EFFECTS OF PULSE FLOWS ON JUVENILE CHINOOK MIGRATION IN THE STANISLAUS RIVER

1998 ANNUAL REPORT

Prepared for

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EXECUTIVE SUMMARY

We fished a rotary screw trap in the Stanislaus River (river mile (RM) 40.1) near Oakdale, California, to index the timing and abundance of down migrating juvenile chinook salmon from January 27 to July 15, 1998. Our index of down migrant abundance was the daily catch of juvenile chinook divided by the predicted trap efficiency. Outmigration of fry peaked in mid February and outmigration of smolts peaked in early May. Estimated passage of chinook for the season was 417,185 fry, 60,041 parr, and 121,647 smolts, for a season total of 598,873 during January 27 to July 15.

We estimated the number of chinook passing our trap each night based on the predicted trapping efficiency for each day of the sampling season. Between March 2 and June 24, we released 11 groups (2 hatchery, 9 natural) of juvenile chinook to evaluate trapping efficiency. Releases were conducted at flows ranging from 1,561 to 3,508 cfs. The percent of the released fish recovered in the screw trap varied from 2.7 to 8.6%, with the recapture rates of natural chinook ranging from 2.7 to 7.6%, and recapture rates of hatchery fish ranging from 6.9 to 8.6%. We found that trapping efficiency was best estimated by a regression on river flow.

In addition to the one trap at Oakdale, we fished two traps near Caswell State Park (Caswell) (RM 8.6) under contract to the USFWS to estimate the number of juvenile chinook migrating out of the lower river. Estimated juvenile chinook passage at Caswell in 1998 was 1.5 to 3 times higher than at Oakdale for parr and smolts, but 1.4 times lesser for fry. There may have been substantial spawning downstream of Oakdale, and there were large numbers of newly-emerged fry that passed the Oakdale trap when it was not fishing. In contrast to 1998, passage at Caswell in 1996 was only estimated to be about one third of that at Oakdale. Flows during January and February 1996 were stable and under 1,000 cfs, while in 1998, flows during these months of fry emergence fluctuated from

1,366 to 5,064 cfs. High flows during fry emergence in 1998 probably disbursed large numbers of emergent fry to areas downstream of Oakdale where they reared until migrating as parr or smolts.

The mean lengths of fish captured at Oakdale and their dates of peak abundance were similar to those of fish captured at Caswell. Marked fish released at Oakdale and recovered at Caswell usually traveled the distance within several days. Each of these pieces of evidence indicates that migrating parr and smolts do not stop and rear for extended periods of time between Oakdale and Caswell.

Mark-recapture tests with hatchery chinook were conducted to estimate survival from Knights Ferry to Oakdale. Survival estimates for hatchery chinook varied from only 16.6 to 22.9%. These low survival rates are far lower than must have occurred to produce the large number of migrants reaching Caswell in 1998, so our assumptions for the mark-recapture tests must have been invalid.

Twenty-six yearling chinook ranging in size from 114 to 193 mm, and twenty rainbow/steelhead ranging in size from 66 to 283 mm were captured during the 1998 sampling season.

ACKNOWLEDGMENTS

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The data reported here were gathered through the efforts of our field staff: Robert Fuller, Andrea Phillips, Ben Griffith, Ryan Cuthbert, Tiffani Bergeron, Gina Ladd, Michael Justice, and Ron Sandling. We are grateful for their dedication and hard work.

We are also grateful to the following participants in this project:

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- The staff at Merced River Fish Facility and CDFG technicians. We recognize and appreciate their efforts to facilitate this study.
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INTRODUCTION

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 (Caswell) (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). Target species include fall-run chinook salmon and steelhead/rainbow trout (Table 1).

Table 1. Date, location and number of rotary-screw traps operated in the Stanislaus River, 1993 - 1998.

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	2	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

In the spring of 1993, SPCA began a juvenile chinook monitoring program in the Stanislaus River to determine the effects of different flow regimes on juvenile chinook migration and growth in the Stanislaus River. In 1993 we (SPCA) fished a rotary screw trap in the Stanislaus River near Oakdale to index the migration timing and abundance of down-migrating juvenile chinook during large manipulations in river flow. The trap fished from April 21, 1993 to June 29, 1993. Catches in the trap indicated that down migration peaked for at least one day, but no more than four days, when the Stanislaus River flow increased from 400 cfs to 1,400 cfs one week after the trap was installed on April 21 (Cramer and Demko 1993). The pattern of daily outmigrant abundance before, during and after the sustained pulse flow events suggested the stimulant effect of flow on chinook migration lasted only a few days and affected only a small portion of the population. There was no indication that the sustained high flows "flushed" juvenile chinook out of the river.

In 1994 the CDFG fished one screw trap near the mouth of the Stanislaus River at Caswell State Park. The trap operated from April 23, 1994, to May 26, 1994. Daily catches of juvenile chinook ranged from 0 to 75 (Loudermilk et al. 1995). Catches were highest following the first pulse in flow (late April), and similarly to 1993, dropped off dramatically within a few days. A second brief increase in catch occurred in late May corresponding to another increase in flow.

In 1995 SPCA fished one screw trap at the site near Oakdale where the trap fished in 1993. The trap operated from March 18, 1995, to July 1, 1995. Sampling in 1995 showed that pulse flows do have a stimulant effect on juvenile chinook, but the effect is relatively short, generally lasting only a few days (Demko and Cramer 1995). Further, pulse flows do not flush juvenile chinook out of the river.

SPCA conducted mark-recapture tests with natural migrants and hatchery chinook in 1995 to estimate survival from Knights Ferry to Oakdale (14.2 miles). Estimated survival to the Oakdale trap of natural migrants varied from 32.4% to 66.7%, and was higher for larger fish (Demko and Cramer 1995). The survival estimates made for two hatchery groups were 4.7% and 8.6%.

In 1996, SPCA fished two screw traps at Caswell and one at Oakdale. Sampling began earlier in 1996 with the goal of estimating the total number of juvenile chinook outmigrants. We began sampling at Oakdale and Caswell in early February, and found that fry were already migrating. Large differences in estimated abundance of juvenile chinook at Oakdale and Caswell in 1996 suggested that there may have been high mortality to juvenile chinook in the 31.5 miles between the Oakdale and Caswell sites (Demko and Cramer 1997).

In 1997, we fished two rotary-screw traps at Caswell. No sampling occurred at Oakdale due to high flows. These high flows also delayed the initiation of sampling at Caswell from January 1 until mid-March (Demko and Cramer 1998).

In 1998, the Oakdale trap fished in the same location used in 1993,1995, and 1996. The trap was installed January 23 but final positioning was delayed by high flows. Sampling began January 26 and continued through July 15. Two traps were also fished at Caswell between January 8 and July 16 (Demko and Cramer 1999). Results of the sampling at Oakdale are the subject of this report.

This sampling of juvenile outmigrants has been designed to resolve 7 pressing flow-related questions concerning chinook migration. They are as follows:

Q1. How high should pulse flows be to stimulate migration?
Q2. How long should pulse flows last to stimulate migration?
Q3. Are there limiting factors before or after the pulse that determine its benefit?
Q4. How long does it take juvenile chinook to migrate out of the Stanislaus River?
Q5. How long does it take juvenile chinook to migrate through the San Joaquin Delta?
Q6. How does flow affect migration rate?
Q7. Will juveniles really stop migrating and be exposed to high mortality in the Delta if pulse flows stop before juveniles pass through the Delta?

The purpose of the work reported here is to begin answering these questions. In addition to the Oakdale trap, SPCA also operated two traps near Caswell State Park under contract to the USFWS in 1998 (Demko and Cramer 1999). Although the projects were under separate contracts with separate research objectives, much of the data collected at the lower river Caswell site is presented and discussed in this report.

DESCRIPTION OF STUDY AREA

The headwaters of the Stanislaus River originate on the western slope of the Sierra Nevada's. 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. The Stanislaus River is dammed at several locations for the purpose of 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 upstream from the San Joaquin River confluence, blocks the upstream migration of adult chinook. Almost all chinook spawning occurs upstream of the town of Riverbank (RM 34), and up to Goodwin Dam (RM 58.4).

Throughout this report we reference river miles on the Stanislaus River. River miles were determined with a map wheel and 7.5 minute series USGS quadrangle maps, (Knights Ferry, 1987 and Oakdale, 1987). The estimated river miles of our trapping and release locations are as follows:

Knights Ferry release site	RM 54.3
Orange Blossom Bridge	RM 46.9
Highway 120/108 release site	RM 41.2
Pipe release site	RM 40.6

Oakdale trapping location	RM 40.1
Caswell trapping location	RM 8.6

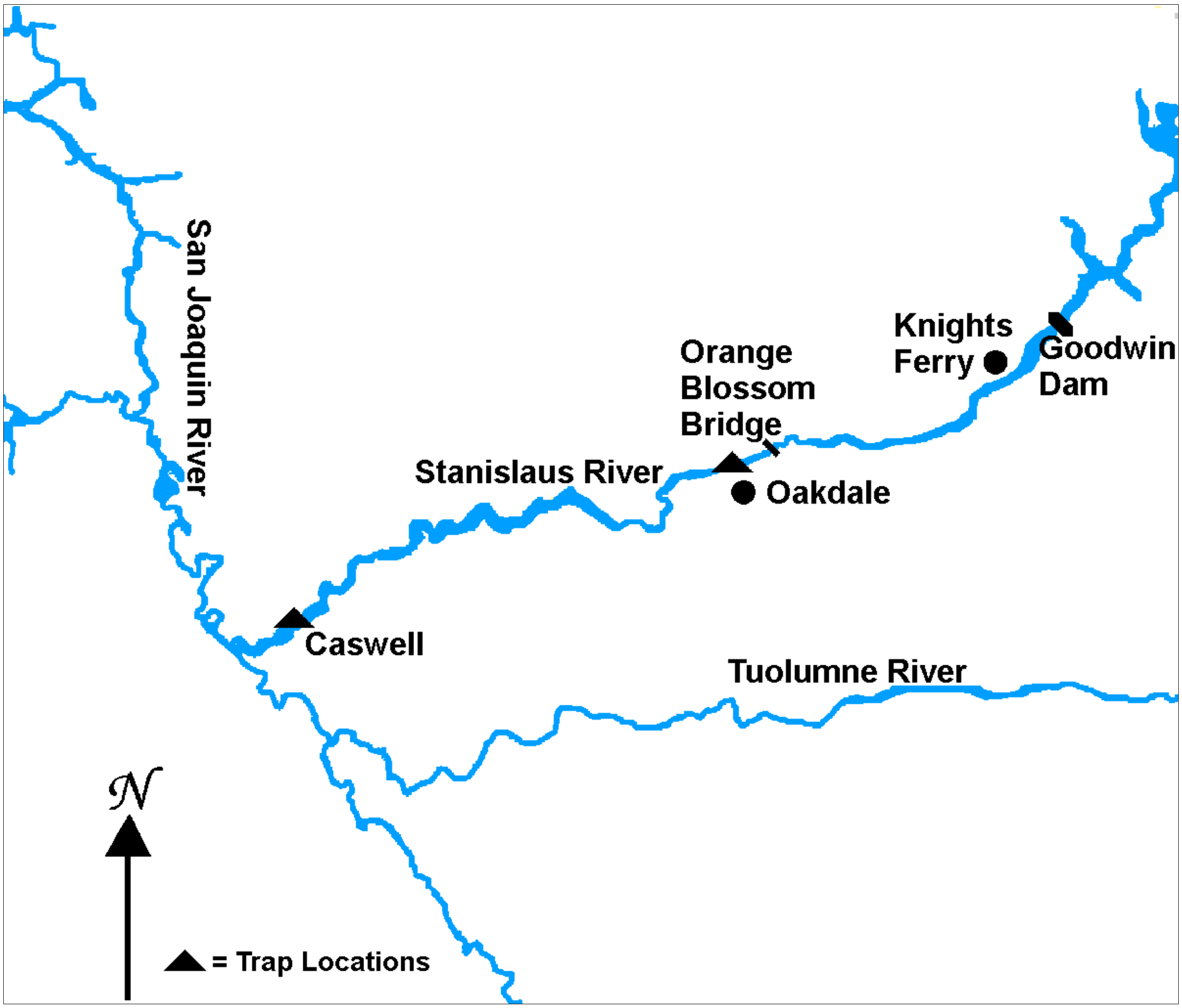

Figure 1. Location map of San Joaquin Basin and Stanislaus River.

METHODS

JUVENILE OUTMIGRANT MONITORING

Trapping Site

We fished a rotary screw trap in the mainstem of the Stanislaus River near the Oakdale Recreation Area, approximately 3 miles west of the town of Oakdale, California, for the purpose of capturing juvenile chinook as they migrate downstream. This trap site was chosen because it was the farthest downstream where we could find adequate water velocities for trap operation. Fast water velocities increase the rotation speed of the trap and increase its capture efficiency. This site (RM 40.1) was downstream from the majority of chinook spawning and juvenile rearing and was the same location we fished in 1993, 1995, and 1996.

The trap, manufactured by E.G. Solutions in Eugene, Oregon, consisted of a funnel shaped core suspended between two pontoons (Figure 2). The trap was positioned in the current so that water enters the 8 ft wide funnel mouth. Water enters the funnel and strikes the internal screw core, causing the funnel to rotate. As the funnel rotates, fish are trapped in pockets of water that are forced rearward into a livebox, where they are held. The trap was held in a static position in the main current by a 3/8 in. cable was suspended across the river about 35 ft above the water surface. This overhead cable was raised approximately 4-5 ft higher to allow for safer passage when the river rises during high flows. Cables fastened to the front of each pontoon were fastened to the overhead cable. This held the trap in position and allowed river users to pass the trap safely.

Figure 2. Photographs of the rotary screw trap.

Trap Monitoring

We installed the rotary screw trap January 23, and began retrieving catches the morning of January 27 (Figure 3). Monitoring continued until July 15. No catch was recorded February 4 through 11, due to high flows and May 21 through 26 due to trap malfunction.

The trap was fished 24 hours per day 7 days per week January 27 to June 20 with the exception of the aforementioned periods in February and May. From June 20 through the end of sampling July 15, the traps did not fish on weekends due to the high volume of rafting traffic passing the trapping site. The trap was raised after sampling Friday mornings and pulled into shore to allow more space for boats to pass. The trap resumed fishing in its usual position Sunday evenings. It was often necessary to clean the trap during the day to clear away debris accumulated against the trap and in the livebox. At times of high turbid flows and when we had recently released marked fish, we monitored the trap during the day to document whether or not we were catching juvenile chinook during the day. Following the releases, we monitored the trap every hour or two, depending on the amount of debris buildup and the number of fish we were capturing.

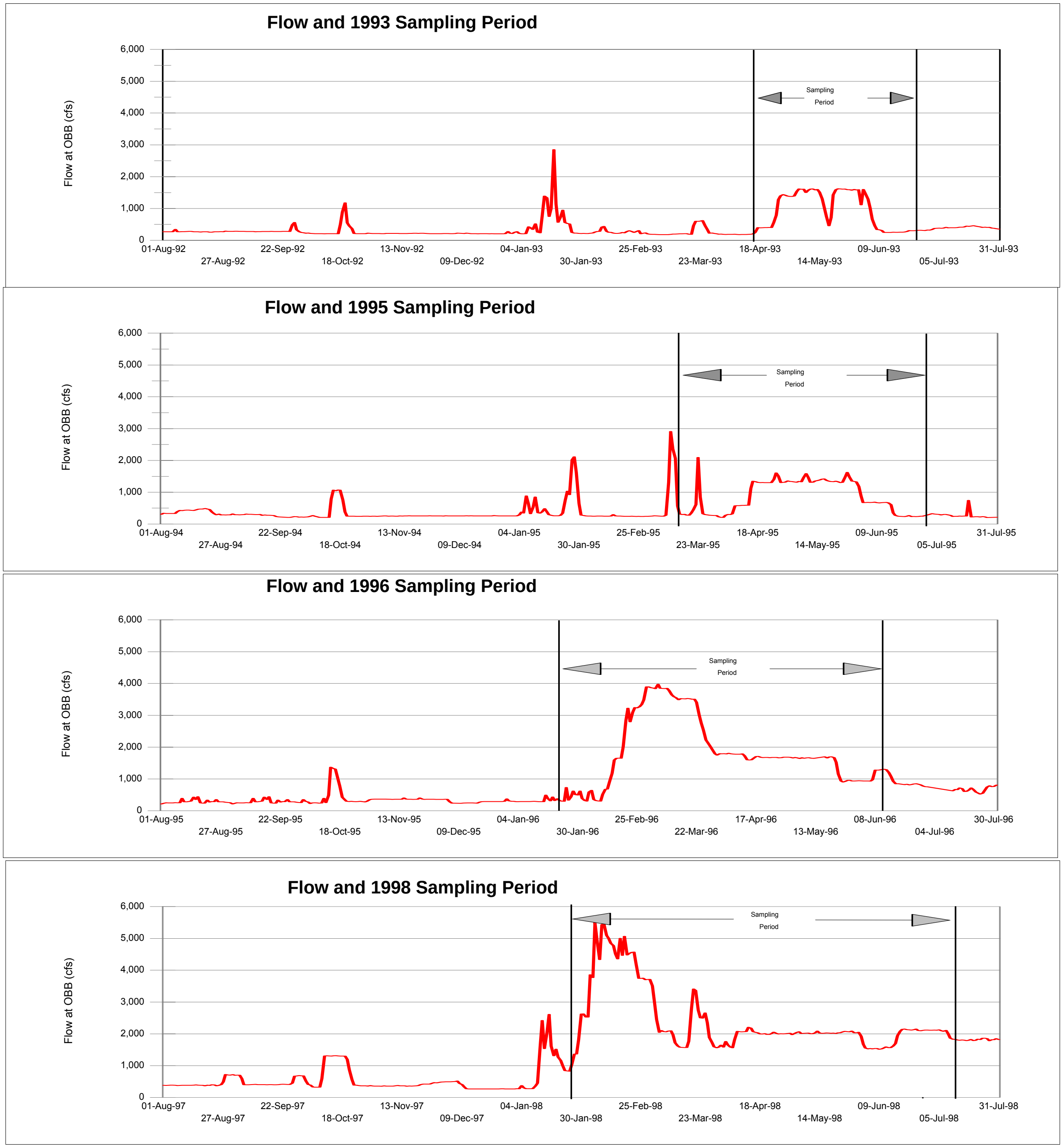

Figure 3. Outmigration sampling period in relation to Stanislaus River flow 1993, 1995, 1996, and 1998.

During natural freshets when fish would accumulate in the livebox fairly rapidly, we monitored the trap every 2 to 3 hours to reduce the chance of mortality to juvenile chinook. To provide fish with areas of refuge and to minimize stress and mortality we used a chicken-wire fence stapled to a wood frame to divide the livebox into front and rear sections. The wire mesh caught wood and plant debris while allowing fish to pass, and also reduced current in the rear portion of the livebox. Bricks and other forms of structure were placed behind the fence to provide additional shelter from current.

Each morning we removed the contents of the live boxes and identified and counted all fish captured. A random sample of 50 chinook and 20 of each other species were measured and their lengths recorded in millimeters. We also measured all rainbow/steelhead and all yearling chinook. After all fish were recorded, the traps were cleaned.

Approximately twice per month we removed scales from a few chinook removed from the livebox. Scale samples were also taken from a majority of the yearling chinook and rainbow/steelhead captured. A small knife was used to scrape away a few scales from the area just posterior to the dorsal fin and above the fishes lateral line. Each sample was placed in a separate envelope with the length of the fish, date, time and smolt index recorded on the outside.

