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Project No. 17: Klamath River Basin Juvenile Salmonid Investigations

Job No. 5: Length of Residency of Juvenile Chinook Salmon in the Klamath River Estuary

California Department of Fish and Game

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I. Summary: A juvenile chinook salmon length of residence study in the Klamath River estuary was conducted during the summers of 1997, 1998 and 1999 to determine if the estuary is important rearing habitat for young-of-the-year (YOY) chinook salmon. We captured 11,709, 7,902 and 8,685 YOY chinook salmon and marked 10,047, 6,545 and 6,439 in 1997, 1998 and 1999, respectively. Annual mean estuarine residence times of recaptured YOY chinook salmon were 8.7, 12.0 and 16.2 days in 1997, 1998 and 1999, respectively, and their individual residence times ranged from 1 to 56 days. The average growth of recaptured chinook salmon was 0.10, 0.37 and 0.58 mm/day in 1997, 1998 and 1999, respectively. In all three years of this study project marked YOY chinook salmon released during the second half of sampling seasons had longer mean residence times than fish marked and released during the first half of the season. Mean residence time for fish marked in the first and second half of the sampling season was 6.4 and 10.0 days respectively in 1997; 6.5 and 13.4 days respectively in 1998; and 12.9 and 17.5 days respectively in 1999. Our estimated catch efficiency (seining and electrofishing June-September) was 0.31% in 1997, 0.42% in 1998 and 0.15% in 1999. It appears a higher portion of YOY chinook salmon rear in the Klamath River estuary in the late summer, and rear there for a longer period of time, compared to fish that emigrate during the time of peak catches in late June and early July. Since these late summer emigrants are composed of a higher portion of natural origin fish than during peak emigration, the Klamath River estuary may be more important to natural origin than hatchery origin YOY chinook salmon.

II. Background: Many researchers have noted that some salmonids use estuaries as rearing areas for extended periods of time (Snyder 1931; Reimers 1971; Healey 1980; Healey 1982; Kjelson et al. 1982 ; Levy and Northcote 1982; and Myers and Horton 1982). In the Klamath River estuary Snyder (1931) concluded, from an analysis of scale circuli spacing, that some juvenile chinook salmon reared there for an extended period of time and that their estuary growth rate approached that in the ocean. In the Sixes River estuary, Oregon, Reimers (1971) observed that the bulk of adult chinook salmon returns were made up from juveniles which had reared in the estuary until they attained a larger than normal size at ocean entry. Nicholas and Hankin (1989), believed that optimum survival is achieved by juvenile chinook salmon that enter the ocean in late summer or early fall at a relatively large size and concluded that extended estuarine rearing provided a survival advantage. Therefore, it seems likely that extended estuarine rearing in the Klamath estuary would be beneficial to adult chinook salmon returns to the Klamath basin.

However, more recent studies have led researchers to conclude that little juvenile chinook salmon rearing now takes place in the Klamath River estuary (Sullivan 1989; Krakker 1991). Ratti (1979) stated that a comparison of 1945 and 1975 adult chinook salmon scales from the Rogue River indicated that juvenile spring and fall chinook salmon spent much less time rearing in the Rogue River estuary than they did 20 years earlier. He hypothesized that extensive modifications to the estuary may be the cause for the apparent decreased residence times. The authors of the Klamath Basin Long Range Plan speculated that increased sediment filled deeper holes in the Klamath River estuary during the 1970's which reduced the estuary s ability to function as a rearing area (Klamath River Task Force 1991). If sufficient changes in the Klamath River estuary have occurred, (such as filling by fine sediments or poorer water quality entering the estuary) then it is possible that juvenile chinook salmon are now rearing in the Klamath River estuary for a shorter period of time than when Snyder conducted his study. This reduction in estuary rearing by juvenile chinook salmon could be another factor depressing adult salmon returns to the basin.

One way to gage the importance of an estuary to juvenile chinook salmon is to determine how long they reside in the estuary. The California Department of Fish and Game's (CDFG) Natural Stocks Assessment Project (NSAP) conducted a juvenile chinook salmon length of residence study in the Klamath River estuary from 1997 through 1999. The study's goal was to determine the value of the estuary as a rearing area for juvenile chinook salmon. The primary objective was to determine if, and how long young-of-the-year (YOY) chinook salmon reside in the estuary. The study also attempted to determine the residency patterns of natural and hatchery origin chinook salmon, of different sized juvenile chinook, and of chinook entering the estuary at different times of the year.

III. <u>Objectives</u>:

1) To determine the length of residency for juvenile chinook salmon in the Klamath River estuary.
2) Differentiate the length of juvenile chinook salmon residency in the Klamath River estuary between natural and hatchery stocks, size of fish, and seasonal estuary entry pattern.

IV. <u>Procedures</u>: I defined the estuary as the lower 6.4 kilometers (km) of the river normally subjected to tidal influence. I further divided the estuary into upper and lower sections demarcated by Hunter Creek near river km 2.4 (Figure 1), because we were unable to use the same sampling gear throughout the entire estuary (see below). We sampled the upper estuary by boat electrofishing and the lower estuary by beach seining. Sampling locations were fixed, and I selected sites sampled in previous years so I could compare catch data to past years. The upper estuary sampling sites were essentially the same all three years, but in the lower estuary they varied somewhat due to changes in location of the river mouth and annual physical changes at some seining locations (Figure 1). The seining sites were in the same locations in 1999 and 1998 with one exception, the southern most site in 1998 was moved north in 1999 adjacent to the next most southern site (Figure 1). We attempted to capture YOY chinook salmon two days/week in each section from May to September to determine their length of estuarine residence. However, due to high or turbid river flows we were unable to begin sampling the upper estuary until early July in 1998 and late June in 1999, or in the lower estuary until late June in 1998.

