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

1996 ANNUAL REPORT

Prepared for

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EXECUTIVE SUMMARY

We fished a rotary screw trap in the Stanislaus River (river mile (RM) 40) near Oakdale, California, to index the timing and abundance of down-migrating juvenile chinook salmon from February 1 to June 8, 1996. We estimated the abundance of down-migrants each day by dividing the catch of juvenile chinook by the predicted trap efficiency. Trap efficiency was estimated by releasing 10 groups (6 natural 4 hatchery) of marked juvenile chinook upstream of the trap between February 12 and May 29. Flows during the releases ranged from 681 to 3,413 cfs, and the percentage of released fish recovered in the screw trap varied from 1.3 to 28.4%. A regression of trapping efficiency on flow accounted for 98% of all variation in estimates of trap efficiency. We used this regression to estimate trap efficiency for each day that we sampled.

There were distinct peaks in the outmigration of fry (< 45 mm) and smolts (>70 mm). Fry down-migration peaked February 6, when we estimated that 14,188 fry passed the trap. The 1-day peak occurred 5 days after the trap was installed, and coincided with an increase in flow from 300 cfs up to 650 cfs. The smolt down-migration peaked during April 22 to May 10, a period of stable river flow (1,700-1,800 cfs). Timing of the smolt migration indicated that pulses in flow are not necessary to stimulate juvenile chinook to migrate.

In addition to the one trap at Oakdale, we fished two traps side-by-side 34 miles downstream near Caswell State Park (RM 6) to estimate the number of juvenile chinook that migrated out of the river. We estimated that 71,000 chinook migrated past Caswell between February 6 and July 1, while we estimated that 284,000 migrated past Oakdale. The difference in the estimates suggests there was a high mortality of juvenile chinook as they migrated the 34 miles from Oakdale to Caswell.

The length distribution of juvenile chinook passing Oakdale was distinctly bimodal, and shows that juveniles either migrated as newly emerged fry (31-40 mm) or as smolts (primarily 70-110 mm). The mean lengths of fish captured at Oakdale were similar to the mean lengths of fish captured at Caswell, indicating that once fish began migrating out of the river they did not stop and rear for extended periods of time between Oakdale and Caswell.

We released three groups of marked, wild chinook at Knights Ferry (RM 54.7) to estimate their migration rate and survival over the 15 miles down to Oakdale. For each release, the number of recaptures at Oakdale was greatest the morning following release, indicating a migration rate of greater than 15 miles per night. Survival estimates for the first two groups, 50.4 and 61.9% were similar to those in 1995, but the estimated survival of the third group , 7.7%, was rejected as a flier, because there was no apparent cause for the radical difference.

ACKNOWLEDGMENTS

The data reported here were gathered through the efforts of our field staff: Robert Fuller, Andrea Phillips, Trevor Arrighi and Tom Phillips. We are grateful for their dedication and hard work.

We are grateful to the USFWS, including Marty Kjelson, Patricia Brandes, Mark Pierce, Sam Lohr and Craig Fleming for their support and cooperation. We thank Bill Loudermilk, George Niellands, Steve Baumgartner, Clarence Mayott and Tim Heynes with the CDFG for their help with planning, permitting and coordinating with our operations. We also thank the staff at Merced River Fish Facility and CDFG technicians for marking and delivering juvenile chinook to our project site.

We are grateful to the US Army Corps of Engineers (USACE), especially Peggy Brooks and Lisa Vacarro at the Knights Ferry office, for granting us special access through their parks, and for their protective surveillance of our equipment.

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INTRODUCTION

Results reported here from sampling in 1996 are from the third year of study initiated by S.P. Cramer & Associates (SPCA) in the spring of 1993 to determine the effects of different flow regimes in the Stanislaus River on juvenile chinook migration and growth. In 1993 we (SPCA) fished a rotary screw trap in the Stanislaus River near Oakdale (RM 40) to index the migration timing and abundance of down-migrating juvenile chinook during large manipulations in river flow. The trap fished from April 21 to June 29. Catches in the trap indicated that down migration peaked briefly following an increase in flow from 400 cfs to 1,400 cfs one week in late April. The pattern of daily outmigrant abundance before, during and after flow was sustained near 1,400 cfs suggested that the stimulatory effect of an increase in 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 California Department of Fish and Game (CDFG) fished the screw trap only from April 23 to May 26 near the mouth of the Stanislaus River at Caswell State Park (RM 6). Daily catches of juvenile chinook ranged from 0 to 75, and most fish were caught during two periods of a few days following increases in flow.

In 1995, SPCA conducted the sampling and moved the screw trap back upstream to the site near Oakdale. The trap operated from March 18 to July 1. Sampling in 1995 showed that artificially pulse flows do have a stimulatory effect on juvenile chinook, but the effect lasts only a few days. Further, pulse flows do not flush juvenile chinook out of the river. Recoveries at Oakdale of marked fish released 14.6 miles upstream at Knights Ferry enabled us to estimate that passage survival through that stretch of river varied from 32.4 to 66.7% for wild fish (survival was higher for larger fish), from 4.7 to 8.6% for hatchery fish.

We identified seven pressing questions concerning juvenile chinook migration that were the basis for our work in 1995 and 1996. 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 work reported here addresses these questions. In addition to the Oakdale trap, SPCA also operated two traps near Caswell State Park under contract to the US Fish and Wildlife Service (USFWS) in 1996. Although the projects were under separate contracts with separate research objectives, much of the data collected at the Caswell site is presented and compared in this report to that at Oakdale.

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, confluencing 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.

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

Goodwin Dam, approximately 58.4 river miles (RM) 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 54.7
Orange Blossom Bridge (OBB) release site	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 6

METHODS

JUVENILE CHINOOK OUTMIGRATION MONITORING

<u>Rotary Screw Trap</u>

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 desirable water velocities for trap operation. Fast water velocities increase the rotation speed of the trap and increases 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 and 1995.

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. A 3/8 in. cable was suspended across the river about 35 ft above the water surface to hold the trap in a static position in the main current. 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.

We installed the rotary screw trap February 1, and began retrieving catches the morning of February 2. The season of our sampling covered the period of highest river flow during the year (Figure 3). Monitoring continued until the trap was removed June 10 when the trap was damaged. No catch was recorded May 7 to May 13, also due to trap malfunction.

The trap fished 24 hours per day 7 days per week. 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.

During natural freshets when fish would accumulate in the livebox 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 in the livebox and to minimize stress and mortality, we placed a chicken-wire fence in the rear portion of the livebox. The wire consisted of 1 in. octagon shaped mesh that, when securely fastened in place, caught wood and plant debris while allowing fish to pass through. Bricks and other forms of structure were placed behind the fence to provide additional shelter.

Figure 2. Photographs of the rotary screw trap.

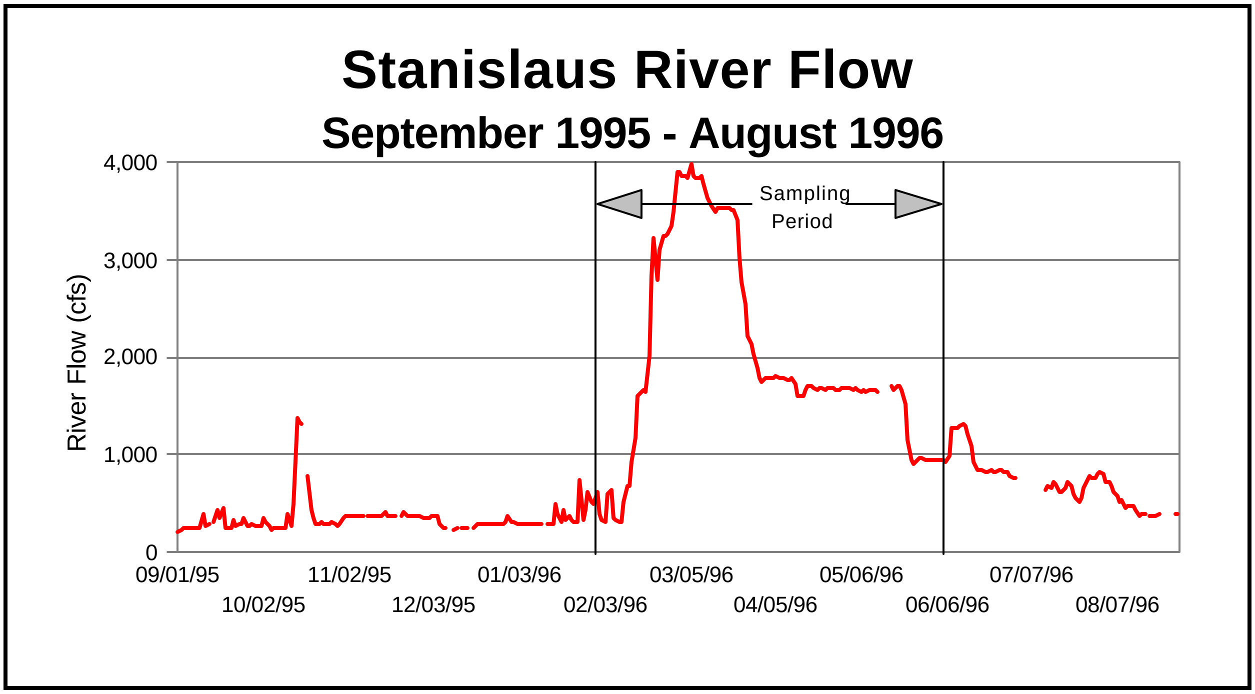


Figure 3. Outmigration sampling period in relation to Stanislaus River flow from September 1995 to August 1996. Flow measured by USGS at Orange Blossom Bridge (RM 46.9).

Each morning we removed the contents of the livebox and counted, measured and recorded all fish captured. Approximately once per week we removed scales from the first 30 chinook removed from the livebox. A small knife was used to peel 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

We recorded the external appearance of smolting characteristics for each juvenile chinook and rainbow trout measured. Smolting was rated on a scale of 1 to 3, with 1 an obvious parr and 3 an obvious smolt.

Experimental Release Groups

A total of 13 groups (9 natural migrants and 4 hatchery) were released either to estimate trapping efficiency or to evaluate migration rate and survival from Knights Ferry (RM 54.7) to Oakdale between February 12 and May 29 (Table 1). Natural chinook used in mark-recapture experiments were juvenile chinook captured in the screw trap. These fish were usually marked the morning of capture and released either that night or the following night. On a few occasions, it was necessary to accumulate fish for more than one day. Fish were marked by dye inoculation. The number of fish in each group ranged from 198 to 1,293. All marked fish were released at dark.

Table 1. Date, stock, location, time, and river flow for mark-recapture tests with juvenile chinook in the Stanislaus River during 1996.

Designated Release Group	Release Date	Mark Applied	Mark Type	Fish Stock	Time of Release	Release Location	OBB Flow (cfs)
O 1	Feb 12	drrn	Brand	Natural	9:15 pm - 10:15 pm	Oakdale	681
O 2	Feb 19	drfn	Brand	Natural	6:30 pm - 7:30 pm	Oakdale	2,014
O 3	Mar 22	tcgh	Panjet	Hatchery	6:45 pm - 8:00 pm	Oakdale	3,413
O 4	Apr 6	drfh	Brand	Hatchery	7:30 pm - 8:00 pm	Oakdale	1,791
O 5	Apr 6	drrh	Brand	Hatchery	6:45 pm - 7:15 pm	Oakdale	1,791
O 6	Apr 13	tcgn1	Panjet	Natural	10:00 pm - 11:00 pm	KF	1,598
O 7	Apr 14	bcgn1	Panjet	Natural	9:30 pm - 10:00 pm	Oakdale	1,595
O 8	Apr 22	bcgn2	Panjet	Natural	11:00 pm - 11:45 pm	Oakdale	1,673
O 9	Apr 22	tcgn2	Panjet	Natural	9:00 pm - 10:00 pm	KF	1,673
O 10	May 4	afgn	Panjet	Natural	9:00 pm - 10:00 pm	Oakdale	1,674
O 11	May 22	tcgn3	Panjet	Natural	7:45 pm - 8:45 pm	KF	1,525
O 12	May 26	bcgh	Panjet	Hatchery	11:00 pm - 11:30 pm	Oakdale	921
O 13	May 29	bcgn3	Panjet	Natural	9:00 pm - 10:00 pm	Oakdale	935

The CDFG also supplied us with juvenile chinook from the Merced River Hatchery on four occasions for trap efficiency tests (Table 1). Hatchery fish were released between March

22 and May 26. The fish were marked by inoculation at the hatchery by CDFG personnel. Fish were transported to the release site by the CDFG during mid-day. Fish were held in a net pen in the river and allowed to acclimate for 8 to 12 hours prior to being released at dark. The number of fish in each group ranged from 304 to 617.

In addition to conducting releases at Oakdale to evaluate trap efficiency, we also released three groups of marked natural migrants 14.6 miles upstream at Knights Ferry to determine migration rate and survival from Knights Ferry to the screw trap (Table 1). The groups were released between April 13 and May 22, and ranged in numbers of fish from 726 to 1,293. The fish for these groups were originally captured in the screw trap and marked by dye inoculation.

Holding Facility and Transport Method

Test fish for mark-recapture experiments 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 filled with sand so it would sink and rest on the river bottom. The net pens were placed inside a 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 release site in 20 gal. insulated coolers. Between 75 and 150 fish were placed in each cooler and then transported to either Knights Ferry (survival and migration rate tests) or 1/4 mile upstream from the trap (trap efficiency tests). Depending on circumstances, the total time fish remained in a cooler ranged from 5 to 35 minutes. Although an aerator was always present in case it was necessary, oxygen was never delivered to the coolers during transport.

Marking Procedure

Juvenile chinook were marked by dye inoculation. The dyes used were Alcian Blue, Alcian Green and Alcian Red (Sigma Chemical Company, St. Louis, Missouri), and were chosen because of their known ability to provide a highly visible, long lasting mark. Before marking, fish were anesthetized with MS-222 (Schoettger and Steucke 1970). Once anesthetized, fish were inoculated by placing the tip of the MadaJet against the top portion of the caudal, dorsal or anal fin (Hart and Pitcher 1969). Minimal pressure was applied as dye was injected into the fin rays. Only 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.

Over the course of sampling, we tested the duration each dye remained visible and the effects of marking on mortality by marking small groups of fish and holding them in a net pen for up to three weeks. Tests were conducted on both natural and hatchery fish. Each time a group of marked fish was held for observation, we also held an unmarked control group. Marked fish were held for as long as 21 days with no loss in mark retention. Although some post-marking mortality was experienced, it occurred within hours of marking or after about 14 days. The results were similar to tests conducted in 1995. For the purposes of conducting mark recapture tests, marked fish which died soon after marking were simply not released, and were subtracted from the number marked to obtain the number released. We attributed the delayed mortality, which usually started after about two weeks, to the stress of captivity rather than the effects of marking. Therefore, we did not make any mortality adjustments to the number of fish released.

Release Procedure

Fish were released to estimate trapping efficiency approximately ¼ mi 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 net pens at the release site, depending on the number of fish in the release group. Fish were usually allowed to acclimate for 6-12 hours in the net pen before being released. Fish were released by dip netting about ten fish from the holding pen, holding the dip net open in the river, and allowing the fish to swim away. After each "dip-net group" was released, we would wait from 1 to 5 minutes before releasing another dip-net group of approximately 10 fish. The amount of time between each group depended on how fast fish swam away after being released. The total time to release each net-pen of fish ranged from 30 to 105 minutes. This release procedure was significantly different than the one used in 1995, where the average time to release one net-pen was about 10 minutes. In both 1995 and 1996 all trap efficiency groups were released under total darkness.

Similar procedures were followed to release marked groups at Knights Ferry. Because the number of fish released was larger at Knights Ferry, the total 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.

Flow Measurements

Average daily flow of the Stanislaus River data was obtained from the California Data Exchange Center (CDEC). All river flows cited throughout this report are those measured at the Orange Blossom Bridge (6.8 miles upstream of the screw trap) by the US Geological Survey (USGS). We also monitored water velocity flowing into our trap with a Global Flow Probe, manufactured by Global Water (Fair Oaks, CA), beginning February 17. The time, in seconds, for one revolution of the trap was recorded each morning. This was timed with a stopwatch for three rotations, and the average time per rotation was recorded.

River Temperature and Relative Turbidity

Daily minimum and maximum temperature of the Stanislaus River was measured with a mercury thermometer at the trap site. 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 6) under contract to the USFWS. The traps were operated from February 5 to July 2 to index juvenile chinook abundance. All data was collected in accordance with criteria established by the USFWS, and all data was supplied to them each week. A report of the Caswell sampling was submitted to the USFWS, Stockton, California (Demko and Cramer 1997).

FINDINGS

GOAL: ASSESS THE EFFECTS OF FLOW ON MIGRATION, GROWTH AND SURVIVAL OF JUVENILE CHINOOK IN THE STANISLAUS RIVER

TRAP CATCHES OF CHINOOK

Daily catches of juvenile chinook from February 2 through June 10 ranged from 0 to 5,452 (Figure 4) and totaled 30,427 over the sampling season. Although most juvenile chinook were captured at night, a few were captured during daylight at times of high, turbid river flows. Catches of juvenile chinook peaked soon after installation of the trap, when high precipitation resulted in increased turbidity and a jump in flow from 300 cfs up to 650 cfs (Figure 4). Few fish were caught during March, catches increased again in April, and declined through May.

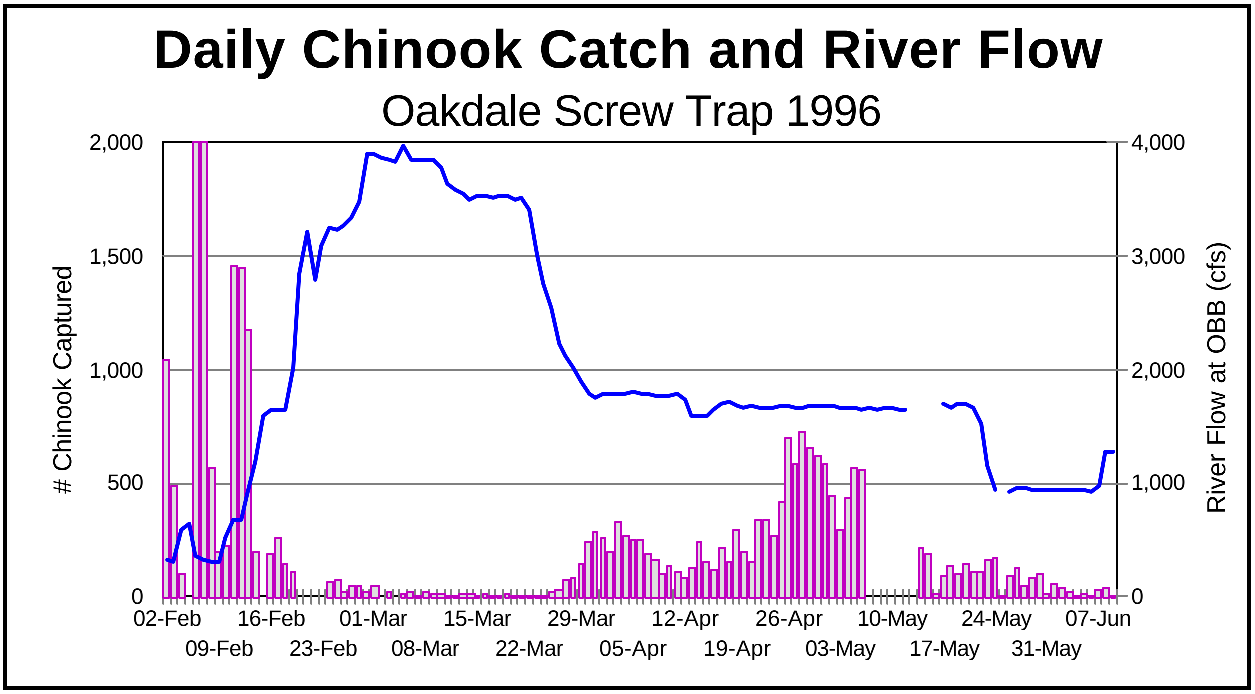


Figure 4. Daily number of juvenile chinook captured in the screw trap and river flow at RM 46.9 (OBB). The catches on February 6 and 7 were 5,452 and 2,289, chinook, respectively.

TRAP EFFICIENCY

Between February 12 and May 29, we released 6 groups of marked natural migrants and 4 groups of marked hatchery chinook to estimate trapping efficiency (Table 2). One release of natural migrants was voided when the trap had to be raised because of high debris loads in the river during the night of release. Flow varied between release groups from 681 to 3,413 cfs. Prior to 1996, the highest flow at which we tested trap efficiency was 1,436 cfs in 1995. Capture rates of marked fish varied from 1.3% at the high flows to 28.38% at the low flows (Table 2).

Table 2. Mark recapture data for all fish released during 1996. Chinook released at "Oakdale" were released to determine trap efficiency. Fish released at "Knights Ferry" were released for migration rate and survival experiments.

Designated Release Group	Release Date	Fish Stock	Release Location	Mark Retention	# Released	# Recaptured	% Recaptured	OBB Flow (cfs)	Mean Length at Release (mm)	Mean Length at Recapture (mm)
O 1	Feb 12	Natural	Oakdale	100 %	969	275	28.4%	681	34	35.1
O 2	Feb 19	Natural	Oakdale	98 %	700	void*	void*	2,014	33.8	34.8
O 3	Mar 22	Hatchery	Oakdale	100 %	617	8	1.3%	3,413	43.9	43.6
O 4	Apr 6	Hatchery	Oakdale	100 %	500	45	9.0%	1,791	70.6	73.2
O 5	Apr 6	Hatchery	Oakdale	100 %	499	32	6.4%	1,791	69.5	71.9
O 6	Apr 13	Natural	KF	100 %	1293	75	5.8%	1,598	78.1	78.3
O 7	Apr 14	Natural	Oakdale	100 %	198	20	10.1%	1,595	78.1	80.4
O 8	Apr 22	Natural	Oakdale	100 %	248	31	12.5%	1,673	88.6	86.6
O 9	Apr 22	Natural	KF	100 %	930	61	6.6%	1,673	86.1	86.9
O 10	May 4	Natural	Oakdale	100 %	547	72	13.2%	1,674	75.5	74.1
O 11	May 22	Natural	KF	100 %	726	7	1.0%	1,525	95.1	88.9
O 12	May 26	Hatchery	Oakdale	100 %	304	77	25.3%	921	72.2	78.0
O 13	May 29	Natural	Oakdale	100 %	507	121	23.9%	935	92.5	91.1

*** Trap was raised the night of the release due to excessive debris.**
February 14, 19 and June 10 release totals are adjusted for mark retention.

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. Because efficiency is expressed as a percentage, we used a logistic regression to quantify the relationship between the response and predictor variables. We examined the following five predictor variables:

- **Ø** - daily flow in cubic-feet/second (cfs) on the day of release;
- **Ù** - turbidity measured on the morning following release;
- **Ú** - time per screw-trap-revolution (time/revolution) measured on the morning following the release (data in Appendix 1) ;
- **Û** - average water velocity on the morning following release (Appendixes A and 1); and

Ü - length of fish.

Although the regression fit was good to water velocity, the regression fit to flow was excellent (Figure 5). Of the five predictor variables, flow had the largest weighted correlation (r = 0.99) (see Appendix A). The relationship used to predict trap efficiency based on this regression, was expressed as:

$$Efficiency = \frac{1}{1 + e^{(0.02416 + 0.00126\ Flow)}}$$

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 a release group (Figure 6). For those releases where chinook were recovered, a paired-t test indicated there was no significant difference ($P > 0.6$) in lengths at release and recovery (Table 3).

ABUNDANCE OF CHINOOK OUTMIGRANTS

Because trapping efficiency varied as flow varied, we estimated the total number of outmigrants passing the trap each day 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.