Smolt Index Rating

We recorded the external appearance of smolting characteristics for each chinook and rainbow trout/steelhead measured. Smolting appearance was rated on a scale of 1 to 3, with 1 an obvious parr (highly visible parr marks) and 3 an obvious smolt (silvery appearance, easily shed scales, blackened fin tips).

EXPERIMENTAL RELEASE GROUPS

Trap Efficiency Releases

A total of 15 groups (9 natural migrants and 6 hatchery) were released to estimate trapping efficiency and evaluate migration rate and survival from Knights Ferry to Oakdale between March 2 and June 24 (Table 2). Natural chinook used in mark-recapture experiments were juvenile chinook captured in the screw trap. Generally, it was necessary to accumulate fish over a couple of days to have enough for a group. Fish were marked by cold brand or dye inoculation. The number of fish in each group ranged from 81 to 2,930. All marked fish were released at dark.

Trap efficiency was also evaluated by releasing lemons upstream of the trap to represent neutrally buoyant objects. Two lemon tests were conducted May 2 and May 30 in conjunction with releases of marked fish. None of the lemons were recovered in the trap.

Survival Releases

Hatchery fish were supplied by the CDFG from the Merced River Hatchery on two occasions for trap efficiency tests and four occasions for survival tests (Table 2). Efficiency groups of 175 and 267 fish were released May 30 and June 13. Survival groups ranging from 2,763 to 2,930 fish were released between April 11 and June 13.

Table 2. Date, stock, location, time, number of fish released and river flow for trap efficiency, migration rate and survival tests in the Stanislaus River during 1998.

Date of Release	Purpose	Release Code	Fish Stock	Adjusted # Released	Time of Release	Total # Recaptured	% Recap.	Avg. Flow at OBB
2 March 1998	Trap Eff.	O1	Natural	929	Night	25	2.7%	3,508
18 March 1998	Trap Eff.	O2	Natural	479	Night	27	5.6%	1,768
6 April 1998	Trap Eff.	O3	Natural	347	Night	23	6.6%	1,561
11 April 1998	Trap Eff.	O4	Natural	168	Night	10	6.0%	2,066
2 May 1998	Trap Eff.	O5	Natural	392	Night	15	3.8%	1,972
30 May 1998	Trap Eff.	O6	Natural	250	Night	19	7.6%	2,034
13 June 1998	Trap Eff.	O8	Natural	146	Night	7	4.8%	1,564
24 June 1998	Trap Eff.	O10	Natural	81	Night	6	7.4%	2,130
24 June 1998	Trap Eff.	O11	Natural	84	Night	4	4.8%	2,130
30 May 1998	Trap Eff.	O7	Hatchery	267	Night	23	8.6%	2,034
13 June 1998	Trap Eff.	O9	Hatchery	175	Night	12	6.9%	1,564
11 April 1998	Survival	KF1	Hatchery	-	Night	21	-	2,066
2 May 1998	Survival	KF2	Hatchery	2,763	Night	36	1.3%	1,972
30 May 1998	Survival	KF3	Hatchery	2,832	Night	26	0.9%	2,034
13 June 1998	Survival	KF4	Hatchery	2,930	Night	41	1.4%	1,564
2 May 1998	Lemons	-	-	100	Night	0	0.0%	1,972
30 May 1998	Lemons	-	-	100	Night	0	0.0%	2,034

Holding Facility and Transport Method

Fish were held in free standing net pens measuring 4 ft x 4 ft x 4 ft and 2 ft x 3 ft x 3 ft. The net pens consisted of 3/16 in. Delta mesh sewn onto frames constructed of ½ in. PVC pipe. The pipe was drilled so it would fill with water, sink and rest on the river bottom. The net pens were placed inside a submerged chain-link style dog kennel, which was constructed in the river to protect fish from predators and human disturbances. The kennel was located near the trap in an area of low velocity.

Prior to release, fish were transported to the efficiency release site in 20 gal. insulated coolers. Between 75 and 150 fish were placed in each cooler and then transported ½ mile upstream from the trap for trap efficiency tests. Depending on circumstances, the total time fish remained in a cooler ranged from 15 to 45 minutes. Although an aerator was always present in case it was necessary, oxygen was never delivered to the coolers during transport.

Fish were transported to Knights Ferry in a 200 gal. insulated aluminum hauling tank equipped with an oxygen supply and aerator.

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 appropriate mark was applied by placing the tip of the branding tool against the front/rear, right/left section of 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 the MadaJet against the caudal (top or bottom lobe), dorsal or anal fin (Hart and Pitcher 1969). Minimal pressure was applied as dye was injected into the fin rays. One mark was applied to each fish, and each group of fish all received the same mark. Location of the mark was varied between groups so that each group could be uniquely identified. The dyes used were Alcian Blue and Alcian Green (Sigma Chemical Company, St. Louis, Missouri), and were chosen because of their known ability to provide a highly visible, long lasting mark.

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 by the expression:

number released = proportion mark retention * number in group.

Release Procedure

Fish were released to estimate trapping efficiency approximately ½ mile upstream from the trap, where the main Oakdale waste pipe crosses over the Stanislaus River. Prior to release fish were placed in one to three coolers, depending on the number of fish in the release group and transported to the release site. Fish were released directly from the coolers by placing a dip net into the cooler and scooping-up about ten fish. The dip net would then be placed into the river and the fish allowed to swim away. After each "net-full" was released we would wait from 30 seconds to 5 minutes before releasing another net-full of approximately 10 fish. The amount of time between release packets depended on how fast fish swam away after being released. The time to release each group ranged from 30 to 105 minutes. This release procedure was slightly different than the one used in 1996, in that the fish were released directly from coolers instead of being transferred to net pens for release. Test fish in 1996 and 1998 were released more slowly than those released in 1995. In 1995, 1996 and 1998 all trap efficiency groups were released under total darkness.

Groups to determine migration rate and survival were released at Knights Ferry (RM 54.3). The procedure used to release trap efficiency groups was also followed for the Knights Ferry releases except fish were transported to the release site in an aluminum hauling tank instead of in coolers. Because the number of fish released was larger at Knights Ferry, the release time was around 60 minutes and fish were allowed to swim away in groups up to 25. These groups were always released under total darkness.

MONITORING OF ENVIRONMENTAL FACTORS

Flow Measurements

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

The following two methods were used to measure the velocity of water entering the traps: (1) Water velocity was measured at the time the traps were checked with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA); (2) An average daily trap rotation speed for each trap was recorded. The time, in seconds, for three contiguous revolutions of each trap was measured every morning. The average time per revolution for each trap was then calculated.

River Temperature and Relative Turbidity

Daily water temperature was measured with a mercury thermometer at the trap site. Onset StowAway recording thermometers were also installed to record water temperature once per hour throughout the sampling season at 6 sites on the Stanislaus between Goodwin and Caswell including the Oakdale and Caswell trapping sites. Daily average temperature was derived by averaging the 24 hourly measurements.

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).

CASWELL TRAPPING SITE

In addition to our screw trap near Oakdale, two screw traps were fished near the mouth of the Stanislaus River, adjacent to Caswell State Park (RM 8.6) under contract to the USFWS. The traps were operated from January 8 to July 16 to index juvenile chinook abundance. All data was collected in accordance with criteria established by the USFWS.

FINDINGS

TRAP CATCHES OF CHINOOK

Daily catches of juvenile chinook between January 27 and July 15 ranged from 0 to 2,078, and totaled 23,539 (Figure 4). However, due to high flows the trap did not sample between February 4 and February 11. It is certain that a significant number of fish outmigrated during this period because fish passage at the Caswell traps was high during that period and high flow and turbidity would have stimulated fry migration. The trap also did not sample from May 21 to May 26 due to a malfunction. Consequently, total catch and the outmigration index underestimate the total number of chinook that migrated past Oakdale from January 27 to July 15.

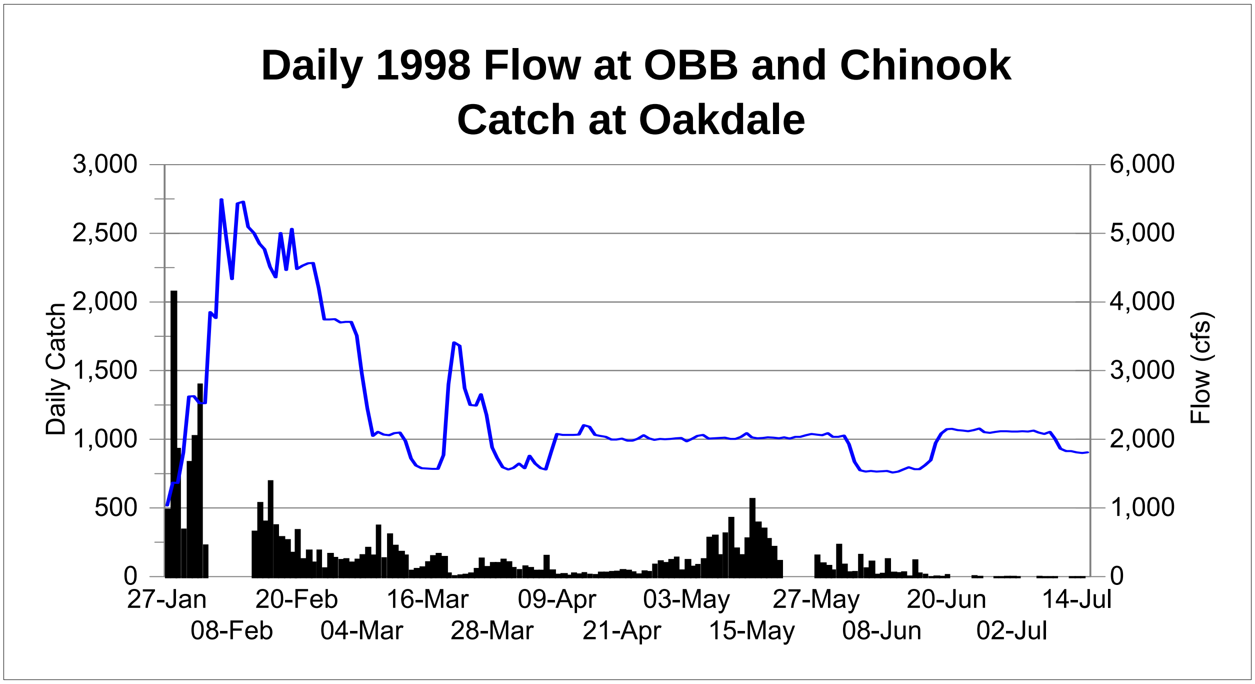

Figure 4. Daily catches of juvenile chinook and Stanislaus River flow, 1998.

TRAP EFFICIENCY

Between March 2 and June 24, we released 9 groups of marked natural migrants and 2 groups of marked hatchery chinook to estimate trapping efficiency (see Table 2). Flow varied between release groups from 1,561 cfs to 3,508 cfs. Capture rates of marked fish ranged 2.7% to 8.6%.

In order to predict the capture efficiency for each day of the sampling season, we needed to relate the efficiency (the response variable) estimated in each of our tests to a predictor variable that was measured on every day that the screw traps were operating.

The predictor variables explored were flow (f) (cubic feet per second, cfs) measured at Orange Blossom Bridge (OBB), fish size (s) (millimeters, mm), and turbidity (t) (NTU's). The analysis revealed that neither fish size nor turbidity contributed significantly to the predictive capability of trap efficiency once flow was included as a predictor variable (Appendix A). Therefore, efficiency (e), the proportion of test fish recovered, was related to flow on the day of release using the logistic equation:

$$e = \frac{1}{1 + \exp^{[-b(0) - b(f) \cdot f]}}$$

This can be rearranged to the "logit" linear transform,

$$logit\ (e) = \ln[\frac{e}{1 - e}] = b(0) + b(f) \cdot f$$

In the above equations "exp" is the exponential function, "ln" is the natural log, "b(0)" is a coefficient associated with the intercept[1], and b(f) is the coefficient relating the logit transform of efficiency to flow. A major reason for choosing the logistic model is that the predicted efficiency in that model can never be less than 0 and can never exceed 1 (100%). The logistic regression used assumes that variation in trap efficiency follows the binomial distribution.

For some outmigration days, not all predictor variable values were available. Linear extrapolations from the nearest straddling days with true variable measures were used to estimate the missing values of flow, fish size, and turbidity, the extrapolation being based on the number of days separating the missing value from the true measures used. The methods are explained in Appendix A.

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

This missing-value-substitution method is different than that used in previous years because there were longer runs of missing values in 1998, especially for turbidity. For consistency, this same method was then used to recompute missing values of flow and turbidity from 1996; therefore, some of the predictor variable values given in this report differ from those given in the previous report for the 1996 passage. The above methods were also used to interpolate missing daily chinook counts.

SIZE SELECTIVITY OF SCREW TRAP

We examined mean lengths of chinook prior to release and mean lengths at recapture to determine if there was evidence that the traps tended to catch more of the smaller or larger fish from the trap efficiency release groups (Figure 5, Table 3). The prediction method assumes that the trapped fish would be representative of all fish passing the trap. The mean size of recaptured fish did not differ significantly from the mean size of fish at release (Table 3), so there was no evidence that trap efficiency changed with fish size.

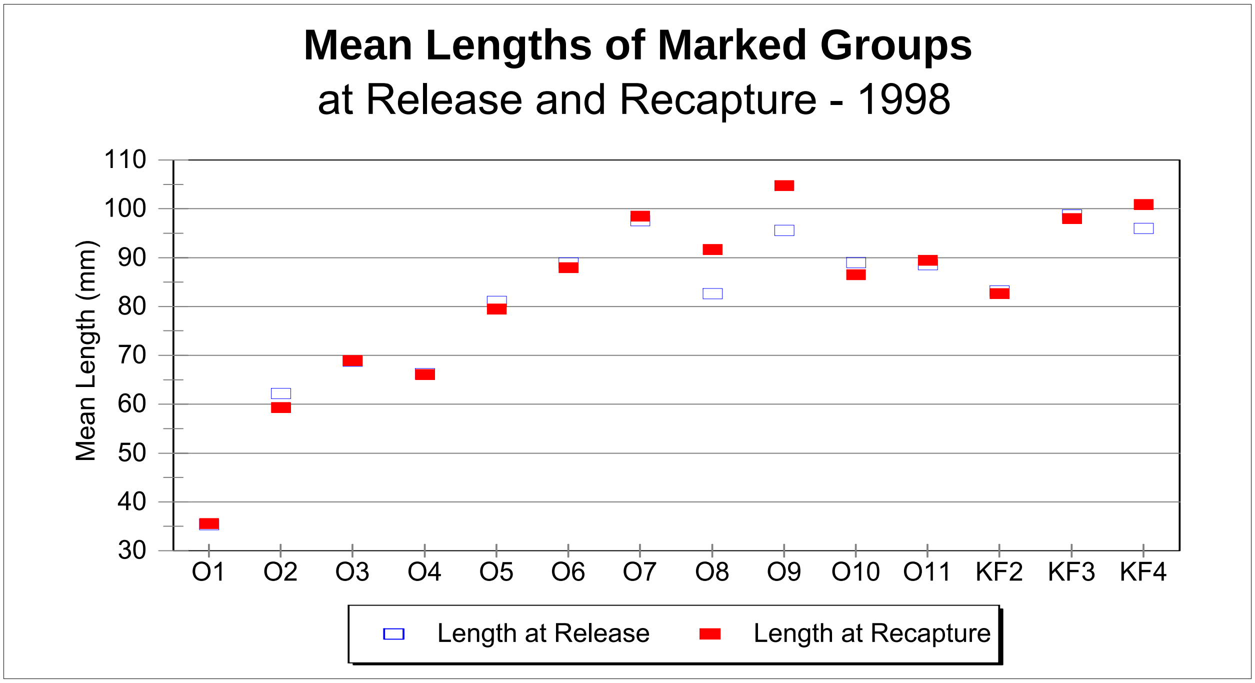


Figure 5. Mean lengths at release and recapture for all marked fish released in 1998.

Table 3. Mean lengths of marked fish at release and recapture.

Date of Release	Fish Stock	Lengths of released (rel) and recovered (rec) fish: Released Fish – Mean Length	Released Fish – Sample size (n)	Recovered Fish – Mean Length	Recovered Fish – Sample size (n)	Difference in mean lengths	Weight for mean comparisons
03/02/98	Natural	35.4	50	35.6	25	0.2	33
03/18/98	Natural	62.2	50	59.3	27	-2.9	35
04/06/98	Natural	68.8	50	69.0	23	0.2	32
04/11/98	Natural	66.3	50	66.1	10	-0.2	17
05/02/98	Natural	81.1	50	79.5	15	-1.6	23
05/30/98	Hatchery	97.6	50	98.5	23	0.9	32
05/30/98	Natural	88.9	50	88.0	19	-0.9	28
06/13/98	Hatchery	95.6	50	104.8	12	9.2	19
06/13/98	Natural	82.7	50	91.7	7	9.0	12
06/24/98	Natural	88.6	50	89.5	4	0.9	7
06/24/98	Natural	89.0	50	86.5	6	-2.5	11
					Weighted[1] mean difference =	0.576	
					Standard error =	1.104	
					t-ratio (10 d.f.) =	0.52	
					Computed Type I Error probability =	0.6133	

[1] Weights are harmonic means of the number of released and recovered fish measured, 2/[1/n(rel)+1/n(rec)], to account for differences in sample numbers within and among pairs

ABUNDANCE OF CHINOOK OUTMIGRANTS

Because trapping efficiency varied as flow varied, we converted our raw trap catches to an index of total outmigrants by the expression:

$$Daily\ Outmigrants = \frac{Count}{Efficiency}$$

where,

Count = the number of fish captured in the screw trap each day,

and,

Efficiency = the estimated trap efficiency based on the regression of recapture percentages and river flow.

The abundance of outmigrants in 1998 was greatest on February 15 (Figure 6) while the fish were still at the fry (< 45 mm) life stage. We estimate that 35,184 chinook fry migrated past the trap that night. The total number of outmigrants for the season was 598,873 (95% CI 377,000-821,000) from January 27 to July 15 (Figures 7, Table 4). This estimate excludes fish that passed Oakdale during February 4-11 and May 21-26.

Revised estimates of total chinook outmigrants for 1996 changed little. In 1996 the estimate was 283,000. The slight difference between this and the current estimate of 280,000 (95% CI 124,000-435,000) is solely attributable to the different method of computing missing values (i.e. flow).