In the upper estuary I established four transects and sampled them at night for 10 min each using a boat-mounted electrofisher. The electrofisher was powered by a 5.0-kilowatt generator. The anodes were two 0.9-m diameter circular clusters of six 6.4-mm diameter stainless steel cables that were extended by booms to 2.4 m in front of the boat. The cathode was an array of seventeen 3.2-mm diameter stainless steel cables

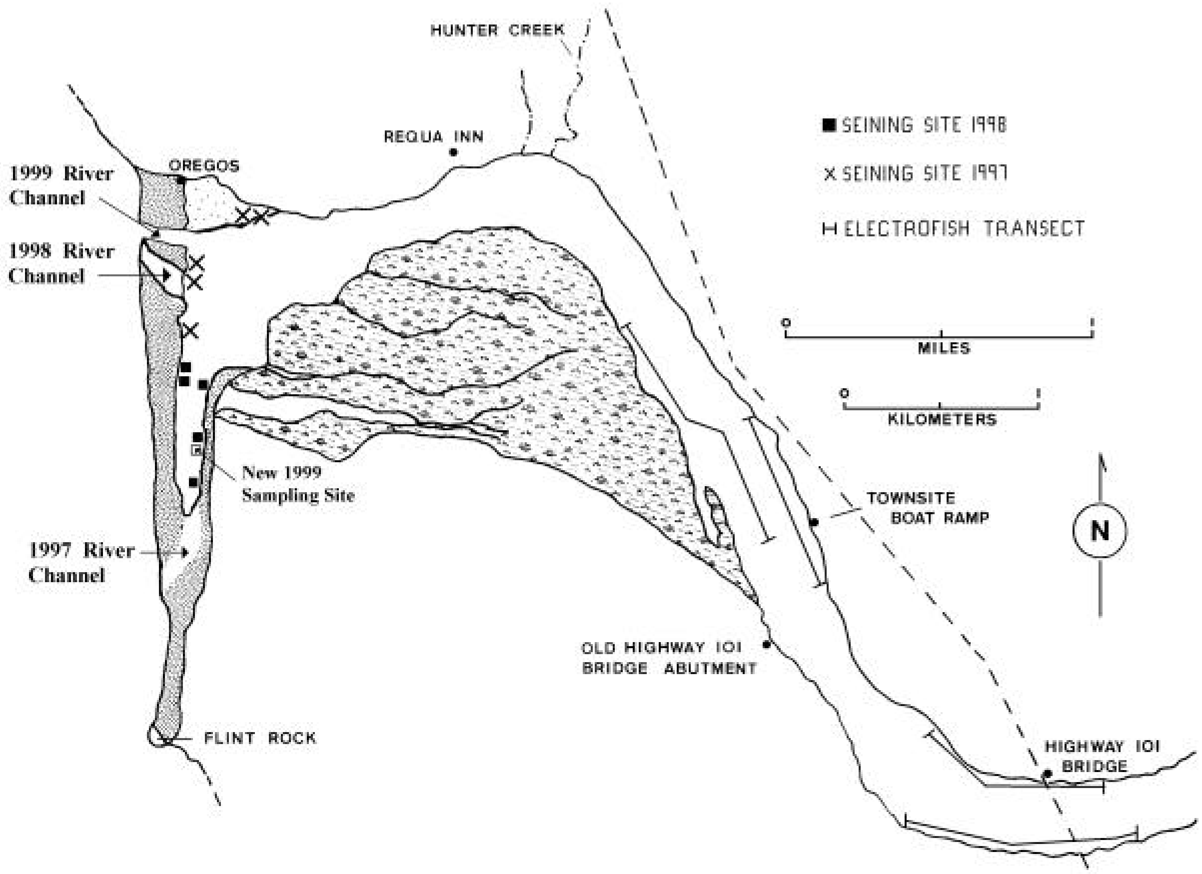

Figure 1. Sampling locations for young-of-the-year chinook salmon in the Klamath River estuary.

hung 152 mm apart and attached to the bow of the boat. We sampled fish at 250-300 v (passing 3-5 amps) at 120 pulses/second DC in 5 to 7 second bursts. Catch-per-unit-effort (CPUE) was calculated as the number of fish captured per minute shocked. I established upstream and downstream boundaries for each transect to minimize the variation in the amount of area NSAP sampled each week and between years. We electrofished in the upper estuary because it allowed us to sample a wider variety of habitats and was more efficient at capturing larger juvenile salmonids than beach seines, and because potential seining sites in the upper estuary were often flooded in the late summer when a sand berm formed at the river mouth and impounded water behind it. In the lower estuary we established five standard locations and sampled them with a 45.7 m X 3.1 m X 6.4 mm mesh beach seine deployed from the bow of a 4.9 m boat (Figure 1). We could not electrofish the lower estuary due to widespread presence of salt water. We estimated the length and width of each seine haul to calculate the area seined. CPUE was calculated as the number of fish captured per 100 m^2 seined.

