Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon (Oncorhynchus tshawytscha)

Paul Maslin
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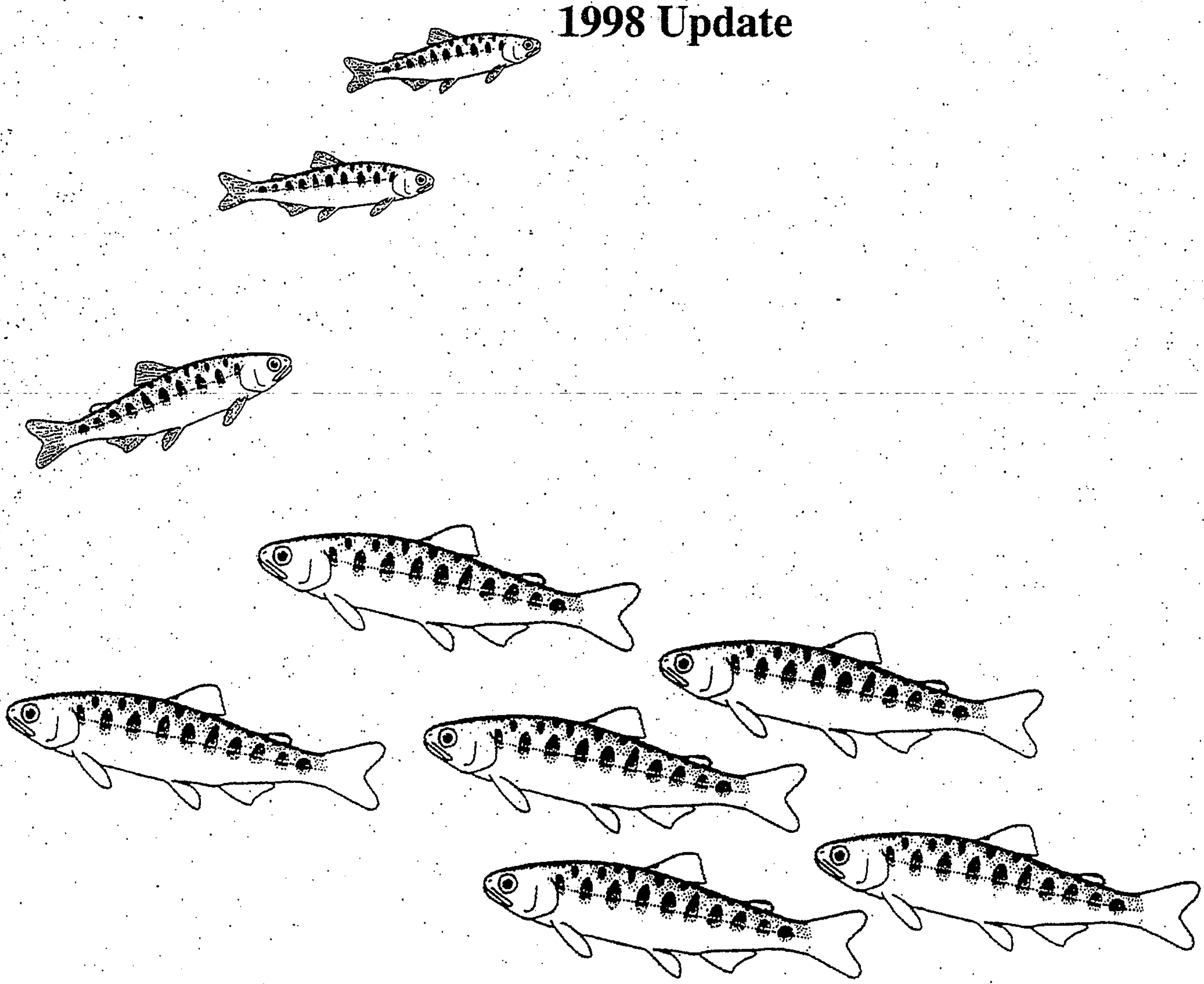
1998 Update



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ABSTRACT

In 1998 we continued to investigate the use of small tributaries of the Sacramento River by juvenile chinook salmon. Although the unusual water conditions brought about by el Nino limited some aspects of the study, we were able to document use of 26 Sacramento River tributaries for non-natal rearing. Continual fluctuations in stream discharge resulted in more movement by the juveniles than observed in 1997. Consequently upstream movement was greater than in 1997, probably as high as would ever be expected. Unfortunately, the continual movement made growth estimation impossible. As in former years, a variety of sizes were present, and by inference, a variety of races. DNA analysis was used to confirm the presence of the listed winter race in Mud Creek. The tributary-rearing juveniles were in excellent condition, comparable to that of former years when they were shown to be in better condition than river-rearing juveniles. Comparison with condition factors obtained for river-juveniles by CaDFG personnel proved infeasible due to differences in methodology. The total population rearing in tributaries was estimated to be between 100,000 and 1,000,000.

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Introduction

The Sacramento River produces four distinct races of chinook salmon *(Oncorhynchus tshawytscha)* : fall, late fall, winter, and spring, based upon their appearance in tide-water (Fisher, 1994). Chinook salmon originating in the Sacramento River account for 90 percent of the San Francisco-to-Monterey commercial catch, 40 percent of the North Coast, and 5 percent of the Oregon catch (DFG, 1978). All races have declined substantially from historic populations. The winter run was listed as "endangered" by the State of California in 1989 and by the National Marine Fisheries Service in 1994. The spring run, once the most abundant chinook in the Central Valley (Reynolds et al. 1990), persists at dangerously low numbers in a few tributaries and has just been added to the California threatened list. In order to reverse the decline of chinook salmon stocks, we need to fully define the habitat used by the different races.

Much of the Sacramento River drainage basin has been lost as salmon habitat due to migration barriers. The remainder has been substantially degraded as rearing habitat for juvenile chinook. Erosion control has resulted in loss of sinuosity and braiding, thereby reducing total area of habitat and degrading the remaining habitat by increasing mean velocity. Current flood control practices require peak flood discharges to be held back and released over a period of weeks. Consequently, the mainstem of the river often remains too high and turbid to provide quality rearing habitat (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Because of this loss of habitat quantity and quality, it is important that all remaining rearing habitats be evaluated and measures taken to preserve or enhance important components.

A component of rearing habitat which was ignored until recent years is the lower ends of small tributaries that have insufficient flow to be used consistently by spawning adults (Maslin, et al., 1996, 1996b, 1997; Moore, 1997). Valley reaches of many intermittent tributaries of the Sacramento River are used by juvenile chinook as rearing sites, (See Table 1.)

Rearing of juvenile chinook in nonnatal tributaries has been reported in other river systems. Murray and Rosenau (1989) suggest that the dispersal and migratory patterns of young chinook salmon increase the use of available rearing areas, and that movements of young salmonids from spawning areas to rearing areas consist of complex local migrations (upstream, downstream, or both) that are genetically and environmentally controlled. Scrivener et al. (1994), concluded that seasonally high sediment levels and cold temperatures in the Fraser River may induce juvenile chinook to move into small, nonnatal tributaries to feed and clear their gills of sediment. Juvenile chinook may also migrate into the tributaries to exploit food resources (Williams, 1987); and to escape unfavorable environmental conditions which occur periodically in the mainstem, such as high turbidity and cold temperatures (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Richards and Cernera, (1992) had some success in development of off-channel habitats to increase rearing habitats for juvenile chinook.

In this study we provide more information about non-natal rearing in small and intermittent Sacramento River tributaries. The main objectives this year were:

1. To provide a rough estimate of the number of juvenile chinook rearing in non-natal streams.
2. To use genetic analysis to verify presence of winter chinook.
3. To provide further information on the spatial and temporal extent of non-natal rearing.
4. To evaluate the quality of rearing habitat based on the condition of the tributary-rearing juveniles.

PROCEDURE:

Sampling by seine and fish processing procedure followed in 1998 was essentially identical to that in 1997 (Maslin, et al., 1997). In addition, we used electrofishing as a supplement to seining in some sites with dense cover. The upstream and downstream ends of the site were first blocked with seines, then a Smith-Root model 12 backpack electrofisher was fished systematically from downstream to upstream with as many as five passes taken and depletion analysis used to calculate population within the site. Before fishing the site, ambient water conductivity was measured, settings were adjusted for voltage, frequency, and pulse width based on experience, then a sample area outside the site was fished and parameters fine-tuned. Because of its inefficiency (see discussion), only a few sites were sampled by electrofishing.

Because Mud Creek was readily accessible everywhere throughout the reach utilized by rearing juvenile chinook, it was chosen for intensive sampling, while other creeks were sampled fewer times. The intent was to use Mud Creek as a model for interpreting the data in other tributaries. The unusually wet year in 1998 forced us to modify our plans. Mud Creek was often difficult to sample quantitatively and larger streams such as Thomes and Pine, were impossible to sample. We compensated for the high water limitations by spending more time than intended documenting upstream distances and presence in some of the smaller streams.

DNA Sampling

Tissue samples were taken from 72 juvenile chinook (of winter-run size or near winter-run size) from Mud Creek. Two approximately 1 square mm bits of caudal fin were snipped with microscissors and placed into separate numbered vials. The vials were kept on ice until we got back to the laboratory, where they were placed in a -70° Freezer for storage. At the end of the sampling season, the vials were packed in an insulated chest with dry ice and transported to the Bodega Bay Marine Laboratory for race analysis based on microsatelite DNA. (Banks, et al. 1996).

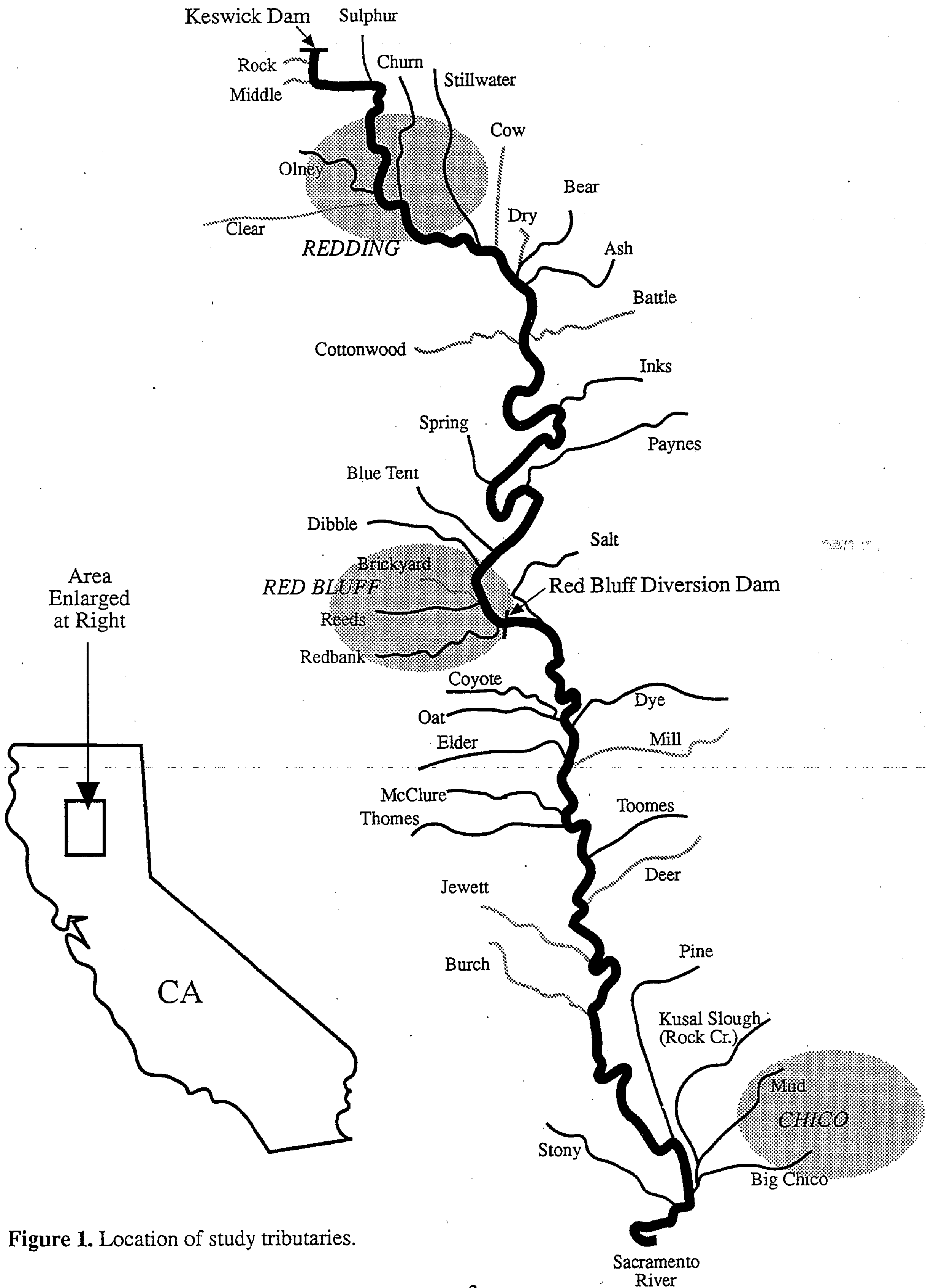


Figure 1. Location of study tributaries.

RESULTS AND DISCUSSION

1998 and El Nino

Sampling this year was affected by the unusual weather conditions created by el Nino. High water in the Sacramento River raised the base level for tributary streams, prohibiting sampling near tributary mouths. Frequent high water in the tributaries resulted in either the inability to sample at all or the inability to sample quantitatively on many dates. Very high water conditions in the river during January most likely swept eggs and fry away to be lost or to rear in the delta. Either way, there would have been relatively few to enter tributaries for rearing so estimates of stream numbers would be expected to be lower than for a "normal" year.

The high water in January precluded sampling during the peak season for winter-chinook juveniles to be in the tributaries. By the time we could get into the creeks for sampling, most of the winter run juveniles had emigrated, so we obtained fewer DNA samples than planned.

It was not a good year for estimating growth rate from modal shifts. Comparison of modes from week to week often suggested that fish were barely growing or even shrinking. Apparently, due to movement induced by the continual high water events, fish collected from week to week at the same site were not the same fish; new ones had arrived, previous ones had moved elsewhere.

Electrofishing

Characteristics of the target species, the size class of interest, and the streams combined to make electrofishing poorly suited to this study. Since the salmon are small and ambient conductivity in most of our streams was low (50-70 microsiemens was typical), applied power had to be high and the fish had to be close to the electrode to be captured. Juvenile salmon also typically stay together in a shoal and flee from a threat, rather than hiding. Consequently, capture probability per pass was low, necessitating many passes. Also the probability of stress or lethality was high because of the high power applied, proximity to the electrode necessary for capture, and possibility of multiple exposures. After several attempts, we concluded that electrofishing would not meet our goals of efficient sampling with minimal stress and mortality.

Tributaries Investigated

Through the 1998 season, 49 different sites in 19 tributaries were sampled to observe 3008 juvenile chinook. Figure 1 shows the tributaries of the Sacramento River between Keswick Dam and Chico. Stream kilometer (str km), the distance from the tributary's confluence with the Sacramento River to the sample site, is used throughout this report to define sample sites. Table 1 lists the tributaries sampled with potential for non-natal chinook rearing. Table 2 provides detail for each sample site. A set of GIS overlays showing the data are in preparation.

Creek	River Mile at Mouth	Grad 1st 0.5km	Grad 1st 5.0 km	Drainage (sq. mi.)	Max dist upstream 1997 (km)	Max dist upstream 1998 (km)	Max dist reported (km)
Big Chico	193	0.13%	0.13%	132	4	NS	4
Kusal (Rock)	193	0.07%	0.08%	50*	13	17.4	18
Mud	193	0.09%	0.09%	48.9	13	14.2	14.4
Pine	197	0.09%	0.09%	70*	10.5	NS	21.4
Rice (Burch)	208	0.07%	0.20%	60*	NS	10.9	10.9
Jewett	215	0.14%	0.19%	52	NS	4.3	4.3
Toomes	223	0.15%	0.56%	61	2.6	2.4	2.6
Thomes	225	0.27%	0.27%	300	14	NS	14
McClure	226.5	0.22%	0.17%	33.7	3.1	7.86	7.86
Elder	230	0.15%	0.15%	140	6.5	NS	6.5
Dye	232	0.16%	0.22%	42	6.7	6.3	6.3
Coyote	233	0.17%	0.14%	30*	2	NS	2
Oat	233	0.17%	0.22%	65.5	3	NS	3
Salt	240	0.17%	0.16%	47	5.8	5.85	5.85
Red Bank	243	0.48%	0.34%	115	4.5	1.59	4.5
Reeds	244.8	0.47%	0.38%	74.4	1	0.67	4.4
Dibble	246	0.54%	0.49%	28.2	NS	0.5	0.5
Blue Tent	247.7	0.68%	0.55%	18.1	NS	0.4	1.3
Sevenmile	251	2.64%	2.45%	30*	0	NS	0
Paynes	253	1.39%	0.88%	92.8	0	NS	0
Spring	257.5	1.66%	1.18%	15*	0	NS	0
Inks	264	0.51%	0.54%	20*	3.3	NS	3.3
Frazier	267	7.62%	1.37%	30*	NS	NS	?
Anderson	274	0.17%	0.17%	40*	NS	<4.2	0.2
Ash	277	0.51%	0.44%	60*	NS	1.82	4.3
Bear	277.5	0.25%	0.29%	75.7	9.5	NS	9.5
Dry	277.5	0.25%	0.33%	40*	NS	6.2	6.2
Stillwater	281	0.22%	0.27%	70*	1	0.4	1
Clover	284	1.04%	0.62%	30*	NS	NS	?
Churn	284.5	0.17%	0.27%	30*	1	17.6	17.6
Olney	292	0.34%	0.40%	30*	1.3	NS	1.3
Sulphur	297	0.81%	1.11%	30*	0.1	NS	0.1
Middle	301	0.33%	1.48%	30*	NS	NS	?
Rock	302	6.10%	2.67%	30*	NS	NS	0 (?)

*estimated
NS Not Sampled
? Not sampled, but assumed close to zero based on gradient

Table 1. Tributaries sampled and maximum distance upstream juvenile chinook were observed.

The following provides a quick discussion of individual creeks in order from south to north:

Little Butte Creek, while outside the geographic zone we have been focusing on, was included because it was sampled on a class field trip and found to contain rearing juvenile chinook. It differs from all the other streams sampled in that it drains a large marshy area that is still an active part of the Sacramento River floodplain and is maintained as perennial water by connection to an irrigation canal.

