) to predict efficiency from environmental variables). Confidence intervals were constructed on this basis by simulation.

For the Stanislaus River data $n_e = 761$, $m_e = 6$, $n_s = 25{,}536$, $m_s = 156$, the survival estimated in this way is

$$\hat{\mathbf{n}}_1 = 0.77$$

with 95% confidence interval

$$0.40 \le \mathbf{n}_1 \le 1.00.$$

Survival from Knights Ferry to RM 40, RM 40 to RM 38, and RM 38 to Caswell, and River-Wide Survival, Using Data from Caswell Trap

The same method described above can be used with recoveries of the Knights Ferry, RM 40, and RM 38 release group at the Caswell Trap, together with data from the Caswell Trap efficiency experiments. The efficiency data at Caswell were n_e ' 4,987 , m_e ' 103 .

Estimates of survivals from Knights Ferry to RM 40 ($\mathbf{n}_1$) and from RM 40 to RM 38 ($\mathbf{n}_2$) can be found as

$\hat{\mathbf{n}}_1$ = Survival from Knights Ferry to Caswell / Survival from RM 40 to Caswell,
$\hat{\mathbf{n}}_2$ = Survival from RM 40 to Caswell / Survival from RM 38 to Caswell.

These are mathematically equivalent to treating the Knights Ferry and RM 40 releases, and the RM 40 to RM 38 releases, as paired release experiments. However, the point estimates are slightly different, because the constraint $\mathbf{n}_2$#1.00 does not affect other parameters, and the confidence intervals are slightly broader, since these experiments are treated independently here:

$$\hat{\mathbf{n}}_1 \text{ ' } 0.77, \quad \hat{\mathbf{n}}_2 \text{ ' } 1.00.$$

$$0.44 \# \mathbf{n}_1 \# 1.00, \quad 0.55 \# \mathbf{n}_2 \# 1.00.$$

Similarly, the confidence interval reported above for survival from RM 38 to Caswell is slightly broader than that found for Task 1, although the estimate itself is identical.

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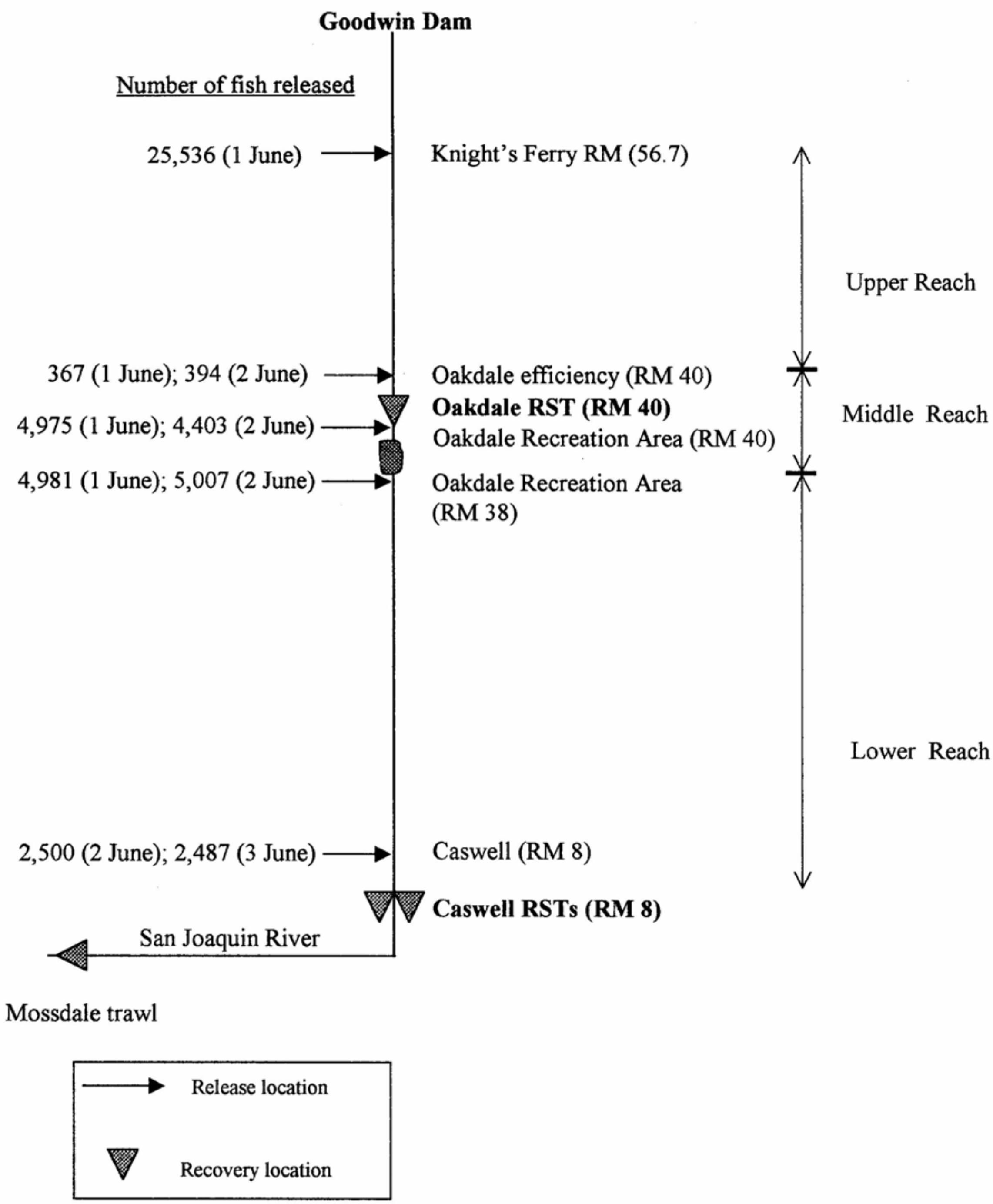