One day/week we conducted quantitative fish sampling in both sections of the estuary at our standard sampling sites to determine the relative abundance and average size of juvenile salmonids in the estuary. Field crews narcotized juvenile salmonids with alka-seltzer prior to measurements, counted all salmonids and examined them for fin clips and marks. They also measured the fork length (FL) of up to 30 fish per species per sampling site in both the upper and lower estuary to determine their weekly mean FL for each section of the estuary. I calculated the annual mean FL of YOY chinook salmon for each section by pooling the FL=s of all fish measured. All adipose fin clipped chinook salmon were retained to recover and read coded-wire tags to determine the origin of these fish. This sampling plan closely followed the same one used in our past field seasons (CDFG 1994; 1996; 1999), which allowed us to compare catch trends in the estuary from 1993 to 1999 (excluding 1995). We also conducted additional opportunistic qualitative sampling by seining and electrofishing throughout the estuary to increase the number of chinook marked and recovered by our project.

Each week we applied a unique mark to all healthy looking YOY chinook salmon $\geq$70 mm FL. We applied the marks by using a MadaJet needleless dental inoculator to inject alcian blue stain (65mg/mL aqueous solution) and cadmium orange Liquitex paint (diluted 3:1 with water) into the fin rays of the fish. All recaptured project marked fish were counted, measured, its= mark type recorded, and released. We also collected scale samples from project marked fish at large for at least one week. During most weeks of sampling we marked YOY chinook salmon on multiple days, therefore, I calculated the days at liberty (DAL) of recaptured YOY chinook salmon as the mean marking date to date of recapture.

I made a rough estimate of our YOY chinook salmon catch efficiency in the Klamath River estuary using marked and recaptured fish from this study. I calculated weekly catch efficiencies by dividing the number of project marked fish recaptured during the same week they were marked by the total number of fish marked and released that week, or as follows:

$$\%E= \quad (r_1+r_2...+r_k)/(m_1+m_2...+m_k)$$

where

E = capture efficiency
r = # of recaptured fish (r_1= day 1, r_2= day 2 etc.)
m = # of project marked fish (m_1= day 1, m_2= day 2 etc.)
k = total # of days fish were marked or recaptured

I did not include fish marked on the final day of the week since they were not available to be captured that week. I did not estimate efficiencies for weeks where no marked fish were recaptured, however, I included these weeks in calculations of monthly and seasonal catch efficiency estimates (Appendix 1). To calculate monthly or seasonal catch efficiencies I pooled weekly mark and recapture data from the appropriate weeks. I did not include project marked fish recaptured in subsequent weeks because I felt that their extended stay in the estuary would increase their chances of being recaptured and artificially inflate the catch efficiency estimate. I was unable to generate separate catch efficiencies for electrofishing and seining due the low numbers of recaptured fish and because of the unknown origin of recaptured fish (was it marked while electrofishing or seining?). Therefore, I combined fish marked and recaptured from both electrofishing and seining to estimate an overall catch efficiency rate.

I used a one way ANOVA to determine if mean estuarine residence times of YOY chinook salmon were different among study years. I then used the Newman-Keuls multiple range test to make pairwise comparisons between years. Since the distribution of residence times was positively skewed I also performed the Kruscal-Wallis test to insure that the non-normal distribution did not cause erroneous results (Zar 1974). I grouped DAL data into weeks at liberty (WAL) and used the chi-squared goodness of fit test to determine if the distributions of YOY chinook salmon estuarine residence times differed between study years. I used the

Mann-Whitney U-test to determine if mean estuarine residence times differed between fish marked during the first and second half of our sampling season.

I also used the Mann-Whitney U-test to determine if recaptured project marked fish were significantly different in size from the week they were marked. I compared the mean FL of all recaptured chinook to their annual mean FL of all measured chinook salmon. Since we only applied one mark type each week I had no way of knowing whether the recaptured fish were originally marked in the upper or lower estuary, so, I only compared mean FL:s of recaptured fish to annual mean FL:s of chinook salmon captured by the same method (electrofishing or seining). I calculated the annual mean FL of YOY chinook salmon by pooling weekly YOY chinook salmon FL:s collected during our quantitative samples. In determining the annual mean FL of chinook salmon I excluded fish which were marked during weeks where we did not subsequently recapture any of them and I excluded fish measured in weeks prior or subsequent to our marking effort. I repeated this test to determine the effects of weeks at liberty (project marked fish recaptured $\geq$ 1, $\geq$2 etc. weeks after release) had on size differences.

V. Findings: We captured 11,709, 7,902 and 8,685 and marked 10,047, 6,545 and 6,439 YOY chinook salmon in 1997, 1998 and 1999, respectively (Table 1). A strong majority of project marked fish were captured and released in the upper estuary in 1997 and 1999, while the number of project marked fish released was fairly evenly split between the upper and lower estuary in 1998. This was not a planned sampling design but was directly related to the total number of YOY chinook salmon captured by our project in the upper and lower estuary. We recaptured only 65, 124 and 83 (0.65, 1.89 and 1.29%) project marked chinook in 1997, 1998 and 1999, respectively (Table 2). Annual mean estuarine residence times were 8.7, 12.0 and 16.2 days in 1997, 1998 and 1999, respectively (Table 2), and were significantly different between years using the one way ANOVA (F=10.37, df=271, p<0.001) and Kruscal-Wallis test (H=13.42, p=0.0012). The distribution of residence time pooled by weeks (Figure 2) was also significantly different between years (1997 vs 1998 X^2= 17.79, df=4, p=0.0014; 1997 vs 1999 X^2= 70.68, df=6, p<0.001; 1998 vs 1999 X^2= 28.06, df=6, p<0.001). Individual fish were recaptured from 1 to 56 days after their release (Table 2). This is within the range of juvenile chinook salmon estuarine residence times reported in other studies (Table 3).