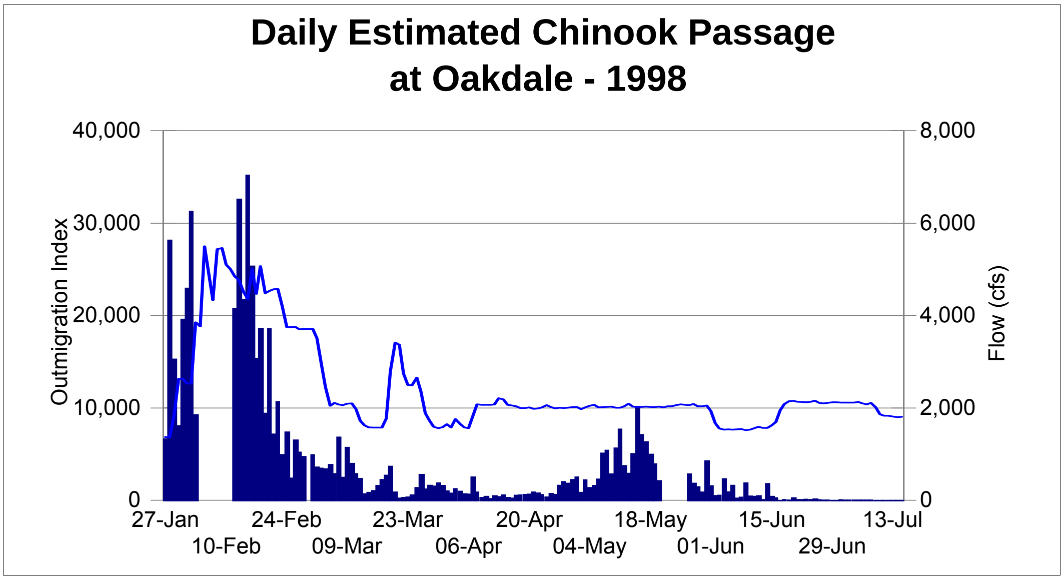


Figure 6. Daily abundance of outmigrant chinook and river flow.

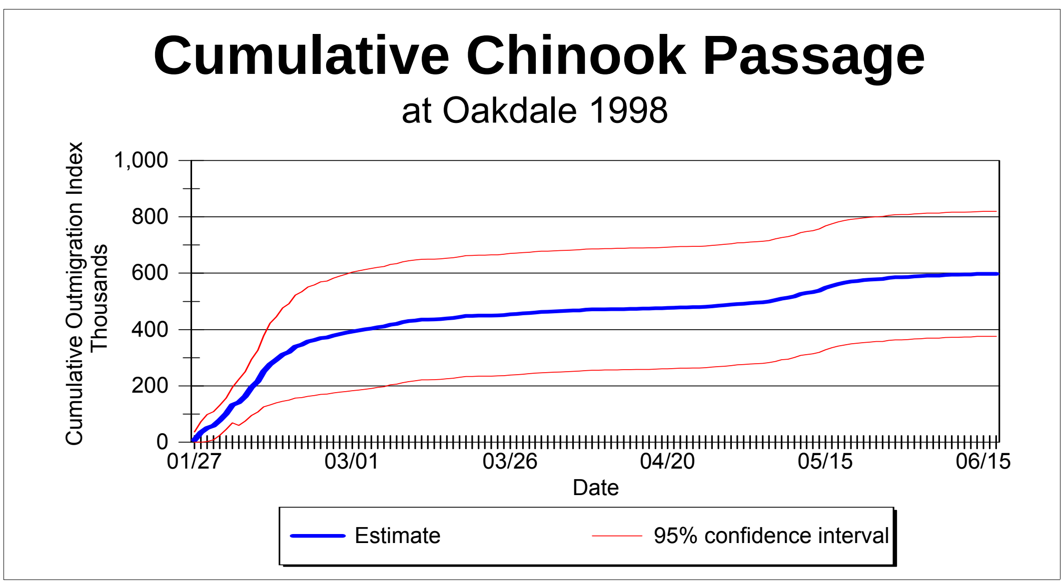


Figure 7. Cumulative outmigration index at Oakdale from January 29 through July 15, 1998.

Table 4. Daily trap catch, predicted trap efficiency, and estimated passage at Oakdale, 1998.

Date	Flow (cfs)	Chinook Caught	Efficiency	Daily Passage		Cumulative Passage	
				Estimate	SE	Estimate	SE
01/27	1,366	491	0.07378	6,655	15,235	6,655	6,655
01/28	1,365	2,078	0.07381	28,155	11,689	34,810	19,368
01/29	1,806	934	0.06115	15,274	14,477	50,084	24,430
01/30	2,623	346	0.0429	8,065	7,414	58,149	25,558
01/31	2,629	839	0.04279	19,609	8,515	77,758	27,075
02/01	2,526	1,027	0.04476	22,945	6,829	100,703	28,304
02/02	2,524	1,401	0.0448	31,274	13,734	131,977	32,168
02/03	3,854	231	0.02489	9,281	26,170	141,258	41,752
02/04	3,767	no sampling					
02/05	5,497	no sampling					
02/06	4,915	no sampling					
02/07	4,333	no sampling					
02/08	5,434	no sampling					
02/09	5,460	no sampling					
02/10	5,095	no sampling					
02/11	5,004	no sampling					
02/12	4,850	331	0.01593	20,782	12,854	162,040	44,805
02/13	4,772	538	0.0165	32,614	14,150	194,653	50,694
02/14	4,508	404	0.01857	21,751	11,017	216,404	55,736
02/15	4,358	699	0.01987	35,184	14,676	251,588	64,300
02/16	5,003	377	0.01487	25,359	17,965	276,947	73,731
02/17	4,468	291	0.01891	15,388	6,106	292,335	77,976
02/18	5,064	269	0.01446	18,598	9,003	310,933	84,543
02/19	4,481	177	0.0188	9,415	5,477	320,348	87,392
02/20	4,530	342	0.01839	18,596	8,938	338,944	93,195
02/21	4,566	130	0.0181	7,184	6,544	346,127	95,609
02/22	4,571	193	0.01806	10,689	4,577	356,816	98,982
02/23	4,201	106	0.02131	4,973	2,811	361,789	100,358
02/24	3,746	193	0.02612	7,390	3,121	369,179	102,001
02/25	3,746	63	0.02612	2,412	2,722	371,591	102,563
02/26	3,751	170	0.02606	6,524	2,657	378,115	104,018
02/27	3,700	139	0.02666	5,214	1,512	383,329	105,139
02/28	3,709	126	0.02655	4,746	1,171	388,075	106,164
03/01	3,713	131	0.0265	4,943	1,304	393,018	107,237
03/02	3,508	105	0.02903	3,617	918	396,634	107,936
03/03	2,967	128	0.03688	3,470	897	400,104	108,385
03/04	2,450	159	0.04627	3,436	1,001	403,541	108,623
03/05	2,048	214	0.05509	3,884	683	407,425	108,709
03/06	2,106	156	0.05373	2,903	2,116	410,328	108,813
03/07	2,071	374	0.05455	6,856	2,487	417,185	109,011
03/08	2,059	137	0.05483	2,498	2,249	419,683	109,094
03/09	2,089	311	0.05413	5,746	1,684	425,429	109,265
03/10	1,974	228	0.05688	4,008	1,195	429,437	109,330
03/11	1,721	183	0.06342	2,886	636	432,323	109,293
03/12	1,620	157	0.06622	2,371	1,120	434,694	109,241
03/13	1,577	47	0.06745	697	898	435,390	109,225
03/14	1,577	59	0.06745	875	196	436,265	109,200
03/15	1,574	70	0.06753	1,037	406	437,302	109,170
03/16	1,570	109	0.06765	1,611	640	438,913	109,125
03/17	1,569	153	0.06768	2,261	519	441,174	109,060
03/18	1,768	168	0.06215	2,703	316	443,877	109,041

				Daily Passage		Cumulative Passage	
Date	Flow (cfs)	Chinook Caught	Efficiency	Estimate	SE	Estimate	SE
03/19	2,798	147	0.03973	3,700	1,974	447,577	109,467
03/20	3,413	27	0.03028	892	2,495	448,468	109,658
03/21	3,365	8	0.03094	259	328	448,727	109,704
03/22	2,744	12	0.04068	295	117	449,022	109,735
03/23	2,499	17	0.04529	375	173	449,397	109,763
03/24	2,491	27	0.04545	594	487	449,991	109,809
03/25	2,657	59	0.04227	1,396	1,322	451,387	109,949
03/26	2,351	135	0.04831	2,795	877	454,182	110,117
03/27	1,883	73	0.05916	1,234	536	455,416	110,126
03/28	1,728	103	0.06323	1,629	323	457,045	110,109
03/29	1,593	104	0.06699	1,553	265	458,597	110,070
03/30	1,561	127	0.06791	1,870	280	460,467	110,017
03/31	1,582	107	0.0673	1,590	487	462,057	109,976
04/01	1,645	67	0.06552	1,023	447	463,080	109,957
04/02	1,580	52	0.06736	772	212	463,852	109,937
04/03	1,758	78	0.06242	1,250	242	465,101	109,929
04/04	1,649	65	0.0654	994	260	466,095	109,911
04/05	1,580	47	0.06736	698	177	466,793	109,893
04/06	1,561	46	0.06791	677	917	467,470	109,878
04/07	1,822	154	0.06073	2,536	1,041	470,006	109,885
04/08	2,080	49	0.05434	902	1,321	470,908	109,919
04/09	2,065	17	0.05469	311	312	471,219	109,929
04/10	2,062	23	0.05476	420	124	471,639	109,940
04/11	2,066	10	0.05467	183	163	471,822	109,946
04/12	2,069	27	0.0546	495	162	472,316	109,960
04/13	2,206	20	0.05145	389	105	472,705	109,977
04/14	2,182	30	0.05199	577	140	473,282	110,001
04/15	2,066	17	0.05467	311	158	473,593	110,010
04/16	2,051	14	0.05502	254	166	473,847	110,017
04/17	2,035	31	0.0554	560	195	474,407	110,031
04/18	1,996	33	0.05635	586	75	474,993	110,043
04/19	1,996	37	0.05635	657	74	475,649	110,057
04/20	2,008	38	0.05605	678	152	476,327	110,072
04/21	1,979	51	0.05676	899	140	477,226	110,089
04/22	1,982	46	0.05669	811	170	478,037	110,104
04/23	2,009	34	0.05603	607	238	478,644	110,118
04/24	2,057	20	0.05488	364	205	479,008	110,128
04/25	2,016	42	0.05586	752	214	479,760	110,146
04/26	1,992	36	0.05644	638	537	480,398	110,160
04/27	2,005	91	0.05613	1,621	728	482,019	110,198
04/28	1,998	114	0.0563	2,025	271	484,044	110,242
04/29	2,004	103	0.05615	1,834	254	485,879	110,283
04/30	2,014	125	0.05591	2,236	393	488,114	110,336
05/01	2,019	141	0.05579	2,527	908	490,642	110,400
05/02	1,972	49	0.05693	861	863	491,502	110,420
05/03	2,008	124	0.05605	2,212	705	493,715	110,473
05/04	2,049	76	0.05507	1,380	469	495,095	110,512
05/05	2,063	88	0.05474	1,608	537	496,702	110,561
05/06	2,011	130	0.05598	2,322	1,875	499,024	110,632
05/07	2,016	* 286	0.05587	5,119	1,759	504,143	110,770
05/08	2,020	* 302	0.05576	5,416	1,473	509,560	110,917
05/09	2,025	160	0.05564	2,875	1,583	512,435	111,003
05/10	2,005	318	0.05613	5,666	2,484	518,101	111,167
05/11	2,004	432	0.05615	7,693	2,106	525,794	111,373
05/12	2,033	208	0.05545	3,751	2,645	529,545	111,509
05/13	2,088	159	0.05415	2,936	1,162	532,482	111,616

		Chinook			Daily Passage		Cumulative Passage	
Date	Flow (cfs)	Caught		Efficiency	Estimate	SE	Estimate	SE
05/14	2,027	281		0.0556	5,054	3,802	537,536	111,820
05/15	2,017	568		0.05584	10,172	2,734	547,708	112,127
05/16	2,019	398		0.05579	7,134	2,133	554,842	112,345
05/17	2,028	352		0.05557	6,334	1,222	561,176	112,536
05/18	2,023	278		0.05569	4,992	1,266	566,168	112,688
05/19	2,016	220		0.05586	3,938	1,491	570,106	112,810
05/20	2,027	118		0.0556	2,122	944	572,229	112,877
05/21	2,010	no sampling						
05/22	2,036	no sampling						
05/23	2,033	no sampling						
05/24	2,061	no sampling						
05/25	2,077	no sampling						
05/26	2,067	no sampling						
05/27	2,060	157		0.05481	2,864	587	575,093	112,975
05/28	2,086	100		0.0542	1,845	740	576,938	113,045
05/29	2,035	82		0.0554	1,480	484	578,418	113,092
05/30	2,034	49		0.05543	884	1,802	579,302	113,134
05/31	2,053	236		0.05498	4,293	1,823	583,595	113,291
06/01	1,929	91		0.058	1,569	1,801	585,164	113,338
06/02	1,671	34		0.06479	525	498	585,689	113,335
06/03	1,551	37		0.0682	543	1,073	586,231	113,330
06/04	1,527	162		0.0689	2,351	993	588,583	113,283
06/05	1,537	64		0.06861	933	722	589,516	113,266
06/06	1,531	112		0.06878	1,628	723	591,144	113,234
06/07	1,536	16		0.06864	233	777	591,377	113,232
06/08	1,539	24		0.06855	350	938	591,727	113,229
06/09	1,515	131		0.06925	1,892	892	593,619	113,190
06/10	1,528	31		0.06887	450	848	594,069	113,183
06/11	1,557	29		0.06802	426	61	594,495	113,176
06/12	1,593	34		0.06699	508	230	595,003	113,169
06/13	1,564	6		0.06782	88	901	595,091	113,171
06/14	1,565	123		0.06779	1,814	940	596,906	113,144
06/15	1,621	28		0.06619	423	882	597,329	113,143
06/16	1,697	17		0.06407	265	222	597,594	113,143
06/17	1,947	0		0.05755	0	152	597,594	113,143
06/18	2,082	5		0.05429	92	47	597,686	113,146
06/19	2,146	2		0.05281	38	118	597,724	113,148
06/20	2,154	14		0.05262	266	123	597,990	113,160
06/21	2,132	4.38	*	0.05313	82	101	598,073	113,164
06/22	2,127	5.08	*	0.05324	95	16	598,168	113,168
06/23	2,119	5.87	*	0.05343	110	14	598,278	113,172
06/24	2,130	4.89	*	0.05317	92	31	598,370	113,176
06/25	2,155	8		0.0526	152	50	598,522	113,183
06/26	2,105	3		0.05375	56	61	598,578	113,185
06/27	2,094	1.8	*	0.05401	33	16	598,611	113,187
06/28	2,110	1.39	*	0.05364	26	18	598,637	113,188
06/29	2,120	0		0.0534	0	15	598,637	113,188
06/30	2,120	0		0.0534	0	32	598,637	113,188
07/01	2,112	3		0.05359	56	29	598,693	113,190
07/02	2,112	2		0.05359	37	19	598,730	113,191
07/03	2,116	1		0.0535	19	10	598,749	113,192
07/04	2,115	1.22	*	0.05352	23	3	598,772	113,193
07/05	2,125	1.15	*	0.05329	22	3	598,793	113,194
07/06	2,097	1.01	*	0.05394	19	10	598,812	113,195
07/07	2,077	2		0.05441	37	11	598,849	113,196
07/08	2,110	1		0.05364	19	19	598,867	113,197

Date	Flow (cfs)	Chinook Caught		Efficiency	Daily Passage Estimate	Daily Passage SE	Cumulative Passage Estimate	Cumulative Passage SE
07/09	2,009	0		0.05603	0	10	598,867	113,197
07/10	1,861	0		0.05972	0	2	598,867	113,197
07/11	1,830	0.2	*	0.06052	3	2	598,871	113,197
07/12	1,828	0.12	*	0.06057	2	2	598,873	113,197
07/13	1,810	0		0.06104	0	1	598,873	113,197
07/14	1,799	0		0.06133	0	0	598,873	113,197
07/15	1,808	0		0.0611	0	0	598,873	113,197

*Missing value estimate

We divided the estimated number of outmigrants in each year into fry, parr and smolt life stages. In order to divide outmigrants into these categories, we used the first three consecutive days that mean length exceeded 45 mm or 80 mm to mark the dividing dates between fry-to-parr and parr-to-smolts, respectively. These criteria appeared to be biologically appropriate, because they were often reached on dates when there was either a sharp change in fish size or a sharp change in outmigrant abundance. The cut-off dates used were the same for both the Oakdale and Caswell traps as we did not see a difference in mean lengths throughout the outmigration.

The period of smolt outmigration was fully sampled in both 1996 and 1998. Smolt abundance was lower in 1998 (121,647) than 1996 (148,369), but not significantly different (Table 5). The difference was less than indicated by these point estimates, because smolt abundance was not estimated in 1998 during May 21 to 26 when passage at the trap was roughly 2,000 - 3,000 fish per day. Juvenile chinook did not reach our smolt size criterion (> 80 mm) until 3 weeks later in 1998 (April 22) than in 1996 (April 1).

Parr abundance was also fully sampled in both years. The abundance of parr migrants, was over 6 times greater in 1998 than in 1996. The period during which outmigrants parr fit the criterion (> 45 mm and < 80 mm) last only 10 days in 1996, but lasted 45 days in 1998. A higher fraction of outmigrants were parr and a lower fraction were smolts in 1998 than in 1996. It appears that environmental conditions in 1998, such as high flows, stimulated a higher fraction of juvenile chinook to emigrate before reaching smolt size.

Fry abundance in 1998 (417,185) was also vastly greater than in 1996 (119,796) (Table 5), the only other year in which fry were sampled. Fry were already abundant on the first day of sampling in both 1996 and 1998, so we are uncertain of the total abundance of fry outmigrants in either year. Large numbers of fry could have outmigrated before the onset of trapping during flow spikes in mid January of both years.

Table 5. Cumulative outmigration at Oakdale during the fry, parr, and smolt life-stages in 1996 and 1998.

1996						
Life Stage	**Dates of Outmigration**		**Outmigration Index Estimate**	**Standard Error (SE)**	**Approximate 95% Confidence Interval**	
					Lower	**Upper**
Fry	02/02/96	03/20/96	119,796	41,156	39,130	200,462
Parr	03/21/96	03/31/96	11,453	3,643	4,312	18,593
Smolt	04/01/96	06/08/96	148,369	36,878	76,088	220,650
	TOTAL		279,618	79,432	123,931	435,304
1998						
Life Stage	**Dates of Outmigration**		**Outmigration Index Estimate**	**Standard Error (SE)**	**Approximate 95% Confidence Interval**	
					Lower	**Upper**
Fry	01/27/98	03/07/98	417,185	109,021	203,503	630,866
Parr	03/08/98	04/21/98	60,041	7,607	45,131	74,951
Smolt	04/22/98	07/15/98	121,647	14,096	94,197	149,452
	TOTAL		598,873	113,204	377,170	820,931

INFLUENCE OF FLOW ON CHINOOK OUTMIGRATION

As in 1996, there was an apparent relationship between flow and fry passage. Peak fry outmigration coincided with peak flows in late January at the onset of trapping and through February. Fry outmigration increased sharply about 2 days after increases in flow on January 30 and again on February 3. Although flows exceeding 5,000 cfs persisted for a week early in February, we were unable to sample during that period. Due to high precipitation, river flow began to rise within a few days of the start of sampling and remained above 4,000 cfs from February 4 to February 24. In early March river flow receded and fluctuated around 2,000 cfs through May. The large fluctuations in abundance of down-migrating fry, and the small size of fish (most < 40 mm) through February (see Figure 8), indicated that emergence of new fry probably continued into early March. The abundance of down-migrating fry declined sharply after the first week in March, signaling that emergence of fry was nearly complete by then. It is likely that many fry migrated past Oakdale in 1998 during a flow spike in mid-January that preceded our sampling, as in 1996 (see Figure 3).