Big Chico Creek, being a relatively large stream, was virtually impossible to sample under the sustained high flow conditions of 1998.

Kusal Slough (**Rock** Creek) had been extensively sampled in the past, so was not emphasized this year. One set of samples were taken at various sites on 3/27/98 to permit a relatively accurate population estimate. Unfortunately the lower 4 km were still too high to sample due to the river backwater effect.

Mud Creek was intended to be our primary focus in 1998, with intent to get population estimates on several dates. Consistently high flow largely foiled that plan. On most sample dates, flow was too high to obtain quantitative samples, and even on good days, no samples could be obtained within about 4 km of the river.

Pine Creek is difficult to sample at best. This year all attempts at quantitative sampling in Pine Creek were frustrated by high flow.

Rice Creek was sampled for the first time this year. We were able to obtain trespass permission for only one site, which was impossible to sample quantitatively. However we found both juvenile chinook and steelhead at that site. Based on the characteristics of the creek and the fact that we found juvenile chinook at a site nearly 11 km from the river, one can hypothesize that Rice Creek supports a good population of rearing chinook.

Jewett Creek was sampled for the first time this year. It is a small stream with a strong tendency to go dry in the lower, somewhat degraded portion. While juvenile chinook were present and appeared to emigrate successfully this year, that is probably not typical. From reports of local residents, it seems likely that in most years any juvenile chinook entering Jewett would be trapped and lost. Probably few enter such a small creek.

Toomes Creek populations seemed similar to last year but were difficult to quantify because of high flows. Many juveniles enter Toomes, but they do not go far upstream.

Thomes Creek is large and difficult to sample even in a low water year. This year it was essentially impossible.

McClure Creek is quite small. Last year many juvenile chinook entered it only to become trapped. This year also produced high numbers, but all appeared to migrate out successfully. Last year it was a salmon trap; this year it was an excellent rearing area.

Elder Creek was difficult to sample under the high flow conditions prevalent this year. We demonstrated presence of juvenile chinook, but were unable to get any quantitative data.

Dye Creek, as usual, had lots of juvenile chinook. Last year we projected an upstream limit of 6.7 km, but this year we were able to sample that reach of stream and found chinook below but not above an old dam at km 6.3. That dam appears no worse than some obstructions we have found juvenile salmon above, but very few make it even to the dam because of the low-water crossing at Shasta Boulevard.

Oat Creek and its tributary, **Coyote** Creek, were not sampled this year.

Salt Creek seemed to be good rearing habitat this year. Consistently high flows in the Sacramento River kept water well above the low-water crossing on Salt Creek Road, eliminating that as a barrier this year.

Red Bank Creek was sampled extensively at stream km 8.4. Habitat there looked good, but no chinook were found. Very probably reduction in numbers by the partial barrier at the railroad and relatively poor habitat in the reach immediately above Highway 99W combine to prevent juveniles from moving upstream to the better habitat.

Reed's Creek was sampled extensively at stream km 2.3. The habitat there and elsewhere in the creek was very poor, with a continuous shallow run and almost no cover. No chinook were found. Reed's Creek has degraded significantly in high flow events of the last two years. Currently almost no habitat exists for chinook rearing.

Dibble Creek is highly degraded with shallow, wide runs and almost no cover beyond 0.5 km from the river. Schools of chinook juveniles were present at the Adobe Road bridge, but none could be found an additional 0.5 km upstream.

Blue Tent Creek has also degraded substantially in the last two years, eroding wider and shallower with almost no cover. Juvenile chinook were present at 0.4 km from the river, but none could be found at stream km 3.

Anderson Creek. No chinook were found at stream km 4.2. The odor and color of water and especially of the sediment suggested that low oxygen conditions were common. The stream in its current degraded condition probably does not support significant chinook rearing. If water quality was better, they would probably be there.

Ash Creek. Terry Moore reported seeing juvenile salmon rearing at stream km 4.3 in 1994. We sampled extensively with seine and electrofishing equipment but could find no chinook upstream of km 1.82. In 1994 Ash Creek provided quality habitat, with many deep pools shaded by extensive growth of button willow. Peak flows in the last two years, perhaps exacerbated by overgrazing in the drainage basin, caused severe habitat damage, probably reducing the attractiveness of the stream.

Bear Creek, being a relatively large stream, was virtually impossible to sample under the sustained high flow conditions of 1998.

Dry Creek, tributary to Bear at 1 km from the river, contained a few juvenile chinook, including one of winter-run size. However, Dry is a small creek and probably does mot support rearing in drier years.

Stillwater Creek was sampled extensively without finding any chinook juveniles upstream of about 0.5 km. Since it has good habitat and a reasonable gradient, the lack of fish remains a mystery.

Churn Creek has a low gradient and lots of good rearing habitat. It is rather large, so quantitative sampling was impossible this year, but juvenile chinook were found up to 17.6 km from the river. Presence of very small juveniles at substantial distance from the river strongly suggest that a significant amount of spawning occurred in the creek.

Olney Creek had juvenile salmon at km 0.54 but none at stream km 1.4. This is consistent with last year's data where we found only a few at stream km 1.3 and consistent with the multiple little barriers inherent in the small size of this creek. We did not attempt to look for evidence of spawning by steelhead or late-fall chinook as reported last year because that is outside the scope of this study.

CREEK	Strm km	DATE	seine haul (m)	No./meter	% Error	mean K	SE (K)	n	FL (min)	FL (max)	FL (mean)	No. Fall	No. Spring	No. Winter	No. Late Fall
Mud	2.0	6-Dec	114	0.000	min										
Mud	3.9	20-Dec	84	0.589	8	1.147	0.0176	47	65	105	80	0	0	46	1
Mud	6.8	20-Dec	113	0.743	16	1.118	0.0110	33	63	108	82	0	0	32	1
Mud	3.9	24-Jan	100	0.060	min	0.978	0.0274	6	40	89	66	1	2	3	0
Mud	6.5	24-Jan	99	0.232	min	1.042	0.0219	23	41	97	78	4	1	18	0
Mud	7.3	24-Jan	126	0.071	min	1.008	0.0517	9	40	100	70	4	0	5	0
Mud	12.0	24-Jan	36	1.611	min	1.124	0.0056	58	87	117	100	0	0	58	0
Dye	3.3	30-Jan	35	0.012	min	0.882	0.0101	57	39	60	47	44	18	0	0
Salt	5.8	30-Jan	80	0.011	min			1	103	103	103	0	0	1	0
Mud	6.8	9-Feb	75	0.267	min	1.136	0.0614	20	42	91	53	13	6	1	0
Mud	5.0	13-Feb	60	0.383	min	0.952	0.0191	22	46	62	52	14	9	0	0
Mud	6.5	13-Feb	99	0.227	min	1.056	0.0215	17	46	107	77	6	1	10	0
Mud	6.8	13-Feb	75	1.224	23	1.080	0.0140	66	39	114	60	35	24	11	0
Jewett	2.1	16-Feb	127	0.214	46	0.918	0.0244	23	37	58	46	22	2	0	0
Jewett	3.5	16-Feb	24	0.000											
Jewett	4.2	16-Feb	45	0.000											
Mud	5.0	27-Feb	49	0.653	min	0.990	0.0169	32	45	68	57	19	12	0	0
Mud	6.5	27-Feb	50	0.040	min	0.812	0.0923	2	50	51	51	2	0	0	0
Mud	8.3	27-Feb	78	0.000	min			0							
Mud	8.8	27-Feb				0.965	0.0179	8	47	63	54	7	1	0	0
Blue Tent	0.4	28-Feb	8	1.250	min	0.886	0.0209	10	43	50	47	10	0	0	0
Blue Tent	3.0	28-Feb	150	0.000	min										
Dye	3.3	28-Feb	45	0.536	35	0.952	0.0111	22	48	66	56	17	8	0	0
Salt	5.8	28-Feb	37	0.012	min	1.006	0.0121	29	47	94	59	21	7	2	0
Salt	5.9	28-Feb	40	0.701	1										
Toomes	1.5	28-Feb	60	0.773	min	0.917	0.0105	45	43	76	53	36	10	0	0
Mud	11.7	2-Mar	100	0.040	min	0.976	0.0814	4	53	112	90	1	0	3	0
Dry	1.6	6-Mar	24	0.638	58	0.713	0.0597	36	37	64	50	35	1	0	0
Ash	1.0	7-Mar	14	0.575	min	0.926	0.0198	16	41	98	58	11	5	1	0
Ash	1.4	7-Mar	28	0.301	19	0.927	0.0333	8	41	69	59	4	5	0	0
Ash	1.8	7-Mar	110	0.000											
Dye	4.7	7-Mar	45	0.400	min	0.988	0.0370	18	55	70	61	10	8	0	0
Little Butte	?	9-Mar	NR					9	50	55	52	9	0	0	0
Mud	3.9	13-Mar	84	3.798	11	0.917	0.0036	314	47	77	59	295	39	0	0
Mud	5.0	13-Mar	22	1.804	11	1.011	0.0073	56	51	87	62	46	15	0	0
Mud	8.4	13-Mar	27	1.481	0	1.107	0.0157	40	52	77	63	29	15	0	0
Mud	10.1	13-Mar	24	0.000											
Churn	0.9	14-Mar	35	0.829	min	0.984	0.0156	28	42	70	55	25	4	0	0
Olney	0.5	14-Mar	12	0.521		4 pass									
Olney	0.5	14-Mar	6	16.73	min	1.006	0.0124	113	36	79	60	82	45	0	0
Stillwater	0.4	14-Mar	140	0.233	min	1.056	0.0165	32	44	117	70	18	6	9	0
Mud	3.9	20-Mar	24	1.761	6	0.996	0.0095	41	53	131	66	27	16	1	0
Mud	7.5	20-Mar	61	0.293	13	1.068	0.0147	17	62	76	68	9	10	0	0
Mud	10.1	20-Mar	6	0.514	5	1.075	0.0101	28	58	80	67	15	15	0	0
Mud	12.4	20-Mar	130	0.558	3	1.118	0.0084	72	57	89	72	15	61	0	0
Mud	13.4	20-Mar	87	0.308	12	1.102	0.0125	19	63	85	72	4	15	0	0
Mud	14.2	20-Mar	55	0.194	26	1.092	0.0174	11	62	85	75	2	9	0	0
Dibble	0.5	21-Mar	76	0.654	9	1.026	0.0203	48	36	72	55	41	8	0	0
Dibble	1.0	21-Mar	NR*	0.000				0							
Dibble	1.6	21-Mar	NR*	0.000				0							

Table 2. Summary of sampling data for 1998.

CREEK	Strm km	DATE	seine haul (m)	No./meter	% Error	mean K	SE (K)	n	FL (min)	FL (max)	FL (mean)	No. Fall	No. Spring	No. Winter	No. Late Fall
McClure	1.5	21-Mar	36	3.171	2	1.079	0.0059	89	50	77	64	72	21	0	0
RedBank	1.6	21-Mar	34	0.412	0	1.058	0.0159	21	59	73	67	14	11	0	0
RedBank	8.4	21-Mar	70	0.000		1 pass									
Reeds	0.7	21-Mar	21	0.298	58	1.037	0.0410	5	63	70	68	3	3	0	0
Reeds	2.8	21-Mar	150	0.000		1 pass									
Jewett	2.1	24-Mar	39	0.668	2	1.134	0.0154	24	58	77	67	19	8	0	0
Jewett	3.5	24-Mar	19	0.410	112	1.100	0.0447	6	65	77	71	3	4	0	0
Jewett	4.2	24-Mar	45	0.044	0	1.199	0.0184	2	78	79	79	0	2	0	0
McClure	3.1	24-Mar	26	0.281	17	1.175	0.0381	24	56	78	69	13	12	0	0
McClure	3.1	24-Mar	25	0.734	3										
McClure	7.9	24-Mar	52	0.054	0	1.198	0.0509	3	73	105	86	0	2	1	0
Rice	11.1	24-Mar	50	0.030	min	1.210	0.0278	3	71	80	76	0	3	0	0
Kusal/Rock	7.1	27-Mar	66	1.642	4	1.045	0.0043	107	63	83	73	35	84	0	0
Kusal/Rock	10.4	27-Mar	185	1.661	5	1.048	0.0065	58	61	91	72	27	35	0	0
Kusal/Rock	16.3	27-Mar	91	0.178	0	1.074	0.0092	33	68	88	77	3	30	0	0
Kusal/Rock	17.4	27-Mar	80	0.088	0	1.105	0.0316	6	70	80	74	2	4	0	0
Churn	3.3	10-Apr	49	1.498	min	1.027	0.0052	74	48	91	68	71	4	0	0
Churn	7.8	10-Apr	104	0.548	min	1.074	0.0084	57	44	88	60	54	3	0	0
Churn	10.0	10-Apr	70	1.200	min	1.046	0.0166	84	41	90	63	75	11	0	0
Olney	0.5	10-Apr	35	0.700	9	0.881	0.0150	24	40	54	46	24	0	0	0
Dye	1.6	11-Apr	62	2.383	17	0.964	0.0068	125	38	78	64	125	1	0	0
Dye	4.6	11-Apr	63	1.751	10	1.022	0.0050	102	52	98	69	76	27	0	0
Dye	6.3	11-Apr	28	0.179	min	1.061	0.0285	5	69	86	76	4	1	0	0
Toomes	1.5	17-Apr	104	1.841	min	1.007	0.0078	72	41	82	65	72	1	0	0
Toomes	2.4	17-Apr	74	0.568	1	1.044	0.0088	42	65	88	76	31	12	0	0
Ash	0.9	18-Apr	54			1.041	0.0105	25	48	77	58	25	0	0	0
Churn	14.2	18-Apr	45	0.301	min	1.033	0.0247	14	38	79	71	14	0	0	0
Churn	17.6	18-Apr	49	0.102	min	1.087	0.0280	5	65	70	67	5	0	0	0
Dry	1.9	18-Apr	75	0.026	min	1.230	0.1247	2	73	81	77	2	0	0	0
Dry	6.3	18-Apr	10	0.100	0			1							
Stillwater	3.9	18-Apr	200	0.000				0							
Stillwater	12.1	18-Apr	150	0.000				0							
Mud	3.9	24-Apr	56	2.801	10	1.112	0.0062	107	68	91	80	98	18	0	0
Mud	5.9	24-Apr	163	0.448	0	1.054	0.0078	73	59	93	79	64	9	0	0
Mud	12.4	24-Apr	158	0.112	14	1.232	0.0218	3	75	115	93	1	2	1	0
Mud	13.7	24-Apr	120	0.025	0			3							
Dibble	0.5	25-Apr	36	0.984	5	1.064	0.0195	35	43	80	55	35	0	0	0
Elder	5.4	25-Apr	50	0.120	min	1.236	0.0241	6	81	101	88	3	5	0	0
McClure	1.5	25-Apr	72	0.599	3	1.172	0.0097	43	60	90	73	42	1	0	0
Oat		25-Apr	20	0.000				0							
Salt	5.8	25-Apr	37	1.501	min	1.242	0.0082	56	77	112	92	9	50	0	0
Pine	9.1	1-May	60	0.100	min	1.175	0.0289	6	75	95	86	4	2	0	0
Pine		1-May	100	0.000				0							
Toomes	1.5	1-May	74	0.705	2	1.035	0.0151	52	47	94	63	51	1	0	0

Table 2 (Cont.). Summary of sampling data for 1998.

Presence and Distance Upstream

A comparison of data obtained in different years provides insight into the movement of juvenile chinook within tributary streams. In years such as 1994 and 1997 when there were few storm events, fish entered the creeks only a few times, found an area of good habitat and remained there until stimulated to move by high temperature, low water, or their own maturation. At a given site, a steady change in sizes can be observed and growth rates are easily estimated. In years such as 1998, repeated storm events keep stream stages in a state of flux. Small juveniles show up at sample sites on most sampling dates and modal shifts in fork length do not correspond to any realistic estimates of growth. Apparently the juveniles both enter and move within the tributaries as a response to stream stage changes. The stimulation to movement by stage changes is probably a function of juvenile chinook seeking good habitat. "Good" habitat changes with stream stage; ideal habitat at one stage is too swift, too shallow, or even nonexistent, at another stage.

One consequence of the continual stimulus to move is that juvenile chinook went further upstream this year than we had seen before although, as usual, relative numbers decreased further from the river. (See Table 1 and Figure 13.) Very probably the upstream distance observed this year is about the maximum that would ever be expected. Maximum distance moved upstream is inversely correlated with stream gradient but does not seem to be related to stream size (Figure 2). Some other factors such as obstacles or water quality must also be involved.

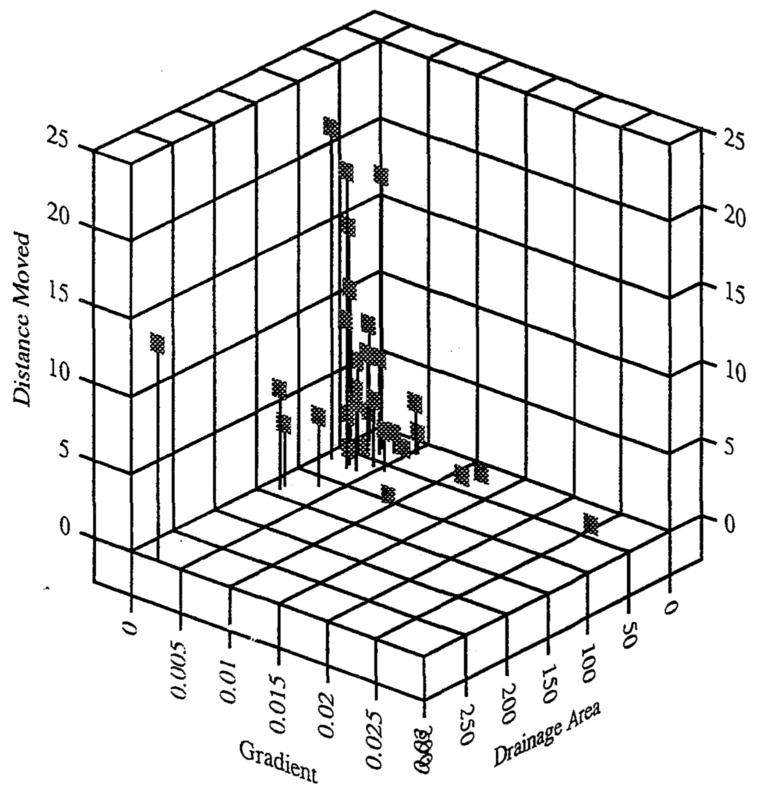


Figure 2. Relationship of upstream distance moved to stream size and gradient.