Our estimated capture efficiency of juvenile chinook was quite low, therefore we captured relatively few project marked chinook salmon. We estimated our overall catch efficiency (seining and electrofishing June-September) in 1997, 1998 and 1999 was 0.31, 0.42 and 0.15%, respectively (Table 2). Weekly catch efficiencies ranged from 0 to 1.59% however, these estimates were based on only 0 to 6 recaptured fish

Table 1. Summary of young-of-the-year chinook salmon captured and marked in the upper and lower Klamath River estuary, 1997-1999.

	Lower Estuary			Upper Estuary			Total		
Year	No. Caught	No. Marked	% Marked	No. Caught	No. Marked	% Marked	No. Caught	No. Marked	% Marked
1997	3763	3279	87.1	7946	6768	85.2	11709	10047	85.8
1998	4006	3458	86.3	3896	3087	79.2	7902	6545	82.8
1999	1478	1348	91.2	7207	5091	70.6	8685	6439	74.1

Table 2. Summary of project marked young-of-the-year chinook salmon recaptures, annual capture efficiencies and days at liberty (DAL) in the Klamath River estuary, 1997-1999.

Year	No. Marked	No. Recaptured	Percent Recaptured	Percent Efficiency	Range of DAL (days)	Mean DAL
1997	10,047	65	0.65	0.31	1.0 - 28.5	8.7
1998	6,545	124	1.89	0.42	1.0 - 41.5	12.0
1999	6,439	83	1.29	0.15	1.5 - 55.5	16.2

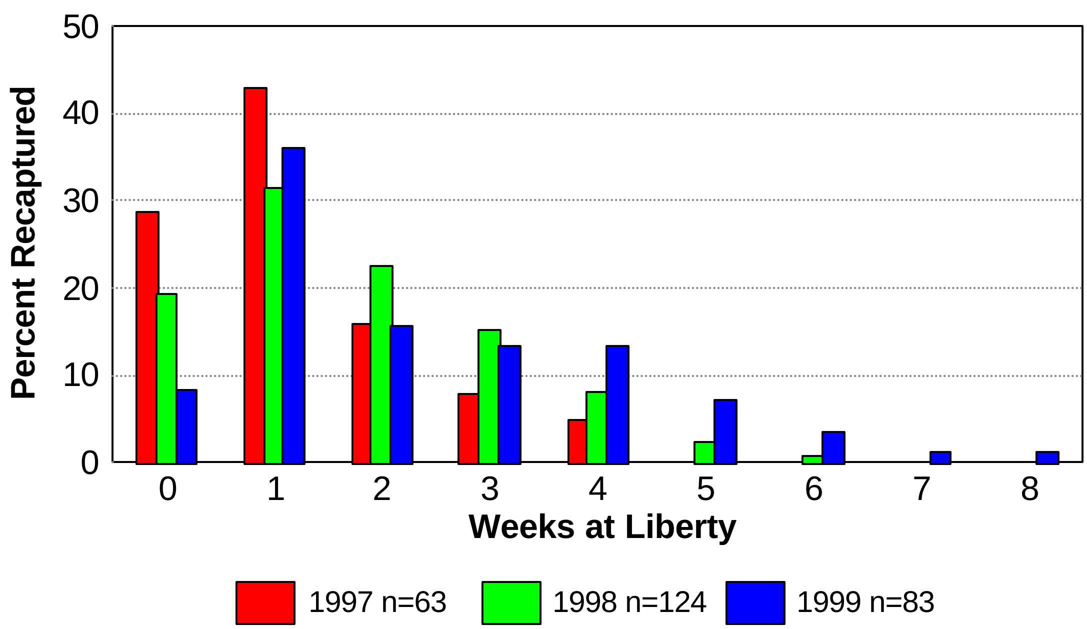

Figure 2. Comparison of the distribution of residence times by week of young-of-the-year chinook salmon captured in the Klamath River estuary in 1997, 1998 and 1999.

Table 3. Juvenile chinook salmon length of residence in other Pacific coast estuaries.

Estuary	Life Stage	Average Residence	Maximum Residence	Citation
Campbell R. British Columbia	smolt	21-47 days	-	MacDonald et al. (1988)
Cambell R. British Columbia	wild fry	65 days	-	Levings et al. (1986)
Cambell R. British Columbia	hatchery fingerlings	31 days	-	Levings et al. (1986)
Nanaimo R. British Columbia	fry	20-25 days	60 days	Healey (1980)
Fraser R. British Columbia	fry	-	30 days	Levy & Northcote (1982)
Washington Estuaries	juveniles	6-29 days	~189 days	Simenstad et al. (1982)
Skagit R. Washington (1984) (1984)	sub-yearling	4 days	6 days	Congleton et al. (1978) *in* Simenstad &Wissmar
Puyallup R. Washington	fry released up-stream of wetland	5 days	40 days	Shreffler et al. (1990)
Puyallup R. Washington	fry released into wetland	38 days	43 days	Shreffler et al. (1990)
Coos B Oregon	smolt	29 days	83 days	Fisher & Pearcy (1990)
Sixes R. Oregon	fingerling smolt	3 months	-	Reimers (1971)
Elk R. Oregon	juveniles	1-6 weeks	-	Nicholas & Hankin (1989)
Rogue R. Oregon	juveniles	-	7-30 days	Nicholas & Hankin (1989)
Sacramento-San Joaquin Delta, CA.	fry	~2 months	64 days	Kjelson et al. (1982)

per week (Appendix 1). Therefore these estimates should be considered as just rough estimates of our overall capture efficiency. These estimates are consistent with efficiency estimates from prior years. Based on the capture of coded-wire tagged chinook salmon released adjacent to the estuary by the Yurok Tribe in 1993 and 1996, our catch efficiency ranged from about 0.2 to 0.4%.