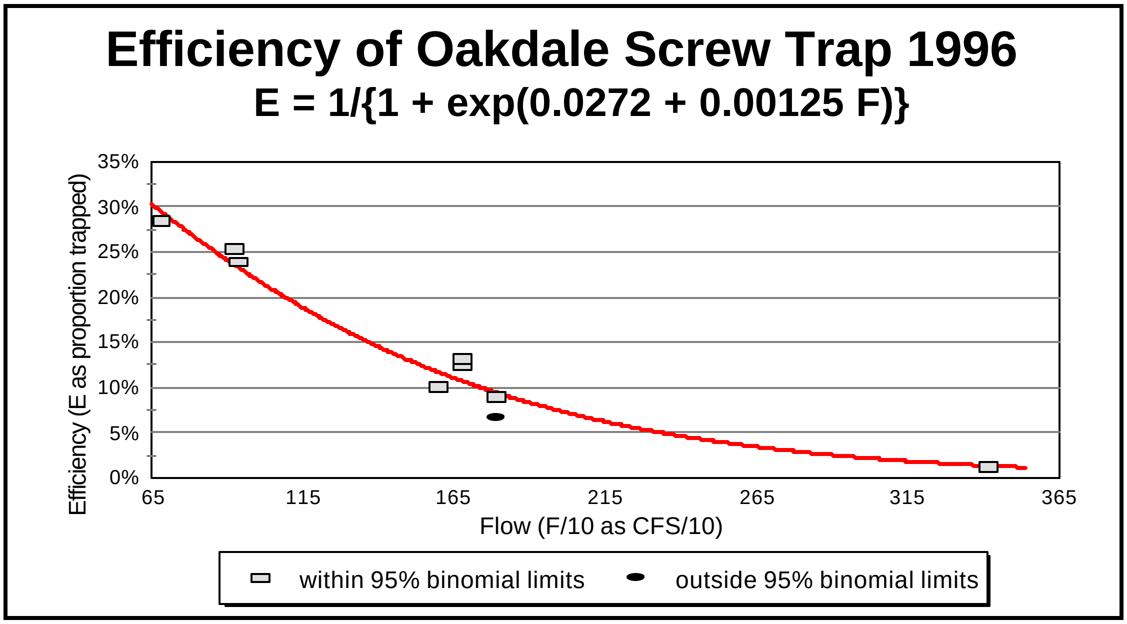


Figure 5. Relationship of screw trap efficiency and Stanislaus River flow at OBB.

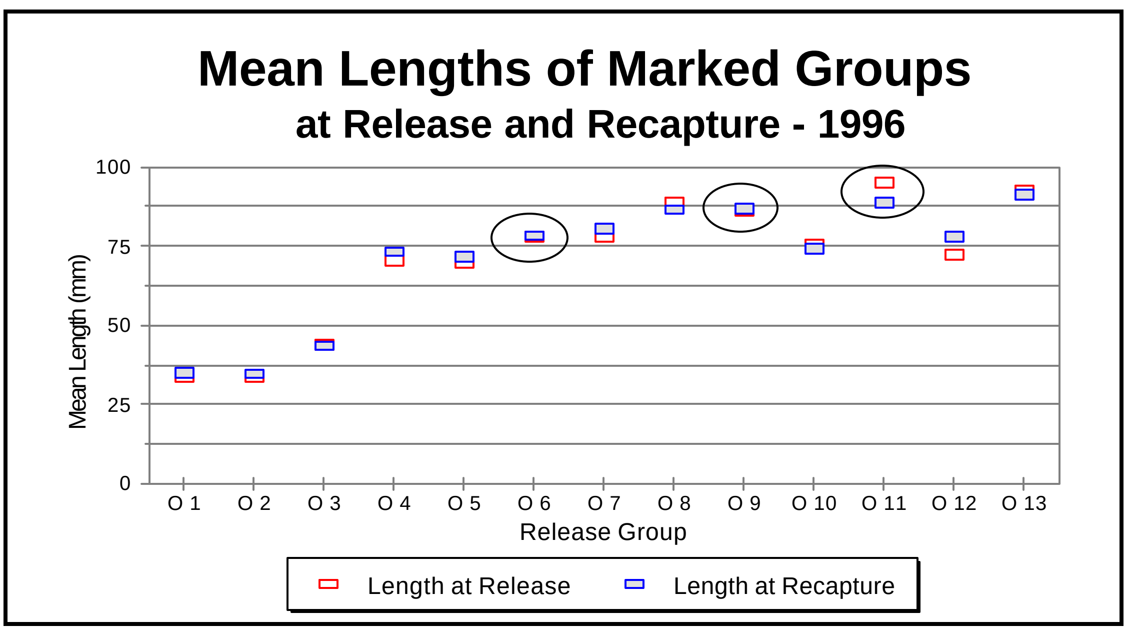


Figure 6. Mean lengths at release and recapture for all marked fish released in 1996. Circled groups were released at Knights Ferry. All other groups were released at Oakdale.

Table 3. Mean lengths of mark-recapture groups at release and recapture.

	Release Groups		Recapture Groups		
Group Code	Mean Length (mm)	# Measured	Mean Length (mm)	# Measured	Recapture Minus Release (mm)
O 1	34	30	35.1	30	1.1
O 2	33.8	30	34.8	5	1.0
O 3	43.9	30	43.6	8	-0.3
O 4	70.6	30	73.2	32	2.6
O 5	69.5	30	71.9	30	2.4
O 6	78.1	30	78.3	63	0.2
O 7	78.1	30	80.4	20	2.3
O 8	88.6	30	86.6	31	-2.0
O 9	86.1	30	86.9	36	0.8
O 10	75.5	30	74.1	31	-1.4
O 11	95.1	30	88.9	7	-6.2
O 12	72.2	30	78.0	30	5.8
O 13	92.5	30	91.1	30	-1.4

Thirty chinook were measured from each release group prior to release. Recapture mean lengths were queried from the "oak96" file.

t-Test: Paired Two-Sample for Means

	Release	Recapture
Mean	70.6	71
Variance	432.6	397.9
Observations	13	13
Pearson Correlation	0.9909	
Pooled Variance	415.2	
Hypothesized mean difference	0	
df	12	
t	-0.467	

The estimated total number of outmigrants passing Oakdale from February 2 through June 8 was 283,658 chinook, with an approximate 95% confidence interval of 240,163 to 327,153 (Table 4 and Figure 7). Capture efficiency for each day was predicted from the logistic regression on flow. Values for the predictor variables were missing on some days, and those values were interpolated as described in Appendix A. Methods for approximating standard errors used in confidence intervals are discussed in Appendix A.

There were distinct peaks in the outmigration of fry (< 45 mm) and smolts (>70 mm). Fry down migration peaked February 6, when we estimated that 14,188 fry passed the trap. The 1-day peak occurred 5 days after the trap was installed, and coincided with an increase in flow from 300 cfs up to 650 cfs. Nearly all migrants captured through March 21 were fry < 45 mm fork length. The estimated total passage of fry from February 6 through March 21 was 119,907 chinook (Table 4). Few fry were captured after March 21, and most fish captured from March 22 through the rest of the season were smolts > 70 mm fork length. The smolt down migration peaked during April 22 to May 10, a period of stable river flow (1,700-1,800 cfs) (Figure 7). Total passage of smolts during March 22 through June 8 was estimated to be 163,751 chinook (Table 4). Thus, about 60% of the juvenile chinook passing Oakdale during the sampling season were smolts, while 40% were fry.

Table 4. Daily trap catch, predicted trap efficiency and estimated passage at Oakdale, 1996. Statistical methods described in Appendix A.

Date	Daily Screw Trap Count (C)		Flow at OBB (cfs)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)		Daily Passage 95% C.I. Lower	Daily Passage 95% C.I. Upper	Cumulative Passage
02-Feb	1,046		317	0.396	2,644		2,291	2,996	2,644
03-Feb	493		302	0.400	1,232		1,067	1,397	3,876
04-Feb	104		591	0.317	328		290	367	4,204
05-Feb	635	*	642	0.303	2,095	*			6,299
06-Feb	5,452		355	0.384	14,188		12,321	16,055	20,487
07-Feb	2,289		320	0.395	5,799		5,026	6,572	26,286

Date	Daily Screw Trap Count (C)	Flow at OBB (cfs)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	Daily Passage 95% C.I. Lower	Daily Passage 95% C.I. Upper	Cumulative Passage
08-Feb	595	306	0.399	1,491	1,292	1,691	27,777
09-Feb	194	300	0.401	484	419	549	28,261
10-Feb	222	516	0.338	658	577	738	28,919
11-Feb	1,305	678	0.293	4,446	3,947	4,946	33,365
12-Feb	1,449	681	0.293	4,950	4,395	5,505	38,315
13-Feb	1,179	913	0.236	4,995	4,497	5,493	43,310
14-Feb	200	1,179	0.181	1,105	996	1,214	44,415
15-Feb	75	1,595	0.116	648	558	739	45,064
16-Feb	112	1,648	0.109	1,027	875	1,179	46,091
17-Feb	196	1,652	0.109	1,806	1,537	2,074	47,897
18-Feb	188	1,650	0.109	1,728	1,472	1,984	49,625
19-Feb	109	2,014	0.072	1,522	1,196	1,848	51,146
20-Feb	18	2,841	0.026	679	414	945	51,826
21-Feb	13 *	3,223	0.017	772 *			52,598
22-Feb	48 *	2,797	0.028	1,709 *			54,307
23-Feb	77 *	3,093	0.019	3,979 *			58,286
24-Feb	65	3,245	0.016	4,038	2,095	5,981	62,323
25-Feb	71	3,232	0.016	4,340	2,264	6,416	66,664
26-Feb	21	3,271	0.016	1,347	691	2,004	68,011
27-Feb	51	3,341	0.014	3,569	1,774	5,364	71,580
28-Feb	47	3,481	0.012	3,915	1,823	6,006	75,495
29-Feb	22	3,894	0.007	3,068	1,143	4,993	78,563
01-Mar	49	3,897	0.007	6,859	2,552	11,167	85,422
02-Mar	37 *	3,866	0.007	5,002 *			90,425
03-Mar	26	3,856	0.008	3,458	1,318	5,597	93,882
04-Mar	29 *	3,836	0.008	3,733 *			97,615
05-Mar	25	3,975	0.006	3,859	1,368	6,350	101,474
06-Mar	34	3,850	0.008	4,488	1,717	7,259	105,962
07-Mar	5	3,847	0.008	658	252	1,063	106,619
08-Mar	18	3,842	0.008	2,352	904	3,800	108,972
09-Mar	12	3,849	0.008	1,582	606	2,558	110,554
10-Mar	13	3,782	0.008	1,576	627	2,525	112,130
11-Mar	6	3,641	0.010	610	262	958	112,740
12-Mar	4	3,584	0.011	379	168	590	113,119
13-Mar	21	3,552	0.011	1,911	859	2,962	115,029
14-Mar	9	3,489	0.012	757	351	1,163	115,786
15-Mar	3	3,529	0.011	265	121	410	116,052
16-Mar	15	3,524	0.011	1,318	601	2,035	117,370
17-Mar	5	3,519	0.011	437	200	674	117,806
18-Mar	8	3,530	0.011	708	322	1,094	118,515
19-Mar	10	3,522	0.011	877	400	1,353	119,391
20-Mar	3	3,503	0.012	257	118	395	119,648
21-Mar	3	3,509	0.012	259	119	399	119,907
22-Mar	3	3,413	0.013	230	110	349	120,136
23-Mar	4	3,010	0.022	186	106	265	120,322
24-Mar	4	2,761	0.029	137	86	188	120,459
25-Mar	18	2,539	0.038	470	318	622	120,929
26-Mar	30	2,226	0.056	538	399	676	121,467
27-Mar	77	2,125	0.063	1,225	935	1,514	122,691
28-Mar	79	2,024	0.071	1,116	875	1,357	123,807
29-Mar	149	1,896	0.082	1,813	1,466	2,160	125,620

Date	Daily Screw Trap Count (C)	Flow at OBB (cfs)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	Daily Passage 95% C.I.		Cumulative Passage
					Lower	Upper	
30-Mar	238	1,790	0.093	2,564	2,123	3,005	128,184
31-Mar	284	1,748	0.097	2,916	2,436	3,396	131,101
01-Apr	262	1,794	0.092	2,835	2,346	3,325	133,936
02-Apr	200	1,791	0.093	2,157	1,786	2,528	136,093
03-Apr	332	1,794	0.092	3,593	2,973	4,213	139,686
04-Apr	265	1,788	0.093	2,848	2,360	3,337	142,534
05-Apr	248	1,809	0.091	2,730	2,252	3,209	145,264
06-Apr	249	1,791	0.093	2,685	2,223	3,148	147,950
07-Apr	188	1,780	0.094	2,002	1,662	2,343	149,952
08-Apr	160	1,779	0.094	1,702	1,413	1,991	151,654
09-Apr	104	1,775	0.094	1,101	915	1,288	152,755
10-Apr	135	1,776	0.094	1,431	1,189	1,674	154,187
11-Apr	114	1,791	0.093	1,229	1,018	1,441	155,416
12-Apr	79	1,731	0.099	796	667	924	156,212
13-Apr	129	1,598	0.115	1,119	962	1,276	157,331
14-Apr	239	1,595	0.116	2,066	1,777	2,355	159,397
15-Apr	158	1,599	0.115	1,372	1,179	1,564	160,768
16-Apr	118	1,656	0.108	1,092	929	1,255	161,860
17-Apr	212	1,706	0.102	2,076	1,749	2,402	163,936
18-Apr	155	1,711	0.102	1,526	1,285	1,768	165,462
19-Apr	295	1,679	0.105	2,802	2,373	3,230	168,264
20-Apr	194	1,670	0.106	1,824	1,548	2,100	170,088
21-Apr	152	1,675	0.106	1,437	1,218	1,656	171,525
22-Apr	340	1,673	0.106	3,207	2,720	3,695	174,732
23-Apr	315	1,668	0.107	2,955	2,508	3,401	177,687
24-Apr	297	1,673	0.106	2,802	2,376	3,227	180,488
25-Apr	415	1,676	0.106	3,928	3,329	4,527	184,416
26-Apr	704	1,676	0.106	6,663	5,647	7,679	191,080
27-Apr	584	1,662	0.107	5,441	4,624	6,258	196,521
28-Apr	727	1,668	0.107	6,819	5,789	7,850	203,340
29-Apr	686	1,684	0.105	6,552	5,544	7,559	209,892
30-Apr	655	1,683	0.105	6,249	5,289	7,209	216,141
01-May	619	1,684	0.105	5,912	5,003	6,821	222,053
02-May	248	1,680	0.105	2,358	1,997	2,719	224,411
03-May	496	1,659	0.108	4,606	3,916	5,295	229,016
04-May	426	1,674	0.106	4,023	3,411	4,635	233,039
05-May	566	1,662	0.107	5,273	4,481	6,065	238,313
06-May	556	1,640	0.110	5,054	4,312	5,795	243,366
07-May	543 *	1,664	0.107	5,073 *			248,440
08-May	552 *	1,650	0.109	5,076 *			253,516
09-May	546 *	1,663	0.107	5,091 *			258,607
10-May	348 *	1,667	0.107	3,260 *			261,868
11-May	225 *	1,653	0.108	2,072 *			263,939
12-May	226 *	1,644	0.110	2,061 *			266,001
13-May	220 *	1,666 *	0.107 *	2,056 *			268,056
14-May	218	1,669 *	0.107 *	2,047 *	1,737	2,356	270,103
15-May	192	1,656 *	0.108 *	1,777 *	1,512	2,042	271,880
16-May	14	1,611 *	0.114 *	123 *	106	141	272,003
17-May	92	1,698	0.103	893	753	1,032	272,896
18-May	132	1,658	0.108	1,224	1,041	1,407	274,120
19-May	101	1,693	0.104	974	823	1,126	275,095

Date	Daily Screw Trap Count (C)	Flow at OBB (cfs)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	Daily Passage 95% C.I. Lower	Daily Passage 95% C.I. Upper	Cumulative Passage
20-May	148	1,697	0.103	1,434	1,211	1,658	276,529
21-May	113	1,670	0.106	1,062	901	1,223	277,592
22-May	108	1,525	0.125	864	752	976	278,455
23-May	164	1,151	0.186	880	794	967	279,336
24-May	176	936	0.231	762	687	838	280,098
25-May	133 *	901	0.239	559 *			280,657
26-May	94	921	0.234	401	361	441	281,058
27-May	71	955	0.227	313	282	344	281,372
28-May	110	958	0.226	487	439	535	281,859
29-May	81	935	0.231	351	316	385	282,209
30-May	99	935	0.231	428	386	471	282,638
31-May	16	939	0.230	70	63	76	282,707
01-Jun	56	945	0.229	245	221	269	282,952
02-Jun	37	939	0.230	161	145	177	283,113
03-Jun	23	933	0.232	99	90	109	283,212
04-Jun	8	936	0.231	35	31	38	283,247
05-Jun	9	933	0.232	39	35	43	283,285
06-Jun	4	929	0.232	17	16	19	283,303
07-Jun	27	976	0.222	122	110	134	283,424
08-Jun	38	1,281	0.163	234	209	258	283,658

* Value to left is an interpolated value or is computed using interpolated value

Estimated Passage of Juvenile Chinook

Daily Chinook Passage and Mean Length

Oakdale Trap - 1996

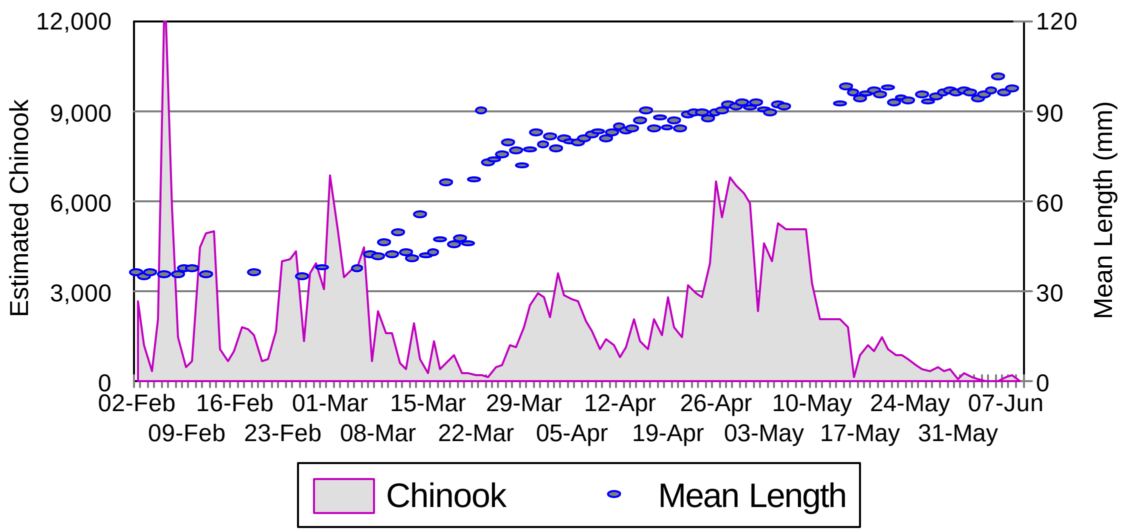


Figure 7. Estimated daily abundance and mean fork length of juvenile chinook passing Oakdale (RM 40.1), compared to river flow at RM 46.9 during 1996.

INFLUENCE OF FLOW ON CHINOOK OUTMIGRATION

During February 6 through March 21 when all migrants were fry, sharp increases in flow were generally followed by 1-3 days of increased down migration by fry (Figure 7). The greatest peak in abundance of migrating fry occurred February 6, and coincided with a small increase in flow from 300 to 640 cfs. Because the flow spike was not the first one of the year (see Figure 3), it is likely that many fry migrated past Oakdale during the several flow spikes that preceded our sampling. The large fluctuations in abundance of down-migrating fry, and their small size (most < 40 mm) through February, indicated that emergence of new fry probably continued through early March, and increases in flow stimulated movement of newly emerged fish. The abundance of down-migrating fry declined sharply after the first week in March, signaling that emergence of fry was nearly complete by then.

Outmigration of smolts was first stimulated near the end of March when flows dropped sharply from around 3,500 cfs down to about 1,800 cfs (Figure 7). Prior to March 21, almost all juvenile chinook captured were fry, so it is likely that most rearing chinook were still under 70 mm fork length by early April. As flows stabilized around 1,800 cfs in early April, down migration of smolts dropped off briefly, but then increased sharply and remained high between April 22 to May 10 (Figure 7). During that 19 day period, 90,343 chinook smolts (> 70 mm fork length) were estimated to have migrated out of the upper river past Oakdale. River flow remained stable near 1,700-1,800 cfs before, during, and after this period, which demonstrates that juvenile chinook will emigrate when they reach smolt size during spring, even in the absence of variation in flow.

INFLUENCE OF TURBIDITY ON CHINOOK OUTMIGRATION

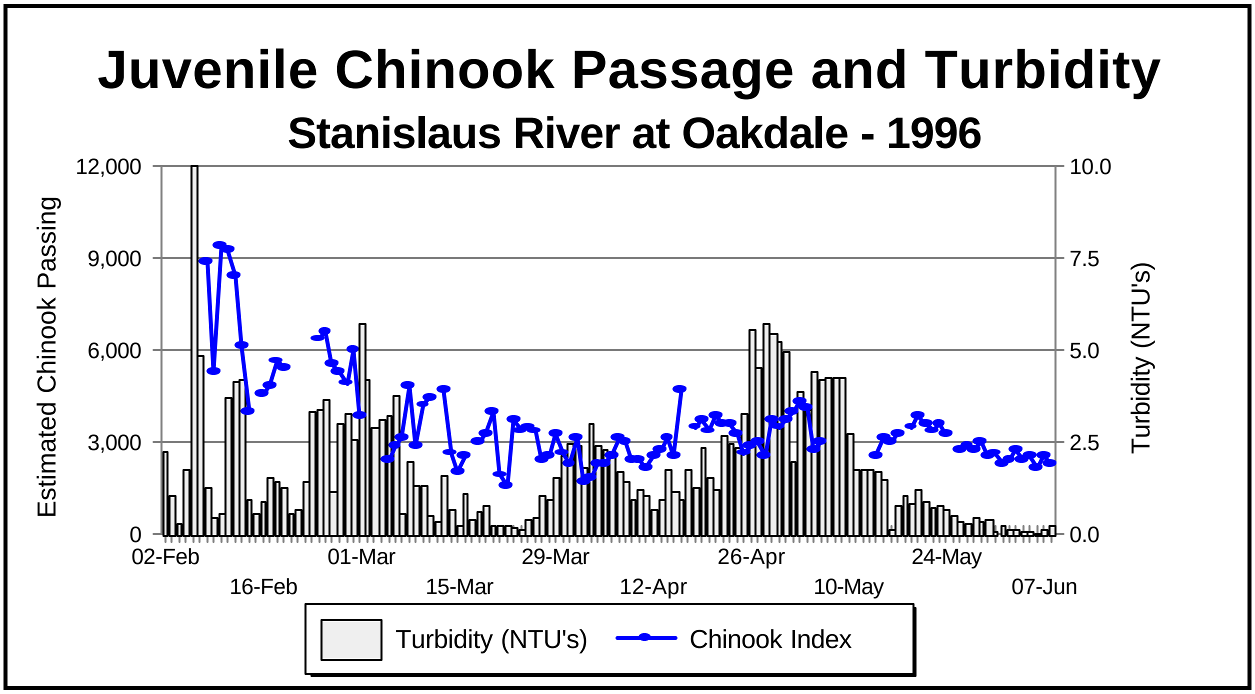
River turbidity was highest following the start of sampling and gradually decreased through March (Figure 8 and Appendix 1). No measurements were made during the first week of sampling, but due to high precipitation, turbidity was probably similar to that in the second week of sampling, when turbidity ranged from 3.3 to 7.8 NTU's. Turbidity gradually decreased in February even as flow increased, because the high flows during February and March were produced by release of stored water from upstream reservoirs. Although the peak in fry migration in early February coincided with high turbidity, later migration spikes did not (Figure 8). During major migration events in late February and late April, turbidity was decreasing as the abundance chinook migrants was increasing.