Condition

Condition factor was calculated from the formula:

$$CF = 100{,}000 \times \text{weight in grams} / (\text{fork length in mm})^3.$$

Figure 3 shows the average condition factor for tributary-rearing juvenile chinook salmon above 50 mm for different dates and different years. At all times average condition for fish greater than 50 mm is 1.0 or better. Figures 4, 6, 8, and 10 provide a more detailed look at condition, showing (A), a plot of all condition factors for juveniles of different sizes regardless of date and (B), a plot of average condition for fish of a particular 10 mm size range against median fork length. In all years condition factor increased as the juveniles grew, leveling off at a value substantially above 1. Figures 5, 7, 9, and 11 show the relationship between condition factor and fork length for juvenile chinook captured from the Sacramento River. Data for 1998 and 1997 (Figures 5 and 7) are DFG data. Unfortunately, they used a slightly different procedure than we did, resulting in a heavier reading (they did not blot excess water from the fish). This, of course, calculates to an artificially high condition factor for the river fish, particularly apparent in the smaller sizes. Because of this procedural difference, no statistical comparisons can be made between tributary and river condition factors for those years. Data from 1996 (Figure 9) and 1995 (Figure 10) were taken by the authors, using the same procedure we used for tributary fish. Although the sample size is smaller, it is large enough to show that condition factor for Sacramento-river-rearing juvenile chinook levels off at approximately 1.0. Based on a t-test of the means of each 10 mm group, juveniles rearing in tributaries showed a significantly higher (α=.05) condition factor for all size ranges from 50 to 90 mm. Apparently juvenile chinook find better living conditions in non-natal tributaries than in the mainstem. Although we are unable to compare river data for 1997 and 1998, the turbid conditions that prevailed in the river as a result of flood water being stored and released gradually from reservoirs may be assumed to have made rearing conditions even less favorable in those years.

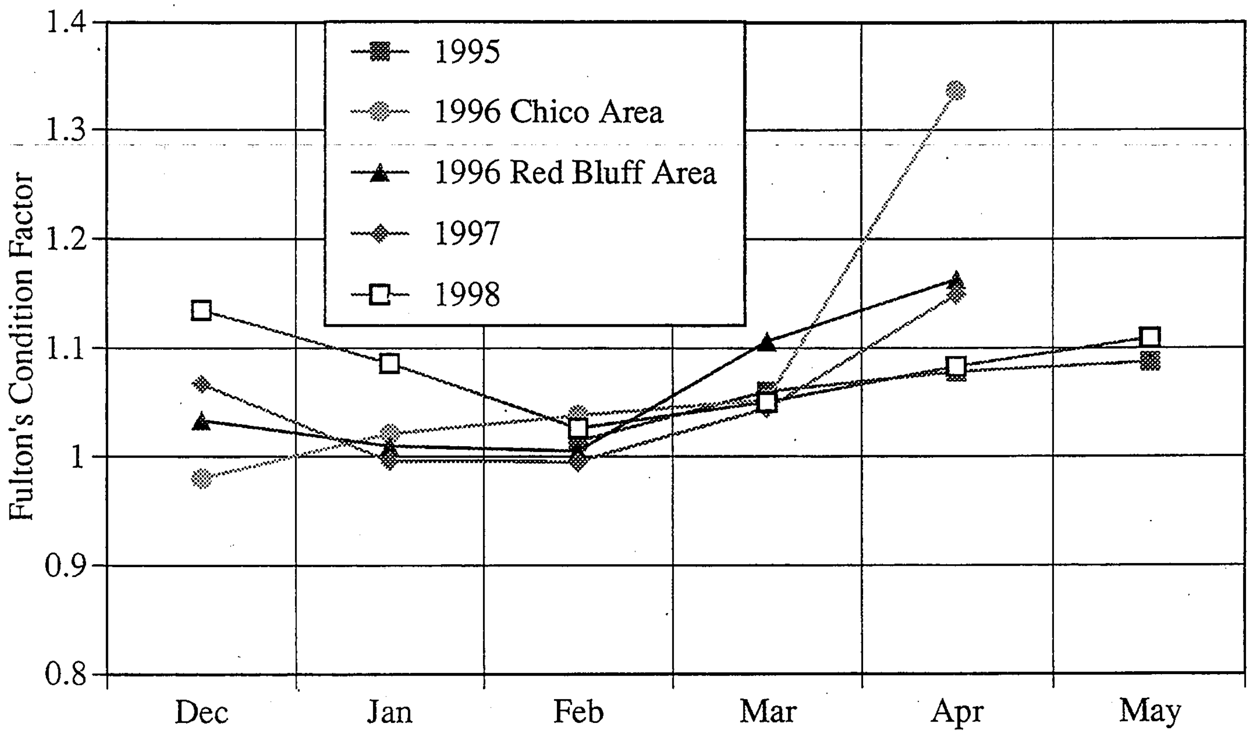


Figure 3. Average condition factor for all tributary-rearing juvenile chinook larger than 50 mm FL at different dates.

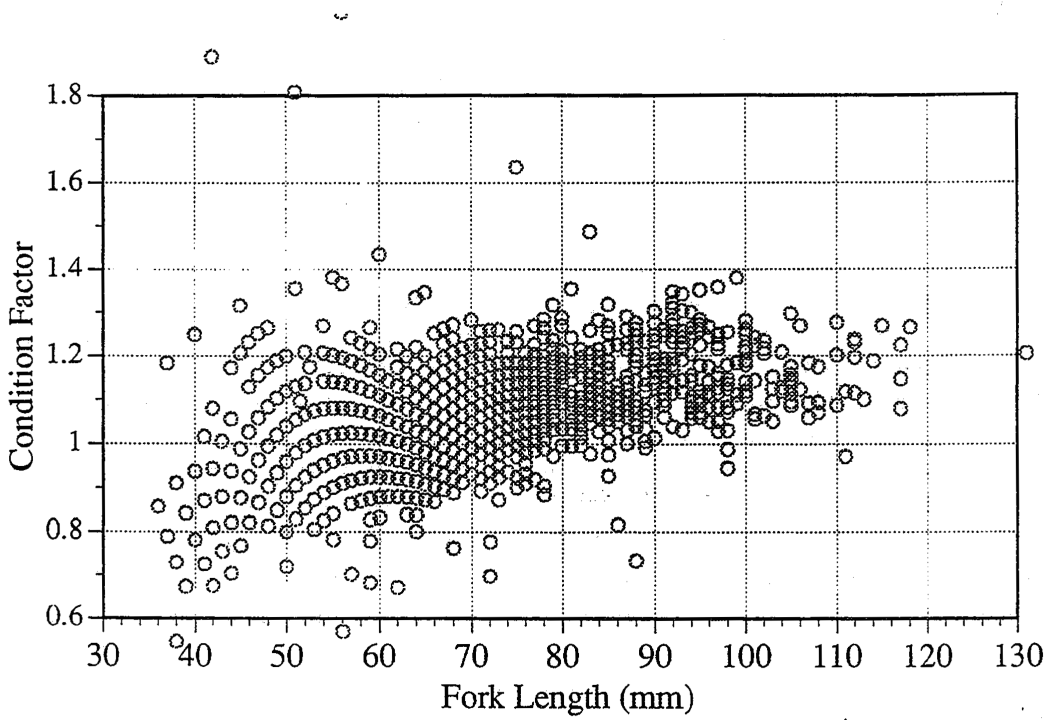


Figure 4A. Condition factor vs fork length for all tributary-rearing juvenile chinook in 1998. (The rooster-tail pattern results from the formula and the discrete units of measurement.)

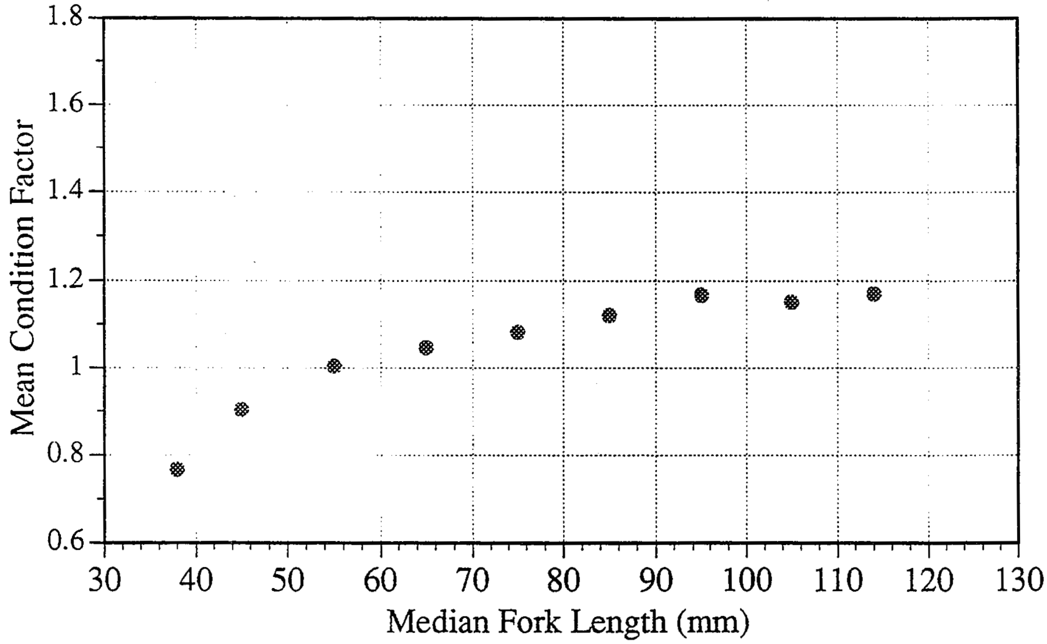


Figure 4B. Average condition factor for 1998 tributary-rearing juvenile chinook within a particular 10 mm size range against median fork length.

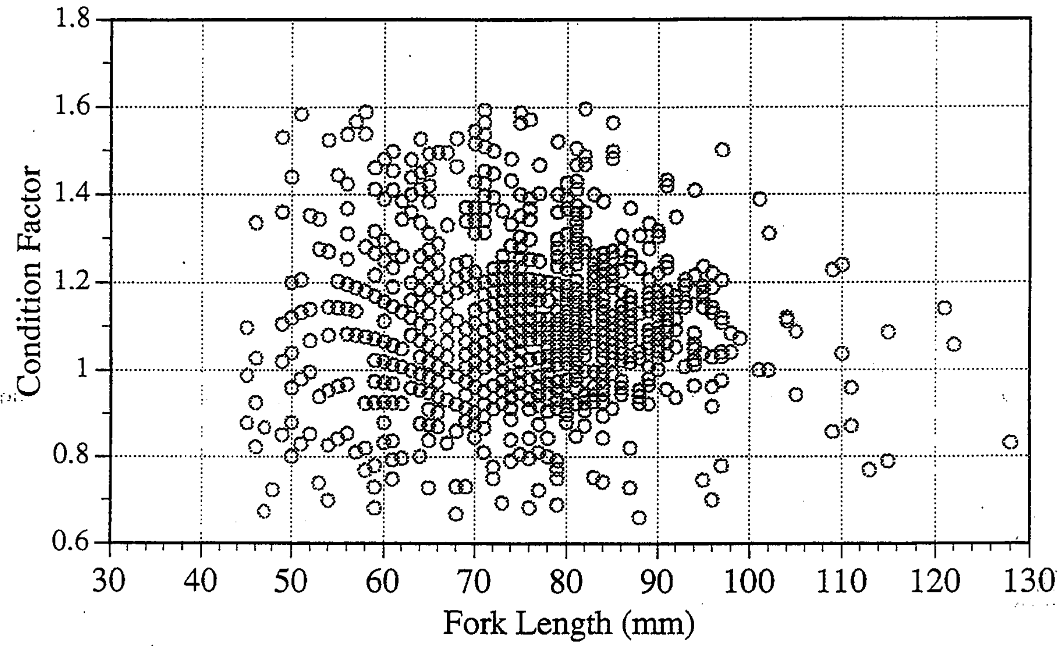


Figure 5A. Condition factor vs fork length for Sacramento River-rearing juvenile chinook in 1998. (Data courtesy of Bill Snider, CA DFG.)

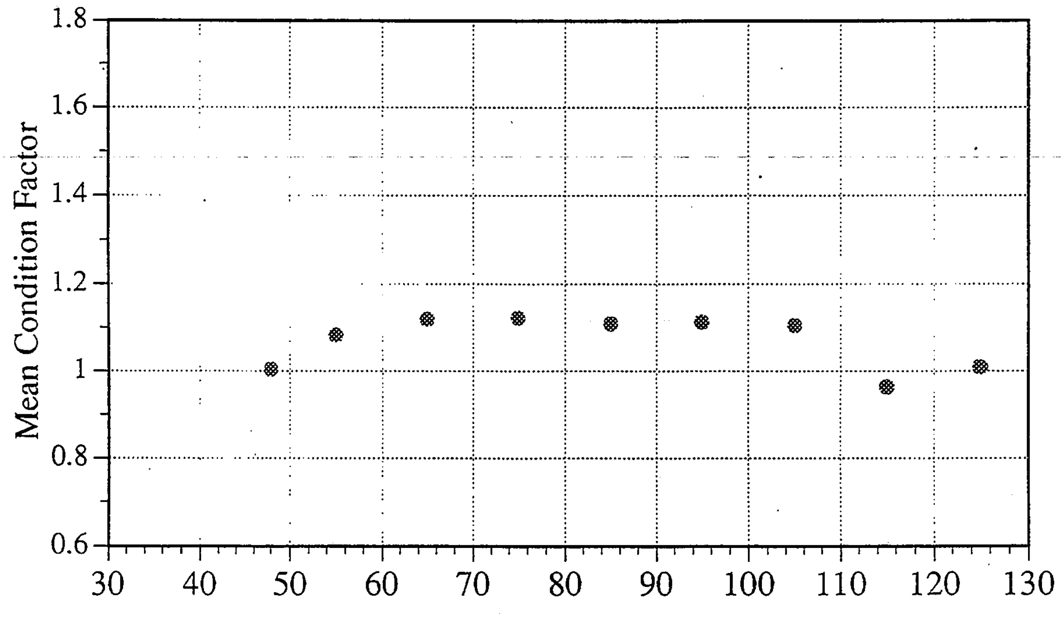


Figure 5B. Average condition factor for 1998 Sacramento River-rearing juvenile chinook within a particular 10 mm size range against median fork length. (Data courtesy of Bill Snider, CA DFG.)

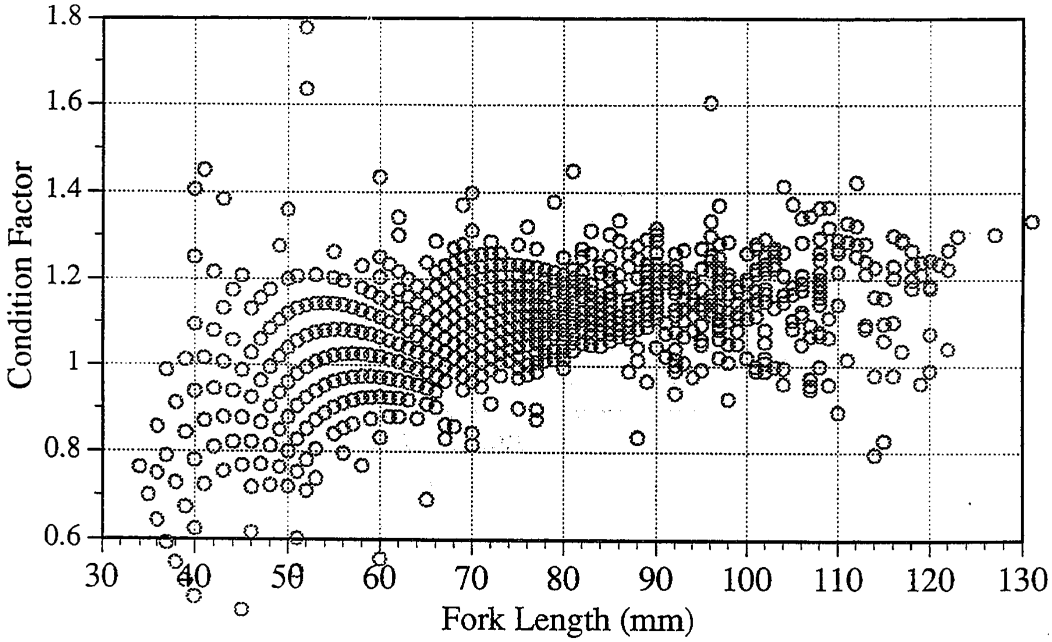


Figure 6A. Condition factor vs fork length for all tributary-rearing juvenile chinook in 1997.

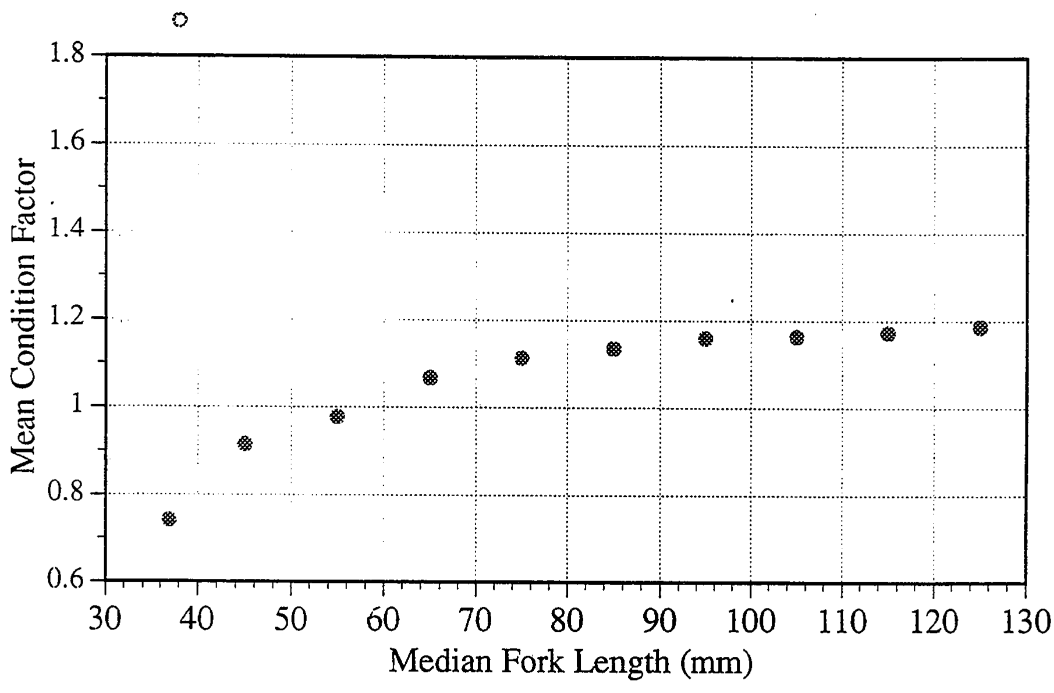


Figure 6B. Average condition factor for 1997 tributary-rearing juvenile chinook within a particular 10 mm size range against median fork length.