The mean FL's of recaptured project marked chinook salmon were longer than the mean annual FL of all measured chinook salmon for all three years of this study and significantly so in 1999 and 1998 (Table 4). The largest size difference occurred in 1999 and the smallest in 1997. Also, not surprisingly, the longer the fish were at liberty the larger their average size. The mean FL of chinook salmon recaptured in the upper estuary one or more weeks after marking was 2, 7 and 12 mm larger than the annual mean FL of all measured fish in the upper estuary in 1997, 1998 and 1999, respectively. The mean FL of chinook salmon recaptured in the upper estuary two or more weeks after marking was 5, 9 and 14 mm larger than the annual mean FL of all measured fish in the upper estuary in 1997, 1998 and 1999, respectively. In 1999 fish which we recaptured three weeks or more after their release were 16 mm larger than annual mean FL of all measured fish. In the lower estuary, 1998 was the only year we recaptured enough chinook salmon to compare their FL's to all measured fish in the lower estuary. Recaptured chinook salmon were 3 mm larger than the annual mean FL of all measured fish and 4 and 8 mm larger ≥1 and ≥2 weeks respectively, after release (Table 4).

Chinook salmon growth in the Klamath River estuary in 1999 and 1998 was comparable to chinook salmon growth in other estuaries, but much lower in 1997 (Table 5). Average increase in FL per day of recaptured chinook salmon was 0.10, 0.37 and 0.58 mm/day in 1997, 1998 and 1999, respectively. The annual variation in growth rates NSAP observed in the Klamath River estuary is typical of other estuaries (Healey 1991; Simenstad and Wissmar 1984). Healey (1991), reported that other studies of marked chinook salmon growth in Pacific coast estuaries found size increases ranging from 0.07 to 1.32 mm/day, and studies of unmarked chinook salmon showed growth rates ranging from 0.22 to 0.61 mm/day (Table 5). However, Healey (1991) showed that growth rates based on unmarked chinook salmon tend to underestimate true growth rate by a factor of about two. However, if estuarine residency is more likely for smaller sized chinook salmon, I probably underestimated their true growth rate in the Klamath River estuary since I based my estimate of starting size on the mean size of all measured chinook salmon. Also, since I pooled all recaptured chinook salmon it is likely I mixed fish from multiple cohorts and life histories which also underestimated their true growth (Healey 1991).

Though most YOY chinook salmon likely pass quickly through the estuary those that choose to rear there do so for a significant period of time. Based on the small number of recaptured fish collected by NSAP (Table 2) and because most YOY chinook salmon are greater than 70 mm FL before they reach the Klamath River estuary, I believe that a majority of the YOY chinook salmon emigrating from the Klamath-Trinity basin move quickly through the estuary. However, in 1998, 81% of the recaptured project marked chinook salmon had been at large one or more weeks following their mark and release and 49% of them had been at large two or more weeks. In 1999, 92% had been at large at least one week and 55% at least two weeks. This indicates that the portion of chinook salmon that rear in the estuary do so for a significant period of time.

Table 4. Comparisons of mean fork-lengths (FL) of recaptured project marked chinook salmon residing in the Klamath River estuary for various weeks at liberty (WAL) and mean FL's of chinook salmon during the week of marking. Comparisons of mean fork-lengths were made using the Mann-Whitney U-test to calculate the Z statistic and the probability (p) of occurrence.

1997 Upper Estuary

	Recaptured Fish		All Fish			
Comparison	n	Mean FL	n	Mean FL	z	p
All recaps vs all chinook	48	95.38	939	94.45	1.52	0.127
WAL>0 weeks vs all chinook	34	96.21	939	94.45	2.08	0.038

1998 Upper Estuary

	Recaptured Fish		All Fish			
Comparison	n	Mean FL	n	Mean FL	z	p
All recaps vs all chinook	68	97.01	841	91.65	5.83	<0.001
WAL>0 weeks vs all chinook	57	98.16	841	91.65	6.40	<0.001
WAL>1 weeks vs all chinook	36	100.31	841	91.65	6.89	<0.001

1998 Lower Estuary

	Recaptured Fish		All Fish			
Comparison	n	Mean FL	n	Mean FL	z	p
All recaps vs all chinook	54	95.26	617	92.35	2.45	0.014
WAL>0 weeks vs all chinook	43	95.81	617	92.35	2.68	0.007
WAL>1 weeks vs all chinook	25	100.00	617	92.35	4.65	<0.001

1999 Upper Estuary

	Recaptured Fish		All Fish			
Comparison	n	Mean FL	n	Mean FL	z	p
All recaps vs all chinook	64	109.52	1131	98.91	6.44	<0.001
WAL>0 weeks vs all chinook	59	110.80	1131	98.91	6.96	<0.001
WAL>1 weeks vs all chinook	42	112.79	1131	98.91	6.67	<0.001
WAL>2 weeks vs all chinook	30	115.30	1131	98.91	6.45	<0.001

Table 5. Juvenile chinook salmon growth rates in other Pacific coast estuaries. All citations found in Healey (1991).