INFLUENCE OF FISH LENGTH ON CHINOOK OUTMIGRATION

Length distributions show that chinook passing Oakdale were either newly emerged fry (31-40 mm) or they were smolts (primarily 71-110 mm)(Figure 9). Thus, if fish did not emigrate immediately as fry, they remained to rear until they had reached the smolt size. The mean lengths of fish captured at Oakdale were very similar to the mean lengths of fish captured at Caswell, indicating that chinook were not pausing to rear for extended periods between RM 40 and RM 6 (Figure 10 and Appendix 2).

The data suggest that fish size influences time of migration, because there was little change in mean length of migrants during the entire month of May (Figure 10). This phenomenon suggests that fish were migrating once they reached a size threshhold for smolting. This is further supported by the finding that a plateau in rate of length increase has occurred each year of our sampling during May at about the same length, 90-100 mm (Figure 11). The distinct bimodal distribution of outmigrant sizes may be related to the circumstance that flows were high and nearly constant at 1,700-1,800 cfs from March 29 through May 21. If flows had fluctuated, the fluctuations might have stimulated fish to migrate at a variety of sizes, as was found at Oakdale in 1995 (Demko and Cramer 1996). There were probably large additional numbers of fry that passed the site before we started trapping on February

2, because our catches of fry were the highest we observed the first week the trap fished.



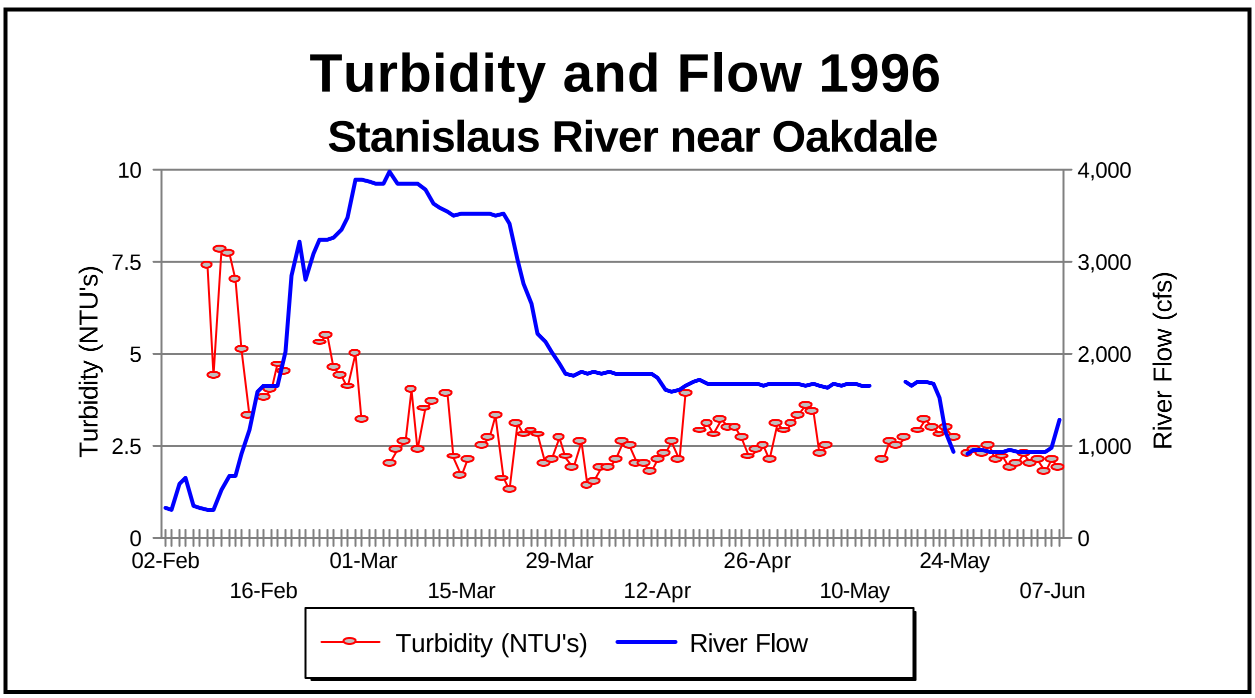
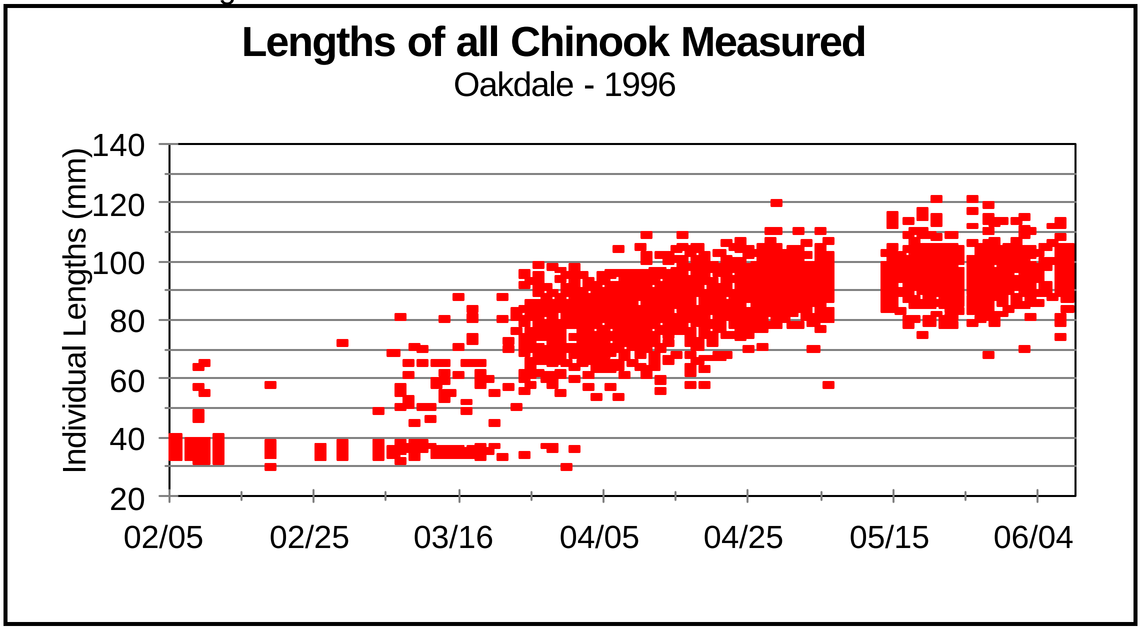


Figure 8. Daily chinook passage, flow and turbidity of the Stanislaus River near Oakdale,

1996. Turbidity was measured at the trap each morning, and flow was the daily average at RM 46.9.



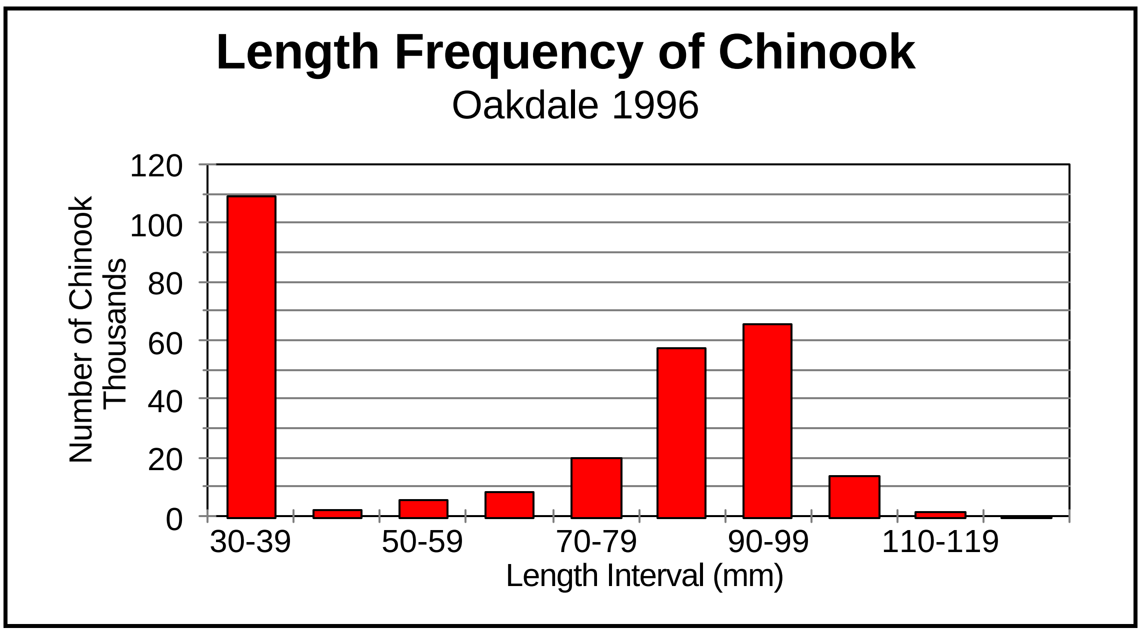


Figure 9. Daily lengths and length frequency distribution of all subyearling chinook passing Oakdale in 1996. Generally, 30 fish were measured daily, and the number of fish measured was expanded to represent the entire set of outmigrants. This was done by determining the percentage of the total passage

that was measured each week, and then using that percentage to expand the number of measured fish that fell into each length interval each week.

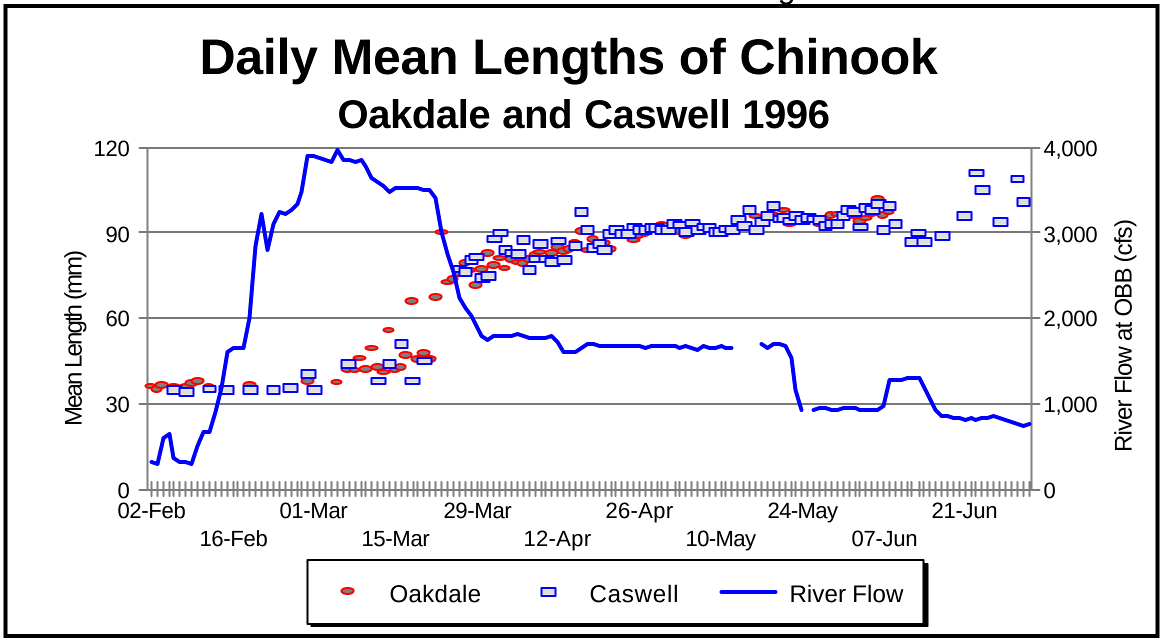


Figure 10. Daily mean lengths of chinook captured at Oakdale and Caswell.

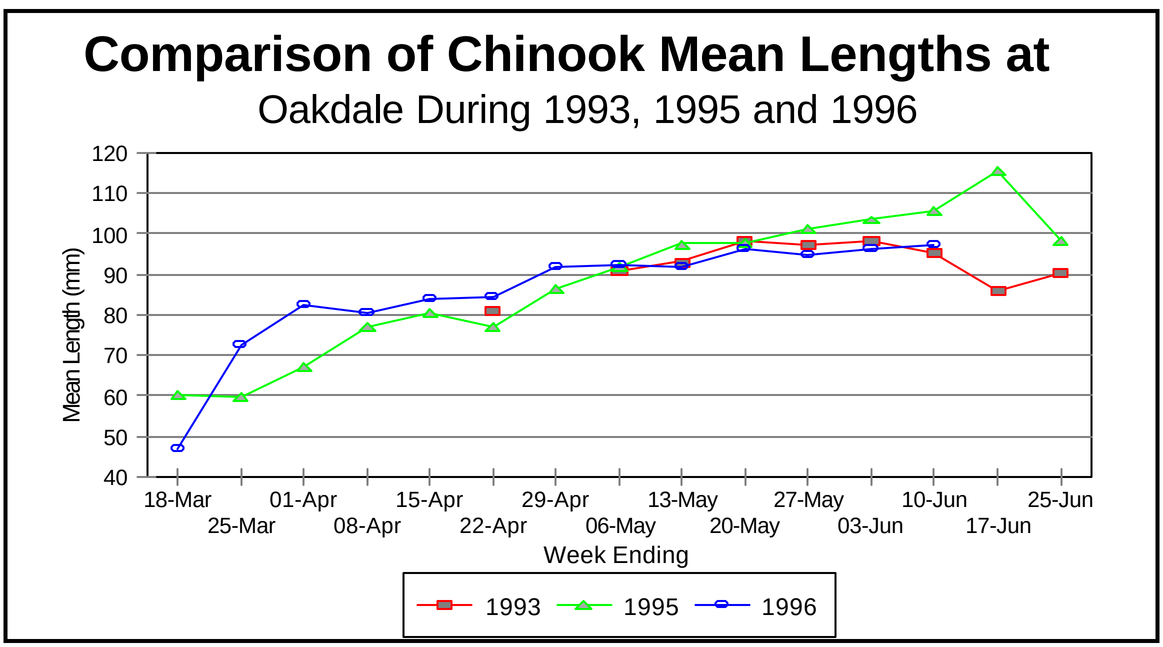


Figure 11. Comparison of mean lengths for chinook captured in the Oakdale screw trap during 1993, 1995, and 1996.

We captured four yearling chinook during 1996 ranging in size from 151 to 233 mm (Figure 12). 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. loose silvery scales and darkened anal and dorsal fin tips). We captured the first yearling February 11 and the last April 4 (see Appendix 2).

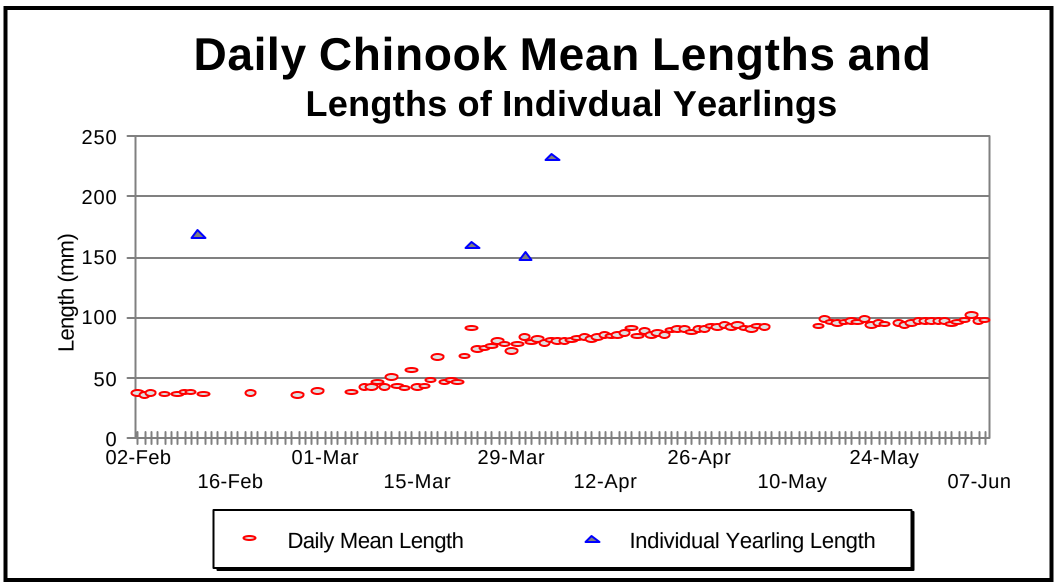
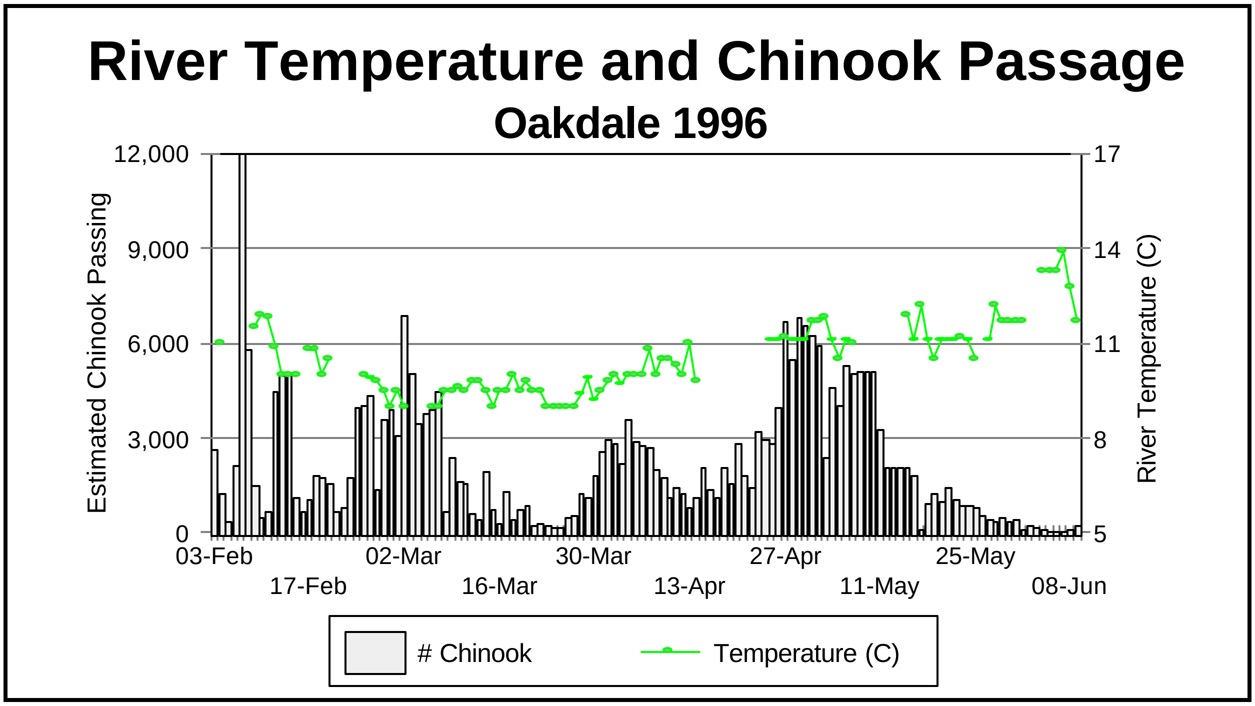


Figure 12. Individual lengths of all yearling chinook captured in the Oakdale screw trap, compared to the daily mean lengths of subyearling chinook, 1996.

INFLUENCE OF RIVER TEMPERATURE ON CHINOOK OUTMIGRATION

River temperature at Oakdale increased steadily starting about 9/C in early March and increased to about 14/C by the end of June (Figure 13). The initiation of smolt emigration in late April occurred as river temperature began to exceed 10/C (Figure 13). Because river flow was constant during all of April and much of May, increasing water temperatures may have played a role in triggering outmigration.



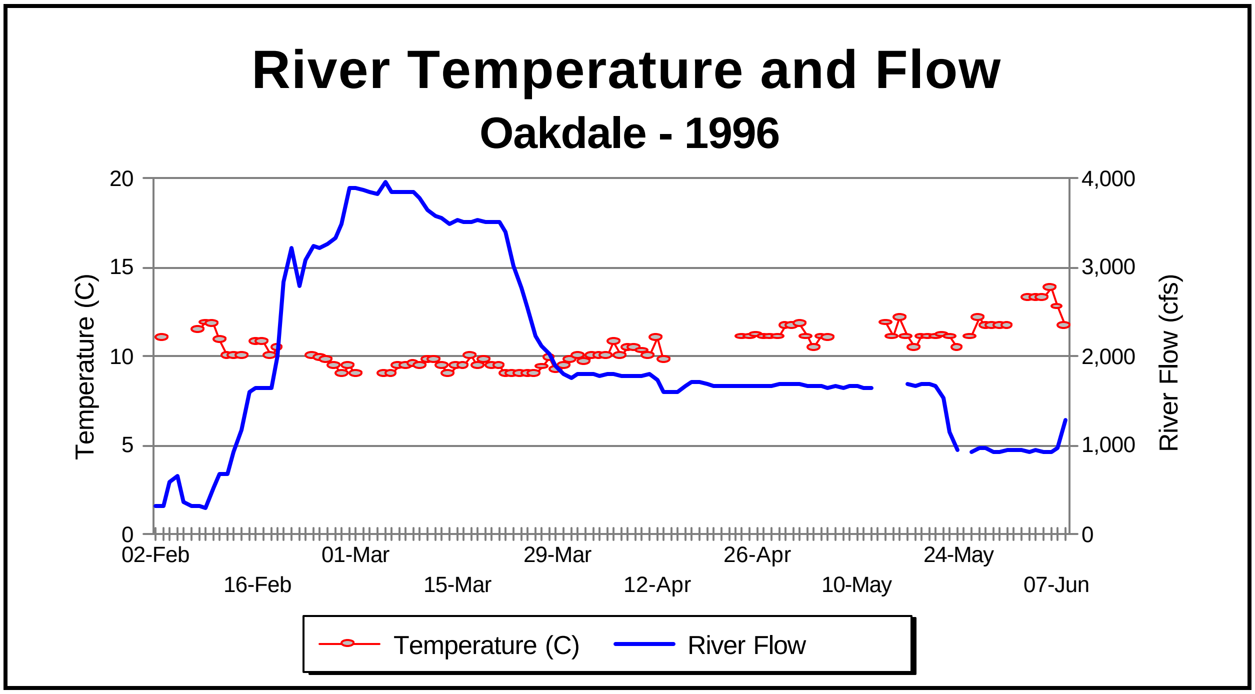


Figure 13. Daily river temperature, flow and juvenile chinook passage at Oakdale, 1996.

Don Chapman Consultants (1989) noted during regular underwater observations of yearling chinook in the Wenatchee River, Washington, that the behavior of overwintering chinook changed from free ranging to hiding themselves in cobble and boulder substrates when temperatures dropped below 10/C. The reverse may also be true, such that chinook begin migrating when temperature rises above 10/C. Triggers to juvenile chinook migration are complex, and it is clear that changes in flow, fish size, and time of year also play roles in triggering emigration.

INFLUENCE OF SMOLTING ON CHINOOK OUTMIGRATION

The external appearance of smolt characteristics among fish captured in the trap increased as sampling progressed (Figure 14). The smolt appearance index remain below 2.0 for most of March, then at or above 2.0 from late March through the end of sampling. The smolt appearance index increased sharply in late March, when mean lengths of captured chinook also increased sharply (Figure 14 and Appendix 3). Thus, the index was correlated to fish size, i.e. larger fish appeared more smolt like.

OTHER SPECIES

We captured 13 rainbow trout/steelhead (*Oncorhynchus mykiss*) in the screw trap in 1996, ranging in size from 34 to 356 mm (Figure 15). Six of the fish over 200 mm long showed advanced signs of smolting and all others showed no signs of smolting (Appendix 4). The first rainbow/steelhead was captured soon after we began sampling on February 4 and the last on May 18. We captured almost half (6) of the rainbow/steelhead during February. In 1995, we did not sample during February, but we captured 26 rainbow/steelhead when we sampled March 18 through July 1. Because we have not sampled July through January, we can not say whether or not rainbow/steelhead migrate during those months.