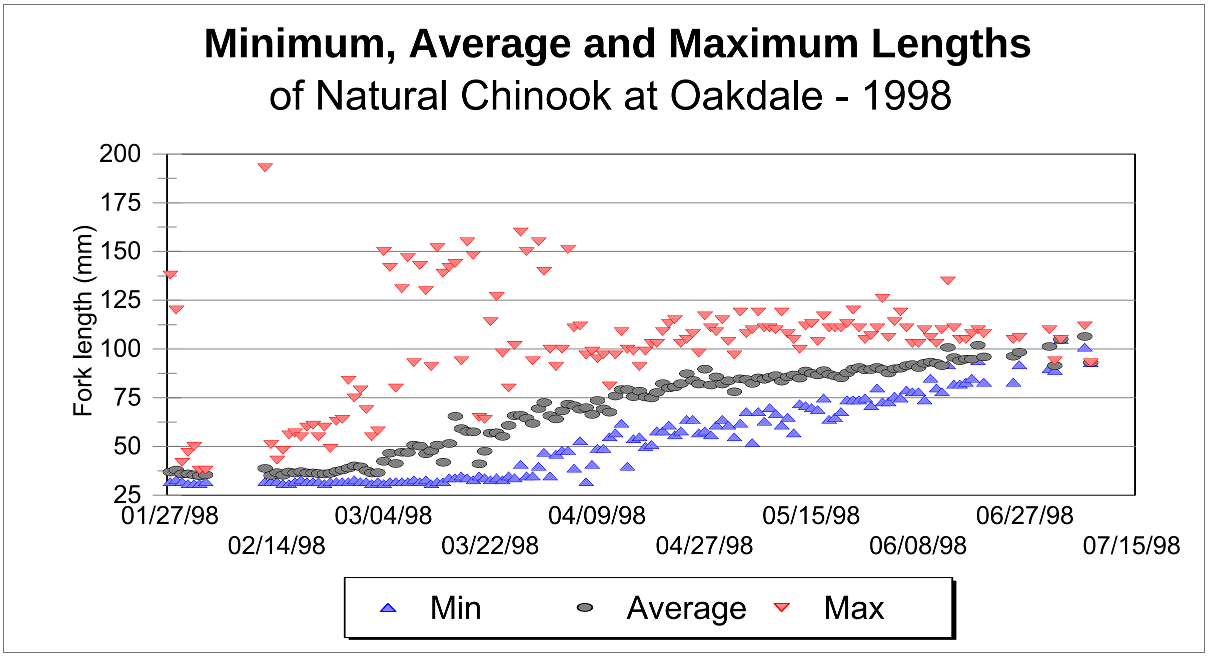
We were unable to monitor chinook passage during the highest flows in February. Based on the pattern observed we would expect that nightly passage would have remained high through the unmonitored period ranging 8,000 to 30,000 fish per night. However, given the high flows, passage may have been much greater during this period. Outmigration of parr (45 - 80 mm) did not show a clear pattern of response to changing flow. Outmigrants were predominately parr during March 8 to April 21, and parr numbers fluctuated whether flow was stable, increasing or decreasing (Table 4)

The smolt outmigration peaked during the typical season from late April to mid May while flows remained steady around 2,000 cfs for all of April and May (see Figure 6). The smolt outmigration in 1998 demonstrates that juvenile chinook will emigrate when they reach smolt size during spring, even in the absence of variation in flow. A similar pattern was observed during the 1996 smolt outmigration.

INFLUENCE OF TURBIDITY ON CHINOOK OUTMIGRATION

As in 1996, we again observed peak fry outmigration coinciding with peak turbidity, but failed to see an obvious pattern for the duration of the study. The smolt outmigration increased through both decreasing and increasing turbidity. Thus, turbidity does not show a distinct influence on smolt migration timing when flows are stable (Figure 8).

Turbidity was highest during and after peak flows in early February (13.1 NTU) and decreased gradually through the end of March to 3.0 NTU (Figure 9). Overall turbidity levels were higher in 1998 than in 1996. April, May, and June of 1998 experienced a high frequency of spring storms created by the El NiÁo weather pattern and this caused several turbidity spikes. Conversely, the spring of 1996 experienced dry conditions more typical of California weather patterns.



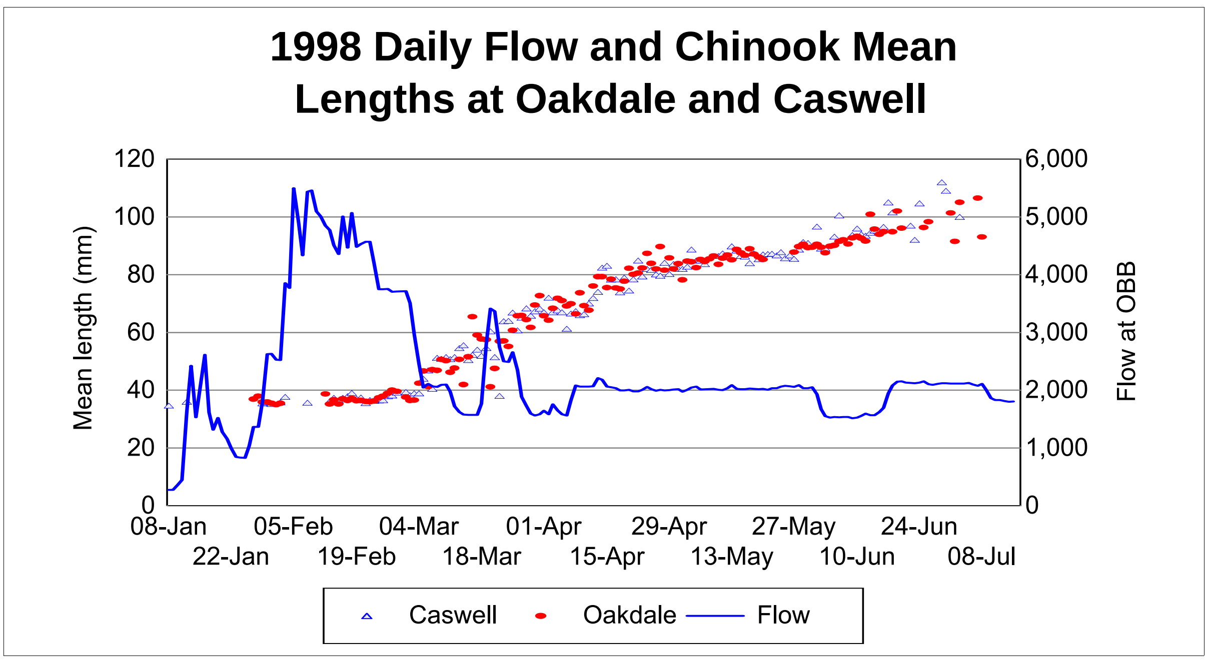


Figure 8. Daily mean lengths of chinook captured at Oakdale and Caswell and river flow.

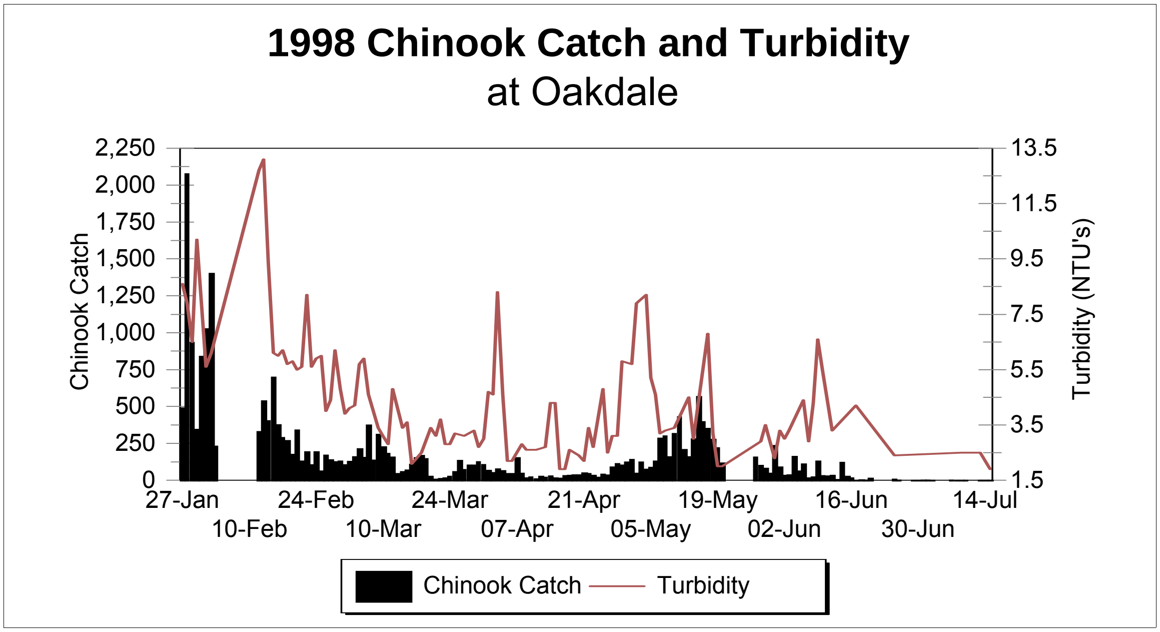
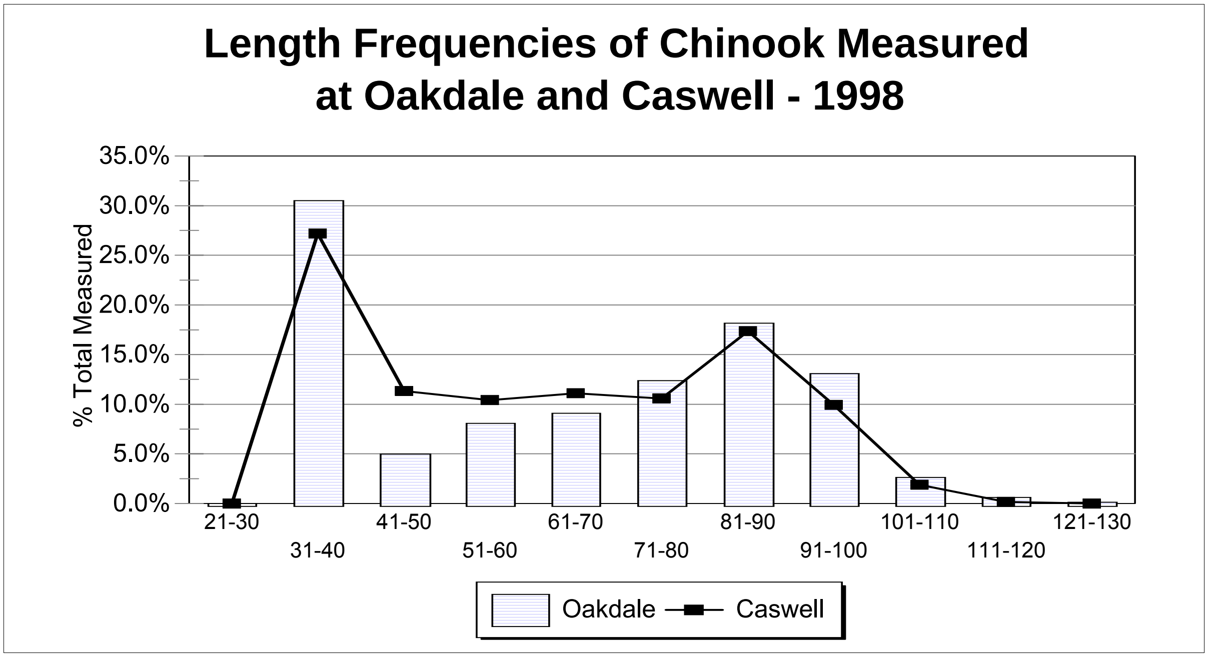


Figure 9. Daily chinook catch and passage index at the Oakdale trap and Stanislaus River turbidity.

INFLUENCE OF FISH LENGTH ON CHINOOK OUTMIGRATION

The mean lengths of chinook captured in the screw trap increased over the course of sampling, ranging from less than 40 mm at the beginning of sampling to around 100 mm in late May and June (Figure 10). Mean lengths were generally below 40 mm until early March and gradually increased to over 80 mm by late April (Figure 10). As in past years, the mean lengths of fish captured at Oakdale were very similar to the mean lengths of fish captured at Caswell throughout the season (Figures 10 and 11), indicating that chinook were not pausing to rear for extended periods between RM 40.1 and RM 8.6. Length frequencies of fish captured at Caswell were also similar to the length frequencies of fish captured at Oakdale (Figure 11). Percentages of mid-sized fish were slightly higher at the Caswell trap suggesting that a small proportion of fry may rear and grow en route to Caswell.



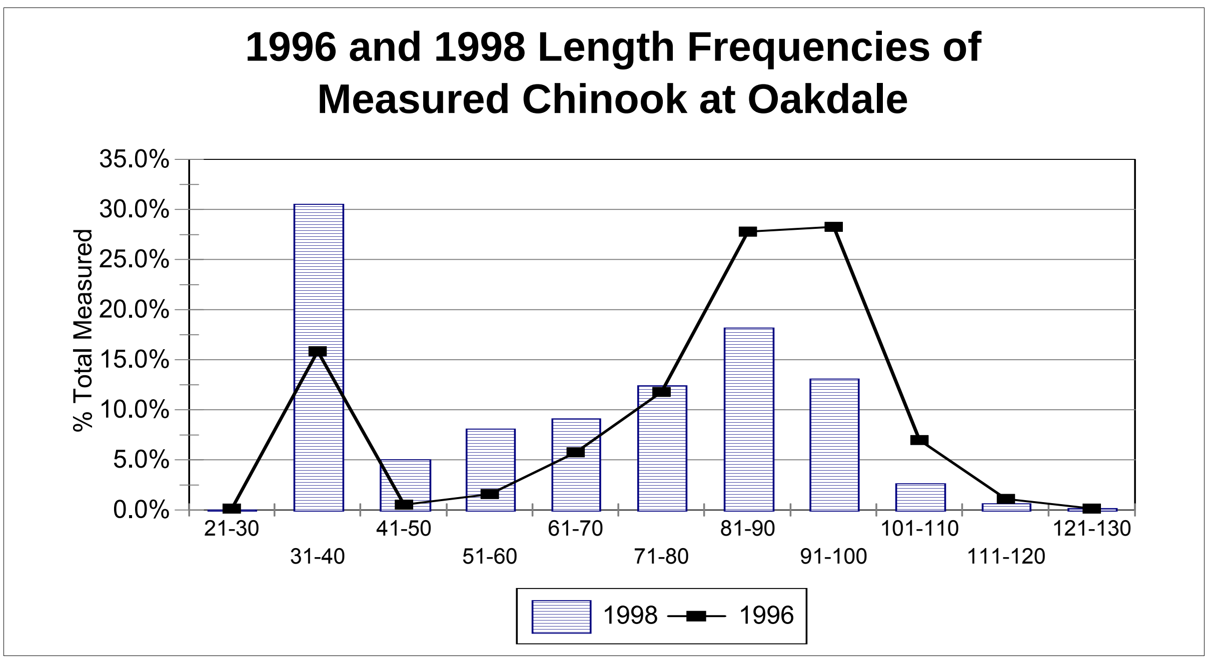


Figure 10. Comparison of Caswell and Oakdale length frequencies in 1998, and length frequency distribution of all chinook <131 mm measured in 1996 and 1998 at Oakdale. Yearlings are not shown.

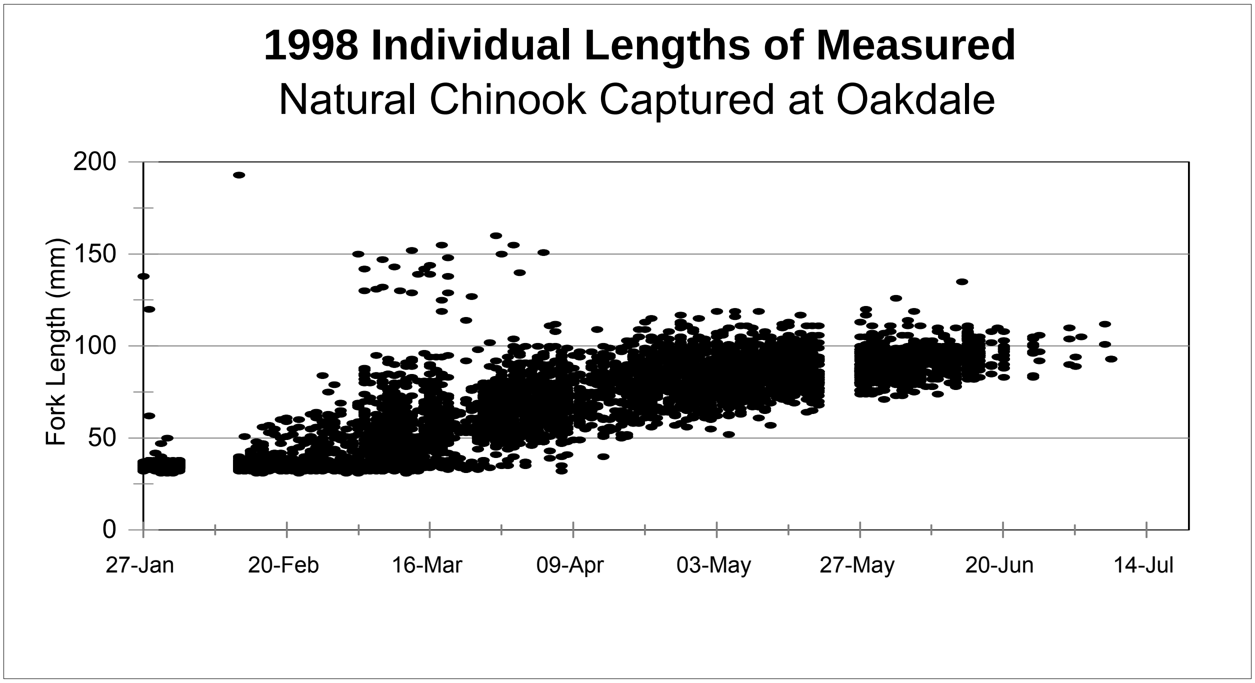


Figure 11. Individual lengths of all juvenile chinook captured in the Oakdale trap during 1998. Yearlings are those fish during January through April that exceeded 110 mm.

The overall length distribution of chinook migrant in 1998 differed from that in 1996. Whereas fry were the most abundant migrants in 1998, smolts where the most abundant migrants in 1996 (Figure 11). Further, many chinook migrated as parr (45-80 mm) in 1998, but not in 1996. Finally, smolts were also smaller in 1998 than in 1996 (Figure 11). These differences between the two years may have been stimulated by more fluctuation in flow during March of 1998, or by greater competition between the more abundant juveniles in 1998. Fluctuating flows stimulated fish to migrate at a variety of sizes in 1995 when juvenile abundance was low (Demko and Cramer 1996).