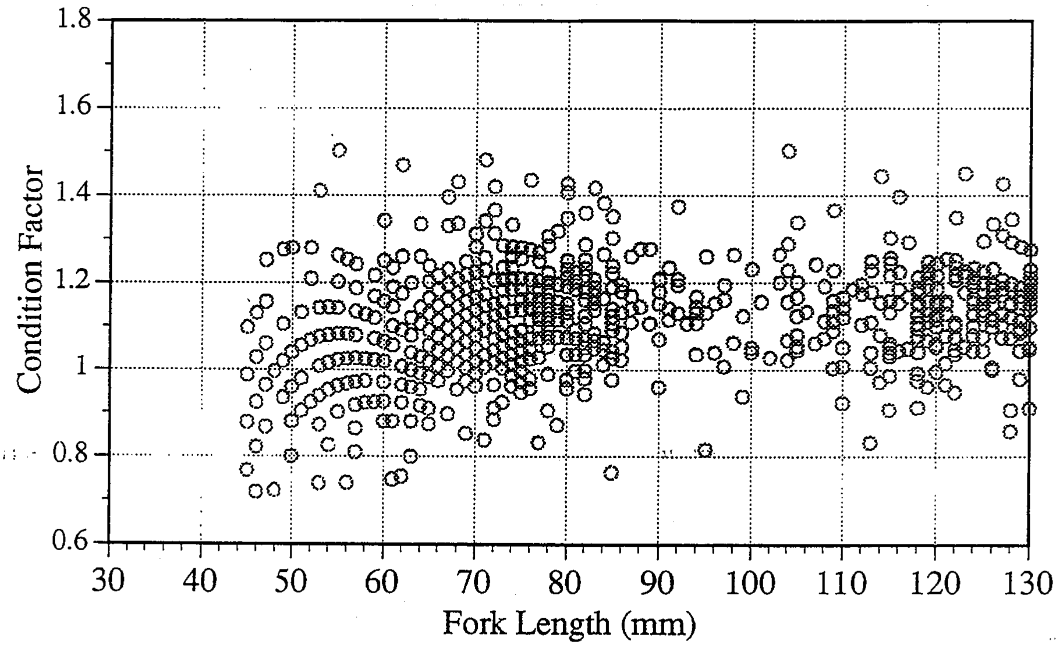


Figure 7A. Condition factor vs fork length for Sacramento River-rearing juvenile chinook in 1997. (Data courtesy of Bill Snider, CaDFG.)

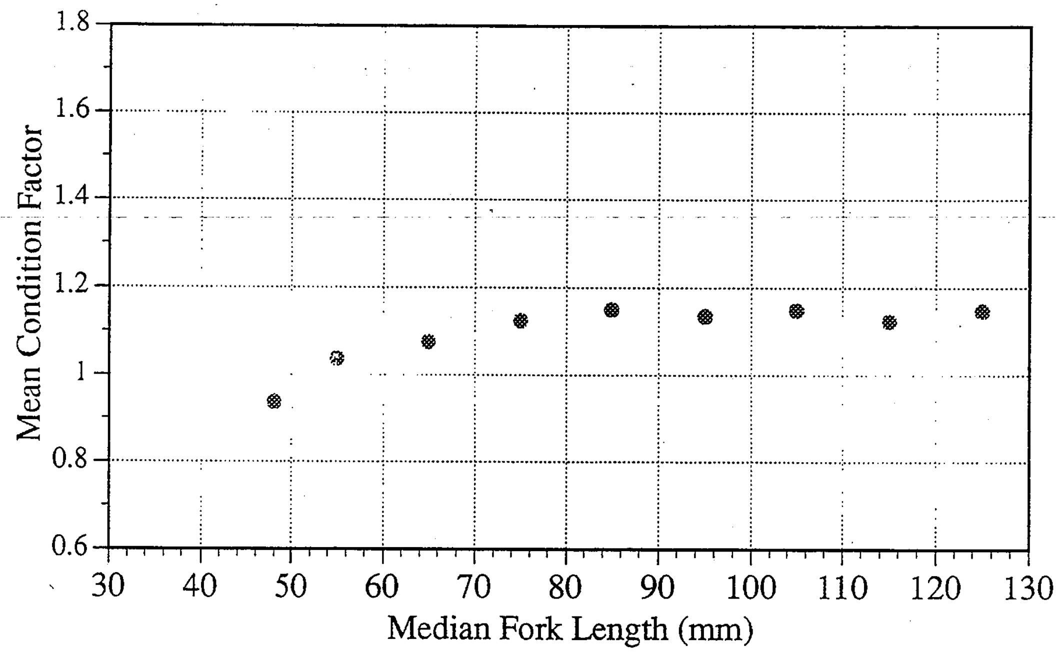


Figure 7B. Average condition factor for 1997 Sacramento River-rearing juvenile chinook within a particular 10 mm size range against median fork length. (Data courtesy of Bill Snider, CaDFG.)

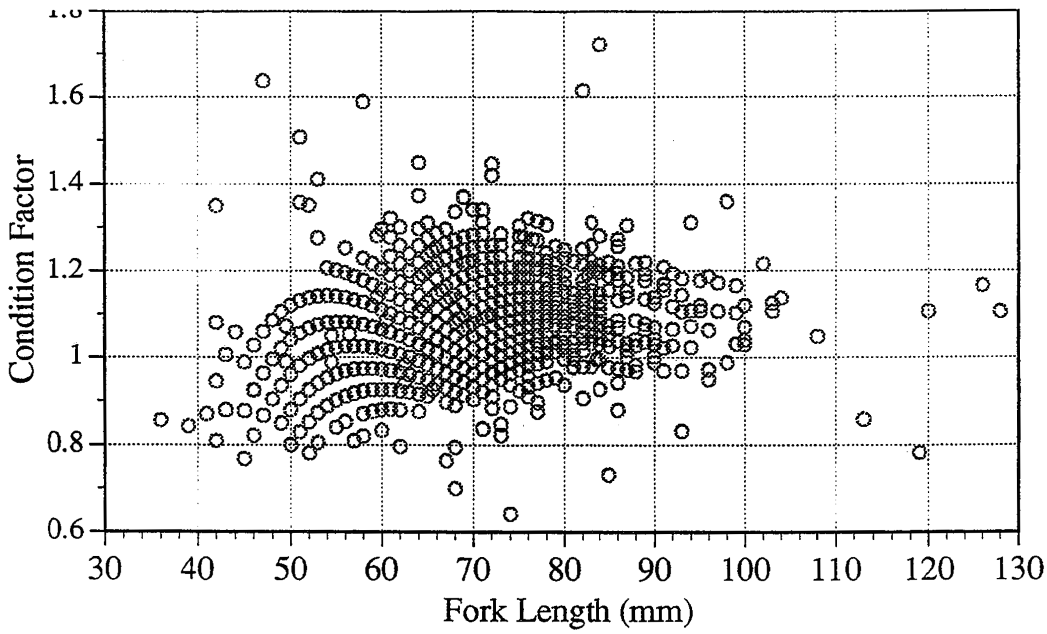


Figure 8A. Condition factor vs fork length for all tributary-rearing juvenile chinook in 1996.

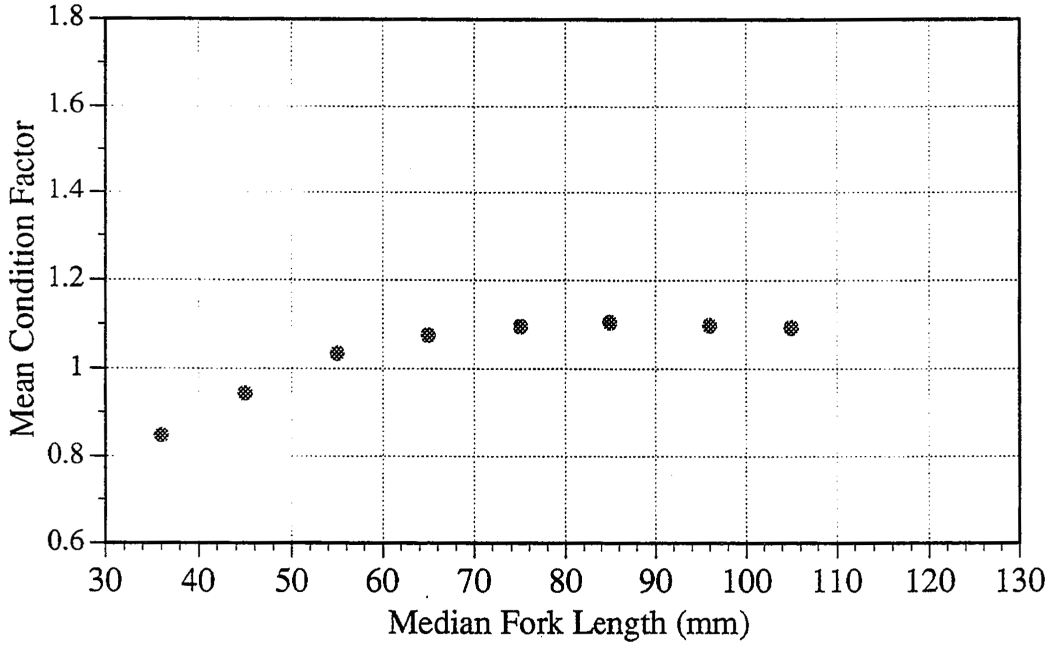


Figure 8B. Average condition factor for 1996 tributary-rearing juvenile chinook within a particular 10 mm size range against median fork length.

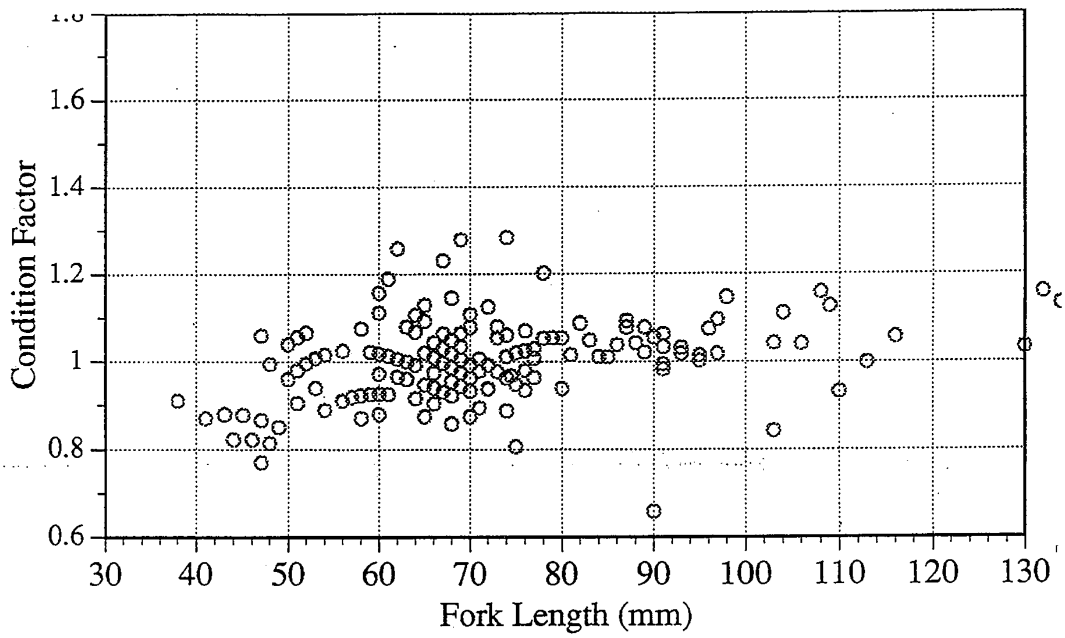


Figure 9A. Condition factor vs fork length for Sacramento River juvenile chinook in 1996.

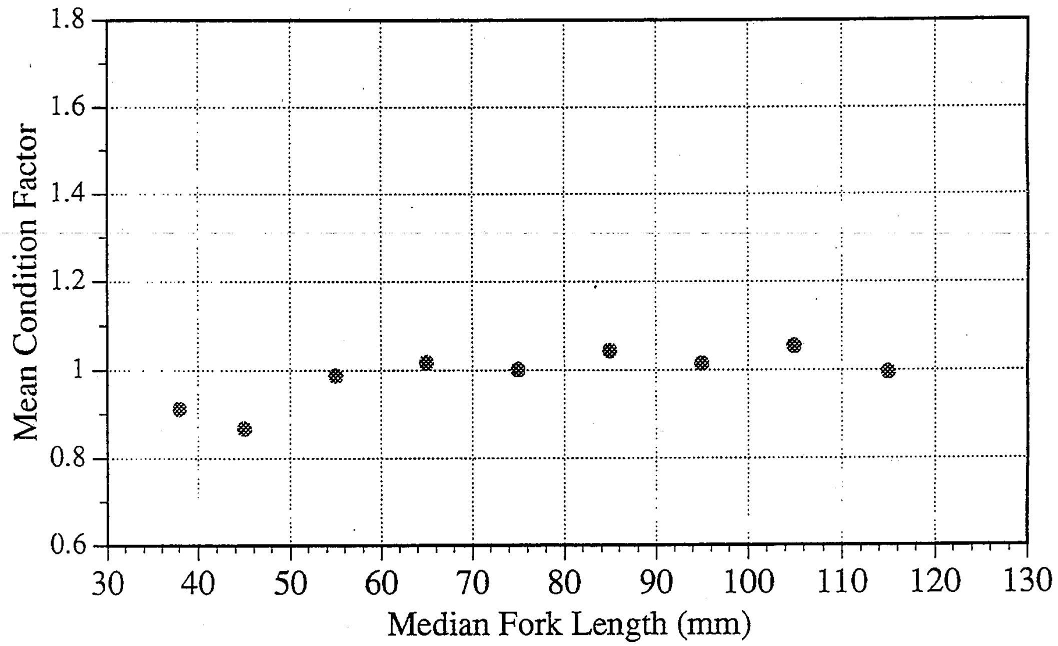


Figure 9B. Average condition factor for 1996 Sacramento river juvenile chinook within a particular 10 mm size range against median fork length.

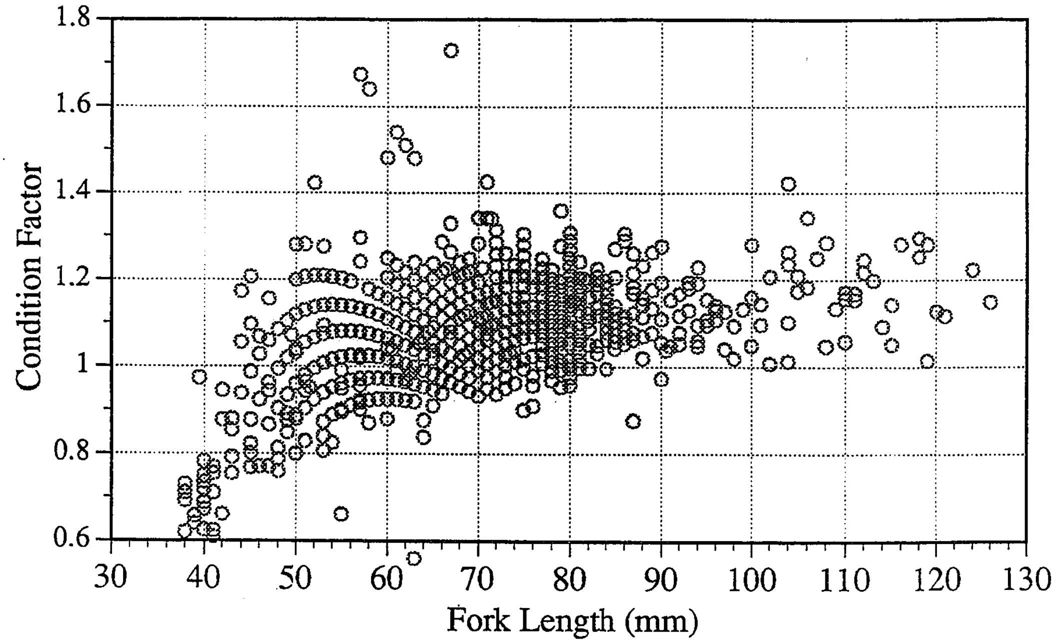


Figure 10A. Condition factor vs fork length for all tributary-rearing juvenile chinook in 1995.

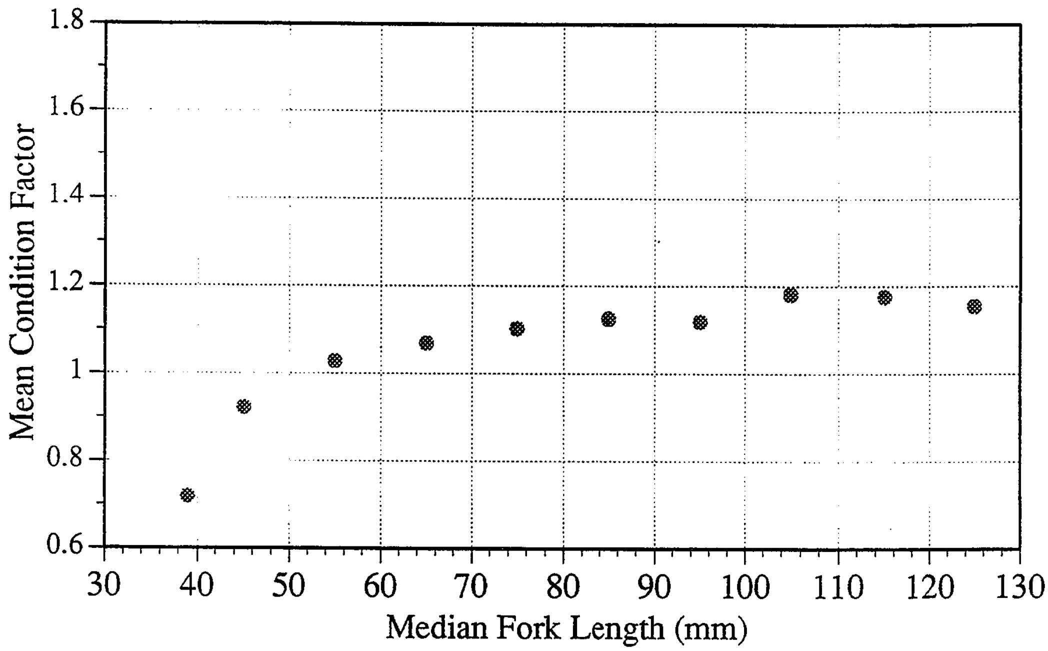


Figure 10B. Average condition factor for 1995 tributary-rearing juvenile chinook within a particular 10 mm size range against median fork length.