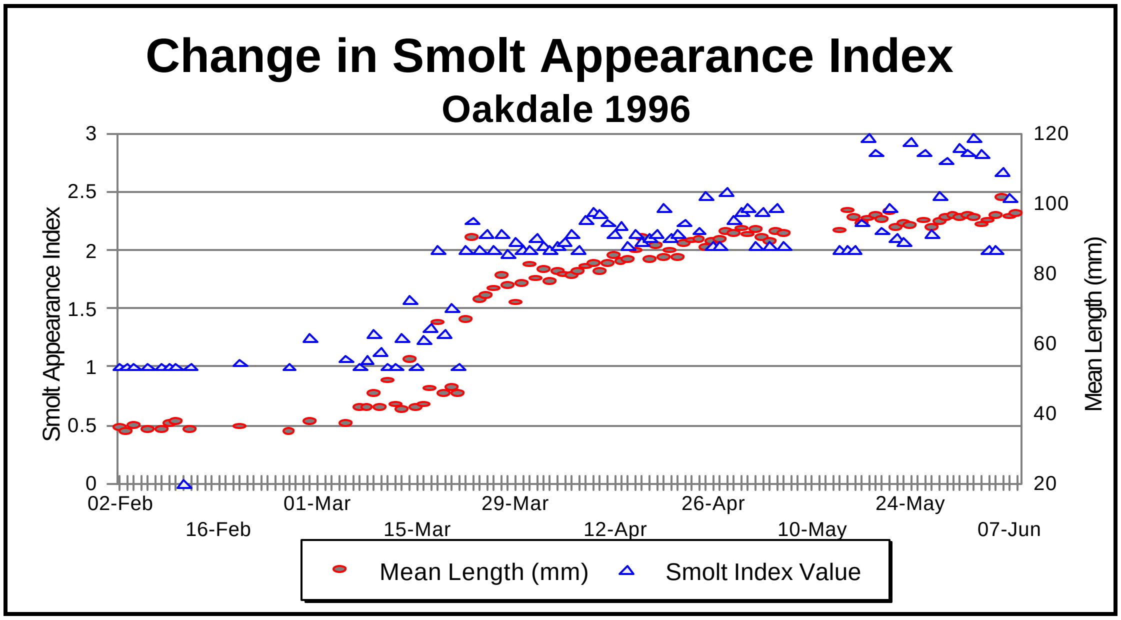


Figure 14. Daily values of the smolt appearance index and of mean lengths of chinook captured at Oakdale, 1996.

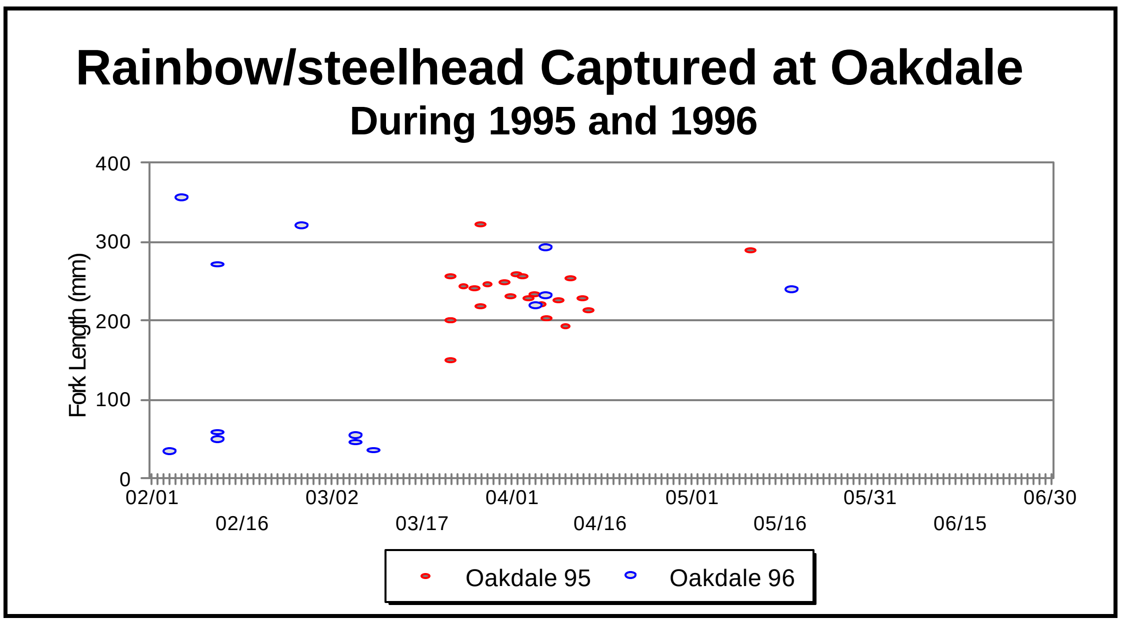


Figure 15. Date and individual lengths of all rainbow/steelhead captured at Oakdale in

1995 and 1996. See Appendix 4 for data on all rainbow/steelhead captured at Oakdale since 1993.

Species other than salmon and trout captured in the screw trap are listed in Appendix 5.

RATE OF JUVENILE CHINOOK MIGRATION

We released three marked groups of wild chinook at Knights Ferry between April 13 and May 22 to determine the rate at which they migrated to Oakdale (14.6 miles). Fish were released at river flows ranging from 1,525 to 1,673 cfs. The elapsed time between the end of each release and when the trap was checked the following morning varied from 8.5 to 10.5 hours, and most fish recaptured arrived within this amount of time (Table 5). We express travel time as the number of nights, because trap catches indicate that few fish move during the day. These rates of movement in 1996 were substantially faster than we observed in 1995, when most fish took 2-3 nights to reach Oakdale (Demko and Cramer 1995). Higher flows in 1996 appear to be the most probable cause of the faster migration. The first two groups of marked fish released at Knights Ferry in 1995 were of smaller size and released at an earlier date than any groups in 1996, so they should not be compared between years. However, the last group of fish in 1995 was released on April 12 at a mean length of 76 mm, similar to the group released on April 13, 1996 at a mean length of 78 mm. About 70% of the recoveries for the April 12, 1995 group took two nights to reach Oakdale and another 20% took three nights. This contrasts with the April 13, 1996 group for which over 90% of the recoveries reached Oakdale in only one night. The main difference between the two years was that flow for the 1995 group was 586 cfs while the flow for the 1996 group was 1,598.

Table 5. Number of nights between release at Knights Ferry and recapture at Oakdale (14.6 miles downstream) for marked wild chinook during 1996.

Release Date	Mean Length	Flow cfs	Travel nights 1	2	3	4	5
04/13/96	78.1	1,598	69	6			
04/22/96	86.1	1,673	53	6	1		1
05/22/96	95.1	1,525	7				

We recovered 11 marked chinook at Caswell that had been released at Oakdale or above, and four of those were fry (Table 6). Eight fish were recaptured from five different groups released at Oakdale and three from one group released at Knights Ferry. These release groups were released at flows ranging from 681 to 3,413 cfs and with mean lengths at release ranging from 34 to 86.1 mm (Table 6), but recoveries were too few to deduce the effects of flow or fish size on migration rate. Three fry made the trip from Oakdale to Caswell (35 miles) in 5 to 7 nights, and the fourth fry took 24 nights. Smolts (> 70 mm) released at Oakdale made the trip in 2-5 nights, and smolts released at Knights Ferry made the trip (49 miles) in 5-8 nights (Table 6).

SURVIVAL OF JUVENILE CHINOOK THROUGH THE STANISLAUS RIVER

Mark-Recapture Tests

Survival of juvenile chinook migrating from Knights Ferry to Oakdale (14.6 miles) was estimated from the release of marked natural chinook at Knights Ferry and their recovery at Oakdale. 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:

- **Ø** Marked and unmarked chinook were equally vulnerable to capture in the trap.
- **Ù** Marked and unmarked fish experienced equal mortality rates.
- **Ú** All marked fish captured at the Oakdale trap were identified.
- **Û** No fish remained upstream of the trap at the conclusion of sampling.

Table 6. Number of nights after release that marked chinook released at Oakdale and Knights Ferry were recaptured at Caswell.

	Release Location and Date					
Nights After Release	**Oakdale Feb 12**	**Oakdale Mar 22**	**Oakdale Apr 6**	**Knights Ferry Apr 22**	**Oakdale May 4**	**Oakdale May 26**
1	-	-	-	-	-	-
2	-	-	-	-	1	-
3	-	-	2	-		-
4	-	-		-		-
5	1	-		1		1
6	1	-		1		
7	1	-		-		
8		-		1		
9		-				
10		-				
11		-				
12		-				
13		-				
14		-				
15		-				
16		-				
17		-				
18		-				
19		-				
20		-				
21		-				
22		-				
23		-				
24		1				
Total # Recap	3	1	2	3	1	1
Mean Length	34	43.9	70.6	86.1	75.5	72.2

River Flow	681	3413	1791	1673	1674	921
Ave mile/day	5.8	1.5	11.7	8.1	17.5	7

Knights Ferry to Caswell = 48.7 miles; Oakdale to Caswell = 35 miles. Mean lengths are at release.
River flow is at OBB on day of release. O9 group released at Knights Ferry, others at Oakdale.

We have no way 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 50.4%, 61.9%, and 7.7% (Table 7). The mean lengths of the fish released varied from 78.1 to 95.1 mm, and a paired T-test indicated that there was not a significant difference between the mean lengths at release and at recapture (P = 0.26)(see Figure 6).

Table 7. Survival estimates for natural chinook released at Knights Ferry and recaptured at Oakdale.

Designated Release Group	Release Date	# Released	# Recaptured	% Recaptured	Predicted Efficiency	Expanded Catch	Survival Index	OBB Flow (cfs)	Mean Length at Release (mm)	Mean Length at Recapture (mm)
O 6	Apr 13	1293	75	5.80	0.115	652	0.504	1598	78.1	78.3
O 9	Apr 22	930	61	6.56	0.106	575	0.619	1673	86.1	86.9
O 11	May 22	726	7	0.96	0.125	56	0.077	1525	95.1	88.9

Estimated survivals for the first two groups released in 1996 were similar to those in 1995. The third group released on May 22, 1996 had an estimated survival of 7.7%, which is lower than all other groups released in 1995 and 1996. The group was released at a flow of 1,525 cfs, lower than the other two groups in 1996, but a higher flow than the three groups in 1995. The group, released on May 22, 1996, also had the largest mean length at release of any group in 1995 or 1996. There are many possible explanations for the unusually low survival of this last group, including that they may have avoided the trap, they may have died, or they may have remained upstream of the trap. In view of the survival estimates for the other groups, it appears unlikely the estimate for the last group reflected true survival rate.

A total of 8,998 marked chinook were released in the upper river at, or above, Oakdale during 1996 and only 11 were recaptured at Caswell. The expanded number estimated to have arrived at Caswell (assuming no mark loss) was 300, or 3.3%. The expanded percentage of fish estimated to have reached Caswell from each of the individual groups that were recovered ranged from 5% to 10%. Thus, all mark-recapture results indicated that survival during passage from Oakdale to Caswell was extremely low.

Outmigration Indexes at Oakdale and Caswell

We also evaluated survival through the river by comparing the passage estimates at Oakdale to those at Caswell. The differences in estimated abundance between the Oakdale and Caswell sites further suggests there is a high rate of mortality of juvenile chinook as they migrate the 34 miles from Oakdale to Caswell. The estimated number of juvenile chinook passing Oakdale between February 2 and June 8 was 284,000, compared to an estimated 71,000 chinook passing Caswell between February 6 and July 1 (Figure 16). We compared the running 7-day averages of estimated chinook passage at each location, and found that the ratio of estimated passage at the two locations showed distinct peaks and valleys during the season. A high proportion of fry passing Oakdale in late February were accounted for passing Caswell (Figure 16; all spawning was believed to have been above Oakdale), and this was a period of high turbidity and rapidly increasing flow (see Figure 8). Caswell passage represented less than 20% of the Oakdale passage from March 1 through April 20. However, the estimated passage at Caswell during peak migration of smolt-sized fish (April 25 to May 10) was near 40% of the passage at Oakdale, and then increased to over 100% in June (Figure 16). The increase in chinook passage at Caswell in early June relative to that at Oakdale, occurred after a sharp drop in flow, and indicates that a high proportion of chinook passing Caswell at the end of May and first week of June had reared in the lower river for over one week (the percentages were 7-day averages). However, less than 10% of the season's passage at Caswell came after May 25. It appears that passage at Caswell would not have continued to exceed that at Oakdale later into June, but we cannot be sure because sampling at Oakdale terminated on June 8. Estimated passage on June 7 and 8 at Oakdale was back up to about triple that at Caswell.

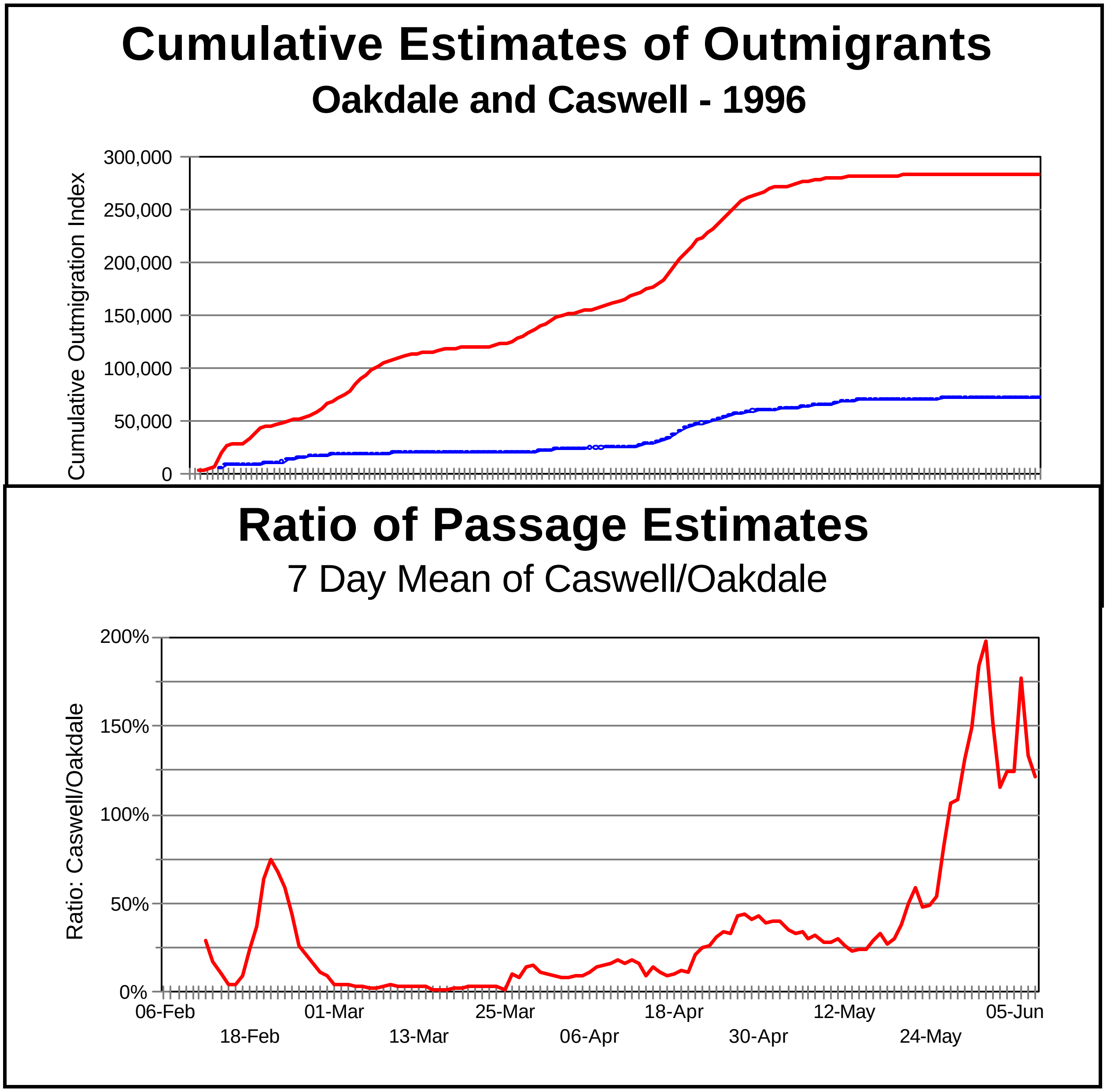


Figure 16. Cumulative estimates of outmigrants passing Oakdale and Caswell during 1996, and the ratio of Caswell:Oakdale for the 7-day running average of chinook passage. Date indicated is the end of the 7-day period.

CONCLUSIONS

1. The estimated number of juvenile chinook that passed Oakdale during February 2 through June 8 was 283,658 with approximate confidence intervals of 240,163 and 327,153. Many fry (< 40 mm) probably passed before sampling began.

2. Juveniles emigrated either as newly emerged fry (<40 mm) or as smolts (70-110 mm). Nearly 40% of migrants during the season sampled were fry, and their passage was essentially complete by mid March. Sharp increases in flow prior to mid March generally stimulated increases in emigration of fry for 1 or 2 days.

3. The initial outmigration of smolts appeared to be triggered by the sharp drop in flow from 3,500 cfs to 1,800 cfs in late March. The outmigration of smolts peaked during an extended period of constant river flow near 1,700-1,800 cfs in late April and early May, which demonstrates that juvenile chinook will emigrate when they reach smolt size during spring, even in the absence of variation in flow.

4. Juvenile chinook generally did not pause to rear for extended periods between RM 40 and RM 6, as indicated by the similarity in mean lengths between fish captured at Oakdale and Caswell, and by the short travel time (2-6 days) of marked fish.

5. The higher flows in spring of 1996 compared to 1995 appeared to accelerate the migration rate of juvenile chinook, but did not appear to improve their survival. Marked groups released at Knights Ferry survived at similar rates between 1995 and 1996 as they migrated the 14.6 miles to Oakdale, but they arrived at Oakdale in half the time during 1996 when flow was 1,525 cfs compared to 1995 when the flow was 586 cfs.

6. The much lower abundance of chinook estimated to have passed the Caswell site than the Oakdale site suggests there is high mortality to juvenile chinook in the 34 miles between sites. About 40% of the estimated number of smolts passing Oakdale during the peak of outmigration (April 25 to May 10) were estimated to have passed Caswell. Prior to April 25, generally less than 15% of the estimated outmigrants at Oakdale were at Caswell, except for fry during a brief period in mid-February, when turbidity was high and flow increased sharply.

RECOMMENDATIONS

1. Monitoring of juvenile outmigration should continue annually at Oakdale in order to distinguish their behavior and survival under the wide variety of flow scenarios that may be proposed for the future.

2. Factors contributing to the low observed survival of juvenile chinook in the 34-mile reach between the Oakdale and Caswell sites should be investigated. Low survival was estimated even when flows were the highest that have occurred in the Stanislaus River for many years. Radio tagging and tracking of juveniles would provide the most timely reconnaissance data on the location and timing of juvenile mortality between the Oakdale and Caswell sites.

3. Mark-recapture tests of survival and migration rate between Knights Ferry and Oakdale should be continued. These tests have proven to be the best opportunity for obtaining desirable numbers of recaptures, and a long term data set is likely to reveal the effects of flow, temperature, and fish size on migration rate and survival.

4. Initiate sampling in January or early February. An attempt should be made to begin sampling before freshets occur in late January and early February, when significant numbers of newly emerged fry may be migrating from of the Stanislaus River.

5. Install an Onset light meter and record hourly light intensity data (lumens) during mark-recapture tests. This would provide an alternative measure to turbidity of underwater visibility.

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APPENDICES

Appendix A. Estimated 1996 Trapping Efficiency and Fish Outmigration Index at Oakdale

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

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

Predicting 1996 Trapping Efficiency

Ten Oakdale releases were made to estimate screw-trap trapping efficiencies. Estimated efficiencies were simply the proportions of released fish that were captured in the Oakdale screw trap. Count data were available for most days from February 2 through June 8 (hereafter referred to as passage days); whereas the efficiency estimates were only available on only eight of those days[1]. In order to predict the efficiency for each passage day, the efficiency had to be related as a response or "dependent" variable to a predictor or "independent" variable that was measured on every day that the screw trap was operating. Substituting a given day's value of the predictor variable into the predictive relation would then provide an estimate of that day's efficiency.

The predictive relation used to relate efficiency to the predictor variable (x) was the logistic:

$$\text{Efficiency} = \frac{1}{1 + e^{(a + b*x)}}$$

1 *Two of the ten releases for efficiency estimation were made on the same day (April 6, 1996) and complete recapture data were not available from one of the nine release dates (February 19, 1996). Regarding the latter, five of the February 19th released fish were actually recaptured the next morning; however, the trap was continually being clogged with debris during the recovery period, and the recovery effort had to abandoned for the remainder of that day and for three subsequent days; therefore, there was no way to estimate the true recapture rate for the February 19 release.*

or, using the "logit" transform,

$$logit\ (\ Efficiency\ )\ =\ \ln[\frac{Efficiency}{1\ -\ Efficiency}]\ =\ -a\ -\ b*x$$

In the above equations "e" is the exponential constant, "ln" is the natural log, "a" is a coefficient associated with the x = 0 intercept [Efficiency = $1/(1+e^{a})$ when x = 0], and "b" is the linear regression coefficient relating the logit transform to predictor variable x. The principle reason for choosing the logistic model is that the predicted efficiency can never be less than 0 and can never exceed 1 (100%). Logistic regression assumes that the underlying distribution of the number of captured fish is binomial when the model is accurate.

Five predictor variables were investigated:

- x(1) - daily flow in cubic-feet/second (CFS) on the day of the release;
- x(2) - turbidity measured on the morning following release;
- x(3) - time/screw-trap-rotation (time/rotation) measured on the morning following the release;
- x(4) - average water velocity measured on the morning following release; and
- x(5) - length of fish.

The values of the variables used in the logistic regression are presented in Table A.1.

The length of fish was based on fish measured at release. This would not typically be the appropriate measure for predictive purposes because the only river-run fish that can be measured are those actually trapped; therefore, length of fish measured at recovery would be more appropriate to use. However, for the March 22nd release, the number of recoveries was so small (8 recovered from 617 released) that the precision of the length measure from recovered fish would be poor. A paired t-test between release and recovery lengths was conducted. The actual differences and the statistical tests are discussed later. Suffice it to state here that the mean of the differences over all efficiency releases was small and not significantly different than 0 (average length of sampled released fish was 0.8 cm or 1% less than that of sampled recovered fish); therefore the length at release was used as the predictor variable.

Table A.1. Variables used to estimate alternative logistic models to predict efficiency.

Date	Predictor (X) Variable: Flow (CFS)	Turbidity*	Time per Rotation*	Water Velocity*	Fish Length	Number Released (Rel)	Number Recovered (Rec)	Response Variable: Estimated Efficiency (Rec/Rel)
02/12/96	681	5.1	7.00	***	34.0	969	275	0.2838
03/19/96	3,522	3.3	9.06	3.74	33.8	700	5	**
03/22/96	3,413	3.1	9.20	3.57	43.9	617	8	0.0130
04/06/96	1,791	2.6	7.50	4.30	70.6	500	45	0.0900
04/06/96	1,791	2.6	7.50	4.30	69.5	499	32	0.0641
04/14/96	1,595	2.1	9.59	4.69	78.1	198	20	0.1010
04/22/96	1,673	3.0	9.52	4.93	86.1	248	31	0.1250
05/04/96	1,674	2.3	9.50	4.44	75.5	547	72	0.1316
05/26/96	921	2.4	10.61	4.89	72.2	304	77	0.2533
05/29/96	935	2.1	9.73	4.66	92.5	507	121	0.2387
Mean	1,800					509	69	0.1445
Pooled								0.1348

*** Information gathered on day following date given**
**** Efficiency could not be estimated because recovery period was incomplete**
***** Information not gathered**

The basis for selecting among the five predictor variables was a measure of variation referred to as the "deviance". The deviance is analogous to the residual sums of squares from least squares regression. Under least squares regression, the predictor variable producing the smallest residual mean square (residual sums of squares divided by residual degrees of freedom) is usually regarded as the "best" predictor variable. The logistic analog to the residual mean square is the deviance/degrees-of-freedom ratio (Dev/DF). I selected the predictor variable, flow, that gave the smallest Dev/DF. Not only was the flow's Dev/DF the smallest (Table A.2), its value of 1.64 was not significantly different from 1 (P>0.2), meaning that the variation does not differ significantly from what would be expected from the binomial distribution and indicating a reasonably accurate fit. Further, flow had the largest weighted R value[2], R = 0.99 (Table A.2), which was also near the maximum possible value, 1. For these reasons, I used flow as the predictor variable.