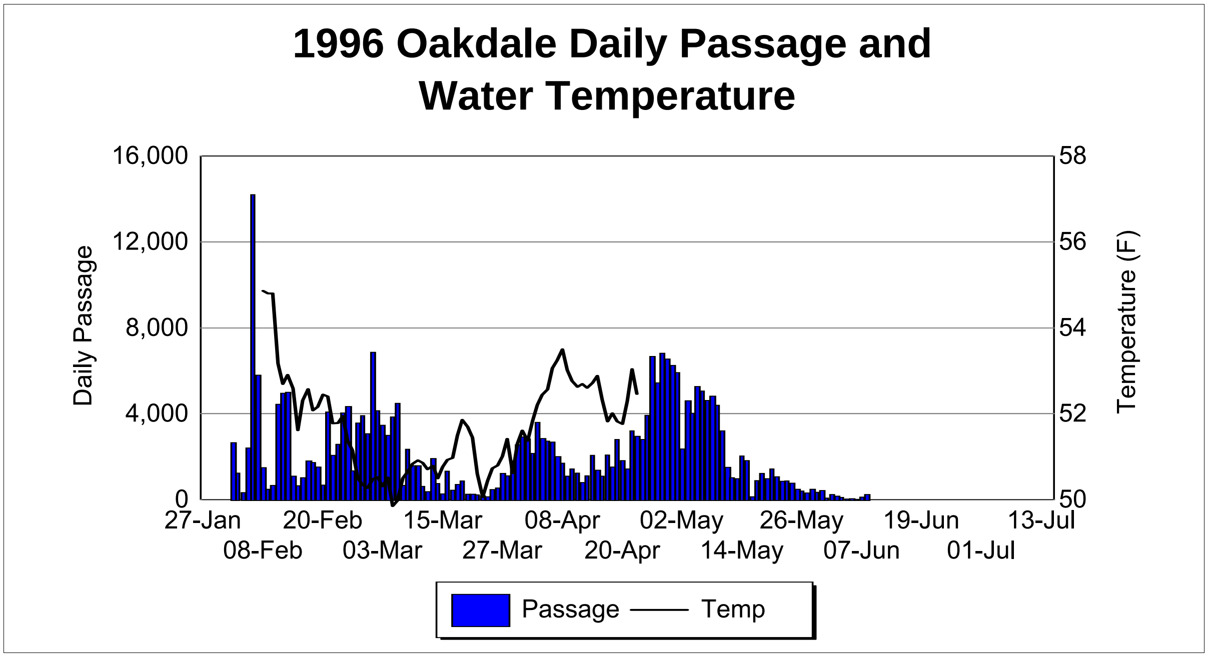
Twenty-six yearling chinook ranging in size from 114 mm to 193 mm were captured during the 1998 sampling season (Figure 11). We distinguished "yearlings" based on their large sizes relative to the length of the majority of the chinook we were catching at the time. All of the yearlings captured had advanced smolting characteristics (i.e. scales and darkened anal and dorsal fin tips). We captured the first yearling January 27 and the last April 4 (see Appendix 1). The bulk of the yearlings were captured in early March compared to late March of the 1995 and 1996 seasons.

INFLUENCE OF RIVER TEMPERATURE ON CHINOOK OUTMIGRATION

Response patterns to temperature in 1996 and 1998 differed. River temperature at Oakdale increased steadily from 10°C in early January to 14°C by mid July (Figure 12). Unlike 1996, increases in temperature during constant flow in 1998 did not appear to trigger smolt outmigration (Figure 12). In fact, smolt outmigration started to increase as temperatures decreased during the month of May. We had speculated in 1996 that the last increase in smolt passage in late April may have been related to the increase in river temperature above 10°C (Figure 12).

INFLUENCE OF SMOLTING ON CHINOOK OUTMIGRATION

The external appearance of smolt characteristics among fish captured in the trap was highly related to fish size (Figure 13). Fish less than 60 mm generally scored a smolt index of 1, those from 60 mm to 90 mm generally scored a smolt index of 2, and fish larger than 90 mm generally scored a smolt index of 3 (Figure 13). Fish of all three indices were outmigrating simultaneously during March and April. Some fish with a smolt index value of 2 continued to be present through June.



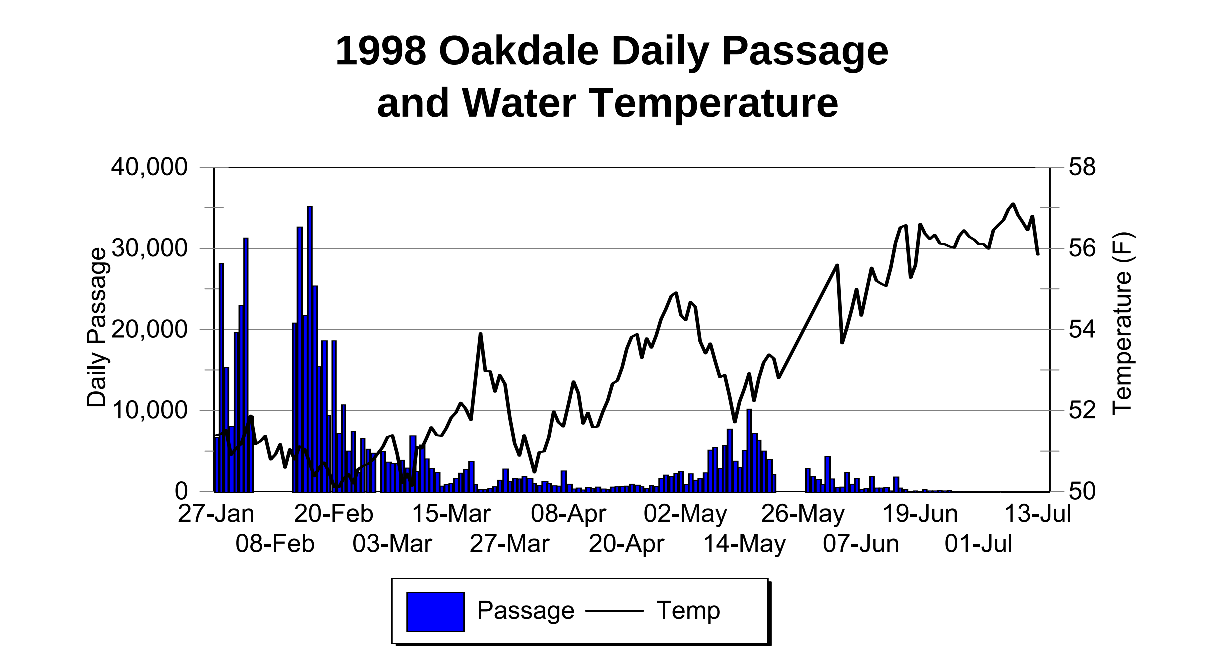


Figure 12. Passage estimates and Stanislaus River temperature for 1996 and 1998.

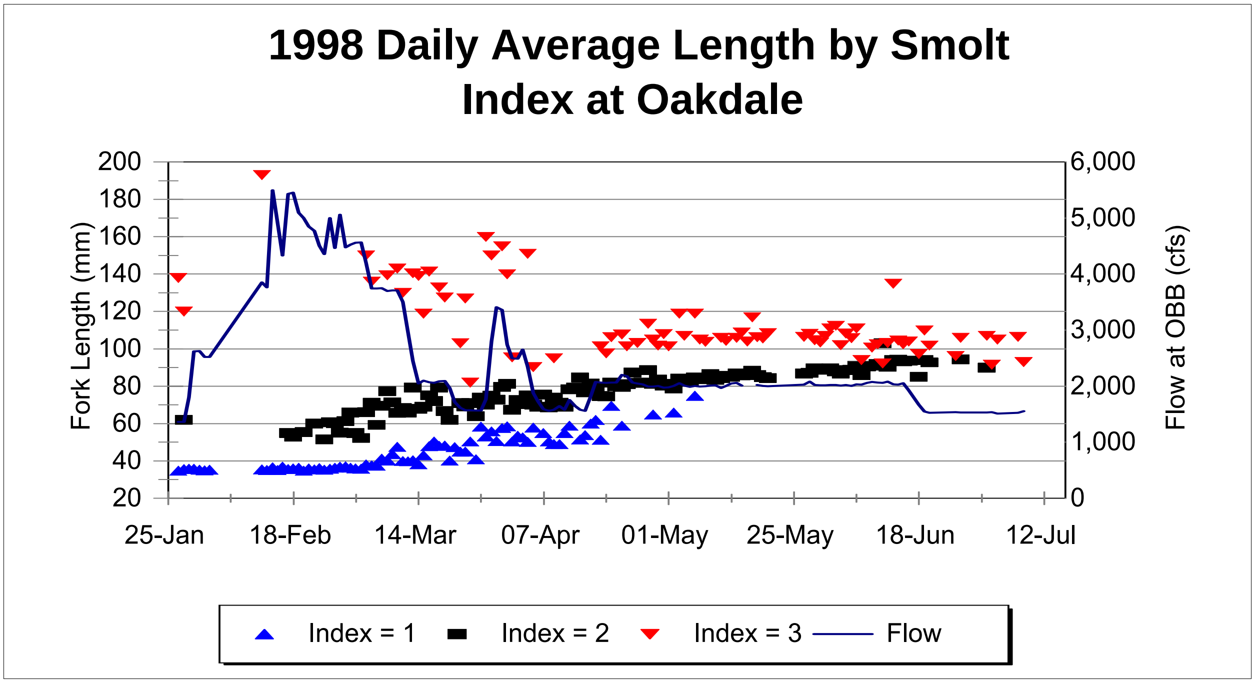


Figure 13. Daily Stanislaus River flow and average length by smolt index value of chinook captured at Oakdale.

RATE OF JUVENILE CHINOOK MIGRATION THROUGH THE STANISLAUS RIVER

We released four marked groups of hatchery chinook at Knights Ferry on April 11, May 2, May 30, and June 13 to determine the rate at which they migrate from Knights Ferry to Oakdale (14.2 miles), and from Knights Ferry to Caswell (45.7 miles). Hatchery fish tend to migrate immediately following release, so they provide an indication of migration rate, but not of migration timing for naturally-produced fish. Fish were released at Knights Ferry at river flows ranging from 1,500 to 2,000 cfs. The elapsed time between when the release and the trap check the following morning varied from 8.5 to 10.5 hours for the Knights Ferry release groups. We express travel time as the number of nights, because trap catches indicate that few fish move during the day. Rates of movement were similar to those recorded in 1996 (Demko and Cramer 1996), as were the stability of flow, although flow was slightly higher in 1998. Average migration rates based on the time from release to recapture and the distance traveled ranged from 1.1 to 14.2 miles per night for the three groups. Of the 103 recaptures, 92% completed the journey in one night (14.2 miles/night). Another 4.8% and 1.9% completed the journey in two (7.1 miles/night) and three nights (4.7 miles/night) respectively (Table 6). One fish took 13 nights to reach Oakdale (1.1 miles/night) indicating a smaller proportion of fish travel slower and rear for short periods.

Table 6. Number of nights between release at Knights Ferry and recapture at Oakdale for marked chinook in 1998.

Release	Mean	Flow	Travel Nights			
Date	Length	cfs	1	2	3	13
11-Apr-98	-	2,066	19	2		
02-May-98	83.2	1,972	32	2	1	1
30-May-98	98.8	2,034	23	3		
13-Jun-98	96.1	1,564	40		1	
Avg. Migration Rate (miles/night) =			**14.2**	**7.1**	**4.7**	**1.1**

We recovered 11 marked chinook at Caswell that had been released at Oakdale or above (Table 7). Four fish were recaptured from three different groups released at Oakdale and seven from two groups released at Knights Ferry. These release groups were released at flows ranging from 1,768 to 3,508 cfs and with mean lengths at release ranging from 35.4 to 83.2 mm (Table 7).

Table 7. Number of days after release that marked chinook released at Oakdale and Knights Ferry were recaptured at Caswell.

Days	KF1	KF2	O1	O2	O5
1	-	-	-	-	-
2	-	1	2	-	1
3	-	1	-	-	-
4	1	-	-	-	-
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	1	-
11	-	-	-	-	-
12	-	2	-	-	-
13	-	1	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-
19	-	-	-	-	-
20	-	1	-	-	-
Total # Recap	**1**	**6**	**2**	**1**	**1**
Mean Length	**-**	**83.2**	**35.4**	**62.2**	**81.1**
River Flow	**2,066**	**1,972**	**3,508**	**1,768**	**1,972**
Avg. miles/night	**11.425**		**15.75**	**3.15**	**15.75**

Migration rates from the time of release to the time of recovery at Caswell varied from 2.3 miles/night to 22.9 miles/night. Migration rates were determined by dividing the number of miles traveled by the number of nights after release that the fish was captured at the Caswell screw traps.

SURVIVAL OF JUVENILE CHINOOK THROUGH THE STANISLAUS RIVER

Mark-Recapture tests

Survival of juvenile chinook migrating from Knights Ferry to Oakdale was estimated from the release of three groups of marked hatchery chinook at Knights Ferry and their recovery at Oakdale. The April 11 release was not used to estimate survival due to errors in the release procedure. Survival was estimated by the expression:

Survival Index = R / (E*M)

where

Survival Index = the estimated proportion of fish surviving to reach the trap

R = the number of marked fish recaptured in the trap

E = the predicted efficiency of the trap, and

M = the number of marked fish released.

Our survival estimates include the following assumptions:

1. Marked and unmarked chinook are equally vulnerable to capture in the trap.
2. Marked and unmarked fish experience equal mortality rates.
3. All marks remain visible and are observed at the Oakdale trap.
4. All fish had passed of the Oakdale trap at the conclusion of sampling.

We had no means of evaluating how well these assumptions were met, so we refer to our survival estimates as survival indexes.

The survival index for the three marked groups released at Knights Ferry was 22.9%, 16.6%, and 20.6% (Table 8). The mean lengths of the fish released varied from 83.2 to 98.8 mm.

Table 8. Survival estimates for natural chinook released at Knights Ferry and recaptured at Oakdale for 1996 and 1998.

Date of Release	Release Code	Fish Stock	Adjusted # Released	Total # Recaptured	% Recap.	Predicted Efficiency	Survival Index	Avg. Flow at OBB	Mean at Release	Mean at Recap.
13-Apr-1996	O6	Natural	1,293	75	5.8%	0.115	50.4%	1,598	78.1	78.3
22-Apr-1996	O9	Natural	930	61	6.6%	0.106	61.9%	1,673	86.1	86.9
22-May-1996	O11	Natural	726	7	1.0%	0.125	7.7%	1,525	95.1	88.9
11-Apr-1998	KF1	Hatchery	-	21	-	0.05467	VOID	2,066	-	-
2-May-1998	KF2	Hatchery	2,763	36	1.3%	0.05693	22.9%	1,972	83.2	82.7
30-May-1998	KF3	Hatchery	2,832	26	0.9%	0.05543	16.6%	2,034	98.8	98.0
13-Jun-1998	KF4	Hatchery	2,930	41	1.4%	0.06782	20.6%	1,564	96.0	100.9

The difference between survival estimates in 1996 and 1998 was most likely due to the use of hatchery fish in 1998 and natural fish 1996. In 1995 when both hatchery and natural fish were released at Knights Ferry, survival of the natural fish to Oakdale was 32.4% to 66.7%, while that of hatchery fish was 4.7% to 8.6% (Demko and Cramer 1995). Estimated survivals were considerably lower than the first two releases in 1996. Fish were also released later in 1998 than in 1996. In 1996, releases with high survival rates were made in April but a group released on May 22 only had a survival of 7.7%. Releases in 1998 were made in May and June as was the third 1996 release. Later releases may correspond to a higher proportion of fish choosing not to migrate, or to an increase in predation.

Of the 8,525 fish in the three Knights Ferry releases, only six survived to Caswell during the May 2 Knights Ferry release for an expanded estimate of 366 fish and 13.2% survival rate. Of the 3,318 fish released for trap efficiency at Oakdale, only four were recaptured at Caswell from 3 releases (expanded to an average of 51.4 fish/release) for a 9.6% average survival rate. These estimates of survival rate are much lower than indicated by comparison of fish numbers arriving at the Caswell trap to those arriving at the Oakdale trap. The much greater sample sizes and sampling effort that go into estimating total fish passage are more reliable than the small mark-recapture experiments, so we conclude that assumptions for the mark-recapture estimates of survival must have been invalid.

Outmigration Indexes at Oakdale and Caswell

The large number of chinook estimated to have passed Caswell (651,000) compared to that at Oakdale (599,000) during 1998 suggest that sampling at Oakdale did not cover the full population of outmigrants , and that survival of migrants through the 31.5 miles between the two sites was high during 1998. However, this comparison provides no dependable means of calculating survival because (1) there were substantial numbers of fish that passed Oakdale during days that were not sampled, and (2) chinook spawning extends at least 6 miles below Oakdale to the town of Riverbank (RM 34). We did not sample nor estimate fry passage at Oakdale during February 4-11, but daily estimates of fry passage on all other days during January 28 to February 20 ranged from 8,065 to 35,184. If fry passage averaged 20,000 fish/day during February 4-11 then another 160,000 fry would have passed Oakdale that week. Additionally, fry passage was already high when sampling began at Oakdale on January 27, and averaged over 15,000 fry/day during the first 5 days of sampling. Thus, large numbers of fry probably passed Oakdale before sampling began.

Estimates of juvenile chinook passage at Caswell in 1998 were higher than at Oakdale for parr and smolt, but not for fry (Table 9). Because other data indicate that migrating fish moved through the river between the two sites within a few days, the consistently higher estimates of chinook passage at the downstream site indicate that spawning and production of juveniles between the two sites was substantial for this brood. It is possible that much of this added production below Oakdale resulted from newly emerged fry that drifted down from upstream of Oakdale and then took up residence until they were stimulated to migrate as parr or smolts. If this latter scenario is true, then growth rates must have been similar above and below Oakdale, because both the size of chinook passing Oakdale and Caswell and the dates of peak passage were similar between sites throughout the migration season.

The difference in estimated fish passage between Oakdale and Caswell reversed signs between 1996 and 1998 (Table 9). In 1996, total passage at Oakdale was nearly three times that at the downstream Caswell site. Total passage at Oakdale in 1998 (if there had been no gaps in sampling) was only about 1.2 times that of Caswell. As shown in Figure 3 (pg. 9), flow patterns in the two years were similar, with the exception that flows greater than 1,000 cfs occurred during fry emergence in January and February of 1998, but not in 1996. The more stable flows during fry emergence in 1996 may have caused less dispersal of fry to downstream rearing areas between Oakdale and Caswell.

Table 9. Estimates of total juvenile chinook passage as fry, parr, and smolts at Oakdale and Caswell in 1996 and 1998.

	1996		1998	
Life Stage	**Oakdale**	**Caswell**	**Oakdale**	**Caswell**
Fry	119,796	28,654	417,185 (a)	287,801
Parr	11,453	1,464	60,041	179,448
Smolt	148,369	65,084	121,647 (b)	183,935

(a) Passage during February 14-20 not sampled or estimated at Oakdale
(b) Passage during May 21-26 not sampled or estimated at Oakdale

RAINBOW TROUT/ STEELHEAD

We captured a total of 20 rainbow/steelhead (*Onchorynchus mykiss*) ranging in size from 66 to 283 mm in the screw trap in 1998 (Figure 14). Seventeen of the fish showed advanced signs of smolting and 3 showed no signs of smolting (Appendix 3). The first rainbow/steelhead was captured after we began sampling on January 27 and the last on July 8. The rainbow/steelhead > 200 mm long were caught during March, April, and May and young-of-year rainbow (<100mm) were caught in February-March and again in June and July.