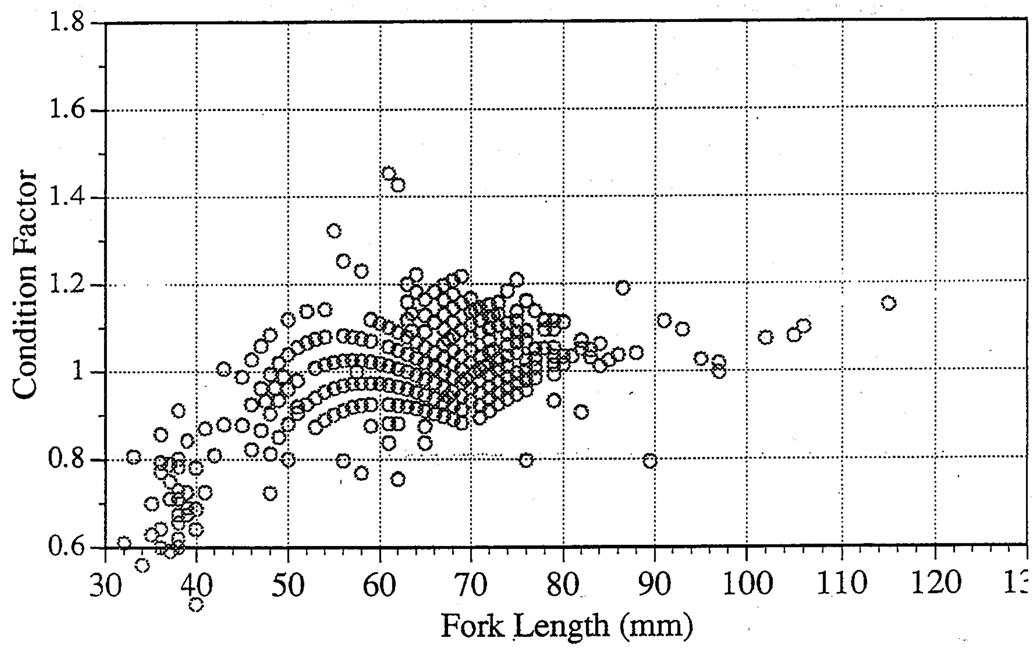


Figure 11A. Condition factor vs fork length for Sacramento River juvenile chinook in 1995.

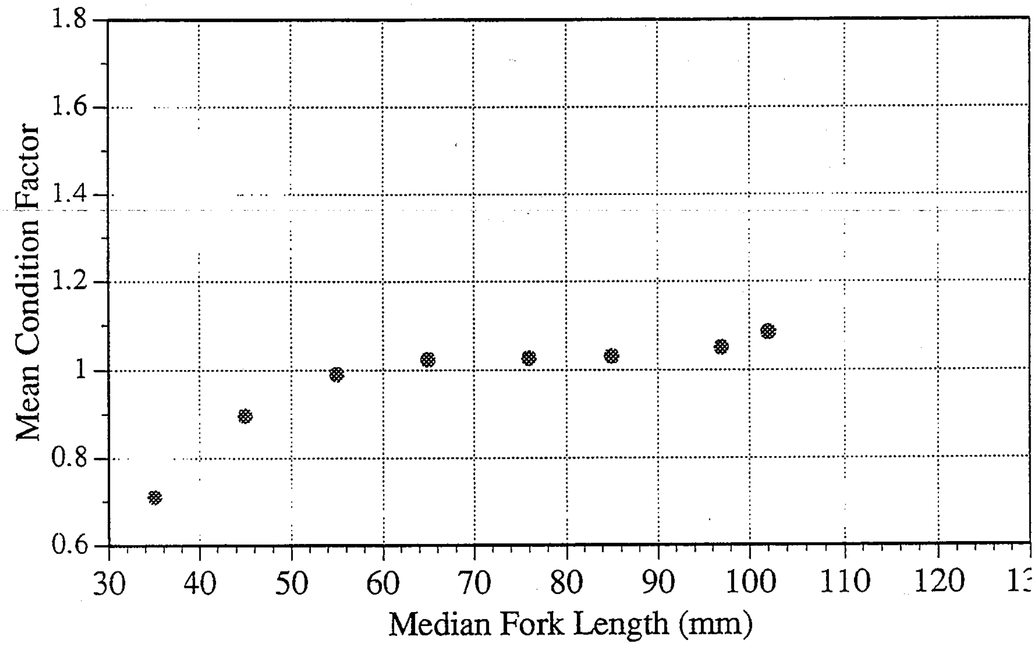


Figure 11B. Average condition factor for 1995 Sacramento River juvenile chinook within a particular 10 mm size range against median fork length.

Density Calculations

Confident density calculations of chinook per sample site were few since quantitative sampling was difficult due to continual high water conditions. Mud Creek, targeted for intensive study in 1998, was often too high for effective sampling. The number of juveniles in the streams varied throughout the season, with the greatest number being present from mid-February through mid-April (Table 2). Density values were roughly comparable in the two years with slightly higher values in 1997 and juveniles found further upstream in 1998 (Figure 13).

Population Estimates

Density estimates were plotted against stream distance and, assuming that densities decline in a linear fashion away from the river, a line relating density to stream distance was drawn, The area under this curve was used as an estimate of stream population. Since densities vary over time as fish migrate in and out of the tributaries and the desired statistic was total fish using the stream, lower values were given less weight than higher values. An example of the procedure is shown for Mud Creek, for which we had the most data (Figure 12). Similar techniques were employed for all streams for which estimates were available for more than one site. Graphs for the various creeks

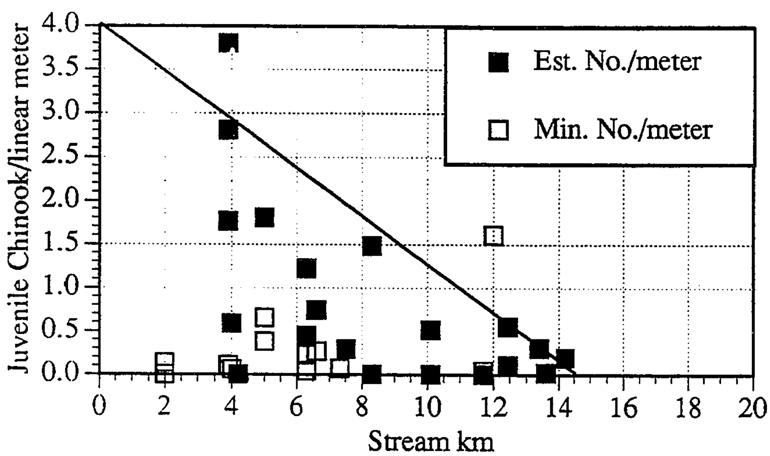


Figure 12. Juvenile chinook densities in Mud Creek in 1998 and the line used for population estimation.

with the line used are shown in Appendix 1.

To approximate juvenile populations rearing in tributaries for which we had less data, assumptions were made and data extrapolated. First, quantitative data from all tributaries was plotted against distance from the stream mouth (Figure 13) This figure shows that density decreases away from the river. Assuming a linear decrease, we can approximate a slope of a loss of one fish/linear meter for every 5 km of stream. This approximation was applied to streams with density estimate(s) at only one site to project a density curve and estimate population. For creeks that we were unable to sample this year either due to high flow or time constraints, data from former years and comparison

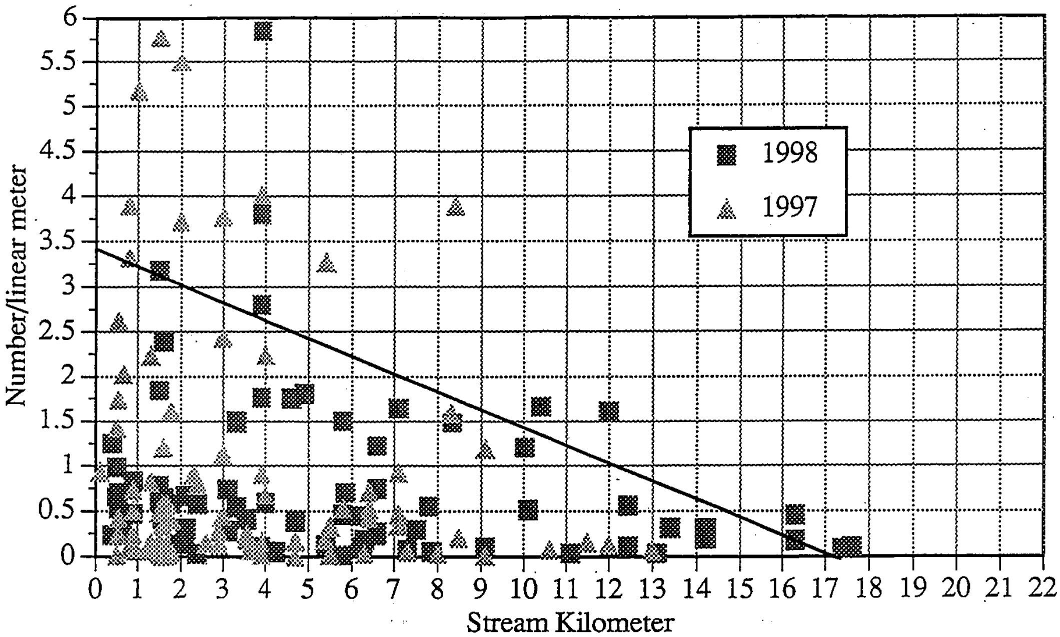


Figure 13. Densities measured at different distances from the river in all tributaries over a two year period.

with similar streams was used to guess populations. Table 4 shows the resulting estimates.

It must be emphasized that these estimates are little more than educated guesses. They are almost certainly low, perhaps by a factor of 2 or more for several reasons:

1. Sampling was difficult this year, in particular we were unable to sample in the lower portions of the creeks where juvenile chinook were most abundant, but, due to backwater effects from the high river, water was consistently too deep for quantitative sampling.
2. The population projections are based on data from the time (February 15 to April 15) when juvenile chinook are most abundant in the tributaries, but does not correct for the different cohorts moving through the system; some have already left and some will arrive later. An example of this can be seen in the data for Mud Creek. During December and January, before the big rains, we captured 176 winter chinook at 6 sampling sites, an average of 0.551 fish / meter (See Table 2.) (We reduced our sampling days during this period because at that rate of take we would have quickly exceeded out quota for winter chinook.) Projecting that data to yield a population estimate gives a value of 10,000 winter chinook in Mud Creek in January, about one third of the population estimate for Mud Creek for February through April. None of those winter chinook were still present at the time counts were made for population estimates.
3. We are simply unable to sample in what is probably the best habitat, deep water with lots of cover.

	meters of stream	maximum fish/meter	calculated population	note
Ash	2000	1	1,000	2
Bear	8200	1.2	4,920	4
Blue Tent	1500	1.5	1,125	1
Churn	18200	2	18,200	2
Coyote	2000	0.4	400	4
Dibble	1000	1	500	1
Dry	7000	0.8	2,800	1
Dye	6200	3.8	11,780	1
Elder	6000	1.2	3,600	3
Inks	2000	0.4	400	4
Jewett	4600	1.25	2,875	1
McClure	6800	2.5	8,500	1
Mud	14200	4	28,400	1
Oat	3000	0.6	900	4
Olney	1450	3	2,175	2
Pine	18000	3.5	28,000	4
Reeds	2000	0.4	400	1
Rice	11000	2.1	11,550	3
Rock	18000	3.1	27,900	1
Salt	11000	2.1	11,550	3
Stillwater	1900	0.3	285	2
Thomes	13000	2.5	16,250	4
Toomes	3000	2.7	4,050	1
TOTAL			**187,560**	

1 based on several good estimates of density
2 based on several minimal estimates of density
3 based on a density estimate at one site and the approximation that density typically decreases by 1 fish/meter over 5 km (see figure 13)
4 based on data from previous years and comparison with similar streams

Table 3. Rough approximations of non-natal rearing chinook in 1998.

While the population estimates for this year are probably low compared to what was actually there, this year's populations were probably lower than many years due to the probability of juveniles or eggs being carried to the delta by high river flows and thus not being available to rear locally. Unfortunately, last year's populations were also probably low for the same reason. It would be nice to have some data from a "normal" year. However, the number of fish we captured per seine haul in 1997 and 1998, while lower, was not drastically different than previous years so the estimates are probably in the right order of magnitude. It is reasonable to conclude that between 100,000 and 1 million juveniles rear non-natally in tributaries.

Chinook Races

By the Upper Sacramento River daily length chart chinook juveniles captured in the 1998 season would break down as follows:

Race	Number Captured
Fall	2032
Spring	770
Winter	204
Late Fall	2

Because the juveniles grow faster in intermittent tributaries than in the mainstem, these breakdowns to race are suspect, juveniles that have been in the tributaries a long time tend to be misidentified to an earlier-spawning race (Maslin, et al., 1997). Winter chinook are most easily separated by size since their spawning period is most isolated.

Tissue samples from 72 juvenile chinook (of winter-run size or near winter-run size) from Mud Creek were collected and sent to Michael Bank's laboratory at the Bodega Bay facility for race analysis based on microsatelite DNA. DNA analysis was possible on 62 of the samples. Figure 13 shows the classification based on DNA against a shaded background of winter size based on the Sacramento River Daily Length Chart.

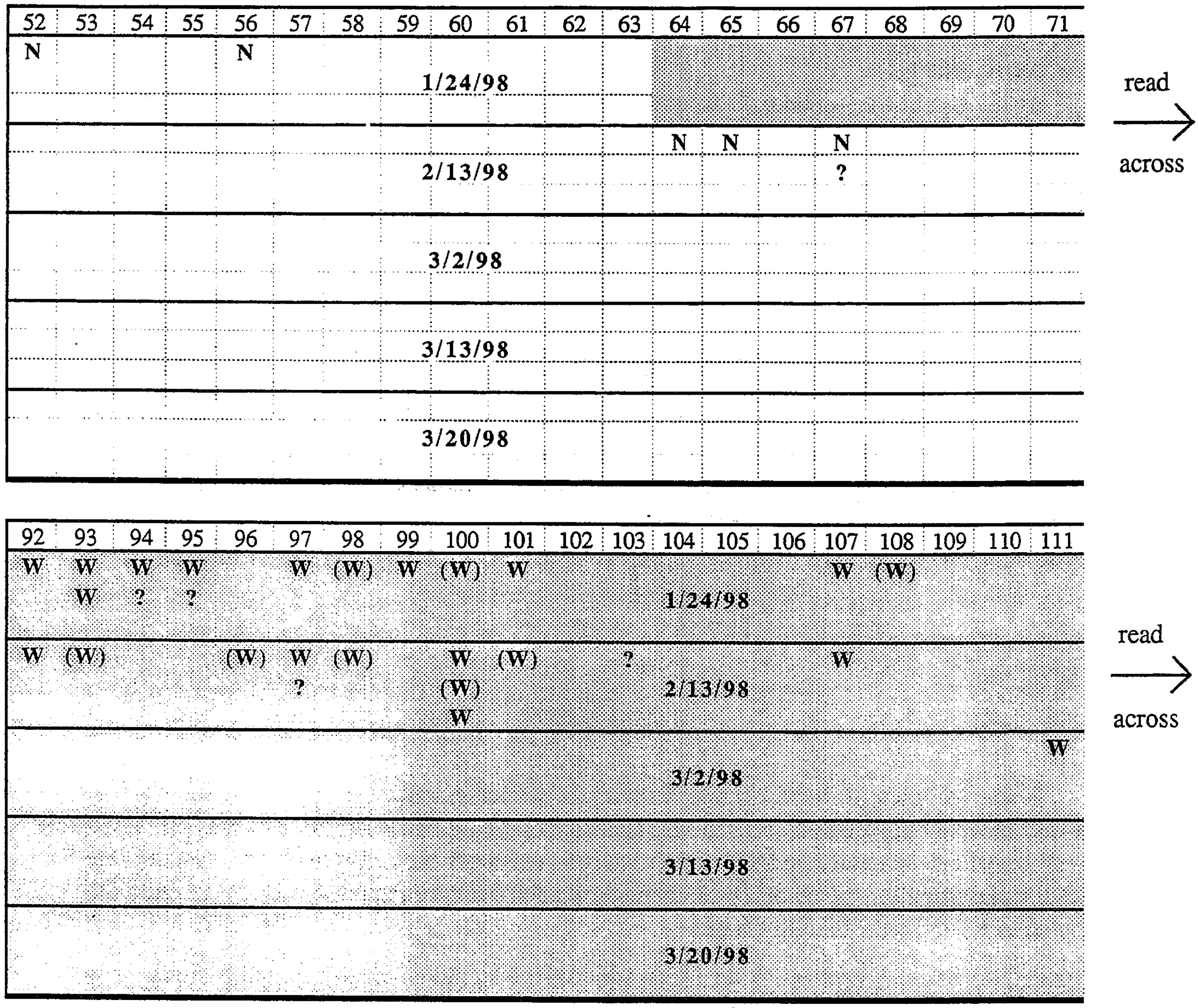


Figure 14. Race based on DNA shown on a background shaded to indicate the size of winter chinook according to the Upper Sacramento River Daily Length Chart.

Table 4. Summary of agreement of DNA race analysis with size-based race analysis.

Category based on size	Category based on DNA	Number
winter	winter	43
non-winter	non-winter	14
winter	non-winter	3
non-winter	winter	2

Table 4 summarizes the results. In 92% of the cases the assignment of race to winter or non winter based on size agreed with the DNA analysis. Unfortunately, insufficient microsatelite loci have been developed to separate other races at this time.

read

ıcross

Date	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
1/24/98							(W)				W W	W W		(W)	W	W N	X	W W		W
2/13/98							W							?	(W)		W		(W) W	W
3/2/98														?						
3/13/98											(W)					?				
3/20/98											N N N			(N) N N	W	N		N		

ʼead

:ross

Date	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131
1/24/98	W	(N)																		
2/13/98			N																	
3/2/98	W																			
3/13/98																				
3/20/98																				W

Fork Length across top
W = winter
(W) = high probability of winter (one locus missing)
N = non-winter
(N) = high probability of non-winter (one locus missing)
? = insufficient loci to call

Although only fish from Mud Creek were analyzed, it seems reasonable to infer that most tributary-rearing juveniles classified by size as winter-run chinook were indeed winter-run chinook. Streams in which winter-size chinook have been collected are listed in Table 5. It should be noted that the number collected in a given year is more dependent on the timing and frequency of sampling than on the actual number of juveniles that may have been in the creek. (See Figure 14 and the accompanying analysis.) If a stream was not sampled in December through February, there was little chance of winter-run chinook being captured. Because winter-chinook have been found in all extensively sampled streams, it seems likely that if enough samples were taken between December and February, winter chinook would be found in any of the tributaries which have non-natal rearing chinook.