Estuary	Marked/ Unmarked	Growth Rate (mm/day)	Comments	Citation
Columbia R. WA./OR.	unmarked	0.44	April-October	Rich 1920
Sacramento R. Delta, CA.	unmarked	0.48	March-July	Rich 1920
Sacramento- San Joaquin	marked	0.53	1981	Kjelson et al. 1982
Delta, CA	marked	0.86	1980	Kjelson et al. 1982
Fraser R.	unmarked	0.39	mid-May-June 1979	Levy & Northcote 1981
B.C.	unmarked	0.56	mid-May-June 1978	Levy & Northcote 1981
	both	0.9	April-early June	Reimers 1971
Sixes R.	both	0.07	June-August	Reimers 1971
Oregon	both	0.5	Sept-November	Reimers 1971
Nanaimo R.	unmarked	0.5	April-June	Healey 1980
B.C.	marked	1.32	April-June	Healey 1980
Cowichan R. B.C.	unmarked	0.22		M.C. Healey unpublished data
Courtenay R. B.C.	unmarked	0.61		M.C. Healey unpublished data
Campbell R. B.C.	unmarked	0.46-0.55		Levings et al. 1982
Nitinat R.	unmarked	0.62	1979	Fedorenko et al. 1979
B.C.	unmarked	0.33	1975-1977	Fedorenko et al. 1979
	marked	0.58	June-Sept 1999	This report
Klamath R.	marked	0.37	June-mid-Sept 1998	This report
CA	marked	0.10	June-Aug 1997	This report

The portion of fish rearing for at least one and at least two weeks varied between years and therefore suggests that YOY chinook salmon reared in the estuary more in 1998 and 1999 than in 1997 (Figure 2). Coupled with the difference in growth rate between years it is apparent that YOY chinook salmon exhibited little estuarine rearing in 1997. Whether lowered estuarine rearing was due to poor rearing conditions in the estuary, or the very high abundance of chinook present in the upper estuary in 1997 (CDFG 1999), or some combination of both, is not known. However, 1997 had the lowest June through August river flow of this 3 year study. This may have adversely affected rearing conditions in the estuary, or reduced fish rearing habitat in the mainstem rivers, forcing fish to emigrate earlier in the summer than in high flow years, resulting in more fish arriving simultaneously in the estuary (Wallace and Collins 1997).

Extended estuarine rearing or late summer ocean entry may be advantageous for Klamath-Trinity basin chinook salmon. A number of studies on Oregon coastal rivers have determined that juvenile chinook salmon which rear in estuaries for significant periods of time and enter the ocean in late summer or fall make up the majority of returning adults compared to juveniles which move quickly through the estuary and enter the ocean in mid summer at the perceived period of peak emigration (Reimers 1971; Nicholas and Hankin 1989). A vast majority of adult chinook salmon returning to the Sixes River reared in its estuary for up to three months and entered the ocean in the late summer and fall at a relatively large size compared to juveniles which entered the ocean earlier in the summer (Reimers 1971). In the Rogue River the mean FL of surviving fall and spring run chinook salmon at ocean entry ranged from about 10 cm to 11 cm over a period of ten years. The peak period of ocean entrance of returning adult fish in the Rogue River is apparently between mid August and early September (Nicholas and Hankin 1989). Based on seining data and scale patterns on mature chinook that returned to the Siuslaw River many juveniles rear in the estuary from June to September. Studies on hatchery origin chinook salmon in the Elk and Trask Rivers found that most returning adults were fish which remained in the river system during the summer and entered the ocean September to November at a larger size than fish which quickly left the system in mid summer (Nicholas and Hankin 1989). Therefore it is reasonable to suspect that juvenile chinook salmon which rear in the mainstem river or estuary and enter the ocean in the late summer or early fall also comprise the majority or at least significant portion of returning adult fish to the Klamath River basin.

However, this type of information presently does not exist for chinook salmon in the Klamath basin and until we know what portion of returning adult chinook salmon are from these Aestuary rearing@ fish, we will be unable to fully describe the importance of estuary rearing to Klamath-Trinity basin stocks. Sullivan (1989), analyzed scales of returning adult chinook salmon from the Klamath-Trinity basin in an attempt to determine their juvenile life history and age composition. He found that most fish exhibited scale patterns indicative of typical summer emigration (type-I), but that a significant portion of some tributary populations showed differences in proportion of life history types (type-II fall or early winter emigration and type-III, yearling emigration). He also found that older age-at-return groups showed higher incidence of extended juvenile freshwater rearing. The study also showed that based on scales collected from the Klamath River during 1921, chinook salmon had a higher incidence of type II and III life histories. He also felt that, based on scale analysis of returning adult chinook salmon, that juveniles from type-II life histories had a broad range in ocean entrance timing (he defined this group as a Acatch-all@ group that likely contained several life history sub-groups he could not distinguish from his scale analysis) while those with type-I life histories showed much more consistent ocean entry relatively soon after emergence. His study also showed evidence that a portion of type-II group showed strong freshwater growth, which he felt indicated productive mainstem or estuary rearing, but he could find no clear distinction in scale patterns to justify separating these from the remaining groups. Further studies along these same lines is needed to ascertain the importance of estuarine rearing to Klamath basin chinook salmon.