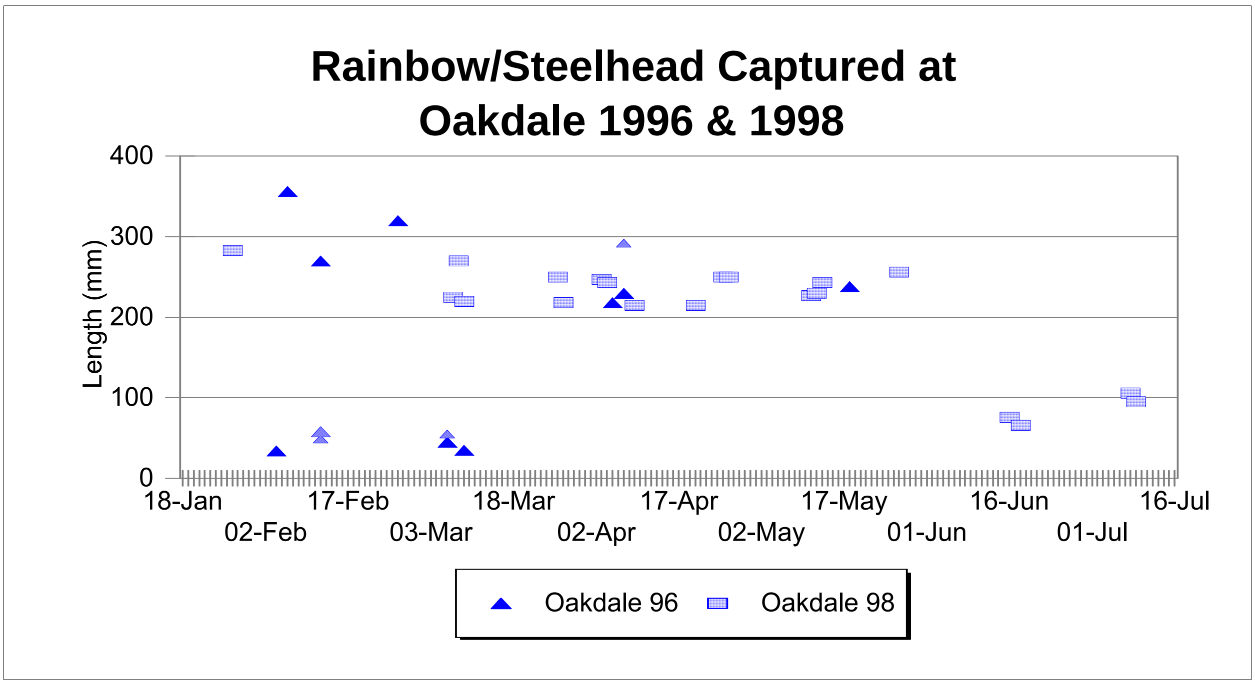


Figure 14. Rainbow/steelhead length and date of capture for 1996 and 1998.

CONCLUSIONS

1. The estimated number of juvenile chinook passing Oakdale January 26 through July 15, 1998 was 598,873 with approximate confidence intervals of 377,170 to 820,931. Many fry passed between February 4 and February 11 when the trap was temporarily out of order and fry passage already averaged 15,000 fry per day during the first 5 days of sampling in February. Thus, the passage of fry was substantially underestimated.

2. Juveniles emigrated as fry (<45 mm), fingerlings (45-80 mm), and smolts (80-110 mm). Nearly 70% of migrants sampled during the season were fry, and their passage was nearly complete by March 7, 1998. Sharp increases in flow stimulated fry outmigration.

3. As in 1996, juvenile chinook reached smolt size (>80 mm) when flows were stable and outmigration of smolts proceeded during late April and the first half of May. This pattern during stable flows demonstrates that juvenile chinook will emigrate when they reach smolt size even in the absence of flow variation.

4. Although some chinook did make the journey from Knights Ferry (and Oakdale) to Caswell in 10-20 days there was no evidence that parr or smolts stopped to rear. This was supported by the similarity in mean lengths of captured chinook at Oakdale and Caswell throughout the trapping season. It is probable that a small portion do migrate slower and rear for short periods.

5. Migration rates were comparable to previous years ranging 1.1-14.2 miles/night. Flows were higher in 1998 (~2,000 cfs) but comparable to 1996 flows (~1,500 cfs) during survival releases.

6. Unlike 1996, outmigrant abundance estimates were higher at the downstream Caswell site than at Oakdale for parr and smolts. Some of the extra fish at Caswell were undoubtedly from spawning below Oakdale, but a large share were probably from emergent fry that drifted below Oakdale during the high and fluctuating flows of January and February.

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APPENDICIES

Appendix A. Estimated 1998 Trapping Efficiency and Fish Outmigration Index at Oakdale (with updated 1996 outmigration index)

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The daily screw-trap count at Oakdale was expanded by dividing it by the predicted daily trapping efficiency (predicted proportion of fish trapped) to estimate the daily outmigration index:

$$\textit{outmigration index } (o) = \frac{\textit{count } (c)}{\textit{efficiency } (e)}$$

Predicted Trapping Efficiency

Daily screw-trap counts were available from February 6 through June 8, 1996 and from January 27 through July 15, 1998 (hereafter referred to as passage days). On 16 days during these monitoring periods, a total of 20 uniquely marked releases were made at a fixed distance upriver from Oakdale screw trap for the purpose of estimating trapping efficiency[2]. 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" variable(s) that was (were) measured on every day that the screw traps were operating. Substituting a given day's value(s) of the predictor variable(s) into the predictive relation would then provide an estimate of that day's efficiency.

The prediction method assumes that the trapped fish would be representative of all fish passing the trap. There were no direct methods of assessing this. However, there was evidence that the trapped fish did not differ in size from released fish (whether trapped or not). The mean size of trapped released fish did not significantly or substantially differ from the mean size of a sample of

[2] In 1996, there were 8 release days; on one of those days there were two fish-trap-efficiency releases made. In 1998 there also were 8 release days; on three of those days, there were two fish-trap-efficiency releases per day.

fish taken at release (Table A.1). Even though for the June 13 releases, the released fish's average length exceeded that of the recovered fish my 9 mm or more, this was not representative of the releases. Partitioning the releases into two groups, those with average lengths greater that 70 mm and those with average lengths less than 70 mm, did not result in significant differences in the weighted means of released and recovered fish with groups. For the smaller fish, the weighted mean difference (released - recovered) was only 0.79, and for the larger fish, it was -1.78 mm; neither significantly different than 0 (P = 0.63 and P = 0.26, respectively).

Table A.1. Comparisons in lengths (mm) of fish at times of release and recovery (Oakdale, 1998).

Date of Release	Fish Stock	Lengths of released (rel) and recovered (rec) fish					
		Released Fish		Recovered Fish		Difference in mean lengths	Weight for mean comparisons
		Mean Length	Sample size (n)	Mean Length	Sample size (n)		
03/02/98	Natural	35.4	50	35.6	25	-0.2	33
03/18/98	Natural	62.2	50	59.3	27	2.9	35
04/06/98	Natural	68.8	50	69	23	-0.2	32
04/11/98	Natural	66.3	50	66.1	10	0.2	17
05/02/98	Natural	81.1	50	79.5	15	1.6	23
05/30/98	Hatchery	97.6	50	98.5	23	-0.9	32
05/30/98	Natural	88.9	50	88	19	0.9	28
06/13/98	Hatchery	95.6	50	104.8	12	-9.2	19
06/13/98	Natural	82.7	50	91.7	7	-9	12
06/24/98	Natural	88.6	50	89.5	4	-0.9	7
06/24/98	Natural	89	50	86.5	6	2.5	11

Weighted[1] mean difference = -0.576
Standard error = 1.104
t-ratio (10 d.f.) = -0.52
Computed Type I Error probability = 0.6133

[1] Weights are harmonic means of the number of released and recovered fish measured, 2/[1/n(rel)+1/n(rec)], to account for differences in sample numbers within and among pairs

The predictor variables explored were flow (f in cubic feet per second, cfs) measured at Orange Blossom Bridge (OBB), fish size (s as length in millimeters, mm), and turbidity (t in nephelometric turbidity units, ntu). A logistic analysis revealed that neither fish size nor turbidity contributed significantly to the predictive capability of the model once flow was included as a predictor variable (discussed later). Therefore, efficiency (e), the proportion of released fish trapped per release, was related to flow on the day of release using the simple logistic:

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

or, using the "logit" linear transform,

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

In the above equations "exp" is the exponential function, "ln" is the natural log, "b(0)" is a coefficient associated with the intercept[3], and b(f) is the partial logistic regression coefficient relating the logit transform of efficiency to flow. 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.

Predictor Variables: For some outmigration days, not all predictor variable values were available. Linear extrapolations from the nearest straddling days with true variable measures were used to estimate the missing values of flow, fish size, and turbidity, the extrapolation being based on the number of days separating the missing value from the true measures used. For example, if there was a flow of 1000 cfs on Day 4 and there was a flow of 1200 cfs on Day 9 and if there were no intervening measures, then the missing values for Day 5 through Day 8 would then be computed as follows:

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

Day 4: 1000 (actual)

Missing Value for day i =
[(days from Day j)(Day i value)+(days from Day i)*(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)

This missing-value-substitution method is different than that used in previous years because there were longer runs of missing values in 1998, especially for turbidity. For consistency, this same method was then used to recompute missing values of flow and turbidity from 1996; therefore, some of the predictor variable values given in this report differ from those given in the previous report for the 1996 passage.

Selected Model: The data used for developing the predictor are given in Appendix A.2.a. A formal analytical partitioning of the variability associated with the logistic fit is presented in Appendix A.2.b. Based on the analysis, it was decided to fit the 1998 data separately from the 1996 sets. This was done because there was a significant difference between the 1996 and 1998 responses to flow ($P = 0.0002$). As indicated in Appendix A.2.b, fish size and turbidity did not significantly increase the precision of the model ($P = 0.21$, $P = 0.22$, respectively); therefore they were not included in the predictor model. Table A.2. gives the estimated flow coefficients for both the 1998 and 1996 predictors[4].

Table A.3 presents the predicted values and associated residuals based on the coefficients given in Table A.2. An approximate z-test of residuals (Pearson's standardized residuals) based on the binomial distribution indicates no significant difference from what would have been expected from the binomial. Only one of the of the nine 1996 and one of the eleven 1997 standardized residuals from Table A.3. have absolute values exceeding 1.96. Pooled over both years, this represents 10% of the releases. If the distributions around the fit were actually binomial, then approximately 5% of the standardized residuals' absolute values would be expected to exceed 1.96. The 10% estimate does not substantially or significantly exceed the expected 5%.

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[4] The coefficients for the 1996 data are no different than those given in a previous report because there were no missing flow data for days on which releases were made.

Even though the residual variation[5] is 41% higher than would be expected from the binomial, the residual variation did not significantly exceed the binomially based expected variation (P=0.1268). Even so, the binomially based standard errors, variances, and covariances were expanded by 1.41 to reflect the higher estimate of variation, giving more conservative estimates than were given in previous report for 1996 passage. This expansion does not effect the passage estimate, but does effect the confidence limits. The expanded standard errors, variances and covariances are what are presented in Table A.2. The nature of the expansion in discussed in Appendix A.1.

Table A.2. Estimated coefficients and associated statistics for the 1998 and 1996 logistic efficiency predictors.

	1998 Logistic Coefficient Estimates				**1996 Logistic Coefficient Estimates**			
Coefficient	Estimate (b)	Standard Error (SE)	"t"-ratio (b/SE)	Computed P	Estimate (b)	Standard Error (SE)	"t"-ratio (b/SE)	Computed P
"Intercept" [b(0)]	-1.9053	0.317	-6.01	0	-0.02418	0.1213	-0.2	0.8445
Flow [b(f)]	-0.0004574	0.0001439	-3.18	0.0058	-0.00126	0.0000964	-13.07	0
	Variance-Covariance Estimates of Coefficient Estimates (based on 16 pooled degrees of freedom)							
	b(0)		b(f)		b(0)		b(f)	
b(0)	1.00484E-01				1.47149E-02			
b(f)	-0.00004365188		2.06994E-08		1.05891E-05		0.00000000929	

5 The variation is measured by deviance/(degrees of freedom), dev/df = 22.53/16 = 1.408. The expected value of dev/df under the binomial is 1.0.

Table A.3. Flow, estimated efficiencies, predicted values, and residuals for the standard release sets.

Release Date	Flow (f) {CFS}	Adjusted number released[1] {N}	Estimated trapping efficiency {p}	Predicted value[2] {P}	Residual (not standardized) {p-P}	Approximate z-ratio based on binomial (Pearson's residuals) $\{(p-P)/[p(1-p)/N]^{1/2}\}$
02/12/96	681	969	0.284	0.293	-0.0092	-0.63
03/22/96	3413	617	0.013	0.013	-0.0002	-0.04
04/06/96	1791	500	0.09	0.093	-0.003	-0.23
04/06/96	1791	499	0.064	0.093	-0.0289	-2.22
04/14/96	1595	198	0.101	0.116	-0.015	-0.66
04/22/96	1673	248	0.125	0.106	0.0187	0.95
05/04/96	1674	547	0.132	0.106	0.0254	1.93
05/26/96	921	304	0.253	0.235	0.0187	0.77
05/29/96	935	507	0.239	0.231	0.0073	0.39
03/02/98	3508	929	0.027	0.029	-0.0021	-0.38
03/18/98	1768	479	0.056	0.062	-0.0058	-0.52
04/06/98	1561	347	0.066	0.068	-0.0016	-0.12
04/11/98	2066	168	0.06	0.055	0.0049	0.28
05/02/98	1972	392	0.038	0.057	-0.0187	-1.59
05/30/98	2034	250	0.076	0.055	0.0206	1.42
05/30/98	2034	267	0.086	0.055	0.0307	2.19
06/13/98	1564	146	0.048	0.068	-0.0199	-0.96
06/13/98	1564	175	0.069	0.068	0.0008	0.04
06/24/98	2130	81	0.074	0.053	0.0209	0.84
06/24/98	2130	84	0.048	0.053	-0.0056	-0.23

[1] Number released multiplied by estimated pre-release survival

[2] 1/[1+exp(-b0- b1*f)], b0=-0.02418, b1=-0.001260 for 1996

1/[1+exp(-b0- b1*f)], b0=-1.9053, b1=-0.0004574 for 1998

Efficiency Test Comparisons

Fish trapping efficiency against a floating standard

One question posed was whether fish trapping is a purely random surface-movement event. To test this, lemons were released at the standard release point, and the proportion of these lemons that were entrained in the screw traps was computed. Pooled estimates of trapping efficiencies from fish and lemons released on the same day respectively were 6.3% and 0.0%. These estimates were substantially and significantly different from each other (P < 0.0001, Table

A.4). If fish simply followed random surface movement and if lemon movement represented this random surface movement, one would not expect a difference of this magnitude. Fish are being entrained at a greater rate than would be expected based on lemons.

River-Run- versus Hatchery-Releases

In 1998 there were paired releases of hatchery and river-run ("natural") fish on two release days (May 30 and June 13). The efficiencies for these paired sets are summarized in Table A.4. The mean difference between the efficiency estimates from these paired releases was not significantly different than 0 (Table A.4: pooled "natural" e = 0.066 and hatchery e = 0.076, P of difference = 0.27).

Table 4. Efficiency test comparisons

Date	Release Type	Stock	Adjusted Number Released	Number Recovered	Efficiency Estimate
		FISH VERSUS LEMON COMPARISON			
05/02/98	Fish	Natural	392	15	0.0383
	Lemon		100	0	0
05/30/98	Fish	Natural and Hatchery Pooled	517	42	0.0207
	Lemon		100	0	0
Pooled over all appropriate releases		Fish	909	57	0.0627
		Lemon	200	0	0
			t-ratio^1 (Night versus Day) = 8.26		
			Within release-day degrees of freedom = 4		
			2-sided Probability = 0.0012		
	[1] t-ratio based square root of F-ratio generated from logistic regression using residual based on variation among releases within release days--non-standard release omitted.				
		NATURAL VERSUS HATCHERY COMPARISON			
05/30/98		Hatchery	267	23	0.0861
		Natural	250	19	0.076
06/13/98		Hatchery	175	12	0.0686
		Natural	146	7	0.0479
Pooled over all appropriate releases		Hatchery	250	19	0.076
		Natural	396	26	0.0657
			t-ratio^2 (Night versus Day) =		1.35
			Within release-day degrees of freedom =		3
			2-sided Probability =		0.2697
	[2] t-ratio based square root of F-ratio generated from logistic regression using residual based on variation among releases within release days				

Outmigration Index Estimation

Substituting the efficiency-to-flow predictor for a given day (day i) into the outmigration index estimation equation gives:

$$o(_i) = \frac{c(_i)}{e(_i)} = \frac{c(_i)}{\dfrac{1}{1+\exp^{[-b(0)-b(f)\times f(_i)]}}} = c(_i) \times [1+\exp^{[-b(0)-b(f)\times f(_i)]}]$$

Methods of interpolating missing values of flow were discussed earlier. There were also days when counts were missing. The missing value computation in 1998 was the following transform based on the five previous and five subsequent days' true counts:

$$\hat{c}(i) = e^{\left[\frac{w(1)\times \ln[c(i+1)+1] + w(1)\times \ln[c(i-1)+1]\;, +\ldots+\; w(5)\times \ln[c(i+5)+1] + w'(1)\times \ln[c(i-1)+1] + \ldots + w'(55)\times \ln[c(i-5)+1]}{2\times \Sigma w(i)}\right]} - 1$$

wherein the weight, w(j) or w'(j), is 0 if the associated count, c(i+j) or w(i-j), is missing, w(j) or w'(j) = 6-j otherwise. Thus, when no proximal values are missing, the weight of the most proximal value is the highest [w(1) = w'(1) = 5] and of the most distal [w(5) = w'(5) = 1] is the lowest. This same procedure was used to recompute missing count values from 1996; therefore, the missing values presented in Appendices A.4 in this report for 1996 will differ somewhat from those presented in previous reports.

1995 passage estimates were not updated. In the earlier report, the efficiency prediction used to estimate 1995 passage was based on the unaltered 1996 efficiency-to-flow fit. Since the current study demonstrates that the 1996 and 1998 efficiency-to-flow predictors are different, there is no basis for believing that the 1996 or 1998 predictors can be used to predict any other year's passage other than their own; therefore the 1995 passage was not re-predicted.

Daily Outmigration

The recomputed daily outmigration indices for 1996 and 1998 are given in Figures A.1 based on the full model prediction. The outmigration index is clearly greater in the early part of the 1998 season than in the early part of the 1996 season and its presentation in the previous report is questionable.