Creek	93/94	94/95	95/96	96/97	97/98
Ash					1
Big Chico	1				
Blue Tent			43		
Churn				9	
Dibble		2	71		
Dry					1
Dye				1	
Kusal/Rock	8	13	28	30	
McClure				1	1
Mud	82	74	220	29	198
Pine	31			78	
Salt				4	3
Stillwater				3	9
Stony		5			
Toomes	2				
Thomes	1	1			
TOTAL WINTE	125	95	362	155	213
TOTAL JUVENI	4173	2828	4356	2910	3008
% WINTER	3.00%	3.36%	8.31%	5.33%	7.08%
GCID					
TOTAL WINTE	614	1078	5937	1459	
TOTAL JUVENI	170294	163282	122105	121033	
% WINTER	0.36%	0.66%	4.86%	1.21%	

Table 5. Number of winter-size juvenile chinook observed in different Sacramento River Tributaries.

Table 5 also shows the percent of all juveniles captured in tributaries that were winter-chinook size along with the percent captured in the screw traps at the Glenn-Colusa Diversion. The tributary data show a higher percent winter chinook for all years where there are comparable figures. Although procedure is different, both sampling techniques are capturing juvenile salmon from the Sacramento System. If we assume that both the GCID screw traps and our seine hauls in the tributaries provide samples from the same larger population, we can compare them in terms of the percent of juveniles which would be classified as winter race. In all years a substantially higher percent of the fish taken from the tributaries were of the size to be winter chinook. Obviously the two data sets do not represent random samples of the same population. Either winter chinook are more likely than other races to use tributaries for rearing or there is a bias to the sampling so that a higher percentage of winter chinook are captured in the tributaries. The tributary sampling is actually biased away from winter chinook since much of the sampling effort is concentrated after March first when most winter chinook have already migrated (See Figure 15). The GCID sampling, by contrast, may be biased in favor of winter chinook, since the screw traps fish more efficiently during the relatively low flow throughout summer and fall when winter chinook are most prevalent in the river and less efficiently in winter and early spring when river flow is higher and most winter chinook have already emigrated. We conclude that winter chinook make relatively more use of non-natal rearing tributaries.

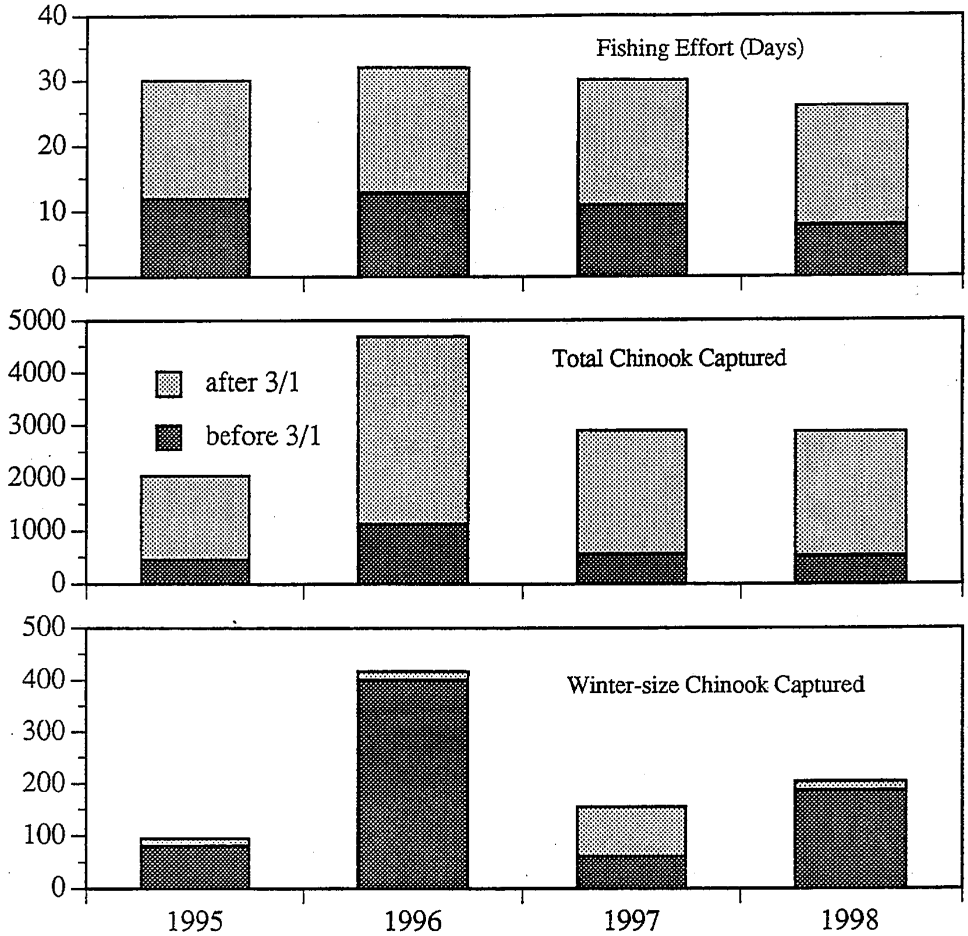


Figure 15. Bias of the tributary sampling away from winter chinook because of timing.

Other Species

Although juvenile chinook were generally the most abundant fish in sample sites, many other species were encountered. Table 6 shows the fish species encountered in each tributary while Table 7 summarizes information about each species. Of all the individual fish captured in intermittent streams, 4.4 % were introduced (compared with 3.7% in 1977). Of the fish species captured 48% were introduced, up from 31% in 1997. The apparent increase in introduced species and numbers is largely due to the inclusion of Little Butte Creek in 1998. If the five introduced species found only in Little Butte Creek are not included, the introduced species fall to 30%. Little Butte Creek differs from all the other streams sampled; it drains a large marshy area that is still an active part of the Sacramento River Floodplain and it is connected to a canal system for transport of irrigation water so is maintained as perennial water.

This year's data reinforces our earlier conclusion that native species, being adapted to California's weather, are conditioned to use seasonal streams for various aspects of their life cycle (Table 7).

TRIBUTARY	bigscale logperch	black crappie	bluegill sunfish	brown bullhead	California roach	carp	chinook salmon	fathead minnow	golden shiner	green sunfish	hardhead	hitch	largemouth bass	mosquitofish	Pacific lamprey	prickly sculpin	riffle sculpin	rainbow/steelhead	Sacramento splittail	Sacramento sucker	smallmouth bass	Sacramento squawfish	speckled dace	threespined stickleback	tule perch	wagasaki	white crappie	SPECIES OBSERVED	INTRODUCED
Ash					x		x											x		x		x	x					6	0
Bear							x				x							x			x							4	1
Big Chico							x				x					x						x						4	0
Blue Tent																x		x				x						3	0
Churn			x		x		x		x	x	x							x		x		x		x				10	3
Coyote							x	x												x		x		x				5	1
Dibble					x		x					x						x		x		x						6	0
Dry			x		x		x			x	x			x			x	x		x		x						10	3
Dye					x		x			x	x			x		x	x			x		x		x				10	2
Elder					x		x			x	x	x						x		x		x						8	1
Inks			x		x		x				x			x				x		x		x						8	2
Jewett			x	x			x		x	x				x		x				x								8	5
Kusal			x				x		x		x	x						x	x	x		x						10	2
Little Butte	x	x				x			x		x	x	x						x	x						x	x	12	7
McClure			x				x		x	x	x		x	x		x		x		x		x		x				12	5
Mud			x				x		x	x	x	x	x	x		x		x		x	x	x			x			14	6
Oat			x		x		x		x					x				x		x		x						8	3
Olney					x		x		x	x	x							x		x		x		x	x			10	2
Paynes											x									x				x				3	0
Pine			x		x		x			x	x		x	x				x		x		x						10	4
Red Bank			x		x		x		x	x						x				x		x		x				9	3
Reeds					x		x				x					x				x		x						6	0
Rice							x		x									x				x						3	1
Salt			x		x		x		x	x	x				x					x				x				9	3
Stillwater							x											x		x	x	x		x				6	1
Sulfur							x											x		x		x		x				5	0
Thomes					x		x				x				x	x		x		x		x						8	0
Toomes					x		x			x	x	x		x	x			x		x		x		x				11	2
																												27	13
CREEKS	1	1	11	1	15	1	24	1	11	12	18	6	4	9	3	9	2	19	2	24	3	23	1	11	2	1	1		

Table 6. Species found in each stream.

Common Name	Scientific Name	Number	Fork Length (mm)	Notes
bigscale logperch*	*Percina macrolepida*	1	75	Observed in Little Butte Creek only.
black crappie*	*Pomoxis nigromaculatus*	7	52 to 218	Observed in Little Butte Creek only.
bluegill sunfish*	*Lepomis macrochirus*	46	22 to 150	Near mouth or in areas with big pools.
brown bullhead*	*Ictalurus nebulosus*	1	218	Jewett Creek.
California roach	*Lavinia symmetricus*	144	30 to 140	permanent pools.
common carp*	*Cyprinus carpio*	7	235 to 636	Observed in Little Butte Creek only.
chinook salmon	*Oncorhynchus tshawytscha*	2882	36 to 600	One adult observed in Mud Creek at Sycamore confluence on 4/24/98.
golden shiner*	*Notemigonus crysoleucas*	43	47 to 138	Near mouth or in areas with big pools.
green sunfish*	*Lepomis cyanellus*	33	25 to 132	Apt to be found in intermittent pools.
hardhead	*Mylopharodon conocephalus*	95	43 to 441	Juveniles apparently migrate into tributaries for rearing.
hitch	*Lavinia exilicauda*	45	67 to 297	Spawn in first 2 km of most tributaries.
largemouth bass*	*Micropterus salmoides*	4	332 to 378	Near mouth or in areas with big pools.
mosquitofish*	*Gambusia affinis*	11	20 to 55	streams but often missed with our sampling technique.
prickly sculpin	*Cottus gulosus*	6	75 to 115	Usually found near mouth.
riffle sculpin	*Cottus gulosus*	5	82 to 135	
Sacramento splittail	*Pogonichthys macrolepidotus*	2	251 to 349	Observed in Little Butte Creek only.
Sacramento squawfish	*Ptychocheilus grandis*	150	23 to 620	Spawn in most tributaries. Juveniles apparently migrate into tributaries for rearing.
Sacramento sucker	*Catostomas occidentalis*	84	11 to 515	Spawn in most tributaries.
smallmouth bass*	*Miscropterus dolomieui*	3	216 to 361	Rare in the intermittent tributaries, common in permanent streams.
speckled dace	*Rhinichthys osculus*	2	65 to 70	Ash Creek.
steelhead/ rainbow	*Oncorhynchus mykiss*	106	30 to 450	Evidence of spawning in Olney, Churn, Mud.
threespine stickleback	*Gasterosteus aculeatus*	16	34 to 54	Usually found near mouth.
tule perch	*Hysterocarpus traski*	1	61	Adult females enter first couple km to give birth.
wakasagi*	*Hypomesus nipponensis*	5	74 to 89	Observed in Little Butte Creek only.
white crappie*	*Pomoxis annularis*	3	53 to 73	Observed in Little Butte Creek only.
		TOTAL	3702	
	* introduced/ exotic species total 164 individuals		4.43%	
	native species total 3538 individuals		95.57%	

Table 7. Summary of fish species found in seasonal streams.

Summary of Conclusions

Non-natal tributaries are part of the overall complex of salmon rearing habitat and are also part of the habitat matrix for many other species. Between 100,000 and 1,000,000 juvenile chinook rear annually in small, non-natal streams. The listed winter-run chinook seems to use tributaries for rearing proportionally more than do other races.

It is doubtful if we can ever gather enough data to answer all the questions necessary to made a definitive evaluation about the value of intermittent streams relative to other parts of the habitat in the Sacramento ecosystem. As discussed previously, (Maslin, et al., 1997) juveniles rearing in the tributaries are in excellent condition and smolt and emigrate earlier than they would in the mainstem, particularly in years like 1997 and 1998, when the mainstem remains turbid throughout the growing season. Predation is also probably less in small tributaries. However, some tributary-rearing juveniles get trapped by receding water, particularly in low water years.

Most intermittent tributaries are being degraded by land use and flood control activities. The average landowner assumes that these seasonal streams have no role as fish habitat and treats them chiefly as drainage ditches. Considering the amount of habitat already lost in the Sacramento Valley, it would seem prudent to protect remaining habitat we can even if we can't place numbers on its importance.

References

Anderson, R.O., and Gutreuter, S.J. 1983. Length, Weight, and Associated Structural Indices, p.283-300. In: L.A. Nielson (ed) Fisheries Techniques. *American Fisheries Society*, Bethesda, Maryland.

Banks, M. A., B. A. Baldwin, and D. Hedgecock. 1996. Research on chinook salmon *(Oncorhynchus tshawytscha)* stock structure using microsatelite DNA. Bull. Natl. Res. Aquacult., Suppl. 2:5-9.

Banks, M. A.,. J. Calavetta, S. Greene, V. Rashbrook, and D. Hedgecock. 1996. The question of run identity for the winter run take in 1996: some genetic perspectives. IEP for the Sacramento- San Joaquin Estuary. Autumn 96 Newsletter. 9 (4): 7-12.

Brower, J. E., J. H. Zar and C. N. von Ende. 1990. Field and Laboratory Methods for General Ecology. 3rd Edition. Wm C. Brown Publishers, Dubuque, Iowa

Johnson, R. R, F.W. Fisher, and D.C. Weigand. 1992. Use of growth data to determine the spatial and temporal distribution of four runs of juvenile chinook salmon in the Sacramento River, California. Report No. AFF!-FRO-92-15. *U.S. Fish and Wildlife Service*, Red Bluff, California.

Fisher, F. 1994. Tables of juvenile chinook sizes. Unpublished. *California Department of Fish and Game.*

Maslin, P.E., and McKinney, W.R.. 1994. Tributary Rearing by Sacramento River Salmon and Steelhead, interim report October 30, 1994. Unpublished. *Dept of Biology, CSU, Chico*, Chico, CA 95929.

Maslin, P.E.,W.R McKinney, and T. L. Moore. 1996. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon, *Internet Report..* http://www.csuchico.edu/~pmaslin/rsrch/Salmon/Abstrt.html.

Maslin, P.E.,W.R McKinney, and T. L. Moore. 1996b. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon. 1996 Update *Internet Report..* http://www.csuchico.edu/~pmaslin/rsrch/Salmon96/Abstrct.html

Maslin, P.E., J. Kindopp and M Lennox. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon. 1997 Update *Internet Report..* http://www.csuchico.edu/~pmaslin/rsrch/Salmon96/Abstrct.html

Maslin, P.E., M Lennox and J. Kindopp. 1997. Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon (Oncorhynchus tshawytscha. Report to U.S. Fish and Wildlife Service, 4001 N. Wilson Way, Stockton, CA 95205.

Moyle, P B., J. E. Williams, and E. D. Wikramanayake. 1989. Fish species of special concern of California. *California Dept. of Fish and Game.*

Moore, T. L. 1997. Condition And Feeding of Juvenile Chinook Salmon in Selected Tributaries of the Upper Sacramento River. Master's thesis, CSU, Chico.

Murray, C. B. and M. L Rosenau. 1989. Rearing of juvenile chinook in nonnatal tributaries of the lower Fraser River, *British Columbia. Trans. Amer. Fish. Soc.* 118(3):284-289.

Murphy, M. L., Heifetz, J. F. Thedinga, S. W. Johnson, and K. V. 1989. Habitat utilization by juvenile Pacific salmon (Oncorhynchus) in the glacial Taku, southeast Alaska. *Can. J. Fish. Aqua. Sci.* 46:1677-1685.

Richards, C., P. J. Cernera, M. P. Ramey and D. W. Reiser. 1992. Development of off-channel habitats for use by juvenile chinook salmon. *Amer. J. Fish, Manag.* 12:721-727.