[2] *R is the correlation between the predicted and actual estimated efficiencies and is analogous to the square root of the coefficient of determination, R^2, from least squares regression. The weighting variable was the number of released fish. Unweighted R values are also given in Table A.2.*

Table A.2. Deviances associated with logistic fits of estimated efficiency on predictor variables and correlations between estimated and predicted efficiencies from those fits.

Predictor Variable	Deviance (Dev)	Degrees of Freedom (DF)	Dev/DF	R*	Weighted R**
Flow	11.48	7	1.64	0.98	0.99
Turbidity	281.67	7	40.24	0.39	0.56
Time/Revolution	353.83	7	50.55	-0.08	0.19
Water Velocity	59.65	6	9.94	0.71	0.79
Fish Length	353.76	7	50.54	0.02	0.19

*** Correlation between predicted and estimated screw-trap efficiencies.**
**** Correlation based on weighting variables by number of fish released.**

The predictive relation is given below with a plot of the estimated efficiencies and the predicted responses plotted against flow in Figure A.1.

$$Efficiency = \frac{1}{1 + e^{(0.02418 + 0.00126\ Flow)}}$$

As indicated in the figure, only one of nine efficiency estimates falls outside the approximate, binomially based confidence intervals[3]. For a binomial distribution around a true model, the probability of having one out of nine data points falling outside of the interval just by chance is quite high, P = .30. This high probability and the near-1 Dev/DF ratio indicates that the efficiency predictor has low or no bias as well as high precision.

3 *The approximate 95% confidence intervals were estimated by*

$$e - 1.96 * \frac{e*(1-e)}{n};\quad e + 1.96 * \frac{e*(1-e)}{n}$$

e being the predicted efficiency for the given flow and n being the number of fish released.

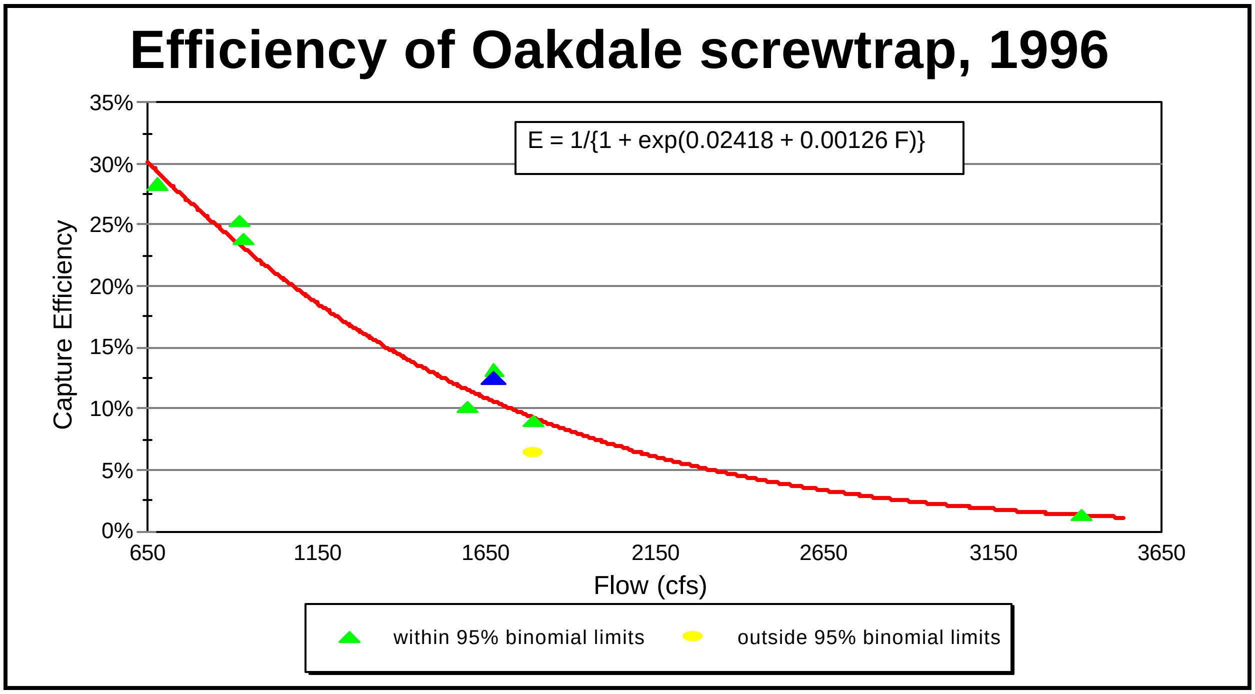

Figure A.1. Predicted efficiency, $1/[1 + e^{.02418 + 0.00126*Flow}]$ (line), and actual efficiency estimates (x) from 1996 Oakdale releases.

1996 Count and Flow Data

Substituting the efficiency-to-flow predictor into the outmigration index estimation equation gives:

$$\text{Outmigration Index} = \frac{\text{Count}}{\text{Efficiency}} = \frac{\text{Count}}{\left[\dfrac{1}{1+e^{(0.02418\ +\ 0.00126\ \text{Flow})}}\right]} = \text{Count}\ [1+e^{(0.02418\ +\ 0.00126\ \text{Flow})}]$$

Within the dates of evaluation there were passage days when flow information was not available and other passage days when counts were not available. Methods of interpolation were developed to compute values of flow and count when they were missing. Interpolated values were needed to estimate the cumulative outmigration index. The methods of interpolation are discussed below.

Missing Flow Information: Missing flows were replaced by the average of available flow data from five days preceding the missing value through five days following the missing value. The basis for selecting this interval was the magnitude of the lag correlations. Flows were correlated between adjacent days (lag = 1), between days that were two days apart (lag = 2), between days that were three days apart {lag = 3), etc. Flows were highly correlated for lags 1 through 5 (refer to Table A.3.), the correlation coefficient only declined about 0.02 per lag-unit increase from 0.99 at lag 1 to 0.89 at lag 5; however, the rate of decline in the correlation coefficient increased for lag > 5. Given that lag correlations were high and since there was little variation among flows within the ±5 day interval around a missing value, the substituted flow probably did not differ greatly from the actual flow.

Table A.3. Time lag correlations among flows, among screw-trap counts, and among natural logs of screw trap counts.

Lag	Correlation between Days	Flow(i) w/ Flow (i+lag)	Count(i) w/ Count(i+1)	ln[Count(i)] w/ ln[Count(i+lag)]
0	i; i	1.000	1.000	1.000
1	i; i+1	0.989	0.815	0.879
2	i; i+2	0.969	0.132	0.782
3	i; i+3	0.947	0.093	0.766
4	i; i+4	0.921	0.243	0.752
5	i; i+5	0.888	0.597	0.751
6	i; i+6	0.847	0.715	0.686
7	i; i+7	0.799	0.451	0.557
8	i; i+8	0.750	0.077	0.491
9	i; i+9	0.696	0.092	0.463
10	i; i+10	0.634	0.138	0.428

<u>**Missing Count Information**</u>. When the day (day i) having no count information was straddled by days (days i-1 and i+1) having count information, the following count substitution was based on:

$$\ln[Count(i)] = a(i) - 0.00104 * [Flow(i) - x(i)]$$

wherein

$$a(i) = \frac{\ln[Count(i-1)] + \ln[Count(i+1)]}{2}; \quad x(i) = [Flow(i) - \frac{Flow(i-1) + Flow(i+1)}{2}]$$

The value "- 0.00104" is the estimated least squares linear regression coefficient between ln[Count] and Flow. The regression coefficient is significantly less than 0 (P<<0.0001, correlation between ln[Count] and Flow = -0.65). The adjustment is based only on adjacent day flows and counts rather than a longer series of day flows and counts because the correlation between the logs of adjacent day (lag = 1) counts is reasonably high (0.88), but the correlation drops to below 0.8 as the lag increases above 1 (refer to Table A.3.)

The above equations for a(i) and x(i) applies to the case where the day with the missing count is straddled on both sides by days with actual counts. If the day with a missing count is adjacent to only one day with an actual count and the other adjacent day has a missing value, then a(i) is based on the actual count and x(i) is the flow associated with the day having that actual count. If the day with a missing count is adjacent to two days with missing counts, then a(i) is replaced by the estimated missing value from the adjacent day that is closest to a day with an actual count, and x(i) is replaced with the flow for that day. If both adjacent days (i-1 and i+1) with missing values are equally close to days with actual counts, then a(i) is replaced by the mean of the estimated missing values from the two adjacent days, and x(i) is replaced by the mean of the flows from those two days. The order of replacing missing values first proceeds with those days that are adjacent to days with actual counts, then with days that are once removed from days with missing counts, then with days that are twice removed, etc.

1996 Outmigration Index

Figure A.2 presents the daily screw trap count and the estimated daily outmigration index (count/efficiency) plotted against daily flow. There was a slight tendency for screw-trap count to decline with increasing flow (correlation coefficient = 0.37); however, there was no apparent linear trend in daily outmigration index (correlation coefficient = -0.05).

Figure A.3 presents the estimated daily outmigration indices. The estimated cumulative outmigration index between February 2 and June 8 and its 95% confidence interval are plotted in Figure A.4. The estimated cumulative outmigration index over that whole period was 327 thousand with an approximate 95% confidence interval of 284 thousand and 327 thousand. The coefficient of variation (CV) of the estimated outmigration index is quite small, probably because of the high precision associated with estimated efficiency that went into the estimation of the outmigration index. The method of estimating the standard errors (SE) used in confidence intervals is discussed in Appendix A.1.

$$CV = 100\left[\frac{\text{Estimated Cumulative Outmigration Index}}{SE\,(\text{Estimated Cumulative Outmigration Index})}\right] = 7.6\%$$

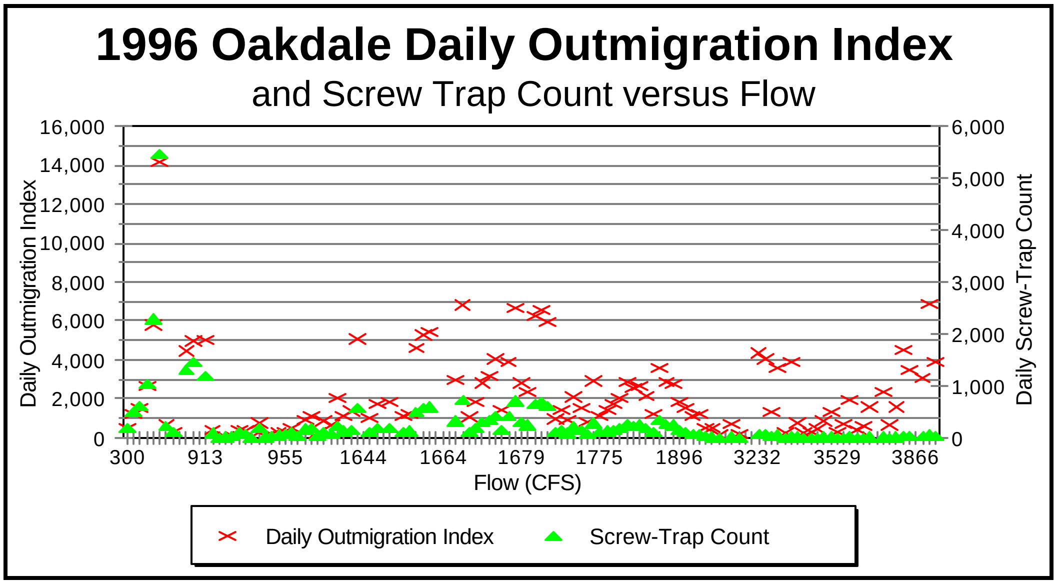

Figure A.2. 1996 Oakdale daily outmigration index and screw-trap count plotted against flow.

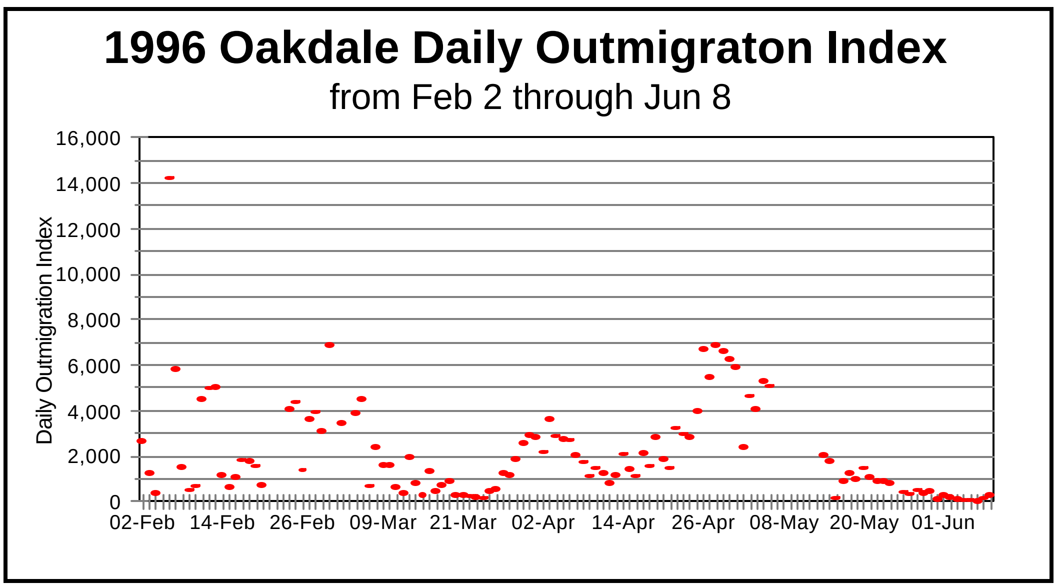

Figure A.3. 1996 Oakdale daily outmigration index over passage days February 2 through June 8.

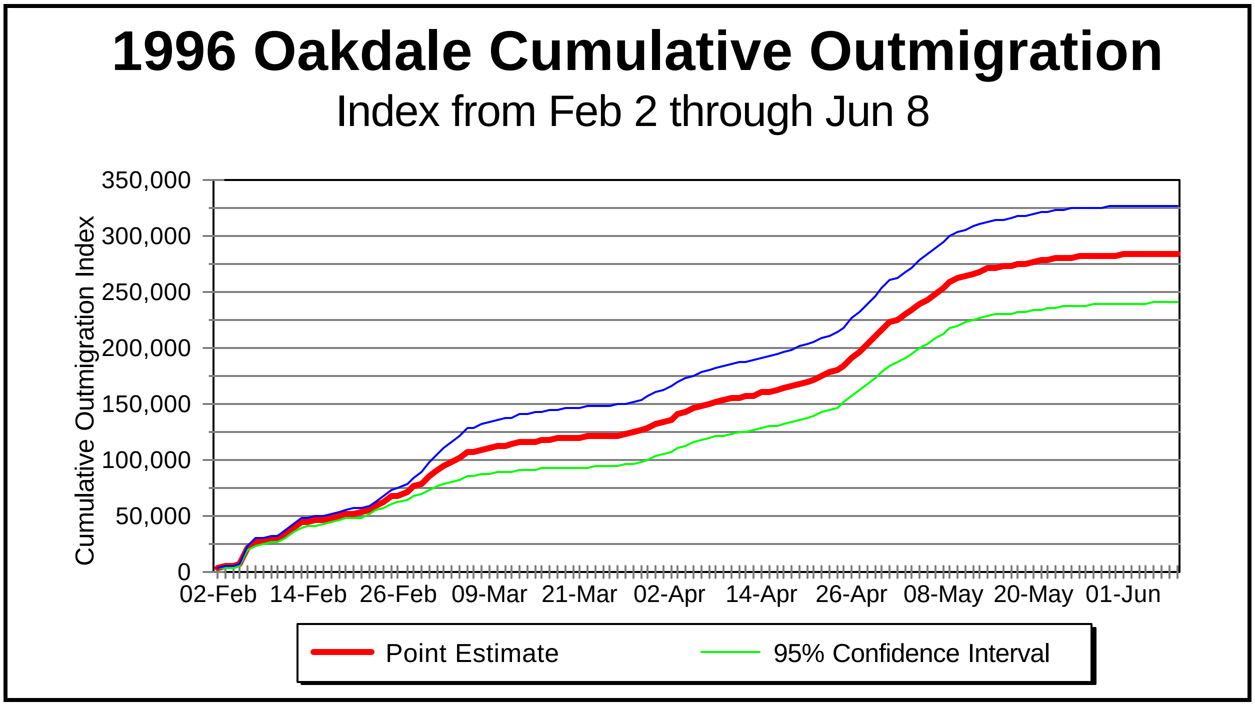

Figure A.4. 1996 Oakdale cumulative outmigration index from February 2 to June 8

Appendix A.2 presents 1996 flows, screw-trap counts, and efficiency predictions, as well as daily and cumulative outmigration index estimates and their approximate standard errors. In the appendix those flow and count data with asterisks are replacements for missing values.

Predicting 1995 Efficiency

A different predictive model was reported for the 1995 season,

$$Efficiency = \alpha \ Flow^{-\beta}$$

Unweighted least squares on the log transform of the model was used to estimate the coefficients. The estimated 1995 predictor equation, given in the 1995 Annual Report and referred to here as Efficiency (1), was

$$Efficiency \ (1) = 3.52.37 \ Flow^{D.485}$$

This model and the fitting procedure used has certain flaws: 1) It is possible for efficiency estimates to exceed 1 (100%) or to be less than 0; 2) the assumed distribution of estimated efficiencies around the model is assumed to be log-normal rather than binomial; 3) zero estimates of efficiency, which existed, cannot be handled; and 4) variability in the number of fish released was not taken into account. Therefore, a logistic fit was also applied to the 1995 data since none of these short-comings is associated with logistic regression, the estimated predictor, referred to as Efficiency (2), being:

$$Efficiency\ (2) = \frac{1}{1 + e^{(1.16776 + 0.0008743 * Flow)}}$$

Efficiency (1) was actually better correlated with the actual estimated efficiency than was Efficiency (2), the respective weighted R values being 0.55 and 0.46, the weights being the number of fish released. However, Efficiency (1) appeared to be biased. The mean of the actual estimated efficiencies was 0.127, but the mean of the predicted values from Efficiency (1) was 0.143. The mean from Efficiency (2)'s predicted values, 0.128, was almost identical to the mean of actual estimated values, 0.127. Based on bias concerns, especially when daily outmigration index values are to be predicted under extremely high or low flow conditions, I decided to use Efficiency (2), hereafter simply referred to as efficiency.

As indicated in Figure A.5, 12 of the 18 estimates fall outside the 95% confidence intervals around the efficiency[4] fit compared to only 1 out of 9 for the 1996 fit. Further, the Dev/DF ratio for the 1995 efficiency fit was 14.56; whereas that for the 1996 fit was 1.64, far closer to 1. Moreover, the weighted R value for the 1995 data was 0.46; whereas the weighted R value for the 1996 data was 0.99, much closer to 1. By any measure, the logistic fit for the 1995 data was far poorer than for the 1996 data.

Figure A.6 presents the daily screw trap count and the estimated daily outmigration index plotted against daily flow. Figure A.7 presents the estimated daily outmigration indices. The estimated cumulative outmigration index between March 18 and June 26 and its 95% confidence interval are plotted in Figure A.8. The estimated cumulative outmigration index over that whole period was 75 thousand with an approximate 95% confidence interval of 53 thousand and 97 thousand. The CV of the estimated outmigration index is 15%. Much larger than the 7.8% for the 1996 outmigration index.

Appendix A.3 presents 1995 flows, screw-trap counts, and efficiency predictions, as well as daily and cumulative outmigration index estimates and their approximate standard errors. In the appendix those flow and count data with asterisks are replacements for missing values.

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4 *12 out of 18 values also fell outside the 95% confidence intervals around the Efficiency (1) fit.*

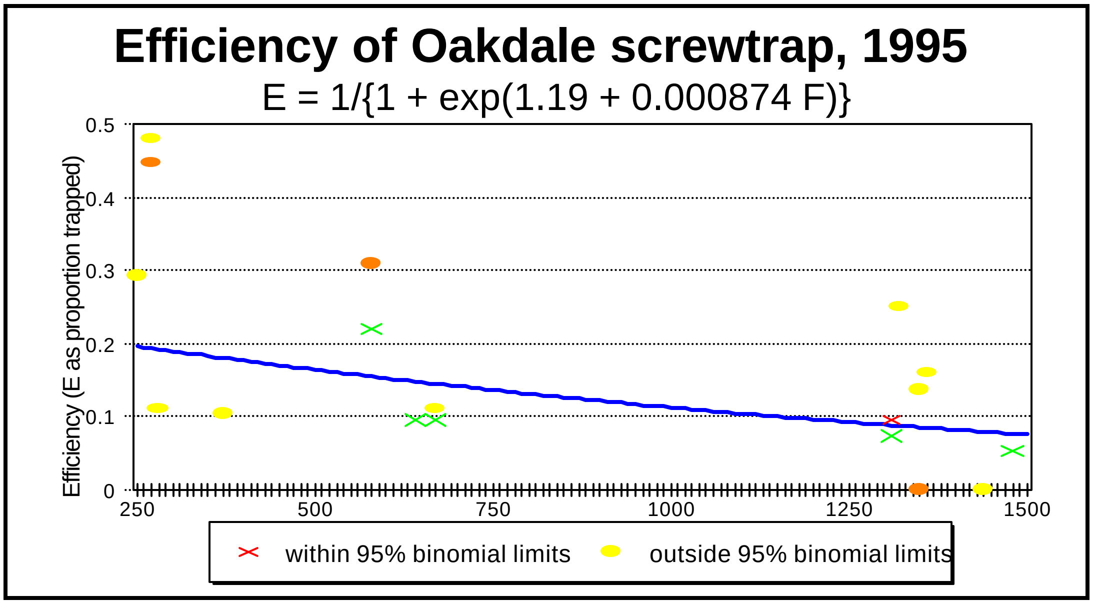


Figure A.5. Predicted efficiencies, $1/[1 + e^{1.188 + 0.000874*Flow}]$ (line), and actual efficiency estimates (x) from 1995 Oakdale releases. Each point was determined by a different sample size, so the width of confidence intervals varies for individual points

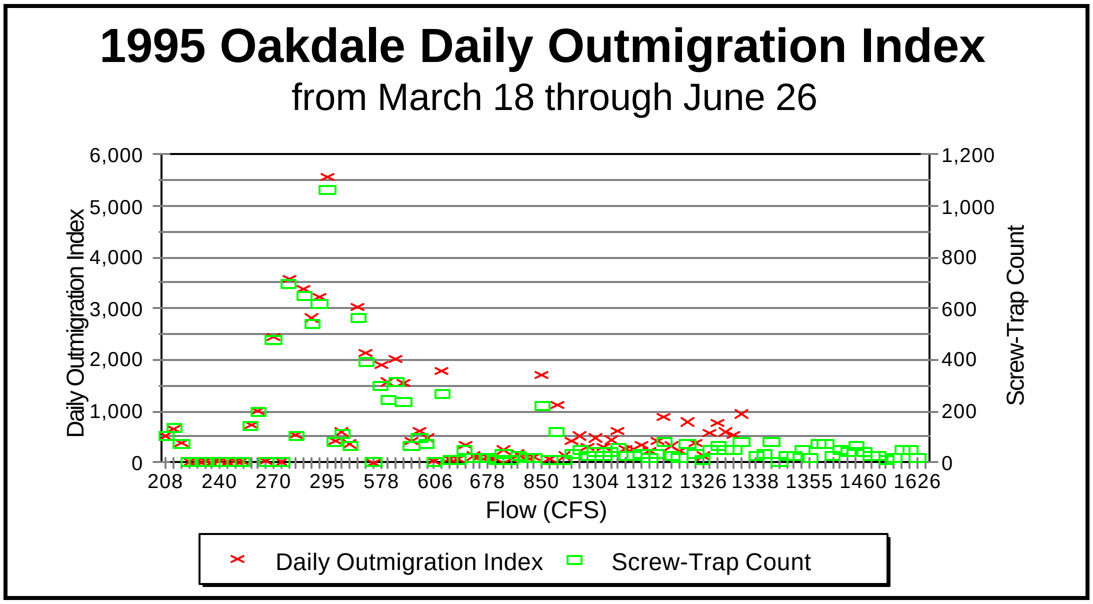


Figure A.6. 1995 Oakdale daily outmigration index and screw-trap count plotted against flow.