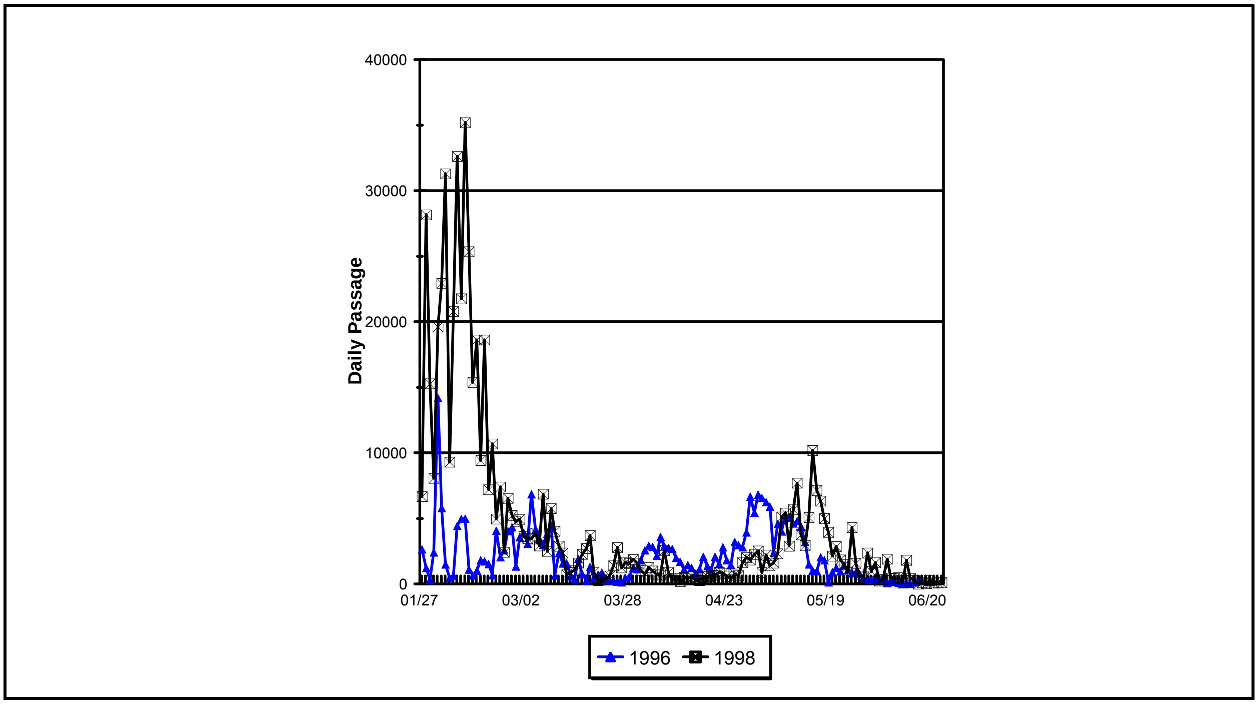

Figure A.1. Computed daily outmigration index by day in 1996 and 1998

The re-estimated cumulative outmigration indices for 1996 is given along with its approximate 95% confidence limits in Figures A.2.a. The 1998 cumulative outmigration index and confidence limits are given is Figure A.2.b. The revised estimated 1996 and 1998 final cumulative outmigration indices (and approximate 95% confidence intervals) for the full model are:

1996: 280 thousand[6] (125 thousand - 435 thousand)
1998: 599 thousand (377 thousand - 821 thousand)

Although the confidence intervals overlap, the 1996 point estimate falls outside the 1998 confidence interval, and the 1998 point estimate lies outside the 1996 confidence interval. An approximate z-test[7] indicates that the cumulative outmigration indices differ (P = 0.02).

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6 1996 estimate was 283 thousand in the 1996 report. The slight difference between this and the current estimate (280 thousand) is solely attributable to the different method of computing missing flows.

7 $z = [o(1998) - o(1996)]/\{SE^2[o(1998)]+SE^2[o(1996)]\}^{½}$; o being the outmigration from the last dates given in Appendices A.3 and A.4.

Appendix A.3 presents 1996 revised flows, screw-trap counts, and efficiency-to-flow predictions, as well as associated full-model daily and cumulative outmigration index estimates and their approximate standard errors. Appendix A.4 presents the corresponding 1998 values.

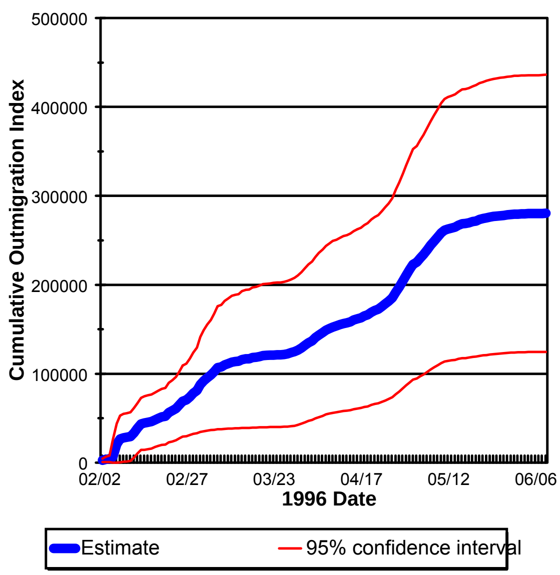

Figure A.2.a. 1996 estimated cumulative outmigration.

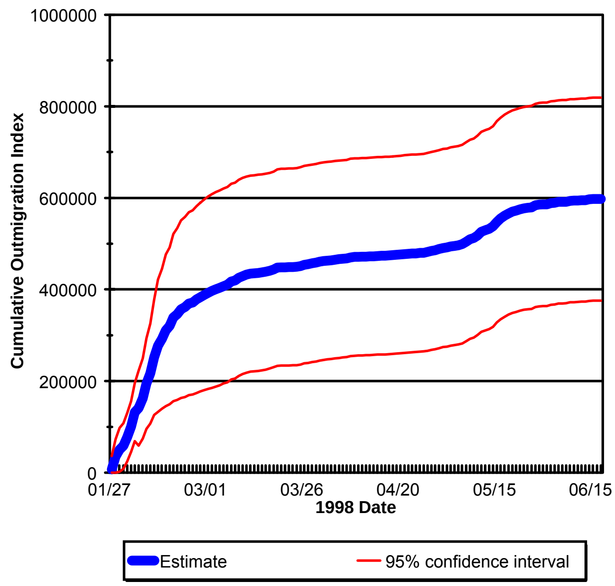

Figure A.2.b. 1998 estimated cumulative outmigration.

Appendix A.1. Standard Error for Cumulative Outmigration Index

In the following discussion, I use upper case letters to represent parameter values and corresponding lower case letters to represent their estimates.

The population daily outmigration index is

$$O_i = \frac{C_i}{E_i}$$

wherein O_i is the true daily outmigration index on day i, C_i is that day's expected count, and E_i is the true trapping efficiency for that day. The true cumulative outmigration index is simply the daily index values added over days:

$$\Sigma_i O_i = \Sigma_i \frac{C_i}{E_i}$$

Substituting lower case letters for upper case letters gives the form of the estimated daily outmigration index

$$o_i = \frac{c_i}{e_i}$$

and the cumulative index

$$\Sigma_i o_i = \Sigma_i \frac{c_i}{e_i}$$

The variance of this cumulative passage is

$$S^2 [\Sigma_i o_i] = \Sigma_i Var[\frac{c_i}{e_i}] + \Sigma_i \Sigma_{i' \neq i} Cov[\frac{c_i}{e_i}, \frac{c_{i'}}{e_{i'}}]$$

wherein Var is the variance of the daily outmigration index (day i) and Cov is the covariance between indices from different days (days i and i'). The standard error, SE, is the square root of the variance, S^2. I discuss in order: 1) $Var[c_i/e_i]$, 2) $Cov[(c_i/e_i),(c_{i'}/e_{i'})]$, 3) the variance and covariances of the estimated coefficients required for $Var[c_i/e_i]$ and $Cov[(c_i/e_i),(c_{i'}/e_{i'})]$, and 4) approximated confidence limits.

1. Var[c_i/e_i]

The variance of c_i/e_i can be approximated by variance of the ratio

$$Var[\frac{c_i}{e_i}] = \frac{C_i^2 \cdot Var[e_i]}{E_i^4} + \frac{Var[c_i]}{E_i^2} - 2 \cdot \frac{C_i \cdot Cov[c_i,e_i]}{E_i^3}$$

The methods used to estimate the components in the above equation are now discussed.

1.a. Estimates of C_i and E_i.

C_i and E_i, the actual parametric (population) values, are estimated by c_i and e_i, respectively. The substitution of c_i and e_i raised to powers 2, 3, and 4 for the corresponding powers of C_i and E_i do lead to biases, but no attempt was made to adjust for those biases or to assess the relative magnitude or direction of those biases.

1.b. Estimate of Var[e_i]

Recalling from the main appendix, the efficiency predictor is

$$e_i = \frac{1}{1 + \exp^{h_i}} \quad wherein \quad h_i = -b(0) - b(f) \cdot f_i - b(s) \cdot s_i - b(t) \cdot t_i$$

The asymptotic form of the estimated variance of e_i can be developed by multiplying the variance-covariance matrix of the b's by the vector of the first derivatives of e_i above with respect to the b's and post multiplying by the transpose of that vector (delta method), giving:

$$Var[e_i] = E_i^4 \cdot [\exp^{h_i}]^2 \cdot Var[b(0) + b(f) \cdot f_i + b(s) \cdot s_i + b(t) \cdot t_i]$$

1.c. Estimate of Var[c_i]

The variance in the count was approximated by taking the variance among the count of that day and the count(s) from immediately adjacent days. Usually,

$$Var[\hat{c}_i] = \frac{[\hat{c}_{i-1} - \bar{c}_i]^2 + [\hat{c}_i - \bar{c}_i]^2 + [\hat{c}_{(i+1)} - \bar{c}_i]^2}{n-1}$$

wherein

$$\bar{c}_i = mean\ of\ c_{(i-1)},\ \hat{c}_i,\ \hat{c}_{i+1}$$

and wherein n = 3 (the usual case). [The equation forms being slightly different and n = 2 if there is only one adjacent day (first and last day of trapping)]. This method was different than that used in the previous report for 1995 and 1996 outmigration which made some erroneous assumptions.

1.d. Estimate of Cov[c_i, e_i]

The count and the predicted efficiency can be regarded as independent since they were based on different fish and since there is no reason to believe the capture of a given released fish used to estimate efficiency affected the probability of capturing a river-run fish used to estimate c_i. Therefore

$$Cov[c_i, e_i] = 0$$

2. Cov[(c_i/e_i),($c_{i'}/e_{i'}$)]

There is a covariance between outmigration indices from different days. It is not equal to zero because the equations for predicting e_i and $e_{i'}$ used the same coefficients estimates, b(0) and b(f). The covariance was developed using the delta method analogous to that used for Var[e_i], the asymptotic covariance being

$$Cov[\frac{c_i}{e_i}, \frac{c_{i'}}{e_{i'}}] =$$

$$(c_i c_{i'})(\exp^{h_i} \exp^{h_{i'}})(Cov + [b(0) + b(f)(f_i + b(s)(s_i + b(t)(t_i], [b(0) + b(f)(f_{i'} + b(s)(s_{i'} + b(t)(t_{i'}]\ ,$$

This estimated covariance is driven by the magnitude of the variance of the coefficients and by the magnitude of the various multipliers.

3. Estimating Variance of Coefficients and Covariances between Coefficients

Logistic regression was used to obtain the estimates of coefficients and their variances and covariances. However, the variances and covariances generated assume that the distribution of residuals is binomial, meaning the expected ratio of the deviance to degrees of freedom (Dev/D.F.) is 1. When this is not the case, the variance and covariance estimates presented in logistic regression packages are underestimated and need to be expanded.

The residual Dev/DF = 22.53/16 = 1.41 did not significantly ($P < 0.12$) exceed 1. However, since this measure of residual variation did exceed that expected from the binomial by 41%, the decision was made to expand the computer-output binomially-based variances and covariances by Dev/D.F. just in case the binomial distribution did not hold.

4. Confidence Intervals

The $100*(1-\alpha)$ confidence intervals of estimates were approximated using

$$\text{estimate} \pm z(\alpha)*SE(\text{estimate})$$

wherein $z(\alpha)$ is the two-sided standardized normal deviate associated with confidence probability $1-\alpha$ and SE is the standard error or square root of the variance of the estimate. This approximation is based on an assumed normal distribution of the estimate.

Appendix A.2.a. Data Used for Logistic Prediction Fit

Date	Number Released (N)	Number Recovered (n)	Estimated Efficiency (e = n/N)	Flow (f in cfs)	Size (s in mm)	Turbidity (t in ntu)
02/12/96	969	275	0.284	681	34	5.1
03/22/96	617	8	0.013	3413	43.9	3.1
04/06/96	500	45	0.09	1791	70.6	2.6
04/06/96	499	32	0.064	1791	69.5	2.6
04/14/96	198	20	0.101	1595	78.1	2.1
04/22/96	248	31	0.125	1673	86.1	3
05/04/96	547	72	0.132	1674	75.5	2.3
05/26/96	304	77	0.253	921	72.2	2.4
05/29/96	507	121	0.239	935	92.5	2.1
03/02/98	929	25	0.027	3508	35.6	0
03/18/98	479	27	0.056	1768	59.3	0
04/06/98	347	23	0.066	1561	69	0
04/11/98	168	10	0.06	2066	66.1	0
05/02/98	392	15	0.038	1972	79.5	0
05/30/98	250	19	0.076	2034	88	0*
06/13/98	146	7	0.048	1564	91.7	0*
06/24/98	81	6	0.074	2130	86.5	0*
06/24/98	84	4	0.048	2130	89.5	0*
05/30/98	267	23	0.086	2034	98.5	0*
06/13/98	175	12	0.069	1564	104.8	0*

*Substitutions for missing values. Substituted values computed using method described in text

Appendix A.2.b. Analysis of Variation Associated with Efficiency Predictor

Source	Deviance[1] (Dev)	Degrees of Freedom (DF)	Dev/DF Ratio[2]	F-Ratio Value	Computed P
Flow (f)	545.94	1	545.94	478.89	0
Separate Intercept and Flows for 1996, 1998	44.8	2	22.4	19.65	0.0002
Additional Affect of Fish Size when Included with Flows	3.95	2	1.975	1.73	0.2183
Additional Affect of Turbidity when Included with Flows	4.06	2	2.03	1.78	0.2103
Residual[3] (separate year flows, sizes, turbidities)	13.68	12	1.14		
Residual[4] for selected model	22.53	16	1.408		

[1] Analogous to "sums of squares" in analysis of variance
[2] Analogous to "mean square" in analysis of variance
[3] Serves as basis of F-test
[4] Used in developing standard errors and confidence intervals

Appendix A.3. **Flow, predicted screw-trap efficiency, and daily and cumulative outmigration index values based on trapping efficiency-to-flow relation, Oakdale, 1996.**

	OBB			Daily Passage		Cumulative Passage	
Date	Flow	Count	Efficiency	Estimate	SE	Estimate	SE
02/02	317	1046	0.39566	2644	1017	2644	1017
02/03	302	493	0.40018	1232	1188	3876	1580
02/04	591	104	0.31673	328	998	4204	1876
02/05	642	729.47*	0.30299	2408	9655	6612	9847
02/06	355	5452	0.38427	14188	6403	20800	11824
02/07	320	2289	0.39475	5799	6267	26598	13461
02/08	306	595	0.39897	1491	2790	28090	13772
02/09	300	194	0.40079	484	560	28574	13792
02/10	516	222	0.33753	658	1878	29231	13934
02/11	678	1305	0.2935	4446	2356	33678	14244
02/12	681	1449	0.29271	4950	789	38628	14417
02/13	913	1179	0.23603	4995	2892	43623	14915
02/14	1179	200	0.18098	1105	3347	44728	15350
02/15	1595	75	0.11569	648	576	45376	15411
02/16	1648	112	0.10903	1027	621	46404	15506
02/17	1652	196	0.10854	1806	614	48209	15670
02/18	1650	188	0.10879	1728	611	49937	15837
02/19	2014	109	0.07164	1522	1265	51459	16057
02/20	2841	18	0.0265	679	1738	52138	16256
02/21	3223	67.48*	0.01654	4079	2322	56217	17117
02/22	2797	57.46*	0.02797	2055	827	58272	17515
02/23	3093	50.02*	0.01943	2575	1107	60847	18094
02/24	3245	65	0.0161	4038	1820	64885	19125
02/25	3232	71	0.01636	4340	2464	69225	20386
02/26	3271	21	0.01559	1347	1712	70572	20839
02/27	3341	51	0.01429	3569	1908	74141	21957
02/28	3481	47	0.01201	3915	2173	78056	23285
02/29	3894	22	0.00717	3068	2571	81124	24523
03/01	3897	49	0.00714	6859	3844	87984	27270
03/02	3866	30.7*	0.00743	4134	2577	92118	28981
03/03	3856	26	0.00752	3458	1739	95576	30403
03/04	3836	23.06*	0.00771	2992	1445	98567	31644
03/05	3975	25	0.00648	3859	2103	102426	33325
03/06	3850	34	0.00758	4488	2912	106914	35300
03/07	3847	5	0.0076	658	1936	107571	35635
03/08	3842	18	0.00765	2352	1412	109924	36659
03/09	3849	12	0.00759	1582	870	111506	37348
03/10	3782	13	0.00825	1576	876	113082	38028
03/11	3641	6	0.00984	610	556	113692	38286
03/12	3584	4	0.01056	379	896	114071	38453
03/13	3552	21	0.01099	1911	1171	115981	39246
03/14	3489	9	0.01189	757	841	116739	39562
03/15	3529	3	0.01131	265	544	117004	39674
03/16	3524	15	0.01138	1318	817	118322	40219

Date	OBB Flow	Count	Efficiency	Daily Passage Estimate	Daily Passage SE	Cumulative Passage Estimate	Cumulative Passage SE
03/17	3519	5	0.01145	437	489	118758	40401
03/18	3530	8	0.0113	708	388	119467	40693
03/19	3522	10	0.01141	877	503	120343	41056
03/20	3503	3	0.01168	257	364	120600	41163
03/21	3509	3	0.01159	259	115	120859	41269
03/22	3413	3	0.01307	230	109	121088	41362
03/23	3010	4	0.02153	186	78	121274	41429
03/24	2761	4	0.02923	137	281	121411	41477
03/25	2539	18	0.0383	470	376	121881	41628
03/26	2226	30	0.05578	538	583	122419	41786
03/27	2125	77	0.06287	1225	573	123644	42127
03/28	2024	79	0.0708	1116	662	124759	42428
03/29	1896	149	0.08218	1813	1089	126573	42898
03/30	1790	238	0.09283	2564	996	129136	43524
03/31	1748	284	0.09738	2916	782	132053	44218
04/01	1794	262	0.0924	2835	877	134888	44911
04/02	1791	200	0.09272	2157	907	137045	45442
04/03	1794	332	0.0924	3593	1178	140638	46326
04/04	1788	265	0.09304	2848	881	143486	47024
04/05	1809	248	0.09083	2730	725	146216	47699
04/06	1791	249	0.09272	2685	795	148902	48360
04/07	1780	188	0.09389	2002	710	150904	48852
04/08	1779	160	0.094	1702	634	152606	49271
04/09	1775	104	0.09443	1101	412	153708	49541
04/10	1776	135	0.09432	1431	407	155139	49892
04/11	1791	114	0.09272	1229	442	156368	50196
04/12	1731	79	0.09928	796	328	157164	50388
04/13	1598	129	0.11531	1119	758	158283	50645
04/14	1595	239	0.11569	2066	695	160349	51113
04/15	1599	158	0.11518	1372	627	161720	51425
04/16	1656	118	0.10806	1092	512	162812	51681
04/17	1706	212	0.10213	2076	697	164888	52177
04/18	1711	155	0.10156	1526	792	166414	52546
04/19	1679	295	0.1053	2802	975	169216	53211
04/20	1670	194	0.10637	1824	824	171040	53643
04/21	1675	152	0.10577	1437	998	172477	53990
04/22	1673	340	0.10601	3207	1246	175684	54753
04/23	1668	315	0.10661	2955	755	178639	55449
04/24	1673	297	0.10601	2802	915	181441	56113
04/25	1676	415	0.10565	3928	2207	185368	57077
04/26	1676	704	0.10565	6663	2144	192032	58672
04/27	1662	584	0.10733	5441	1515	197473	59959
04/28	1668	727	0.10661	6819	1815	204292	61578
04/29	1684	686	0.1047	6552	1661	210844	63146
04/30	1683	655	0.10482	6249	1582	217093	64644
05/01	1684	619	0.1047	5912	2604	223005	66098
05/02	1680	248	0.10518	2358	1889	225363	66687
05/03	1659	496	0.10769	4606	1638	229968	67790
05/04	1674	426	0.10589	4023	1193	233991	68756