Figure 1. Smolt survival study design for the Stanislaus River.

Appendix E. Results of mark-recapture tests to estimate survival of juvenile chinook migrating through the Stanislaus River to Caswell, 1996-1999. Release locations labeled Oakdale refer to efficiency releases in which individuals were recaptured at the Caswell traps.

Release Location	Date of Release	Fish Stock	Adjusted # Released	Total # Recap.	% Recap.	Predicted Efficiency	Expanded Catch	Survival Index	Avg. Flow at OBB	Mean Release	Mean Recap.
KF	11-Apr-98	Hatchery	-	1	-	0.01565	64	VOID	2,066	-	78.0
KF	02-May-98	Hatchery	2763	6	0.217%	0.01399	429	15.5%	1,972	83.2	88.7
Oakdale	02-Mar-98	Natural	929	2	0.215%	0.03909	51	5.5%	3,508	35.4	36.0
Oakdale	18-Mar-98	Natural	479	1	0.209%	0.15736	6	1.3%	1,768	62.2	71.0
Oakdale	02-May-98	Natural	392	1	0.255%	0.02794	36	9.1%	1,972	81.1	85.0
Oakdale	12-Feb-96	Natural	969	3	0.310%	0.03477	86	8.9%	681	34	35
Oakdale	22-Mar-96	Hatchery	617	1	0.162%	0.02726	37	5.9%	3,413	43.9	100
Oakdale	06-Apr-96	Hatchery	500	2	0.400%	0.02355	85	17.0%	1,791	70.6	76.5
KF	22-Apr-96	Natural	930	3	0.323%	0.0249	120	13.0%	1,673	86.1	88.3
Oakdale	04-May-96	Natural	547	1	0.183%	0.0256	39	7.1%	1,674	75.5	80
Oakdale	26-May-96	Hatchery	304	1	0.329%	0.04369	23	7.5%	921	72.2	80
Oakdale	19-Feb-99	Natural	326	1	0.307%	0.02597	39	11.8%	4,129	34.2	37
Oakdale	22-Feb-99	Natural	316	3	0.949%	0.02597	116	36.6%	4,158	35.8	37.7
Oakdale	01-Mar-99	Natural	193	1	0.518%	0.02597	39	20.0%	3,535	35.2	45
Oakdale	05-Mar-99	Natural	519	1	0.193%	0.02597	39	7.4%	2,641	35.8	38
Oakdale	30-Mar-99	Natural	391	1	0.256%	0.02597	39	9.8%	1,146	49.6	75
KF	01-Jun-99	Hatchery	25536	35	0.137%	0.02597	1348	5.3%	1,229		89.2
RM38	01-Jun-99	Hatchery	4981	8	0.161%	0.02597	308	6.2%	1,229	85.3	85.4
RM38	02-Jun-99	Hatchery	5007	8	0.160%	0.02597	308	6.2%	1,365	84.8	86
RM40	01-Jun-99	Hatchery	4975	10	0.201%	0.02597	385	7.7%	1,229	84.4	87.3
RM40	02-Jun-99	Hatchery	4403	7	0.159%	0.02597	270	6.1%	1,365	83.2	85.7