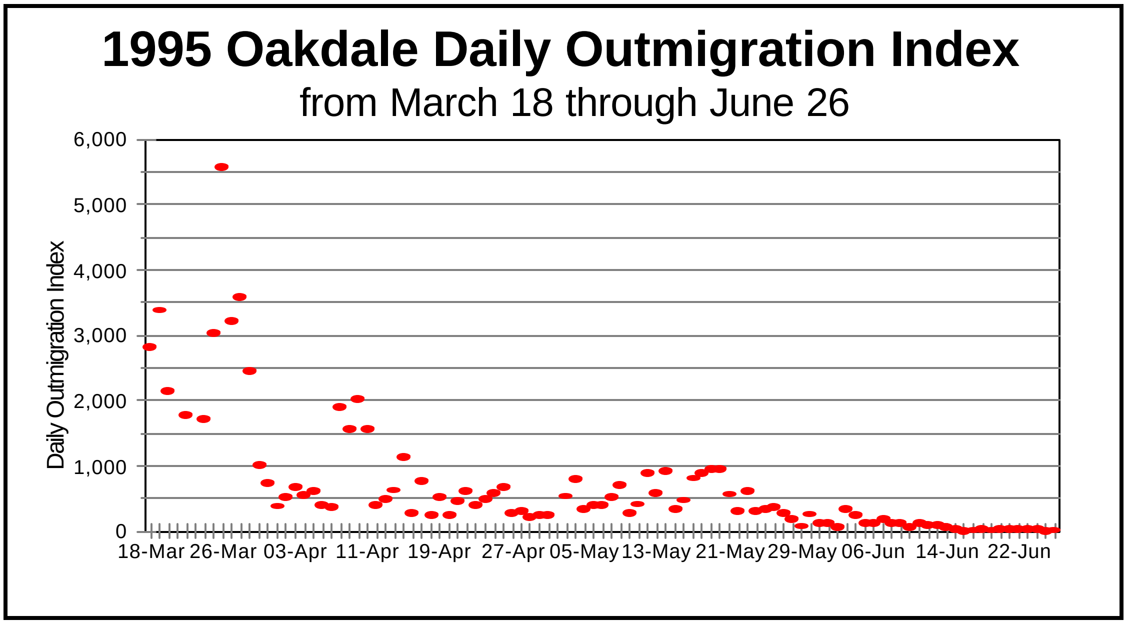


Figure A.7. 1995 Oakdale daily outmigration index over passage days March 18 to June 26.

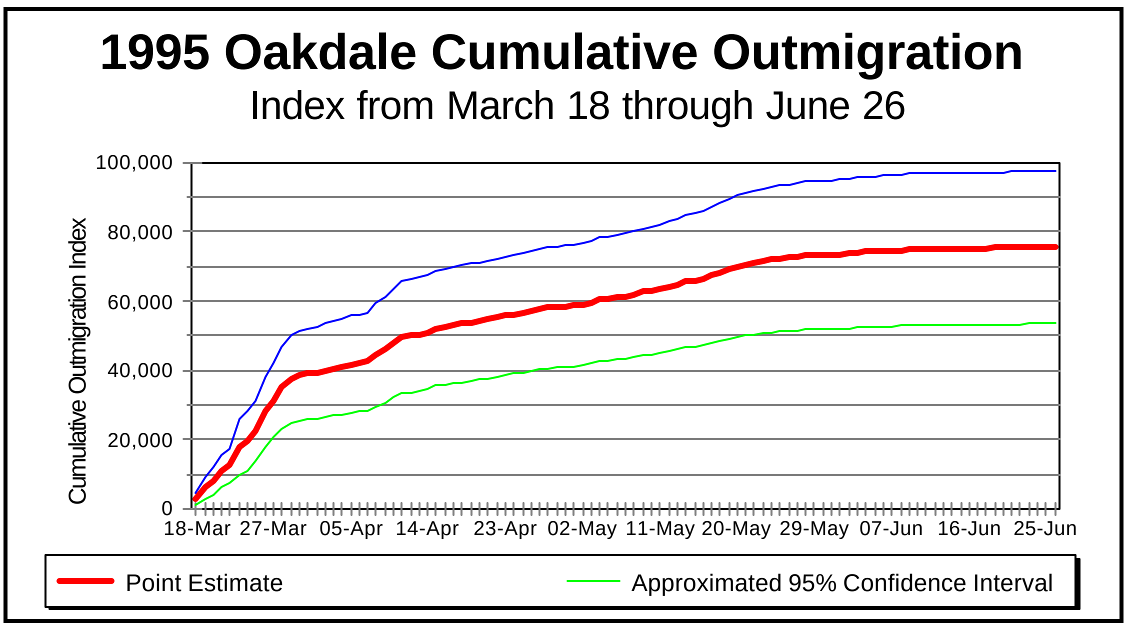


Figure A.8. 1995 Oakdale cumulative outmigration index from March 18 to June 26.

1996 versus 1995 Fish Size Bias

Improved experimental procedures may have led to reduced trapping bias as well as improved precision, both leading to a greater accuracy in the estimate of the 1996 efficiency and outmigration index. One indication of a possible bias is that the larger released fish tended to be trapped in 1995. Table A.4 presents the 1995 and 1996 estimated fish sizes from releases and recoveries made for efficiency fits.

Table A.4. Comparative differences between the size of fish at the time of release and the size at the time of recovery based on 1995 and 1996 Oakdale efficiency releases.

1995 Efficiency Releases					1996 Efficiency Releases				
		Mean Length					Mean Length		
Date	Source	At Release	At Recapture	Difference	Date	Source	At Release	At Recapture	Difference
24-Mar	Natural	56	56	0	12-Feb	Natural	34	30	4
27-Mar	Natural	64	65	-1	14-Apr	Natural	78.1	80.4	-2.3
30-Mar	Natural	60	65	-5	22-Apr	Natural	86.1	86.9	-0.8
30-Mar	Natural	60	65	-5	29-May	Natural	92.5	91.1	1.4
08-Apr	Natural	76	74	2	19-Mar	Hatchery	33.8	34.8	-1
10-Apr	Natural	78	82	-4	22-Mar	Hatchery	43.9	43.6	0.3
14-Apr	Natural	72	78	-6	06-Apr	Hatchery	70.6	73.2	-2.6
21-Apr	Natural	81	78	3	06-Apr	Hatchery	69.5	71.9	-2.4
16-May	Natural*	98			04-May	Hatchery	75.5	74.1	1.4
19-May	Natural*	96			26-May	Hatchery	72.2	78	-5.8
21-Apr	Hatchery	72	72	0					
01-May	Hatchery	79	79	0					
12-May	Hatchery	79	83	-4					
19-May	Hatchery	84	88	-4					
26-May	Hatchery	88	92	-4					
14-Jun	Hatchery	97	98	-1					
14-Jun	Hatchery	100	101	-1					
29-Jun	Hatchery	108	108	0					
* Excluded from mean computation									
All	Count	16	16	16	All	Count	10	10	10
	Mean	78.38	80.25	-1.88		Mean	65.62	66.40	-0.78
	Variance			7.32		Variance			7.45
	t-ratio			-2.77		t-ratio			-0.90
Natural	Count	8	8	8	Natural	Count	4	4	4
	Mean	68.38	70.38	-2.00		Mean	72.68	72.10	0.57
	Variance			12.00		Variance			7.52
	t-ratio			-1.63		t-ratio			0.42

Hatchery	Count	8	8	8	Hatchery	Count	6	6	6
	Mean	88.38	90.13	-1.75		Mean	53.00	56.40	-3.40
	Variance			3.64		Variance			6.44
	t-ratio			-2.59		t-ratio			-3.28

Sample recoveries in 1995 were, on the average, 1.9 cm larger than sampled releases. Contrary to the evaluation presented in the 1995 Annual Report, the difference was significantly greater than zero (P < 0.05). This difference cannot be attributable to growth between release and recovery since almost all recovered fish were recovered within a 24-hour period following their release. It is possible that there was greater post-release mortality for smaller fish than for larger fish. Roughly the same size differential was observed in both river-run ("natural") and hatchery sources of released fish.

However, in 1996, sampled recovered fish were, on the average, only 0.9 cm larger than sampled released fish and the difference was not significant (P > 0.2). This indicates that release procedures in 1996 may not have only resulted in an increase in precision but also a decrease in size bias. There is an indication that the average length of hatchery recoveries may have been larger than that of hatchery releases.

It is worth noting that the mean of the estimated efficiencies did not significantly differ between 1) the 1995 mean efficiency of 0.17 (17%) for a 859 CFS average flow and 2) the 1996 mean efficiency of 0.14 (14%) for a 1800 CFS average flow.

Appendix A.1. Standard Error Estimation for Daily and 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

$$oO_i = \frac{cC_i}{eE_i}$$

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

$$\sum_i oO_i = \sum_i \frac{cC_i}{eE_i}$$

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

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

The variance of this cumulative passage is

$$Var[\sum_i o_i] = \sum_i Var[\frac{c_i}{e_i}] + \sum_i \sum_{i'} Cov[\frac{c_i}{e_i}, \frac{c_{i'}}{e_{i'}}]$$

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 is the square root of the variance. In developing $Var[G_i o_i]$, I first discuss $Var[c_i/e_i]$ followed by $Cov[c_i/e_i, c_{i'}/e_{i'}]$.

1. Var[c_i/e_i]

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

$$Var[\frac{c_i}{e_i}] = \frac{C_i^2 Var[e_i]}{E_i^4} + \frac{Var[c_2]}{E_i^2} - 2*\frac{C_i Cov[c_i,e_i]}{E_i^3}]$$

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 estimates 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 lead to biases. No attempt was made to adjust for those biases.

1.b. Estimate of Var[e_i]

Recalling from the main appendix, the efficiency predictor is

$$e_i = \frac{1}{1 + e^{(a + b*f_i)}}$$

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

$$Var[e_i] =$$
$$E_i^4 \exp^2(-a-b*f_i)*[Var(b_0) + f_i^2*Var[b_i] + 2*f_i*Cov(a,b))$$

1.c. Estimate of Var[c_i]

I could not identify any direct estimate of the variance of c_i. The count would be the total daily outmigration multiplied by the efficiency; therefore the estimated count would be

$$c_i = O_i * e_{2,i}$$

where $e_{2,i}$ is the efficiency for that day, which is not directly estimable. The variance of c_i is

$$Var[c_i] = O_i^2 * Var_2(e_{2,i})$$

I used $o_i^2 = [c_i/e_i]^2$ as an estimate of O_i^2. I used $Var[e_i]$ presented in 1.a. for $Var(e_{2,i})$ above; however $Var[e_i]$ isn't the appropriate variance since e_i is based on a predicted estimate of the efficiency using that day's flow for the predictor variable rather than on a direct estimate of efficiency for that specific day.

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 entrainments and since there is no reason to believe that the fact a given released fish used to estimate efficiency was captured affected the probability that a river-run fish used to estimate c_i was captured. Therefore

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

Substituting the estimates of C_i, E_i, $Var[e_i]$, $Var[c_i\}$, and $Cov[c_i,e_i]$ presented in 1.a through 1.d into

$$Var[\frac{c_i}{e_i}] = \frac{C_i^2 Var[e_i]}{E_i^4} + \frac{Var[c_2]}{E_i^2} - 2 * \frac{C_i Cov[c_i, e_i]}{E_i^3}]$$

gives

$$Var[\frac{c_i}{e_i}] = 2*[\frac{(c_i)^2}{(e_i)^4}]*Var[e_i]$$

Var[e_i] being given under **1.b. Estimate of Var[e_i]**.

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

There is a covariance between outmigration indices from different days because the equations for predicting e_i and $e_{i'}$ used the same estimates of the intercept (a) and slope (b) parameters. The covariance was developed in a method analogous to that used for Var[e_i], the asymptotic covariance being

$$Cov[(\frac{c_i}{e_i}),\frac{c_{i'}}{e_{i'}}]=(c_i c_{i'})(e_i e_{i'})*[Var(a) + f_i*f_{i'}*Var(b) + (f_i+f_{i'})*Cov(a,b)$$

3. Estimating Var(a), Var(b), and Cov(a,b)

Logistic regression was used to obtain the estimates of a and b and their variances and covariance. However, the variances and covariance so generated assumes that the distribution of the data points around the model is actually binomially distributed, meaning the expected ratio of the deviance to degrees of freedom (Dev/DF) is 1. When this is not the case, the variances and covariance estimates presented in logistic regression packages are underestimated. When there Dev/DF significantly differed from 1 ($P < 0.1$), the variance-covariance output was expanded (multiplied) by Dev/DF to obtain the estimates of Var(a), Var(b), and Cov(a,b). The only case in which such an expansion did not occur was for the 1996 Oakdale outmigration.

4. Confidence Intervals

The 100*(1-") confidence intervals of estimates were approximated using

estimate ± z(")*SE(estimate)

wherein z(") is the two-sided standardized normal deviate associated with " and SE is the standard error or square root of the variance of the estimate. This approximated confidence interval is too small since the use of z(") is based on the assumption that SE is known. SE is not known, but itself is estimated, and the use of z(") will produce a smaller confidence interval than is appropriate.

Appendix A.2. 1996 Flow, screw-trap count, and predicted screw-trap efficiency and daily and cumulative outmigration index values.

Date	Daily Screw-Trap Count (C)		Orange Blossom Bridge (OBB) Flow	Predicted Efficiency (E)	Estimated Daily Passage (C/E)		SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
02-Feb	1,046		317	0.396	2,644		180.0	2,644	180
03-Feb	493		302	0.400	1,232		84.3	3,876	234
04-Feb	104		591	0.317	328		19.7	4,204	245
05-Feb	635	*	642	0.303	2,095	*		6,299	330
06-Feb	5,452		355	0.384	14,188		952.4	20,487	1,183
07-Feb	2,289		320	0.395	5,799		394.4	26,286	1,446
08-Feb	595		306	0.399	1,491		101.9	27,777	1,509
09-Feb	194		300	0.401	484		33.2	28,261	1,530
10-Feb	222		516	0.338	658		41.1	28,919	1,555
11-Feb	1,305		678	0.293	4,446		254.7	33,365	1,720
12-Feb	1,449		681	0.293	4,950		283.1	38,315	1,908
13-Feb	1,179		913	0.236	4,995		254.3	43,310	2,061
14-Feb	200		1,179	0.181	1,105		55.7	44,415	2,083
15-Feb	75		1,595	0.116	648		46.2	45,064	2,084
16-Feb	112		1,648	0.109	1,027		77.5	46,091	2,085
17-Feb	196		1,652	0.109	1,806		136.9	47,897	2,089
18-Feb	188		1,650	0.109	1,728		130.7	49,625	2,098
19-Feb	109		2,014	0.072	1,522		166.3	51,146	2,088
20-Feb	18		2,841	0.026	679		135.5	51,826	2,064
21-Feb	13	*	3,223	0.017	772	*		52,598	2,031
22-Feb	48	*	2,797	0.028	1,709	*		54,307	2,013
23-Feb	77	*	3,093	0.019	3,979	*		58,286	2,138
24-Feb	65		3,245	0.016	4,038		991.5	62,323	2,465
25-Feb	71		3,232	0.016	4,340		1059.3	66,664	2,969
26-Feb	21		3,271	0.016	1,347		334.9	68,011	3,128
27-Feb	51		3,341	0.014	3,569		915.7	71,580	3,642
28-Feb	47		3,481	0.012	3,915		1067.2	75,495	4,292
29-Feb	22		3,894	0.007	3,068		982.0	78,563	4,904
01-Mar	49		3,897	0.007	6,859		2197.8	85,422	6,439
02-Mar	37	*	3,866	0.007	5,002	*		90,425	7,519
03-Mar	26		3,856	0.008	3,458		1091.6	93,882	8,253
04-Mar	29	*	3,836	0.008	3,733	*		97,615	9,050
05-Mar	25		3,975	0.006	3,859		1270.9	101,474	9,923
06-Mar	34		3,850	0.008	4,488		1413.7	105,962	10,904
07-Mar	5		3,847	0.008	658		206.9	106,619	11,043
08-Mar	18		3,842	0.008	2,352		738.8	108,972	11,547
09-Mar	12		3,849	0.008	1,582		498.2	110,554	11,885
10-Mar	13		3,782	0.008	1,576		484.2	112,130	12,214

Date	Daily Screw-Trap Count (C)	Orange Blossom Bridge (OBB) Flow	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
11-Mar	6	3,641	0.010	610	177.5	112,740	12,335
12-Mar	4	3,584	0.011	379	107.7	113,119	12,407
13-Mar	21	3,552	0.011	1,911	536.5	115,029	12,775
14-Mar	9	3,489	0.012	757	207.1	115,786	12,916
15-Mar	3	3,529	0.011	265	73.8	116,052	12,966
16-Mar	15	3,524	0.011	1,318	365.8	117,370	13,217
17-Mar	5	3,519	0.011	437	120.9	117,806	13,299
18-Mar	8	3,530	0.011	708	197.1	118,515	13,434
19-Mar	10	3,522	0.011	877	243.1	119,391	13,600
20-Mar	3	3,503	0.012	257	70.7	119,648	13,648
21-Mar	3	3,509	0.012	259	71.4	119,907	13,697
22-Mar	3	3,413	0.013	230	60.8	120,136	13,738
23-Mar	4	3,010	0.022	186	40.6	120,322	13,766
24-Mar	4	2,761	0.029	137	26.1	120,459	13,784
25-Mar	18	2,539	0.038	470	77.8	120,929	13,837
26-Mar	30	2,226	0.056	538	70.6	121,467	13,886
27-Mar	77	2,125	0.063	1,225	147.8	122,691	13,986
28-Mar	79	2,024	0.071	1,116	123.1	123,807	14,069
29-Mar	149	1,896	0.082	1,813	177.1	125,620	14,187
30-Mar	238	1,790	0.093	2,564	224.9	128,184	14,334
31-Mar	284	1,748	0.097	2,916	244.9	131,101	14,492
01-Apr	262	1,794	0.092	2,835	249.8	133,936	14,656
02-Apr	200	1,791	0.093	2,157	189.4	136,093	14,780
03-Apr	332	1,794	0.092	3,593	316.5	139,686	14,989
04-Apr	265	1,788	0.093	2,848	249.3	142,534	15,153
05-Apr	248	1,809	0.091	2,730	244.3	145,264	15,315
06-Apr	249	1,791	0.093	2,685	235.8	147,950	15,471
07-Apr	188	1,780	0.094	2,002	173.8	149,952	15,585
08-Apr	160	1,779	0.094	1,702	147.6	151,654	15,682
09-Apr	104	1,775	0.094	1,101	95.1	152,755	15,745
10-Apr	135	1,776	0.094	1,431	123.7	154,187	15,827
11-Apr	114	1,791	0.093	1,229	108.0	155,416	15,898
12-Apr	79	1,731	0.099	796	65.6	156,212	15,941
13-Apr	129	1,598	0.115	1,119	80.0	157,331	15,990
14-Apr	239	1,595	0.116	2,066	147.3	159,397	16,081
15-Apr	158	1,599	0.115	1,372	98.2	160,768	16,142
16-Apr	118	1,656	0.108	1,092	83.1	161,860	16,195
17-Apr	212	1,706	0.102	2,076	166.7	163,936	16,303
18-Apr	155	1,711	0.102	1,526	123.2	165,462	16,383
19-Apr	295	1,679	0.105	2,802	218.6	168,264	16,525
20-Apr	194	1,670	0.106	1,824	141.0	170,088	16,616
21-Apr	152	1,675	0.106	1,437	111.7	171,525	16,688
22-Apr	340	1,673	0.106	3,207	248.7	174,732	16,849

Date	Daily Screw-Trap Count (C)	Orange Blossom Bridge (OBB) Flow	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
23-Apr	315	1,668	0.107	2,955	227.9	177,687	16,996
24-Apr	297	1,673	0.106	2,802	217.2	180,488	17,138
25-Apr	415	1,676	0.106	3,928	305.5	184,416	17,337
26-Apr	704	1,676	0.106	6,663	518.3	191,080	17,678
27-Apr	584	1,662	0.107	5,441	416.9	196,521	17,951
28-Apr	727	1,668	0.107	6,819	525.9	203,340	18,298
29-Apr	686	1,684	0.105	6,552	514.0	209,892	18,639
30-Apr	655	1,683	0.105	6,249	489.7	216,141	18,965
01-May	619	1,684	0.105	5,912	463.8	222,053	19,274
02-May	248	1,680	0.105	2,358	184.2	224,411	19,396
03-May	496	1,659	0.108	4,606	351.8	229,016	19,629
04-May	426	1,674	0.106	4,023	312.3	233,039	19,837
05-May	566	1,662	0.107	5,273	404.1	238,313	20,106
06-May	556	1,640	0.110	5,054	378.2	243,366	20,356
07-May	543 *	1,664	0.107	5,073 *		248,440	20,616
08-May	552 *	1,650	0.109	5,076 *		253,516	20,872
09-May	546 *	1,663	0.107	5,091 *		258,607	21,133
10-May	348 *	1,667	0.107	3,260 *		261,868	21,301
11-May	225 *	1,653	0.108	2,072 *		263,939	21,406
12-May	226 *	1,644	0.110	2,061 *		266,001	21,509
13-May	220 *	1,666 *	0.107 *	2,056 *		268,056	21,615
14-May	218	1,669 *	0.107 *	2,047 *	158.0	270,103	21,721
15-May	192	1,656 *	0.108 *	1,777 *	135.3	271,880	21,811
16-May	14	1,611 *	0.114 *	123 *	8.9	272,003	21,817
17-May	92	1,698	0.103	893	71.1	272,896	21,865
18-May	132	1,658	0.108	1,224	93.4	274,120	21,928
19-May	101	1,693	0.104	974	77.2	275,095	21,980
20-May	148	1,697	0.103	1,434	114.1	276,529	22,057
21-May	113	1,670	0.106	1,062	82.1	277,592	22,112
22-May	108	1,525	0.125	864	57.2	278,455	22,148
23-May	164	1,151	0.186	880	44.0	279,336	22,164
24-May	176	936	0.231	762	38.5	280,098	22,168
25-May	133 *	901	0.239	559 *		280,657	22,170
26-May	94	921	0.234	401	20.4	281,058	22,171
27-May	71	955	0.227	313	15.7	281,372	22,173
28-May	110	958	0.226	487	24.4	281,859	22,176
29-May	81	935	0.231	351	17.7	282,209	22,178
30-May	99	935	0.231	428	21.6	282,638	22,181
31-May	16	939	0.230	70	3.5	282,707	22,181
01-Jun	56	945	0.229	245	12.3	282,952	22,182
02-Jun	37	939	0.230	161	8.1	283,113	22,183
03-Jun	23	933	0.232	99	5.0	283,212	22,184
04-Jun	8	936	0.231	35	1.7	283,247	22,184

Date	Daily Screw-Trap Count (C)	Orange Blossom Bridge (OBB) Flow	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
05-Jun	9	933	0.232	39	2.0	283,285	22,184
06-Jun	4	929	0.232	17	0.9	283,303	22,184
07-Jun	27	976	0.222	122	6.1	283,424	22,185
08-Jun	38	1,281	0.163	234	12.4	283,658	22,191

*** Value to left is an interpolated value or is computed using interpolated value**

Appendix A.3. 1995 Flow, screw-trap count, and predicted screw-trap efficiency and daily and cumulative outmigration index values.