Date	OBB Flow	Count	Efficiency	Daily Passage Estimate	Daily Passage SE	Cumulative Passage Estimate	Cumulative Passage SE
05/05	1662	566	0.10733	5273	1485	239265	70016
05/06	1640	556	0.11002	5054	1277	244319	71208
05/07	1664	494.36*	0.10709	4616	1170	248935	72311
05/08	1650	523.97*	0.10879	4816	1201	253751	73455
05/09	1663	470.69*	0.10721	4390	1387	258142	74510
05/10	1667	342*	0.10673	3204	1646	261346	75292
05/11	1653	163.57*	0.10842	1509	1172	262855	75660
05/12	1644	112.22*	0.10952	1025	382	263879	75903
05/13	1655*	105.88*	0.1082	979	629	264858	76139
05/14	1666*	218	0.1069	2039	743	266897	76630
05/15	1676*	192	0.1056	1818	1143	268715	77075
05/16	1687*	14	0.10433	134	856	268849	77112
05/17	1698	92	0.10306	893	623	269742	77332
05/18	1658	132	0.10781	1224	358	270966	77625
05/19	1693	101	0.10365	974	335	271941	77862
05/20	1697	148	0.10318	1434	429	273375	78212
05/21	1670	113	0.10637	1062	332	274438	78467
05/22	1525	108	0.12503	864	317	275302	78661
05/23	1151	164	0.18627	880	254	276182	78819
05/24	936	176	0.23085	762	188	276944	78937
05/25	901	113.73*	0.23877	476	194	277421	79009
05/26	921	94	0.23422	401	111	277822	79071
05/27	955	71	0.22662	313	100	278135	79120
05/28	958	110	0.22596	487	119	278622	79196
05/29	935	81	0.23107	351	84	278973	79251
05/30	935	99	0.23107	428	201	279401	79317
05/31	939	16	0.23018	70	181	279471	79328
06/01	945	56	0.22884	245	96	279715	79366
06/02	939	37	0.23018	161	76	279876	79391
06/03	933	23	0.23152	99	65	279975	79407
06/04	936	8	0.23085	35	37	280010	79412
06/05	933	9	0.23152	39	13	280049	79418
06/06	929	4	0.23242	17	52	280066	79421
06/07	976	27	0.22202	122	81	280188	79440
06/08	1281	38	0.1627	234	67	280421	79486

*Missing value estimate

Appendix A.4. **Flow, predicted screw-trap efficiency, and daily and cumulative outmigration index values based on trapping efficiency-to-flow relation, Oakdale, 1998.**

	OBB			Daily Passage		Cumulative Passage	
Date	Flow	Count	Efficiency	Estimate	SE	Estimate	SE
01/27	1366	491	0.07378	6655	15235	6655	6655
01/28	1365	2078	0.07381	28155	11689	34810	19368
01/29	1806	934	0.06115	15274	14477	50084	24430
01/30	2623	346	0.0429	8065	7414	58149	25558
01/31	2629	839	0.04279	19609	8515	77758	27075
02/01	2526	1027	0.04476	22945	6829	100703	28304
02/02	2524	1401	0.0448	31274	13734	131977	32168
02/03	3854	231	0.02489	9281	26170	141258	41752
02/12	4850	331	0.01593	20782	12854	162040	44805
02/13	4772	538	0.0165	32614	14150	194653	50694
02/14	4508	404	0.01857	21751	11017	216404	55736
02/15	4358	699	0.01987	35184	14676	251588	64300
02/16	5003	377	0.01487	25359	17965	276947	73731
02/17	4468	291	0.01891	15388	6106	292335	77976
02/18	5064	269	0.01446	18598	9003	310933	84543
02/19	4481	177	0.0188	9415	5477	320348	87392
02/20	4530	342	0.01839	18596	8938	338944	93195
02/21	4566	130	0.0181	7184	6544	346127	95609
02/22	4571	193	0.01806	10689	4577	356816	98982
02/23	4201	106	0.02131	4973	2811	361789	100358
02/24	3746	193	0.02612	7390	3121	369179	102001
02/25	3746	63	0.02612	2412	2722	371591	102563
02/26	3751	170	0.02606	6524	2657	378115	104018
02/27	3700	139	0.02666	5214	1512	383329	105139
02/28	3709	126	0.02655	4746	1171	388075	106164
03/01	3713	131	0.0265	4943	1304	393018	107237
03/02	3508	105	0.02903	3617	918	396634	107936
03/03	2967	128	0.03688	3470	897	400104	108385
03/04	2450	159	0.04627	3436	1001	403541	108623
03/05	2048	214	0.05509	3884	683	407425	108709
03/06	2106	156	0.05373	2903	2116	410328	108813
03/07	2071	374	0.05455	6856	2487	417185	109011
03/08	2059	137	0.05483	2498	2249	419683	109094
03/09	2089	311	0.05413	5746	1684	425429	109265
03/10	1974	228	0.05688	4008	1195	429437	109330
03/11	1721	183	0.06342	2886	636	432323	109293
03/12	1620	157	0.06622	2371	1120	434694	109241
03/13	1577	47	0.06745	697	898	435390	109225
03/14	1577	59	0.06745	875	196	436265	109200
03/15	1574	70	0.06753	1037	406	437302	109170
03/16	1570	109	0.06765	1611	640	438913	109125
03/17	1569	153	0.06768	2261	519	441174	109060
03/18	1768	168	0.06215	2703	316	443877	109041
03/19	2798	147	0.03973	3700	1974	447577	109467

Date	OBB Flow	Count	Efficiency	Daily Passage Estimate	Daily Passage SE	Cumulative Passage Estimate	Cumulative Passage SE
03/20	3413	27	0.03028	892	2495	448468	109658
03/21	3365	8	0.03094	259	328	448727	109704
03/22	2744	12	0.04068	295	117	449022	109735
03/23	2499	17	0.04529	375	173	449397	109763
03/24	2491	27	0.04545	594	487	449991	109809
03/25	2657	59	0.04227	1396	1322	451387	109949
03/26	2351	135	0.04831	2795	877	454182	110117
03/27	1883	73	0.05916	1234	536	455416	110126
03/28	1728	103	0.06323	1629	323	457045	110109
03/29	1593	104	0.06699	1553	265	458597	110070
03/30	1561	127	0.06791	1870	280	460467	110017
03/31	1582	107	0.0673	1590	487	462057	109976
04/01	1645	67	0.06552	1023	447	463080	109957
04/02	1580	52	0.06736	772	212	463852	109937
04/03	1758	78	0.06242	1250	242	465101	109929
04/04	1649	65	0.0654	994	260	466095	109911
04/05	1580	47	0.06736	698	177	466793	109893
04/06	1561	46	0.06791	677	917	467470	109878
04/07	1822	154	0.06073	2536	1041	470006	109885
04/08	2080	49	0.05434	902	1321	470908	109919
04/09	2065	17	0.05469	311	312	471219	109929
04/10	2062	23	0.05476	420	124	471639	109940
04/11	2066	10	0.05467	183	163	471822	109946
04/12	2069	27	0.0546	495	162	472316	109960
04/13	2206	20	0.05145	389	105	472705	109977
04/14	2182	30	0.05199	577	140	473282	110001
04/15	2066	17	0.05467	311	158	473593	110010
04/16	2051	14	0.05502	254	166	473847	110017
04/17	2035	31	0.0554	560	195	474407	110031
04/18	1996	33	0.05635	586	75	474993	110043
04/19	1996	37	0.05635	657	74	475649	110057
04/20	2008	38	0.05605	678	152	476327	110072
04/21	1979	51	0.05676	899	140	477226	110089
04/22	1982	46	0.05669	811	170	478037	110104
04/23	2009	34	0.05603	607	238	478644	110118
04/24	2057	20	0.05488	364	205	479008	110128
04/25	2016	42	0.05586	752	214	479760	110146
04/26	1992	36	0.05644	638	537	480398	110160
04/27	2005	91	0.05613	1621	728	482019	110198
04/28	1998	114	0.0563	2025	271	484044	110242
04/29	2004	103	0.05615	1834	254	485879	110283
04/30	2014	125	0.05591	2236	393	488114	110336
05/01	2019	141	0.05579	2527	908	490642	110400
05/02	1972	49	0.05693	861	863	491502	110420
05/03	2008	124	0.05605	2212	705	493715	110473
05/04	2049	76	0.05507	1380	469	495095	110512
05/05	2063	88	0.05474	1608	537	496702	110561
05/06	2011	130	0.05598	2322	1875	499024	110632
05/07	2016	* 286	0.05587	5119	1759	504143	110770

	OBB					Daily Passage		Cumulative Passage	
Date	Flow		Count		Efficiency	Estimate	SE	Estimate	SE
05/08	2020	*	302		0.05576	5416	1473	509560	110917
05/09	2025		160		0.05564	2875	1583	512435	111003
05/10	2005		318		0.05613	5666	2484	518101	111167
05/11	2004		432		0.05615	7693	2106	525794	111373
05/12	2033		208		0.05545	3751	2645	529545	111509
05/13	2088		159		0.05415	2936	1162	532482	111616
05/14	2027		281		0.0556	5054	3802	537536	111820
05/15	2017		568		0.05584	10172	2734	547708	112127
05/16	2019		398		0.05579	7134	2133	554842	112345
05/17	2028		352		0.05557	6334	1222	561176	112536
05/18	2023		278		0.05569	4992	1266	566168	112688
05/19	2016		220		0.05586	3938	1491	570106	112810
05/20	2027		118		0.0556	2122	944	572229	112877
05/27	2060		157		0.05481	2864	587	575093	112975
05/28	2086		100		0.0542	1845	740	576938	113045
05/29	2035		82		0.0554	1480	484	578418	113092
05/30	2034		49		0.05543	884	1802	579302	113134
05/31	2053		236		0.05498	4293	1823	583595	113291
06/01	1929		91		0.058	1569	1801	585164	113338
06/02	1671		34		0.06479	525	498	585689	113335
06/03	1551		37		0.0682	543	1073	586231	113330
06/04	1527		162		0.0689	2351	993	588583	113283
06/05	1537		64		0.06861	933	722	589516	113266
06/06	1531		112		0.06878	1628	723	591144	113234
06/07	1536		16		0.06864	233	777	591377	113232
06/08	1539		24		0.06855	350	938	591727	113229
06/09	1515		131		0.06925	1892	892	593619	113190
06/10	1528		31		0.06887	450	848	594069	113183
06/11	1557		29		0.06802	426	61	594495	113176
06/12	1593		34		0.06699	508	230	595003	113169
06/13	1564		6		0.06782	88	901	595091	113171
06/14	1565		123		0.06779	1814	940	596906	113144
06/15	1621		28		0.06619	423	882	597329	113143
06/16	1697		17		0.06407	265	222	597594	113143
06/17	1947		0		0.05755	0	152	597594	113143
06/18	2082		5		0.05429	92	47	597686	113146
06/19	2146		2		0.05281	38	118	597724	113148
06/20	2154		14		0.05262	266	123	597990	113160
06/21	2132		4.38	*	0.05313	82	101	598073	113164
06/22	2127		5.08	*	0.05324	95	16	598168	113168
06/23	2119		5.87	*	0.05343	110	14	598278	113172
06/24	2130		4.89	*	0.05317	92	31	598370	113176
06/25	2155		8		0.0526	152	50	598522	113183
06/26	2105		3		0.05375	56	61	598578	113185
06/27	2094		1.8	*	0.05401	33	16	598611	113187
06/28	2110		1.39	*	0.05364	26	18	598637	113188
06/29	2120		0		0.0534	0	15	598637	113188
06/30	2120		0		0.0534	0	32	598637	113188
07/01	2112		3		0.05359	56	29	598693	113190

Date	OBB Flow	Count		Efficiency	Daily Passage Estimate	Daily Passage SE	Cumulative Passage Estimate	Cumulative Passage SE
07/02	2112	2		0.05359	37	19	598730	113191
07/03	2116	1		0.0535	19	10	598749	113192
07/04	2115	1.22	*	0.05352	23	3	598772	113193
07/05	2125	1.15	*	0.05329	22	3	598793	113194
07/06	2097	1.01	*	0.05394	19	10	598812	113195
07/07	2077	2		0.05441	37	11	598849	113196
07/08	2110	1		0.05364	19	19	598867	113197
07/09	2009	0		0.05603	0	10	598867	113197
07/10	1861	0		0.05972	0	2	598867	113197
07/11	1830	0.2	*	0.06052	3	2	598871	113197
07/12	1828	0.12	*	0.06057	2	2	598873	113197
07/13	1810	0		0.06104	0	1	598873	113197
07/14	1799	0		0.06133	0	0	598873	113197
07/15	1808	0		0.0611	0	0	598873	113197

*Missing value estimate

Appendix 1. Daily captures of yearling chinook during 1998.

Date	Length	Smolt Index
01-27-98	138	3
01-28-98	120	3
02-12-98	193	3
03-04-98	150	3
03-05-98	130	3
03-05-98	142	3
03-07-98	131	3
03-08-98	147	3
03-08-98	132	3
03-10-98	143	3
03-11-98	130	3
03-13-98	129	3
03-13-98	152	3
03-14-98	139	3
03-16-98	139	3
03-16-98	144	3
03-18-98	155	3
03-18-98	125	3
03-18-98	119	3
03-18-98	148	3
03-19-98	129	3
03-22-98	114	3
03-27-98	160	3
03-28-98	150	3
03-31-98	140	3
04-04-98	151	3

Appendix 2. Daily chinook length by smolt index during 1998.

	Index Value		
Date	1	2	3
27-Jan-98	34.86		138.00
28-Jan-98	35.74	62.00	120.00
29-Jan-98	35.90		
30-Jan-98	35.94		
31-Jan-98	35.40		
01-Feb-98	34.96		
02-Feb-98	35.48		
12-Feb-98	35.66		193.00
13-Feb-98	35.18		
14-Feb-98	36.64		
15-Feb-98	35.22		
16-Feb-98	37.00		
17-Feb-98	35.73	55.00	
18-Feb-98	36.14	53.00	
19-Feb-98	36.39		
20-Feb-98	34.85	55.50	
21-Feb-98	36.16		
22-Feb-98	35.54	60.00	
23-Feb-98	36.22		
24-Feb-98	35.32	51.57	
25-Feb-98	35.98	60.75	
26-Feb-98	36.51	60.17	
27-Feb-98	37.00	55.22	
28-Feb-98	37.18	61.40	
01-Mar-98	36.51	66.00	
02-Mar-98	36.06	55.00	
03-Mar-98	35.95	52.33	
04-Mar-98	38.22	66.20	150.00
05-Mar-98	37.69	71.12	136.00
06-Mar-98	37.60	59.30	
07-Mar-98	41.41	69.64	
08-Mar-98	40.33	77.29	139.50
09-Mar-98	43.75	71.32	
10-Mar-98	47.66	65.78	143.00
11-Mar-98	40.14	68.33	130.00
12-Mar-98	39.84	65.96	
13-Mar-98	40.38	79.29	140.50
14-Mar-98	38.23	68.00	139.00
15-Mar-98	43.17	69.00	119.00
16-Mar-98	48.00	75.22	141.50
17-Mar-98	50.43	72.10	
18-Mar-98	48.21	79.38	133.00
19-Mar-98	48.40	66.71	127.50
20-Mar-98	40.32	62.00	
21-Mar-98	47.50		

Date	Index Value 1	2	3
22-Mar-98	45.11	71.00	103.00
23-Mar-98	45.09	69.20	127.00
24-Mar-98	50.59	71.00	82.00
25-Mar-98	41.00	64.06	
26-Mar-98	58.35	73.88	
27-Mar-98	53.17	70.12	160.00
28-Mar-98	55.84	75.00	150.00
29-Mar-98	50.72	72.80	
30-Mar-98	57.63	79.70	155.00
31-Mar-98	58.64	81.25	140.00
01-Apr-98	50.50	67.38	95.50
02-Apr-98	53.50	72.57	
03-Apr-98	52.67	70.41	
04-Apr-98	50.40	75.22	151.00
05-Apr-98	57.92	70.12	90.20
06-Apr-98		69.09	
07-Apr-98	55.04	75.58	
08-Apr-98	50.50	68.70	
09-Apr-98	49.00	73.87	95.00
10-Apr-98	49.00	71.14	
11-Apr-98	55.00	69.11	
12-Apr-98	59.00	78.43	
13-Apr-98		79.30	
14-Apr-98	51.60	84.80	
15-Apr-98	54.00	76.88	
16-Apr-98	60.00	81.50	
17-Apr-98	62.00	79.33	
18-Apr-98	51.50	74.79	101.50
19-Apr-98		74.66	97.60
20-Apr-98	69.60	81.93	106.33
21-Apr-98		80.10	
22-Apr-98	59.00	79.59	107.67
23-Apr-98		81.09	101.50
24-Apr-98		87.35	
25-Apr-98		81.79	103.25
26-Apr-98		82.00	
27-Apr-98		88.67	113.50
28-Apr-98	65.00	81.28	105.00
29-Apr-98		83.59	101.83
30-Apr-98		80.34	108.00
01-May-98		81.36	101.50
02-May-98	66.00	78.68	
03-May-98		84.19	119.00
04-May-98		83.00	107.00
05-May-98		82.42	
06-May-98	75.00	84.69	119.00
07-May-98		84.18	105.00

Date	Index Value 1	2	3
08-May-98		83.89	103.75
09-May-98		86.44	
10-May-98		83.49	
11-May-98		84.36	106.00
12-May-98		85.66	104.33
13-May-98		85.08	
14-May-98		86.80	106.00
15-May-98		85.76	108.75
16-May-98		86.37	104.00
17-May-98		88.29	117.00
18-May-98		85.89	106.33
19-May-98		84.91	105.67
20-May-98		84.29	108.50
27-May-98		86.96	106.50
28-May-98		87.18	108.17
29-May-98		89.55	104.67
30-May-98		88.79	103.50
31-May-98		89.33	107.00
01-Jun-98		89.62	111.00
02-Jun-98		88.03	112.50
03-Jun-98		86.80	102.00
04-Jun-98		88.66	108.33
05-Jun-98		88.80	105.75
06-Jun-98		91.08	111.00
07-Jun-98		86.00	94.08
08-Jun-98		90.58	
09-Jun-98		90.98	100.67
10-Jun-98		91.96	102.50
11-Jun-98		103.00	92.25
12-Jun-98		90.45	103.33
13-Jun-98		94.00	135.00
14-Jun-98		94.27	104.58
15-Jun-98		93.27	102.50
16-Jun-98		93.67	104.00
18-Jun-98		85.00	97.25
19-Jun-98		94.00	110.00
20-Jun-98		92.89	101.80
25-Jun-98			96.25
26-Jun-98		94.50	106.00
01-Jul-98		90.00	107.00
02-Jul-98			91.50
03-Jul-98			105.00
07-Jul-98			106.50
08-Jul-98			93.00

Appendix 3. Rainbow/steelhead captured in the Oakdale trap during 1998.

Date	Length (mm)	Smolt Index
01-27-98	283	3
03-08-98	270	3
03-08-98	225	3
03-09-98	220	3
03-26-98	250	3
03-26-98	218	3
04-04-98	243	3
04-04-98	247	3
04-09-98	215	3
04-20-98	215	3
04-25-98	250	3
04-25-98	250	3
05-11-98	227	3
05-12-98	230	3
05-13-98	243	3
05-27-98	256	3
06-16-98	76	2
06-18-98	66	2
07-08-98	106	3
07-08-98	95	2