Scrivener, J. C., T. C. Brown, and B. C. Anderson. 1994. Juvenile Chinook Salmon *(Oncorhynchus tshawytscha)* utilization of Hawks Creek, a small and nonnatal

tributary of the upper Fraser River. *Can. J. Fish. Aquatic Sci.* 51:1139-1146.
Upper Sacramento Fisheries and Riparian Habitat and Advisory Council, 1989. Upper Sacramento River fisheries and riparian habitat management plan. *State of California Resources Agency*. 158 p.
Zippin, C. 1958. The removal method of population estimation. Journal of Wildlife Management. 22(1):82-90

Appendix I. Juvenile Chinook Densities

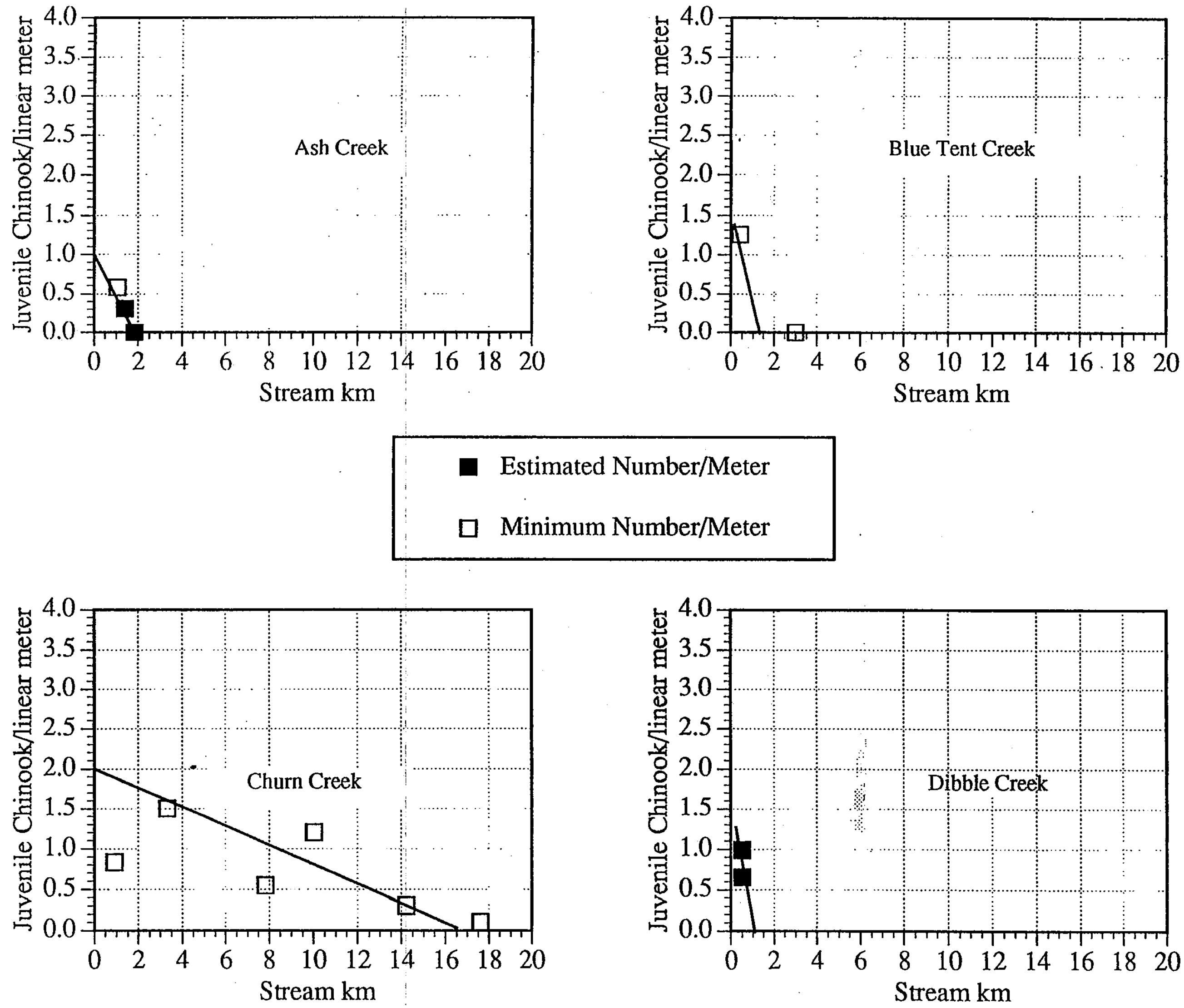


Figure 16. Density of juvenile chinook in Ash, Blue Tent, Churn and Dibble Creeks in 1998.

34

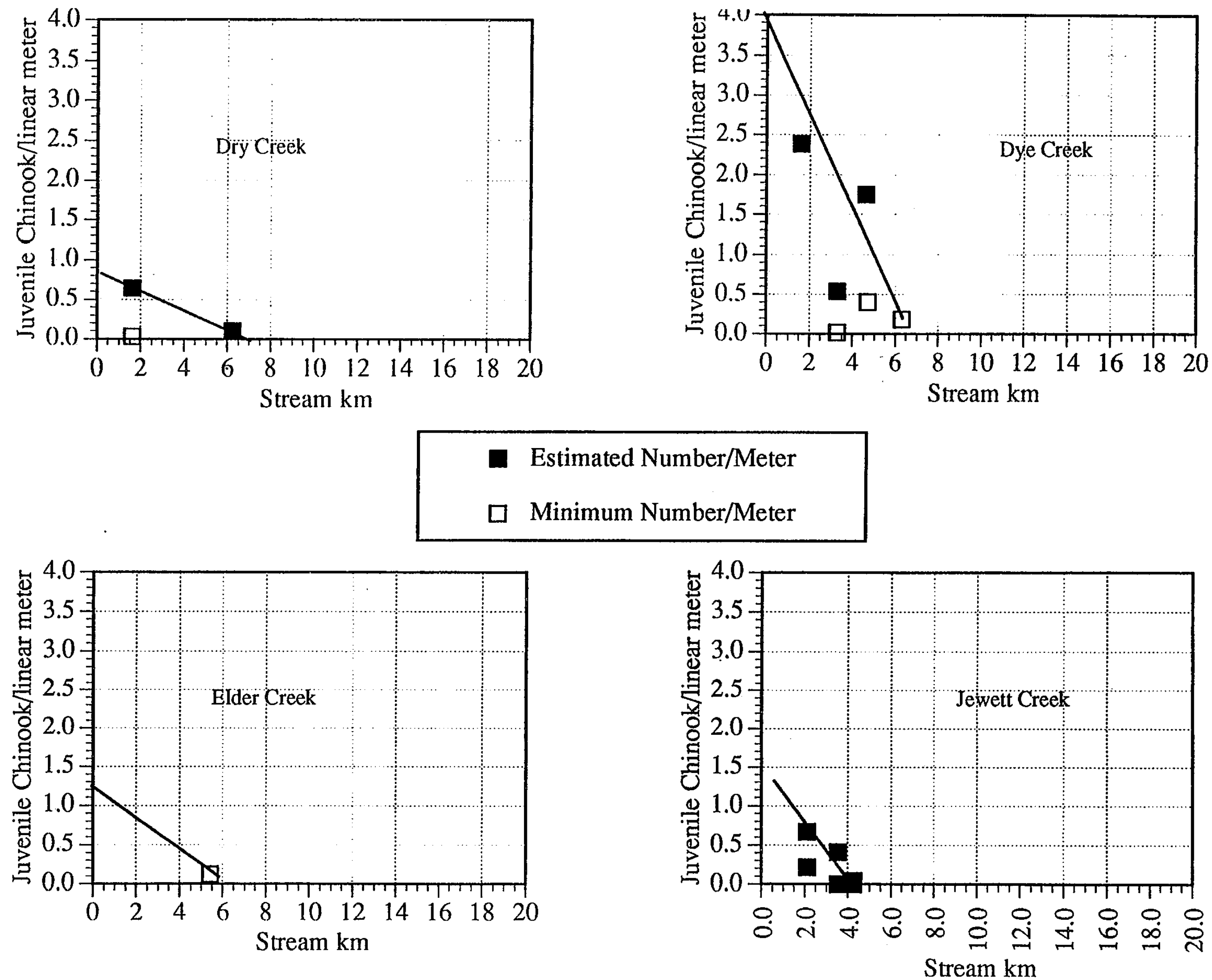


Figure 17. Density of juvenile chinook in Dry, Dye, Elder, and Jewett Creeks in 1998.

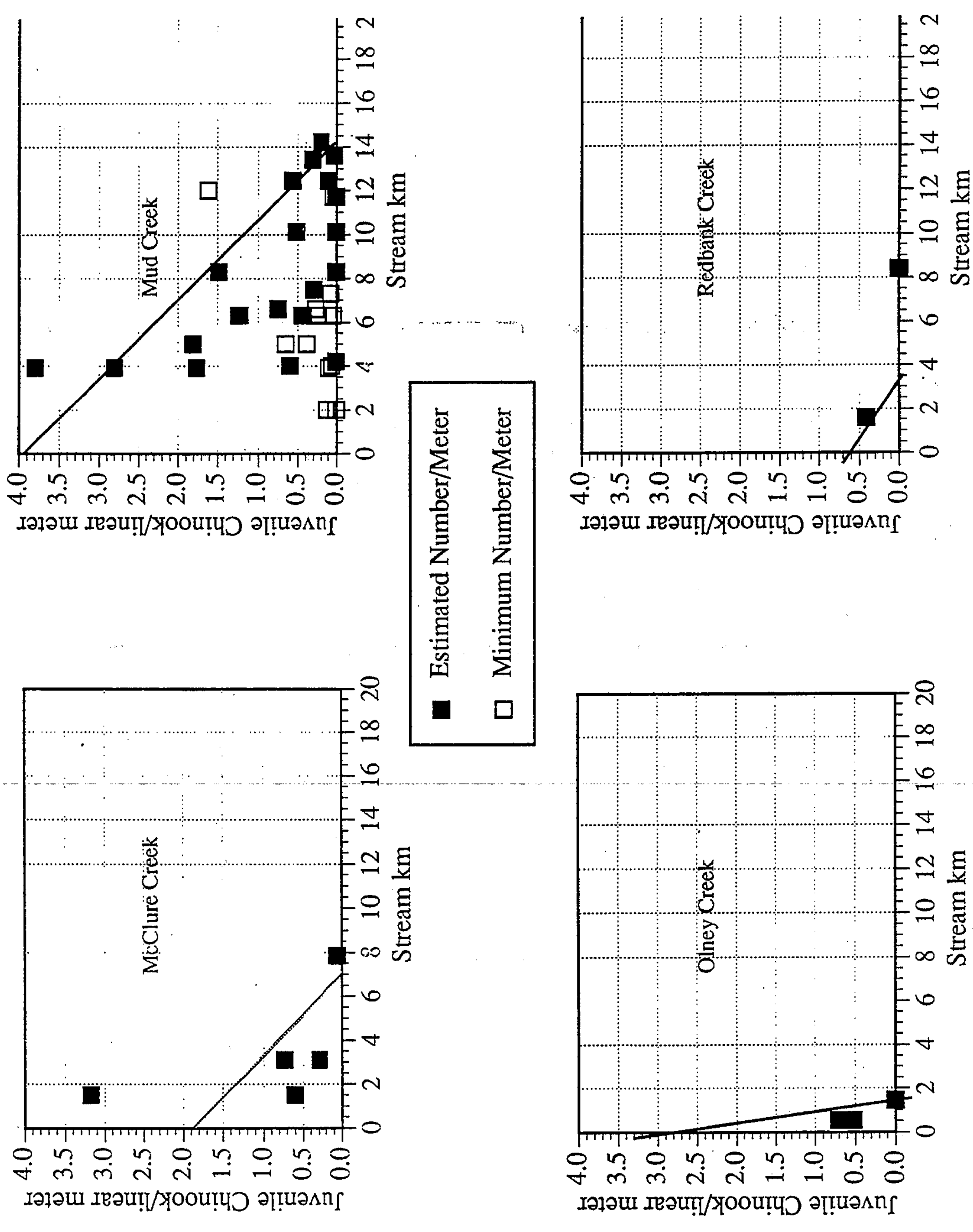


Figure 18. Density of juvenile chinook in McClure, Mud, Olney, and Redbank Creeks in 1998.

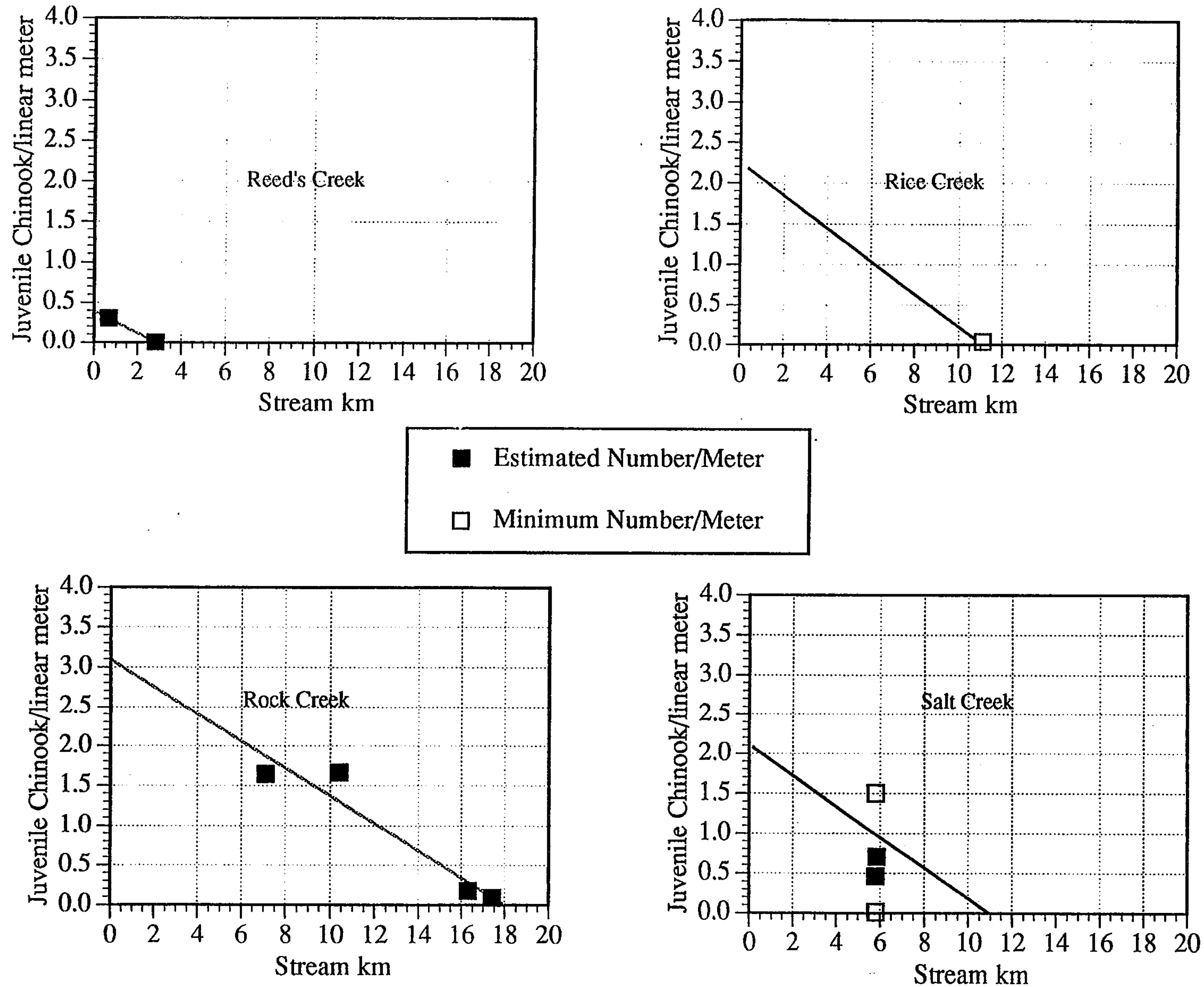


Figure 19. Density of juvenile chinook in Reed's, Rice, Rock (Kusal), and Salt Creeks in 1998.

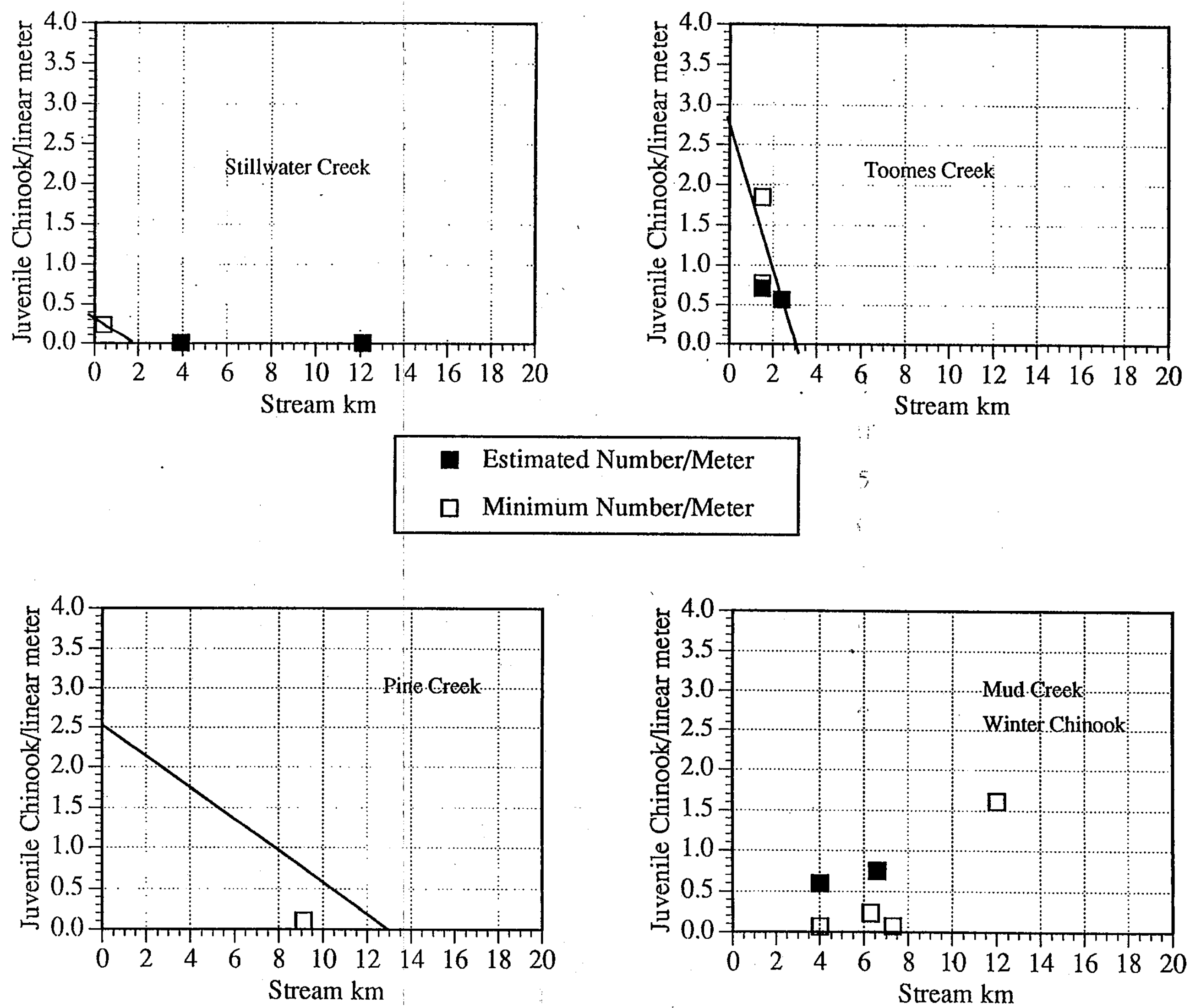


Figure 20. Density of juvenile chinook in Stillwater and Toomes Creeks in 1998. Projected density in Pine Creek. Density of winter-chinook in Mud Creek.

Appendix II. Size of Chinook Juveniles.