Date	Orange Blossom Bridge (OBB) Flow	Daily Screw-Trap Count (C)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
18-Mar	278	543	0.1930	2,814	868	2,814	868
19-Mar	276	653	0.1932	3,379	1,044	6,193	1,658
20-Mar	347	392	0.1838	2,133	608	8,326	2,069
21-Mar	831 *	330 *	0.1285 *	*		10,895	2,279
22-Mar	612	268	0.1515	1,769	375	12,664	2,517
23-Mar	2,090	242.5 *	0.0468 *	*		17,851	4,174
24-Mar	850	217	0.1266	1,713	345	19,564	4,340
25-Mar	325	565	0.1867	3,027	885	22,591	4,526
26-Mar	295	1062	0.1907	5,570	1,685	28,161	5,122
27-Mar	287	616	0.1917	3,213	981	31,374	5,524
28-Mar	273	692	0.1937	3,573	1,108	34,947	6,042
29-Mar	270	474	0.1941	2,443	760	37,390	6,418
30-Mar	267	197	0.1945	1,013	316	38,403	6,575
31-Mar	264	140	0.1949	718	225	39,121	6,688
01-Apr	224	75	0.2004	374	122	39,495	6,749
02-Apr	208	104	0.2027	513	171	40,008	6,834
03-Apr	209	133	0.2025	657	218	40,665	6,944
04-Apr	274	103	0.1935	532	165	41,197	7,031
05-Apr	302	113	0.1897	596	179	41,793	7,128
06-Apr	297	77	0.1904	404	122	42,197	7,195
07-Apr	320	67	0.1873	358	105	42,555	7,253
08-Apr	578	295	0.1554	1,899	416	44,454	7,514
09-Apr	581	242	0.1550	1,561	341	46,015	7,730
10-Apr	582	314	0.1549	2,027	442	48,042	8,013
11-Apr	586	239	0.1545	1,547	336	49,589	8,229
12-Apr	586	62	0.1545	401	87	49,991	8,285
13-Apr	590	74	0.1540	481	104	50,471	8,351
14-Apr	589	95	0.1541	616	134	51,088	8,437

Date	Orange Blossom Bridge (OBB) Flow	Daily Screw-Trap Count (C)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
15-Apr	1,117	115	0.1030	1,117	304	52,204	8,517
16-Apr	1,347	24	0.0858	280	105	52,484	8,529
17-Apr	1,328	66	0.0872	757	277	53,241	8,568
18-Apr	1,311	22	0.0883	249	89	53,490	8,581
19-Apr	1,301	46	0.0891	517	182	54,006	8,612
20-Apr	1,308	22	0.0886	248	88	54,255	8,627
21-Apr	1,305	39	0.0888	439	156	54,694	8,655
22-Apr	1,305	54	0.0888	608	216	55,302	8,696
23-Apr	1,301	36	0.0891	404	143	55,707	8,725
24-Apr	1,304	42	0.0888	473	167	56,179	8,760
25-Apr	1,409	48	0.0817	588	238	56,767	8,800
26-Apr	1,607	47	0.0696	675	345	57,442	8,840
27-Apr	1,516	21	0.0749	280	129	57,723	8,860
28-Apr	1,303	27	0.0889	304	107	58,026	8,887
29-Apr	1,312	19	0.0883	215	77	58,241	8,906
30-Apr	1,318	20	0.0879	228	82	58,469	8,927
01-May	1,355	20	0.0853	234	89	58,704	8,948
02-May	1,338	33	* 0.0865	*	*	59,085	8,984
03-May	1,332	46	0.0869	529	195	59,615	9,035
04-May	1,319	69	0.0878	786	284	60,401	9,116
05-May	1,316	28	0.0880	318	115	60,719	9,150
06-May	1,339	35	0.0864	405	150	61,124	9,193
07-May	1,323	34	0.0875	389	141	61,512	9,235
08-May	1,460	41	0.0784	523	226	62,035	9,292
09-May	1,588	49	0.0707	693	347	62,729	9,371
10-May	1,463	22	0.0782	281	122	63,010	9,404
11-May	1,313	36	0.0882	408	146	63,418	9,454
12-May	1,315	78	0.0881	886	318	64,304	9,567
13-May	1,353	49	0.0854	574	217	64,877	9,642
14-May	1,366	76	0.0846	899	345	65,776	9,765
15-May	1,389	27	0.0830	325	129	66,101	9,810
16-May	1,413	38	0.0814	467	190	66,568	9,876
17-May	1,424	65	0.0807	805	333	67,373	9,994
18-May	1,370	75	0.0843	890	344	68,263	10,128
19-May	1,345	81	0.0860	942	352	69,205	10,274
20-May	1,334	82	0.0867	945	348	70,151	10,423
21-May	1,328	49	0.0872	562	206	70,713	10,512
22-May	1,347	25	0.0858	291	109	71,004	10,559
23-May	1,329	52	0.0871	597	219	71,601	10,656
24-May	1,305	27	0.0888	304	108	71,905	10,706
25-May	1,311	30	0.0883	340	121	72,245	10,761
26-May	1,479	27	0.0772	350	155	72,595	10,823

Date	Orange Blossom Bridge (OBB) Flow	Daily Screw-Trap Count (C)	Predicted Efficiency (E)	Estimated Daily Passage (C/E)	SE of Daily Passage	Cumulative Passage	SE of Cumulative Passage
27-May	1,626	18	0.0685	263	137	72,857	10,873
28-May	1,482	13	0.0770	169	75	73,026	10,903
29-May	1,347	6	0.0858	70	26	73,096	10,915
30-May	1,338	22	0.0865	254	94	73,350	10,958
31-May	1,326	11	0.0873	126	46	73,476	10,980
01-Jun	1,185	12	0.0976	123	37	73,599	10,999
02-Jun	889	8	0.1229	65	13	73,664	11,008
03-Jun	673	49	0.1448	338	69	74,003	11,049
04-Jun	679	35	0.1441	243	49	74,246	11,078
05-Jun	684	15	0.1436	104	21	74,350	11,091
06-Jun	678	17	0.1442	118	24	74,468	11,106
07-Jun	684	24	0.1436	167	34	74,635	11,126
08-Jun	688	15	0.1432	105	21	74,740	11,139
09-Jun	674	18	0.1447	124	25	74,864	11,154
10-Jun	666	9	0.1455	62	13	74,926	11,161
11-Jun	675	17	0.1446	118	24	75,044	11,176
12-Jun	678	11	0.1442	76	15	75,120	11,185
13-Jun	682	12	0.1438	83	17	75,203	11,195
14-Jun	671	8	0.1450	55	11	75,259	11,202
15-Jun	606	3	0.1522	20	4	75,278	11,204
16-Jun	352	0	0.1831	0	0	75,278	11,204
17-Jun	271	2	0.1939	10	3	75,289	11,205
18-Jun	246	4	0.1974	20	6	75,309	11,207
19-Jun	245	2	0.1975	10	3	75,319	11,208
20-Jun	240	3	0.1982	15	5	75,334	11,209
21-Jun	237	4	0.1986	20	6	75,354	11,211
22-Jun	250	3	0.1968	15	5	75,370	11,212
23-Jun	268	3	0.1943	15	5	75,385	11,214
24-Jun	237	4	0.1986	20	6	75,405	11,216
25-Jun	238	0	0.1985	0	0	75,405	11,216
26-Jun	234	2	0.1990	10	3	75,415	11,217

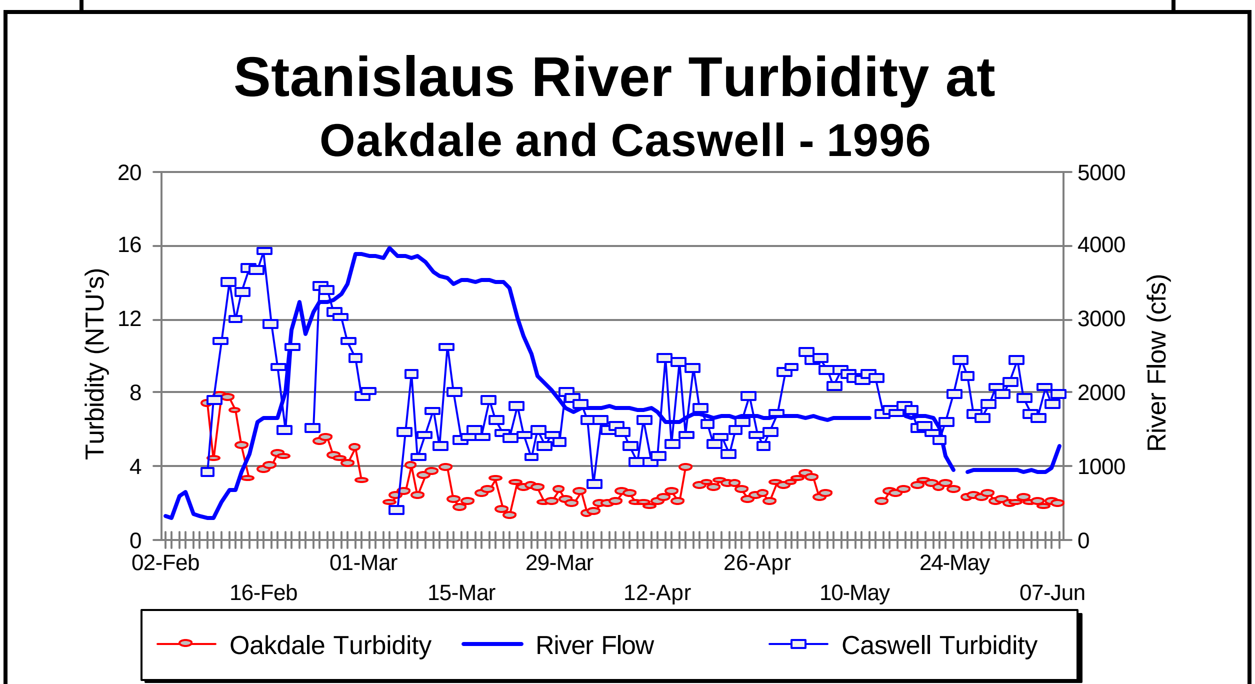
*** Value to left is an interpolated value or is computed using interpolated values**

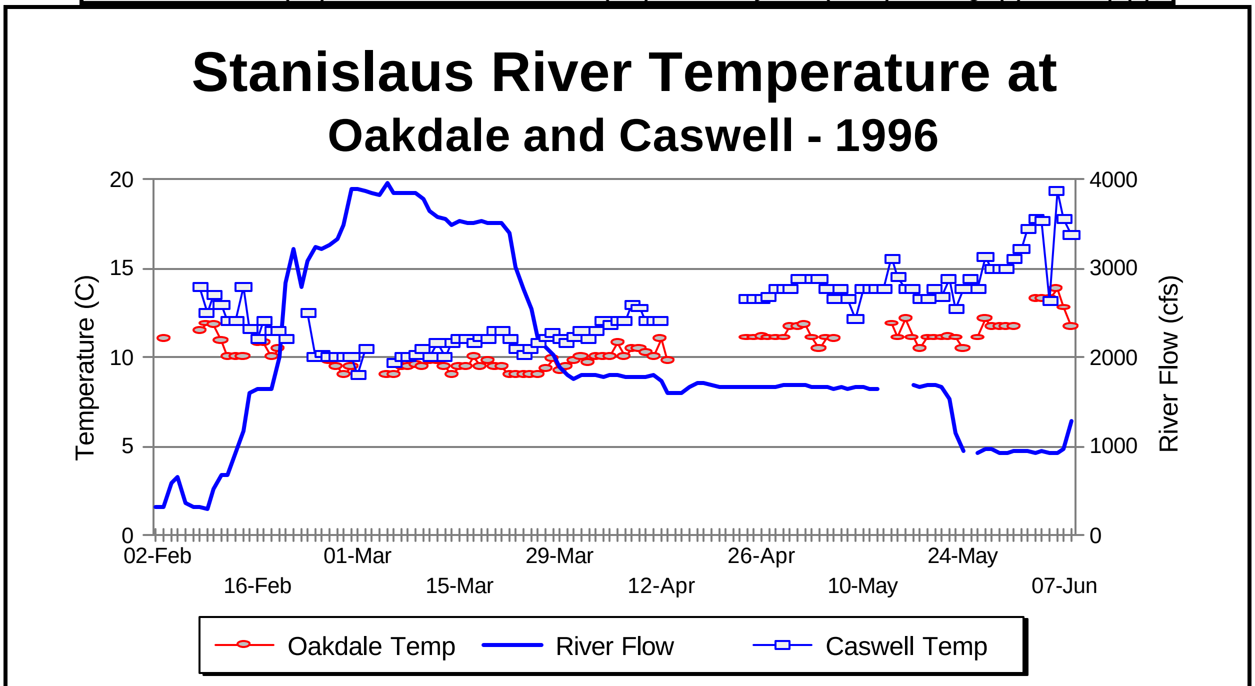
Appendix 1. Oakdale environmental data. Average daily flow measured at Orange Blossom Bridge and obtained from the CDEC Internet site. Water velocity is in ft/sec and was collected at a depth of 2 feet, directly in front of the screw trap. Water temperature was measured each morning with a hand-held thermometer.

Date	Ave. Daily Flow (cfs)	Time Trap Checked	Time per Revolution (sec)	Water Velocity	Turbidity (NTU's)	Stream Gage (ft)	Water Temp (C)
02-Feb	317	800	nd	nd	nd	nd	nd
03-Feb	302	700	nd	nd	nd	nd	11.0
04-Feb	591	700	nd	nd	nd	nd	nd
05-Feb	642	nd	nd	nd	nd	nd	nd
06-Feb	355	700	8.51	nd	nd	nd	nd
07-Feb	320	630	8.39	nd	nd	nd	nd
08-Feb	306	730	8.45	nd	7.4	nd	11.5
09-Feb	300	700	8.09	nd	4.4	0.30	11.9
10-Feb	516	700	8.00	nd	7.8	0.31	11.8
11-Feb	678	700	8.23	nd	7.7	1.40	10.9
12-Feb	681	700	7.00	nd	7.0	1.30	10.0
13-Feb	913	700	nd	nd	5.1	1.40	10.0
14-Feb	1179	700	nd	nd	3.3	2.20	10.0
15-Feb	1595	2200	nd	nd	nd	nd	nd
16-Feb	1648	600	8.44	nd	3.8	5+	10.8
17-Feb	1652	730	8.00	5.60	4.0	5+	10.8
18-Feb	1650	700	9.28	nd	4.7	5+	10.0
19-Feb	2014	700	nd	5.85	4.5	5+	10.5
20-Feb	2841	nd	nd	nd	nd	nd	nd
21-Feb	3223	nd	nd	nd	nd	nd	nd
22-Feb	2797	nd	nd	nd	nd	nd	nd
23-Feb	3093	nd	nd	nd	nd	nd	nd
24-Feb	3245	700	8.38	nd	5.3	5+	10.0
25-Feb	3232	730	7.87	nd	5.5	5+	9.9
26-Feb	3271	800	9.23	3.70	4.6	nd	9.8
27-Feb	3341	730	8.13	5.30	4.4	5+	9.5
28-Feb	3481	700	9.12	3.32	4.1	5+	9.0
29-Feb	3894	730	9.73	4.00	5.0	5+	9.5
01-Mar	3897	700	8.99	3.61	3.2	5+	9.0
02-Mar	3866	1900	nd	nd	nd	nd	nd
03-Mar	3856	nd	nd	nd	nd	nd	nd
04-Mar	3836	1100	nd	nd	nd	nd	nd
05-Mar	3975	700	9.03	3.57	2.0	2.10	9.0
06-Mar	3850	730	8.15	4.02	2.4	2.15	9.0
07-Mar	3847	800	8.19	3.98	2.6	2.10	9.5
08-Mar	3842	700	8.69	3.72	4.0	2.00	9.5
09-Mar	3849	730	8.70	3.85	2.4	2.10	9.6
10-Mar	3782	730	8.60	4.50	3.5	1.95	9.5
11-Mar	3641	700	8.48	3.46	3.7	1.90	9.8
12-Mar	3584	700	6.94	4.22	nd	1.80	9.8
13-Mar	3552	700	9.63	4.52	3.9	1.70	9.5
14-Mar	3489	730	8.12	3.64	2.2	1.45	9.0
15-Mar	3529	700	7.99	4.82	1.7	1.40	9.5
16-Mar	3524	800	8.14	4.50	2.1	1.60	9.5
17-Mar	3519	730	8.50	3.90	nd	1.60	10.0

Date	Ave. Daily Flow (cfs)	Time Trap Checked	Time per Revolution (sec)	Water Velocity	Turbidity (NTU's)	Stream Gage (ft)	Water Temp (C)
18-Mar	3530	700	8.26	3.30	2.5	1.60	9.5
19-Mar	3522	700	11.92	5.40	2.7	1.55	9.8
20-Mar	3503	800	9.06	3.74	3.3	1.50	9.5
21-Mar	3509	730	10.00	4.35	1.6	1.50	9.5
22-Mar	3413	700	7.11	3.86	1.3	1.60	9.0
23-Mar	3010	700	9.20	3.57	3.1	0.80	9.0
24-Mar	2761	700	8.77	4.53	2.8	0.40	9.0
25-Mar	2539	700	7.48	5.40	2.9	0.20	9.0
26-Mar	2226	700	nd	nd	2.8	nd	9.0
27-Mar	2125	700	10.85	6.73	2.0	nd	9.4
28-Mar	2024	700	8.59	5.35	2.1	5+	9.9
29-Mar	1896	700	7.59	5.41	2.7	5+	9.2
30-Mar	1790	700	9.11	4.85	2.2	5+	9.5
31-Mar	1748	730	9.04	5.07	1.9	nd	9.8
01-Apr	1794	700	9.62	4.76	2.6	5+	10.0
02-Apr	1791	700	10.37	3.56	1.4	5+	9.7
03-Apr	1794	700	8.45	4.75	1.5	nd	10.0
04-Apr	1788	700	9.33	4.62	1.9	5+	10.0
05-Apr	1809	700	10.37	4.75	1.9	nd	10.0
06-Apr	1791	700	8.23	4.91	2.1	2.30	10.8
07-Apr	1780	700	7.50	4.30	2.6	2.21	10.0
08-Apr	1779	700	nd	4.66	2.5	2.25	10.5
09-Apr	1775	700	10.09	4.76	2.0	2.25	10.5
10-Apr	1776	700	8.48	5.02	2.0	2.20	10.3
11-Apr	1791	700	8.58	6.00	1.8	2.20	10.0
12-Apr	1731	930	9.65	3.70	2.1	2.16	11.0
13-Apr	1598	700	11.07	4.29	2.3	1.88	9.8
14-Apr	1595	730	8.47	4.80	2.6	1.85	nd
15-Apr	1599	800	9.59	4.69	2.1	1.90	nd
16-Apr	1656	700	9.55	5.07	3.9	1.86	nd
17-Apr	1706	700	10.23	4.64	nd	1.90	nd
18-Apr	1711	700	10.77	4.61	2.90	2.00	nd
19-Apr	1679	730	8.76	4.93	3.1	1.85	nd
20-Apr	1670	700	9.79	4.71	2.8	1.82	nd
21-Apr	1675	730	8.96	5.10	3.2	1.80	nd
22-Apr	1673	730	8.67	5.12	3.0	1.80	nd
23-Apr	1668	830	9.52	4.93	3.0	1.80	nd
24-Apr	1673	730	9.01	5.20	2.7	1.79	11.1
25-Apr	1676	700	9.64	4.34	2.2	1.80	11.1
26-Apr	1676	700	9.81	4.81	2.4	1.86	11.2
27-Apr	1662	800	9.89	4.77	2.5	1.80	11.1
28-Apr	1668	700	9.33	4.87	2.1	1.80	11.1
29-Apr	1684	800	9.99	4.61	3.1	1.83	11.1
30-Apr	1683	730	9.03	5.12	2.9	1.80	11.7
01-May	1684	1130	10.07	4.48	3.1	1.79	11.7
02-May	1680	1000	nd	nd	3.3	1.80	11.8
03-May	1659	700	11.00	4.26	3.6	1.80	11.1
04-May	1674	700	8.59	4.89	3.4	1.80	10.5
05-May	1662	800	9.50	4.44	2.3	1.78	11.1
06-May	1640	730	nd	5.13	2.5	1.80	11.0
07-May	1664	nd	nd	nd	nd	nd	nd

Date	Ave. Daily Flow (cfs)	Time Trap Checked	Time per Revolution (sec)	Water Velocity	Turbidity (NTU's)	Stream Gage (ft)	Water Temp (C)
08-May	1650	nd	nd	nd	nd	nd	nd
09-May	1663	nd	nd	nd	nd	nd	nd
10-May	1667	nd	nd	nd	nd	nd	nd
11-May	1653	nd	nd	nd	nd	nd	nd
12-May	1644	nd	nd	nd	nd	nd	nd
13-May	-	nd	nd	nd	nd	nd	nd
14-May	-	700	8.24	4.80	2.1	1.80	11.9
15-May	-	900	8.89	4.85	2.6	1.76	11.1
16-May	-	700	8.51	5.62	2.5	2.08	12.2
17-May	1698	700	9.35	5.03	2.7	1.88	11.1
18-May	1658	800	8.96	4.88	nd	1.82	10.5
19-May	1693	830	9.57	4.66	2.9	1.80	11.1
20-May	1697	830	9.26	4.97	3.2	1.88	11.1
21-May	1670	700	8.29	4.75	3.0	1.80	11.1
22-May	1525	700	8.61	4.87	2.8	1.80	11.2
23-May	1151	700	9.26	4.95	3.0	0.96	11.1
24-May	936	800	10.54	4.43	2.7	0.72	10.5
25-May	-	nd	nd	nd	nd	nd	nd
26-May	921	815	9.80	4.80	2.3	0.18	11.1
27-May	955	700	10.61	4.89	2.4	0.02	12.2
28-May	958	700	10.72	5.30	2.3	0.32	11.7
29-May	935	730	10.93	4.48	2.5	0.20	11.7
30-May	935	700	9.73	nd	2.1	0.02	11.7
31-May	939	800	9.73	4.84	2.2	1.18	11.7
01-Jun	945	745	11.04	4.30	1.9	1.20	nd
02-Jun	939	800	11.59	6.03	2.0	0.20	nd





Date	Ave. Daily Flow (cfs)	Time Trap Checked	Time per Revolution (sec)	Water Velocity	Turbidity (NTU's)	Stream Gage (ft)	Water Temp (C)
03-Jun	933	630	8.83	5.03	2.3	0.20	13.3
04-Jun	936	730	10.34	4.80	2.0	0.20	13.3
05-Jun	933	700	nd	5.33	2.1	0.16	13.3
06-Jun	929	700	9.18	5.20	1.8	0.16	13.9
07-Jun	976	700	9.48	5.00	2.1	0.04	12.8
08-Jun	1281	845	9.54	4.89	1.9	0.93	11.7

Stanislaus River flow measured at Orange Blossom Bridge. Temperature measured with hand-held thermometer.

Appendix 2. Mean lengths of chinook captured at Oakdale and Caswell during 1996. Extreme Lengths are the lengths of individual fish captured that fell outside the range of the average fall-run captured.