Rearing conditions in the Klamath River estuary are probably more favorable in the latter half of the summer or early fall compared to early summer. A larger portion of YOY chinook salmon seem to rear in the estuary, and for a longer period of time, later in the summer compared to the time of their peak abundance in the early summer (Table 6). Project marked YOY chinook salmon released during the second half of our sampling seasons had longer mean estuarine residence times than fish marked during the first half of our sampling seasons in all three years of this study. The difference was significant in 1997 and 1998. In 1997, the mean residence time for fish marked in the first and second half of the sampling season was 6.4 and 10.0 days respectively ($Z= 2.73$, $p< 0.01$); in 1998 it was 6.5 and 13.4 days respectively ($Z= 3.67$, $p< 0.001$); and in 1999 it was 12.9 and 17.5 days respectively ($Z= 1.19$, $p=0.263$). Also, our estimated catch efficiencies were higher in the second half than the first half of the sampling season in all three years of this study. However, in 1997 and 1998 increased second half efficiency was 45% and 39% respectively, of the increased second half catch rate of marked chinook salmon, suggesting that most of the increase in the number of recaptured chinook salmon was due to an increase in the portion of fish residing in the estuary, not increased sampling efficiency. However, in 1999 increased second half efficiency was about 80% of the increased catch rate of marked chinook salmon, indicating that most of the increase in catch rate could be explained by increased catch efficiency. Therefore, in two out of three years our increased capture rate of YOY chinook salmon in the second half of our sampling season could not be explained by increased capture efficiency.

Table 6. Annual estuarine residence times in days at liberty (DAL), percent recapture and capture efficiency of project marked young-of-the-year chinook salmon captured in the first half of the sampling season vs the second half of the sampling season in the Klamath River estuary, 1997-1999.

	First Half			Second Half		
Year	Mean DAL(days)	Percent Recaptured	Percent Efficiency	Mean DAL(days)	Percent Recaptured	Percent Efficiency
1997*	6.4	0.46	0.29	10.0	0.84	0.33
1998**	6.5	0.84	0.37	13.4	2.78	0.47
1999***	12.9	0.60	0.08	17.5	2.04	0.23

* first half May 14 - July 10; second half July 14 - Aug 27
** first half June 22 - July 30; second half Aug 3 - Sept 23
*** first half June 14 - July 28; second half Aug 2 - Oct 6

One reason why this may occur is because a higher portion of fish in June and July have reached suitable ocean entry size. Larger hatchery fish tend to migrate more quickly out of the Klamath-Trinity basin than smaller sized fish (USFWS 1998; CDFG 1999) and in many years the average size of YOY chinook salmon is slightly larger in late June and early July than in late July and early August (Wallace 1993). For example, Trinity River Hatchery (TRH) spring chinook are the largest sized YOY chinook salmon released from basin hatcheries and they typically have the fastest emigration rate to the estuary (Wallace 1993; Wallace 1995; CDFG

1999). Most TRH spring chinook salmon were captured by our project in the first half of the sampling season. Another reason juvenile fish rear longer later in the summer might be that the number of chinook salmon in the estuary during their peak abundance may overwhelm available food and space resources there, creating poor rearing conditions and resulting in the fish migrating quickly through the estuary. The authors of the Klamath Basin Long Range Plan hypothesized that there could be a high rate of density dependent mortality in the Klamath River estuary due to a combination of large numbers of emigrating juvenile salmon and estuary habitat degradation due to the filling of deep holes with fine sediment (Klamath River Task Force 1991). Wallace and Collins (1995b), found that the abundance of preferred chinook salmon prey items in the estuary was lowest in the summer immediately after peak catches of chinook salmon. Reimers (1971) suggested, and was later supported by Neilson et al. (1985), that high juvenile chinook salmon abundances reduced their growth rate in the Sixes River estuary, Oregon. He theorized it was a density dependent growth reduction related to prey availability. Other estuary studies have also suggested that juvenile salmonid growth and survival are possibly limited by the availability of prey (Reimers 1971; Healey 1979; Kjelson et al. 1982; Simenstad et al. 1982; Neilson et al. 1985). The high abundance of chinook salmon in the upper estuary in 1997 coupled with their lowered growth and shorter estuarine rearing time seems to support this hypothesis.

Physical processes in the estuary also likely play a role in changing rearing conditions in the Klamath estuary. Sand bars and sills form at the mouths of most northern California rivers. In the Klamath River sill formation usually becomes evident in the mid to late summer. In other studied Pacific coast estuaries nutrients and detritus become trapped behind their sills (Reimers 1978; Barnes 1980; Simenstad 1983) and form the base of a food web that supports populations of anadromous salmonids (Sibert et al. 1977; Healey 1979). Reimers (1971), felt that production in the Sixes River estuary increased in the late summer due to sill formation. Anderson (1992), noted that the number of Corophium amphipods (an important prey item of juvenile chinook salmon) as well as fish and invertebrate habitat increased in the Redwood Creek estuary, California, after bar closure. Also, the abundance of Corophium amphipods in the Klamath River estuary increased after a sill formed at its mouth (Wallace and Collins 1995b). It therefore seems reasonable to expect that the formation of the sill at the mouth of the Klamath River will also trap nutrients and increase the productivity of the estuary, especially during the second half of our sampling season. Therefore, lower chinook abundances in the late summer and early fall coupled with increased estuary production as the sill forms in the late summer are the most likely reasons for increased use of the estuary by YOY chinook salmon in the second half of the sampling season.

YOY chinook salmon abundance in the late summer, though less than peak emigration in June and July, is still substantial in most years (Wallace 1993; Wallace 1995; Wallace and Collins 1995a; Wallace and Collins 1997; CDFG 1999), especially during years when river flows are relatively high (CDFG unpublished data). Also, a higher proportion of these later emigrating fish are of natural origin compared to the time of peak emigration (CDFG 1999; CDFG unpublished data). For example, NSAP's peak catches of chinook salmon emigrating from lower Klamath River tributaries consistently occurs in the second half of the sampling season (mid to late summer) after times of chinook salmon peak emigration (CDFG 1999). Based on this study, the late summer is also when increased chinook salmon rearing occurs in the estuary. Therefore, it is plausible that the Klamath River estuary is more important to natural origin, or certain stocks of natural origin chinook salmon than to hatchery origin chinook salmon.

VI. Recommendations:

Analysis of YOY chinook salmon scales collected from the Klamath River estuary should be conducted to ascertain if biologists can identify estuarine growth or residence from scale patterns. Scales from different stocks of returning adult chinook salmon should also be analyzed for estuarine growth and residence. If the scales are usable to identify estuarine residence then biologists should be able to make an estimate of the portion of juvenile fish which rear in the estuary, the portion of surviving adults which reared in the estuary and determine if certain stocks of chinook salmon are more dependent upon the estuary than others.

Adequate river flows from Klamath-Trinity basin dams need to be maintained throughout the summer months. YOY chinook salmon emigration are protracted over a longer time period in high flow years compared to low flow years, which reduces the likelihood that high concentrations of fish reach the estuary at once thereby minimizing the chances of overwhelming estuary food and space resources. Also by protracting chinook salmon emigration a greater portion of them reach the estuary in the late summer when estuary production may be at its highest level and, based on Nicholas and Hankin (1989), marine survival is highest for fish that enter the ocean in late summer and early fall. Increased river flows also likely increase rearing habitat in the mainstem rivers thereby reducing the burden of the estuary to act as the primary rearing area.

Sill formation at the mouth of the river should not be disrupted since numerous studies (Reimers 1971 and 1978; Wallace 1998; Barnes 1980; Simenstad 1983; Sibert et al. 1977; Healey 1979; Anderson 1992) suggest sill formation increases estuary production and improves rearing conditions for fish.

Basin hatcheries should continue to strive to release YOY chinook salmon as large as possible to reduce their residence times in the mainstem river and estuary thereby minimizing competition with natural origin salmonids.

VII. Estimated FY 99-00 Job Cost: (Allotment= $87,641)

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Appendix 1. Capture efficiency estimates of young-of-the-year chinook salmon from the Klamath River estuary for 1997-1999. Estimates are for seining and electrofishing combined.

1997

Dates	Days Marked	No. Marked	No. Recaptured	Percent Recaptured	Percent Efficiency
5/14-15	2	3	0	0	-
5/21-23	3	5	0	0	-
5/26-29	4	12	0	0	-
6/2-3	2	1	0	0	-
6/9-12	4	96	0	0	-
6/16-19	4	83	0	0	-
6/23-27	4	454	1	0.22	0.22
6/30-7/3	4	1480	6	0.41	0.41
7/7-10	4	1728	4	0.23	0.23
First Half Total		**3862**	**11**	**0.28**	**0.28**
7/14-17	4	989	4	0.40	0.40
7/21-24	4	503	0	0	-
7/28-31	4	526	1	0.19	0.19
8/4-7	4	321	0	0	-
8/11-14	3	208	3	1.44	1.44
8/17-21	4	145	1	0.69	0.69
Second Half Total		**2692**	**9**	**0.33**	**0.33**
Grand Total		**6554**	**20**	**0.31**	**0.31**

1998

Days	No.	No.	Percent	Percent	
Dates	Marked	Marked	Recaptured	Recaptured	Efficiency
6/22-25	4	161	1	0.62	0.62
6/29-7/2	4	362	5	1.38	1.38
7/6-9	4	166	0	0	-
7/13-16	4	697	1	0.14	0.14
7/20-23	4	621	0	0	-
7/28-30	3	432	2	0.46	0.46
First Half Total		**2439**	**9**	**0.37**	**0.37**
8/3-6	4	499	0	0	-
8/10-13	4	818	6	0.73	0.73
8/17-19	2	301	0	0	-
8/24-28	4	600	2	0.33	0.33
8/31-9/2	3	411	3	0.73	0.73
9/6-10	3	126	2	1.59	1.59
Second Half Total		**2755**	**13**	**0.47**	**0.47**
Annual Total		**5194**	**22**	**0.42**	**0.42**

Appendix 1 (con't). Capture efficiency estimates of young-of-the-year chinook salmon from the Klamath River estuary for 1997-1999. Estimates are for seining and electrofishing combined.

1999

Dates	Days Marked	No. Marked	No. Recaptured	Percent Recaptured	Percent Efficiency
6/14-15	2	25	0	0	-
6/21-24	3	55	0	0	-
6/28-7/1	3	248	1	0.40	0.40
7/6-8	3	366	0	0	-
7/12-15	4	333	0	0	-
7/19-22	4	1072	1	0.09	0.09
7/26-28	3	313	0	0	-
First Half Total		**2412**	**2**	**0.08**	**0.08**
8/2-5	4	366	1	0.27	0.27
8/9-12	4	502	2	0.40	0.40
8/16-19	4	341	2	0.59	0.59
8/23-27	3	396	0	0	-
8/30-9/3	4	134	0	0	-
9/7-9	3	128	0	0	-
9/13-17	3	274	0	0	-
Second Half Total		**2141**	**5**	**0.23**	**0.23**
Annual Total		**4553**	**7**	**0.15**	**0.15**