		Oakdale			Caswell	
Date	OBB Flow (cfs)	# Chinook Captured	Mean Length (mm)	Extreme Length (mm)	# Chinook Captured	Mean Length (mm)
02-Feb	317	1046	35.9		-	-
03-Feb	302	493	34.7		-	-
04-Feb	591	104	36.3		-	-
05-Feb	642	ND	-		-	-
06-Feb	355	5452	35.4		89	34.9
07-Feb	320	2289	-		42	-
08-Feb	306	565	35.5		44	34.1
09-Feb	300	194	37.2		13	-
10-Feb	516	222	37.5		2	-
11-Feb	678	1454	-	169	0	-
12-Feb	681	1449	35.4		6	35.2
13-Feb	913	1179	-		2	-
14-Feb	1179	200	-		28	-
15-Feb	1595	ND	-		39	34.8
16-Feb	1648	187	-		16	-
17-Feb	1652	257	-		44	-
18-Feb	1650	149	-		57	-
19-Feb	2014	109	36.2		52	34.8
20-Feb	2841	ND	-		37	-
21-Feb	3223	ND	-		-	-
22-Feb	2797	ND	-		-	-
23-Feb	3093	ND	-		113	35
24-Feb	3245	65	-		3	-
25-Feb	3232	71	-		24	-

		Oakdale			Caswell	
Date	OBB Flow (cfs)	# Chinook Captured	Mean Length (mm)	Extreme Length (mm)	# Chinook Captured	Mean Length (mm)
26-Feb	3271	21	34.9		11	35.5
27-Feb	3341	51	-		16	-
28-Feb	3481	47	-		11	-
29-Feb	3894	22	37.6		5	40.4
01-Mar	3897	49	-		6	34.8
02-Mar	3866	ND	-		1	-
03-Mar	3856	26	-		-	-
04-Mar	3836	ND	-		-	-
05-Mar	3975	16	37.3		-	-
06-Mar	3850	24	-		0	-
07-Mar	3847	5	41.8		4	44
08-Mar	3842	18	41.6		4	-
09-Mar	3849	11	45.8		1	-
10-Mar	3782	13	41.8		0	-
11-Mar	3641	6	49.3		0	-
12-Mar	3584	4	42.5		1	38
13-Mar	3552	16	40.9		0	-
14-Mar	3489	9	55.5		1	44
15-Mar	3529	3	41.7		0	-
16-Mar	3524	15	42.5		1	51
17-Mar	3519	5	47.0		0	-
18-Mar	3530	8	65.9		2	38
19-Mar	3522	10	45.4		0	-
20-Mar	3503	3	47.5		1	45
21-Mar	3509	3	45.7		0	-
22-Mar	3413	3	67.0		0	-
23-Mar	3010	4	90.0	160	0	-
24-Mar	2761	4	72.5		0	-
25-Mar	2539	18	73.6		0	-
26-Mar	2226	30	75.5		4	77.5
27-Mar	2125	74	79.2		2	76.5
28-Mar	2024	82	76.7		7	80.4
29-Mar	1896	149	71.6		10	81.7
30-Mar	1790	238	76.9		3	74
31-Mar	1748	284	82.4	151	5	74.8
01-Apr	1794	262	78.5		3	88
02-Apr	1791	200	81.1		3	90
03-Apr	1794	332	77.5		8	84
04-Apr	1788	265	80.5	233	18	82.9
05-Apr	1809	249	79.5		9	82.8
06-Apr	1791	249	79.4		14	87.5
07-Apr	1780	188	80.3		13	76.9
08-Apr	1779	160	81.9		1	81
09-Apr	1775	104	82.9		8	86.2
10-Apr	1776	135	80.7		4	80.8
11-Apr	1791	114	82.7		2	79.7
12-Apr	1731	79	84.9		9	87.1
13-Apr	1598	129	83.3		2	80.5
14-Apr	1595	239	84.0		0	-
15-Apr	1599	158	86.5		10	85.5

		Oakdale			Caswell	
Date	OBB Flow (cfs)	# Chinook Captured	Mean Length (mm)	Extreme Length (mm)	# Chinook Captured	Mean Length (mm)
16-Apr	1656	118	90.2		2	97.5
17-Apr	1706	212	83.8		3	91.3
18-Apr	1711	155	87.7		6	84.7
19-Apr	1679	295	84.3		15	86.2
20-Apr	1670	194	86.4		1	84
21-Apr	1675	152	84.2		22	89.8
22-Apr	1673	340	88.6		36	91.1
23-Apr	1668	343	89.3		20	89.7
24-Apr	1673	269	89.5		38	89.7
25-Apr	1676	415	87.2		39	92.2
26-Apr	1676	704	89.1		38	91.2
27-Apr	1662	584	89.8		95	91
28-Apr	1668	727	91.8		109	91.6
29-Apr	1684	655	91.3		89	91.9
30-Apr	1683	625	92.7		121	90.9
01-May	1684	589	91.0		40	91.2
02-May	1680	448	92.6		84	93.4
03-May	1659	296	90.3		44	92.8
04-May	1674	435	89.1		67	90.5
05-May	1662	566	92.1		107	93.5
06-May	1640	556	91.1		73	91
07-May	1664	-	-		42	92.1
08-May	1650	-	-		47	91.9
09-May	1663	-	-		47	90.6
10-May	1667	-	-		21	90.6
11-May	1653	-	-		60	91.5
12-May	1644	-	-		20	91.2
13-May	-	-	-		6	94.8
14-May	-	219	92.2		16	92.4
15-May	-	191	97.8		5	98.2
16-May	-	14	95.7		19	91.2
17-May	1698	92	94.2		10	93.7
18-May	1658	132	95.6		14	95.8
19-May	1693	101	96.4		10	99.5
20-May	1697	148	95.2		19	95
21-May	1670	113	97.7		23	95.5
22-May	1525	108	92.8		8	94.1
23-May	1151	164	94.3		9	95.9
24-May	936	176	93.5		18	94.6
25-May		0	-		20	95.1
26-May	921	94	95.0		52	95
27-May	955	130	92.9		30	94.6
28-May	958	51	94.6		15	92.4
29-May	935	81	96.0		22	93
30-May	935	99	96.5		9	93.3
31-May	939	15	96.1		10	95.9
01-Jun	945	56	96.5		10	98
02-Jun	939	37	96.0		11	97.3
03-Jun	933	23	93.8		2	92
04-Jun	936	8	95.0		2	99

Date	OBB Flow (cfs)	Oakdale # Chinook Captured	Oakdale Mean Length (mm)	Oakdale Extreme Length (mm)	Caswell # Chinook Captured	Caswell Mean Length (mm)
05-Jun	933	9	96.7		7	98
06-Jun	929	4	101.5		3	100
07-Jun	976	27	96.1		1	91
08-Jun	1281	38	97.1		4	99.3
09-Jun	1275	0	-		2	93
10-Jun	1279	-	-		0	-
11-Jun	1300	-	-		0	-
12-Jun	1308	-	-		3	87
13-Jun	1292	-	-		2	90
14-Jun	1200	-	-		2	87
15-Jun	1077	-	-		0	-
16-Jun	928	-	-		0	-
17-Jun	848	-	-		1	89
18-Jun	850	-	-		0	-
19-Jun	844	-	-		0	-
20-Jun	829	-	-		0	-
21-Jun	821	-	-		1	96
22-Jun	833	-	-		0	-
23-Jun	811	-	-		1	111
24-Jun	825	-	-		1	105
25-Jun	842	-	-		0	-
26-Jun	852	-	-		0	-
27-Jun	831	-	-		1	94
28-Jun	815	-	-		0	-
29-Jun	776	-	-		0	-
30-Jun	757	-	-		1	109
01-Jul	752	-	-		1	101
02-Jul	763	-	-		-	-

Appendix 2b. Length frequencies of juvenile chinook captured in the rotary screw trap at Oakdale each week, 1996.

Length Interval (mm)	Julian Week 5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Full Year
0-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

21-30	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3
31-40	85	114	30	28	36	44	33	11	5	1	0	0	0	0	0	0	0	0	0	387
41-50	2	2	0	0	0	3	4	2	0	0	0	0	0	0	0	0	0	0	0	13
51-60	2	2	0	1	0	4	7	5	7	5	3	2	0	0	1	0	0	0	0	39
61-70	0	2	0	0	0	3	7	4	40	43	24	12	2	1	0	0	0	2	0	140
71-80	0	0	0	0	1	1	2	6	53	74	53	44	26	10	2	4	7	3	2	288
81-90	0	0	0	0	0	1	1	5	62	90	84	83	98	89	9	38	45	54	20	679
91-100	0	0	0	0	0	0	0	0	18	22	42	57	86	93	17	95	93	114	54	691
101-110	0	0	0	0	0	0	0	0	0	1	5	12	16	18	2	21	29	45	21	170
111-120	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	10	4	9	3	27
121-130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3
131-140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
141-150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151-160	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
161-170	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
171-180	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181-190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201-210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
211-220	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221-230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
231-240	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Appendix 3. Smolt appearance ratings for al chinook evaluated at Oakdale during 1996.

Date	Total Chn Captured	Total Chn Indexed	Smolt Index 1	Smolt Index 2	Smolt Index 3
02-Feb	1,046	30	30	0	0

Date	Total Chn Captured	Total Chn Indexed	Smolt Index 1	Smolt Index 2	Smolt Index 3
03-Feb	493	30	30	0	0
04-Feb	104	30	30	0	0
05-Feb	-	-	-	-	-
06-Feb	5,452	30	30	0	0
07-Feb	2,289	0	0	0	0
08-Feb	595	30	30	0	0
09-Feb	194	30	30	0	0
10-Feb	222	30	30	0	0
11-Feb	1,305	1	0	0	1
12-Feb	1,449	30	30	0	0
13-Feb	1,179	0	0	0	0
14-Feb	200	0	0	0	0
15-Feb	75	0	0	0	0
16-Feb	112	0	0	0	0
17-Feb	196	0	0	0	0
18-Feb	188	0	0	0	0
19-Feb	109	30	29	1	0
20-Feb	18	0	0	0	0
21-Feb	-	-	-	-	-
22-Feb	-	-	-	-	-
23-Feb	-	-	-	-	-
24-Feb	65	0	0	0	0
25-Feb	71	0	0	0	0
26-Feb	21	15	15	0	0
27-Feb	51	0	0	0	0
28-Feb	47	0	0	0	0
29-Feb	22	4	3	1	0
01-Mar	49	0	0	0	0
02-Mar	-	-	-	-	-
03-Mar	26	0	0	0	0
04-Mar	-	-	-	-	-
05-Mar	25	15	14	1	0
06-Mar	34	0	0	0	0
07-Mar	5	4	4	0	0
08-Mar	18	16	15	1	0
09-Mar	12	7	5	2	0
10-Mar	13	8	7	1	0
11-Mar	6	2	2	0	0
12-Mar	4	2	2	0	0
13-Mar	21	12	9	3	0
14-Mar	9	7	3	4	0
15-Mar	3	2	2	0	0
16-Mar	15	13	10	3	0
17-Mar	5	3	2	1	0
18-Mar	8	6	2	2	2
19-Mar	10	7	5	2	0
20-Mar	3	2	1	1	0
21-Mar	3	2	2	0	0
22-Mar	3	2	1	0	1
23-Mar	4	4	0	3	1
24-Mar	4	4	0	4	0

Date	Total Chn Captured	Total Chn Indexed	Smolt Index 1	Smolt Index 2	Smolt Index 3
25-Mar	18	15	1	11	3
26-Mar	30	15	0	15	0
27-Mar	77	30	0	26	4
28-Mar	79	30	1	29	0
29-Mar	149	30	3	22	5
30-Mar	238	30	0	30	0
31-Mar	284	32	1	30	1
01-Apr	262	30	1	25	4
02-Apr	200	30	0	29	1
03-Apr	332	30	0	30	0
04-Apr	265	31	0	30	1
05-Apr	248	30	0	28	2
06-Apr	249	30	0	26	4
07-Apr	188	30	0	30	0
08-Apr	160	30	0	22	8
09-Apr	104	30	0	20	10
10-Apr	135	32	0	22	10
11-Apr	114	30	0	23	7
12-Apr	79	30	0	26	4
13-Apr	129	28	0	22	6
14-Apr	239	30	0	29	1
15-Apr	158	30	0	26	4
16-Apr	118	30	0	28	2
17-Apr	212	30	0	27	3
18-Apr	155	30	0	26	4
19-Apr	295	30	0	19	11
20-Apr	194	30	0	27	3
21-Apr	152	30	0	26	4
22-Apr	340	30	0	23	7
23-Apr	315	0	0	0	0
24-Apr	297	30	0	25	5
25-Apr	415	30	0	16	14
26-Apr	704	30	0	29	1
27-Apr	584	30	0	29	1
28-Apr	727	30	0	15	15
29-Apr	686	30	0	22	8
30-Apr	655	30	0	20	10
01-May	619	30	0	19	11
02-May	248	30	0	29	1
03-May	496	30	0	20	10
04-May	426	30	0	29	1
05-May	566	30	0	19	11
06-May	556	30	0	29	1
07-May	-	-	-	-	-
08-May	-	-	-	-	-
09-May	-	-	-	-	-
10-May	-	-	-	-	-
11-May	-	-	-	-	-
12-May	-	-	-	-	-
13-May	-	-	-	-	-
14-May	218	29	0	29	0

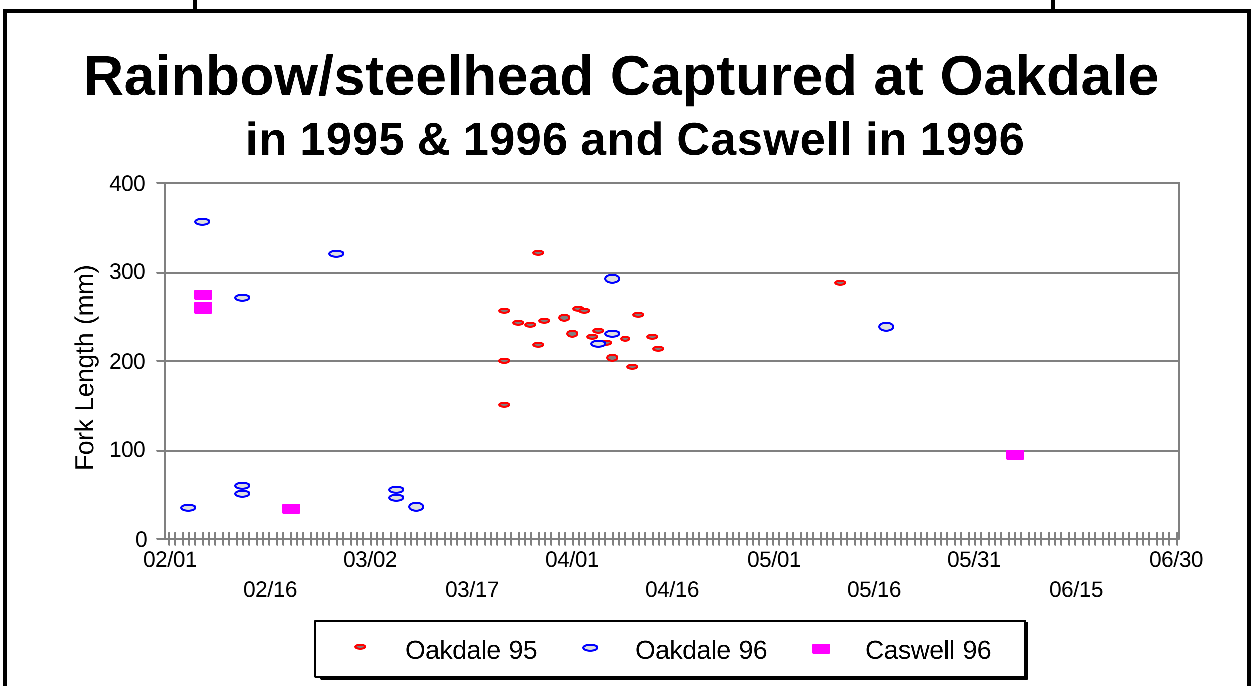
Date	Total Chn Captured	Total Chn Indexed	Smolt Index 1	Smolt Index 2	Smolt Index 3
15-May	192	30	0	30	0
16-May	14	11	0	11	0
17-May	92	30	0	23	7
18-May	132	30	0	1	29
19-May	101	30	0	5	25
20-May	148	30	0	25	5
21-May	113	30	0	19	11
22-May	108	30	0	27	3
23-May	164	30	0	28	2
24-May	176	30	0	2	28
25-May	-	-	-	-	-
26-May	94	30	0	5	25
27-May	71	30	0	26	4
28-May	110	60	0	32	28
29-May	81	30	0	7	23
30-May	99	0	0	0	0
31-May	16	16	0	2	14
01-Jun	56	30	0	5	25
02-Jun	37	30	0	1	29
03-Jun	23	23	0	4	19
04-Jun	8	4	0	4	0
05-Jun	9	3	0	3	0
06-Jun	4	3	0	1	2
07-Jun	27	27	0	15	12
08-Jun	38	0	0	0	0
	30,411		380	1,363	494

Appendix 4. Date and individual lengths of rainbow/steelhead captured at Oakdale and Caswell by S. P. Cramer & Associates since 1993. Data does not include fish captured by CDFG at Oakdale in 1994, or at Caswell in 1994 or 1995.

Date	Number	Fork Length (mm)	Smolt Index	Sampling Location
04/22/93	1	nd	nd	Oakdale
04/26/93	1	nd	nd	Oakdale
04/27/93	1	nd	nd	Oakdale
05/02/93	3	nd	nd	Oakdale
05/12/93	1	nd	nd	Oakdale
05/18/93	1	nd	nd	Oakdale
05/29/93	1	nd	nd	Oakdale
06/08/93	1	nd	nd	Oakdale
03/22/95	1	200	3	Oakdale
03/22/95	1	150	3	Oakdale
03/22/95	1	200	1	Oakdale
03/22/95	1	255	1	Oakdale
03/24/95	1	242	1	Oakdale
03/26/95	1	240	1	Oakdale
03/27/95	1	217	3	Oakdale
03/27/95	1	321	3	Oakdale
03/28/95	1	245	3	Oakdale
03/31/95	1	248	3	Oakdale
04/01/95	1	230	3	Oakdale
04/02/95	1	258	3	Oakdale
04/03/95	1	256	3	Oakdale
04/04/95	1	227	1	Oakdale
04/05/95	1	233	3	Oakdale
04/06/95	1	219	3	Oakdale
04/07/95	1	203	3	Oakdale
04/09/95	1	224	3	Oakdale
04/10/95	1	193	3	Oakdale
04/11/95	1	252	3	Oakdale
04/13/95	1	227	3	Oakdale

Date	Number	Fork Length (mm)	Smolt Index	Sampling Location
04/14/95	1	213	3	Oakdale
05/11/95	1	288	3	Oakdale
02/04/96	1	34	1	Oakdale
02/06/96	1	356	3	Oakdale
02/12/96	1	270	3	Oakdale
02/12/96	1	49	1	Oakdale
02/12/96	1	58	1	Oakdale
02/26/96	1	320	1	Oakdale
03/06/96	1	45	1	Oakdale
03/06/96	1	55	1	Oakdale
03/09/96	1	35	1	Oakdale
04/05/96	1	218	3	Oakdale
04/07/96	1	230	3	Oakdale
04/07/96	1	292	3	Oakdale
05/18/96	1	238	3	Oakdale
02/06/96	1	275	3	Caswell
02/06/96	1	260	3	Caswell
02/19/96	1	34	1	Caswell
06/06/96	1	94	2	Caswell

nd = no data



Date	Number	Fork Length (mm)	Smolt Index	Sampling Location

Smolt Index: 1 = obvious parr; 3 obvious smolt

All sampling conducted with rotary screw traps.

One trap fishing at Oakdale and two at Caswell.

Appendix 5. Species other than salmon and trout captured in the screw trap.

Date	bcat	bcrp	blcat	blg	bow	car	cat	chcat	crp	crw	gld	gshn	hit	hsqf	lam	lgb	min	mqf	per	rsun	sas	sck	scp	shn	sqf	stl	sun	thf	tlp	unk	wcat	wcrp
02-Feb						1	4												3				5		5							
03-Feb									1						3		1		1				2		3							
04-Feb					1		1		2						1								2		3							
06-Feb					1		7				2				3				1			7	1		2		1					
07-Feb							1		2															1	4		1			1		
08-Feb						1			2												1											
09-Feb									1		1								2				2									
10-Feb									1						1							1	2		2							
11-Feb											1											5	1		4				1			
12-Feb					2				1									1				3		1	2	1						
13-Feb																																
14-Feb									1															1	2							
15-Feb																																
16-Feb																						1	1		1							
17-Feb									1													2	1		1							
18-Feb																									1		1					
19-Feb									1																1							
24-Feb											2											12	4		7							
25-Feb																						4			2							
26-Feb					1				1													4	1		8		1					
27-Feb																						1	2		8							
28-Feb							1											1							3				1			
29-Feb																						7	3		42							
01-Mar															1							5			28							
02-Mar																						4	1		101							1
04-Mar																						2			1							
05-Mar																							1		20							
06-Mar					2																	2			15							
07-Mar																									2							
08-Mar											1											8	2		57							
09-Mar					1						2				2							3	1		15							
10-Mar																						1	1		6							

Date	bcat	bcrp	blcat	blg	bow	car	cat	chcat	crp	crw	gld	gshn	hit	hsgf	lam	lgb	min	mgf	per	rsun	sas	sck	scp	shn	sgf	stl	sun	thf	tlp	unk	wcat	wcrp
11-Mar	1																						1			6							
12-Mar															1								1			9							
13-Mar																							1			6							
14-Mar																							4			2							
15-Mar											1																6							
16-Mar																							3			10							
17-Mar																										4							
18-Mar																							6			10							
19-Mar																							2			8							
20-Mar															4										3							
21-Mar															1								3			10							
22-Mar															2								2	1	1	5							
23-Mar																							1			1							
24-Mar		1													2								5	1		10							1
25-Mar															1								4			17							
26-Mar															4										9							
27-Mar			1							2	1					1								2			6							
28-Mar															4								2			15							
29-Mar																							2			14							
30-Mar											1				7			1				4			7							
31-Mar															8			1				5			11							
01-Apr															1								5			1							
02-Apr																							4			12							
03-Apr															5								8			7							
04-Apr																							10	1		18							
05-Apr		1																				2			10	1					
06-Apr																							5			11							3
07-Apr				1											1			3				2			5	2					
08-Apr						1																									1			
09-Apr																							7			7							
10-Apr															1								1			3							
11-Apr		1													7										4							
12-Apr															1								3			4							4
13-Apr																										2							3
14-Apr		2											1		2								3			2							
15-Apr															1								2			3							
16-Apr						1		1															2			2							
17-Apr																																
18-Apr																																
19-Apr													1																			
20-Apr																																
21-Apr															2								2			1							
22-Apr				1																			1			1							
23-Apr																							3			5							
24-Apr		1											1													2							
25-Apr		1									1	4			2								2		3	5							2
26-Apr		3										2							1					4	3							
27-Apr												7				3			1				1			8							
28-Apr															3								4		8	3			1	2			
29-Apr		2													2										3	1							
30-Apr											1											2			5			2				
01-May		1													2										1	2							
02-May															1			1						1	3							1
03-May																																
04-May																		2		1		7						1			1	
05-May															3								2		1	2							
06-May												1														1							
14-May																							2			2				1			
15-May																										3							
16-May															3																	
17-May								1																						1			

Date	bcat	bcrp	blcat	blg	bow	car	cat	chcat	crp	crw	gld	gshn	hit	hsqf	lam	lgb	min	mgf	per	rsun	sas	sck	scp	shn	sqf	stl	sun	thf	tlp	unk	wcat	wcrp
18-May											1				2							1				1						
19-May															2					1												
20-May	1										2																		1			
21-May																									2				1			
22-May				1																												
23-May																							1									
24-May											1				5	5				1		4			1							
26-May																						1			1							
27-May																						2			1				1			
28-May																									1				2		1	
29-May						1																			2							
30-May											1			1															1			
31-May	1																			1		2										
01-Jun																									1				1			
02-Jun		1													1																	
03-Jun																									2							
04-Jun								1																	1							
05-Jun											1				1																	
06-Jun																									2				1			
07-Jun															2							3			3				1			
08-Jun															1										2							