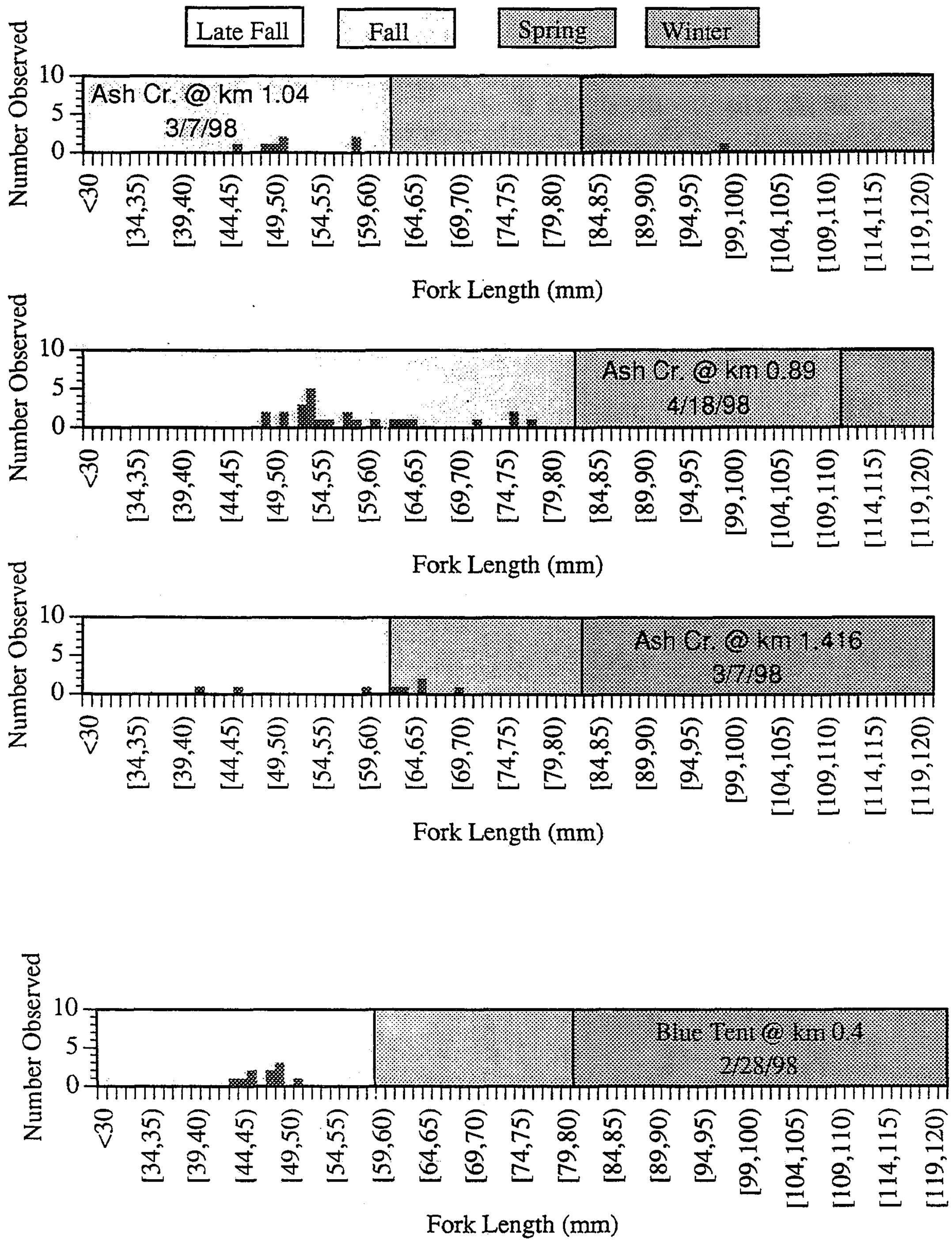


Figure 21. Size distribution of juvenile chinook observed in Ash and Blue Tent Creeks in 1998.

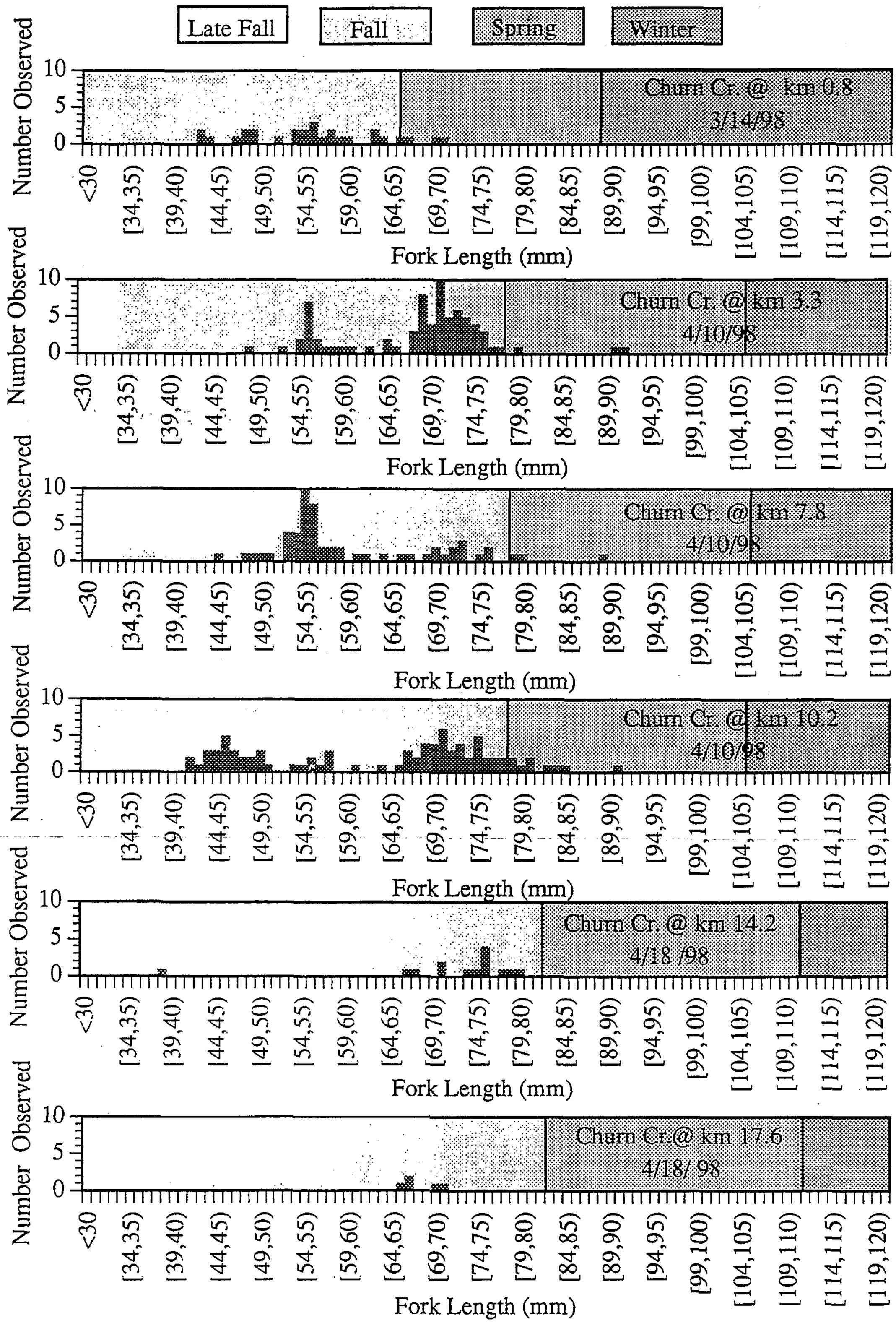


Figure 22. Size distribution of juvenile chinook observed in Churn Creek in 1998.

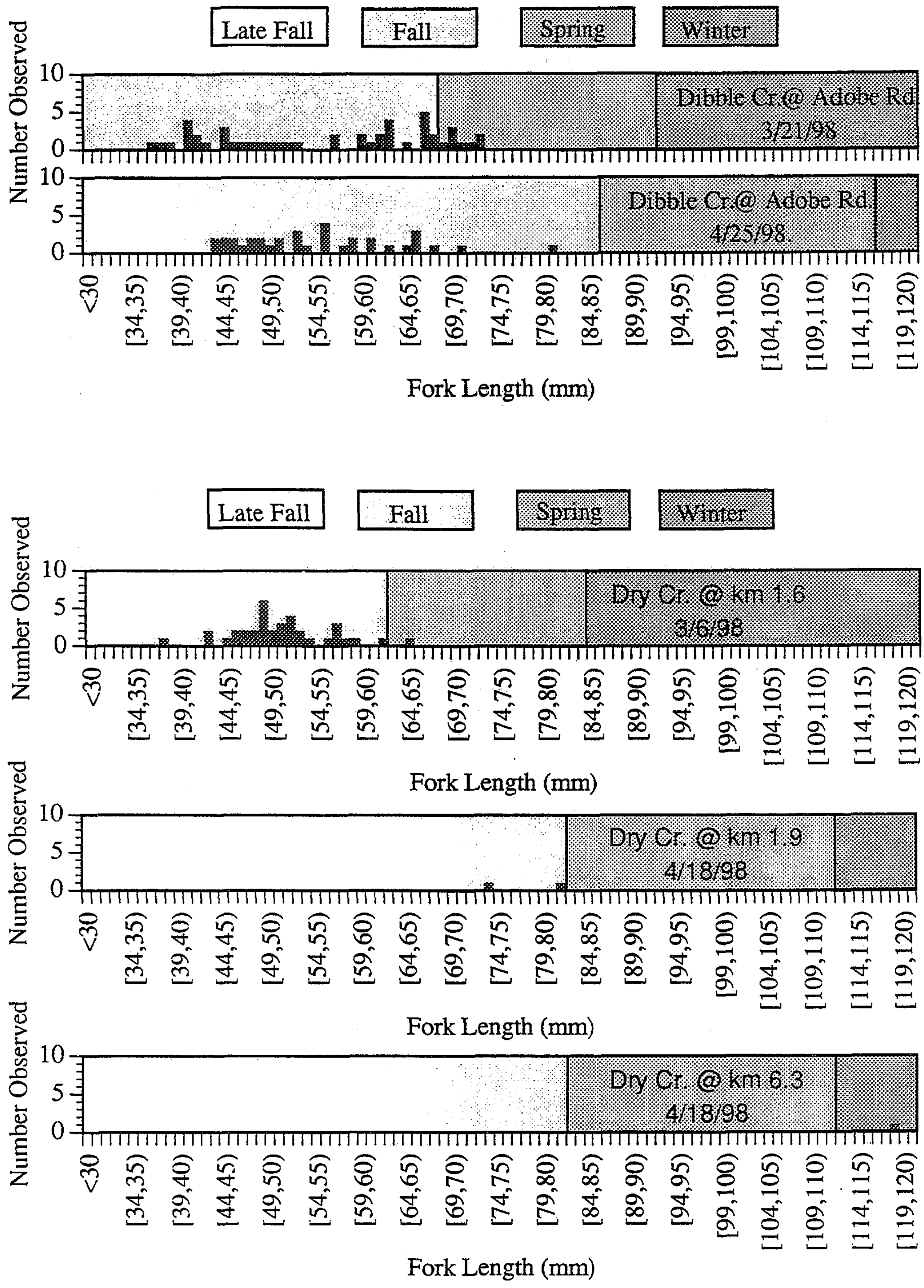


Figure 23. Size distribution of juvenile chinook observed in Dibble and Dry Creeks in 1998.

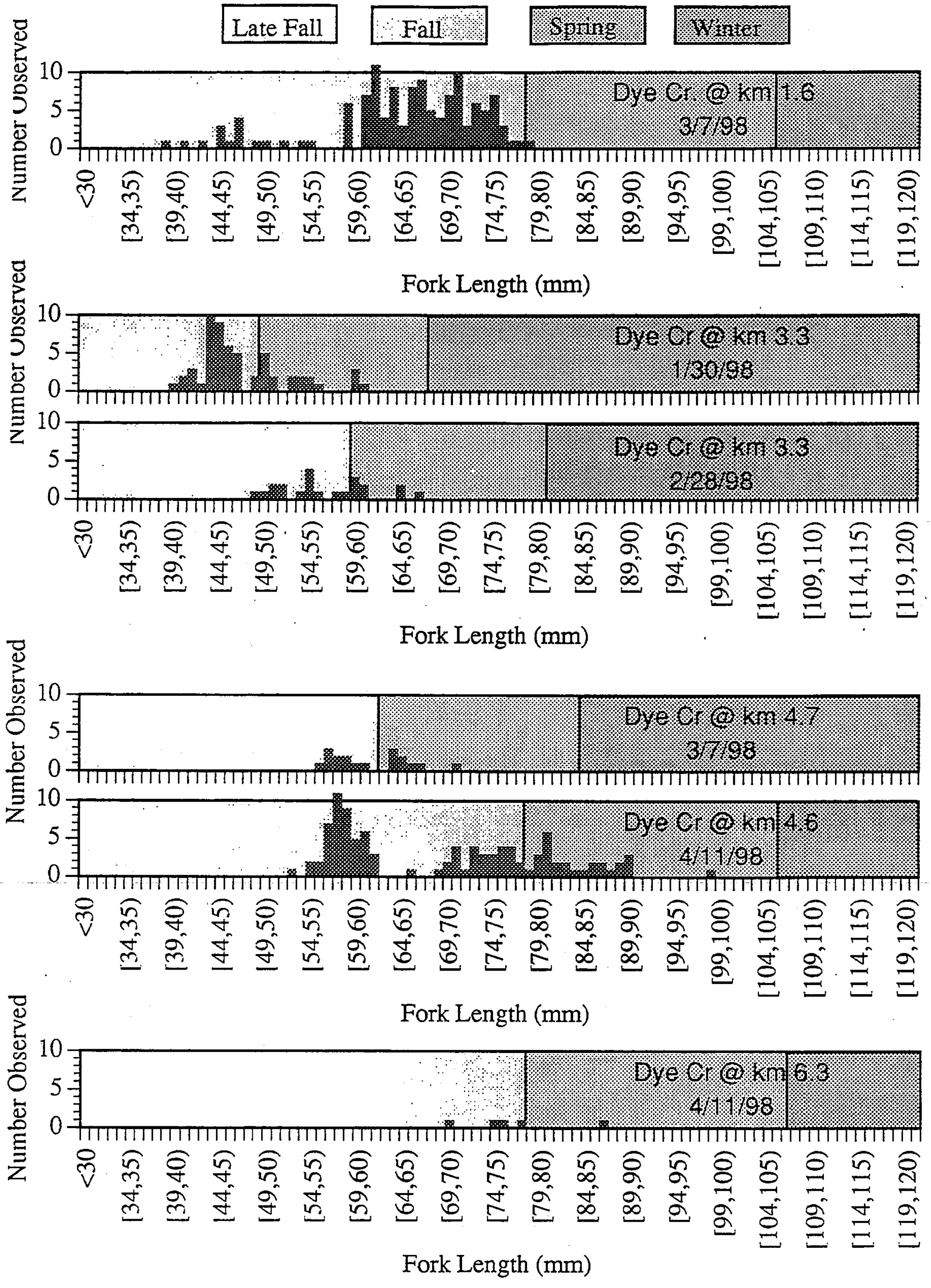


Figure 24. Size distribution of juvenile chinook observed in Dye Creek in 1998.

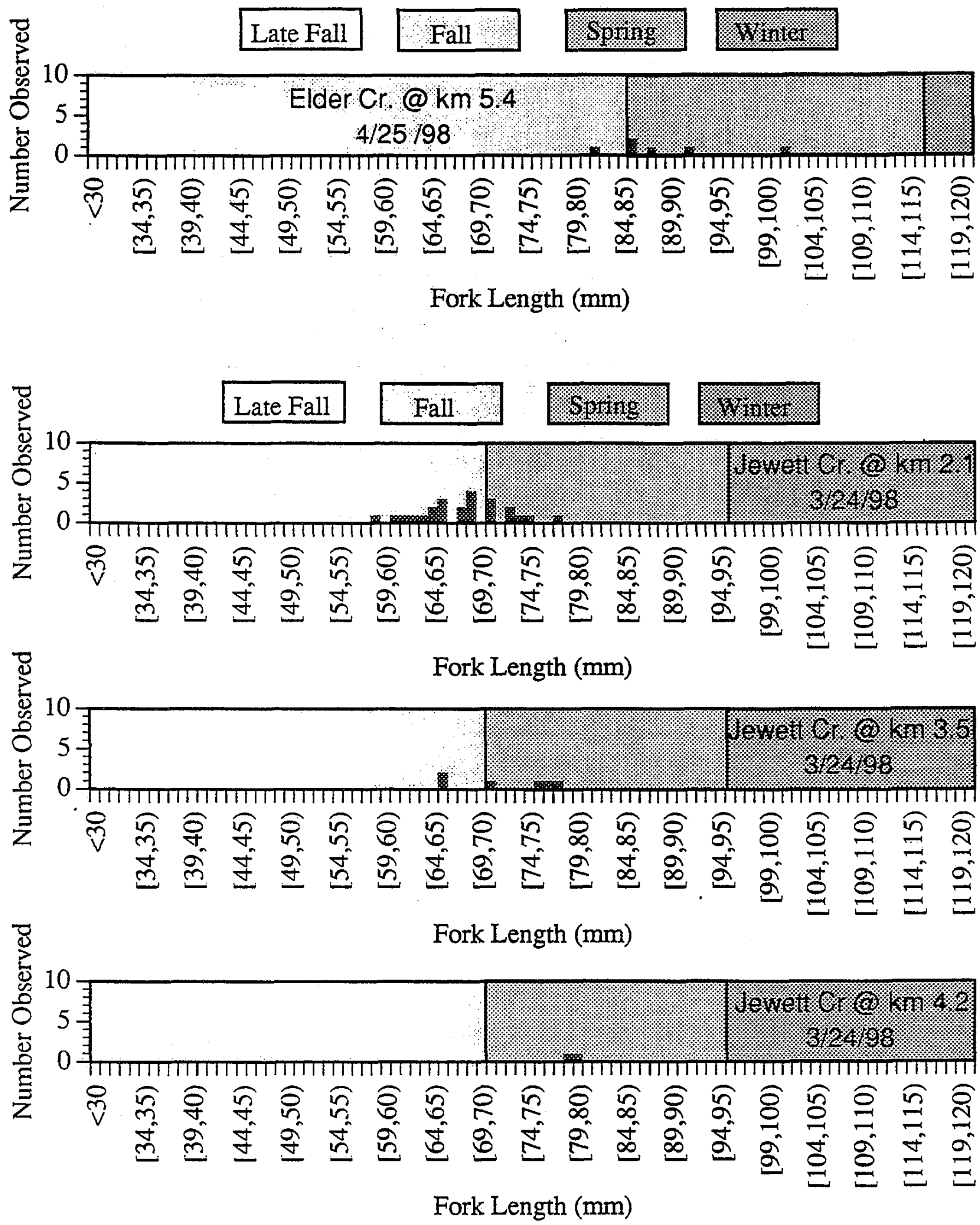


Figure 25. Size distribution of juvenile chinook observed in Elder and Jewett Creeks in 1998.

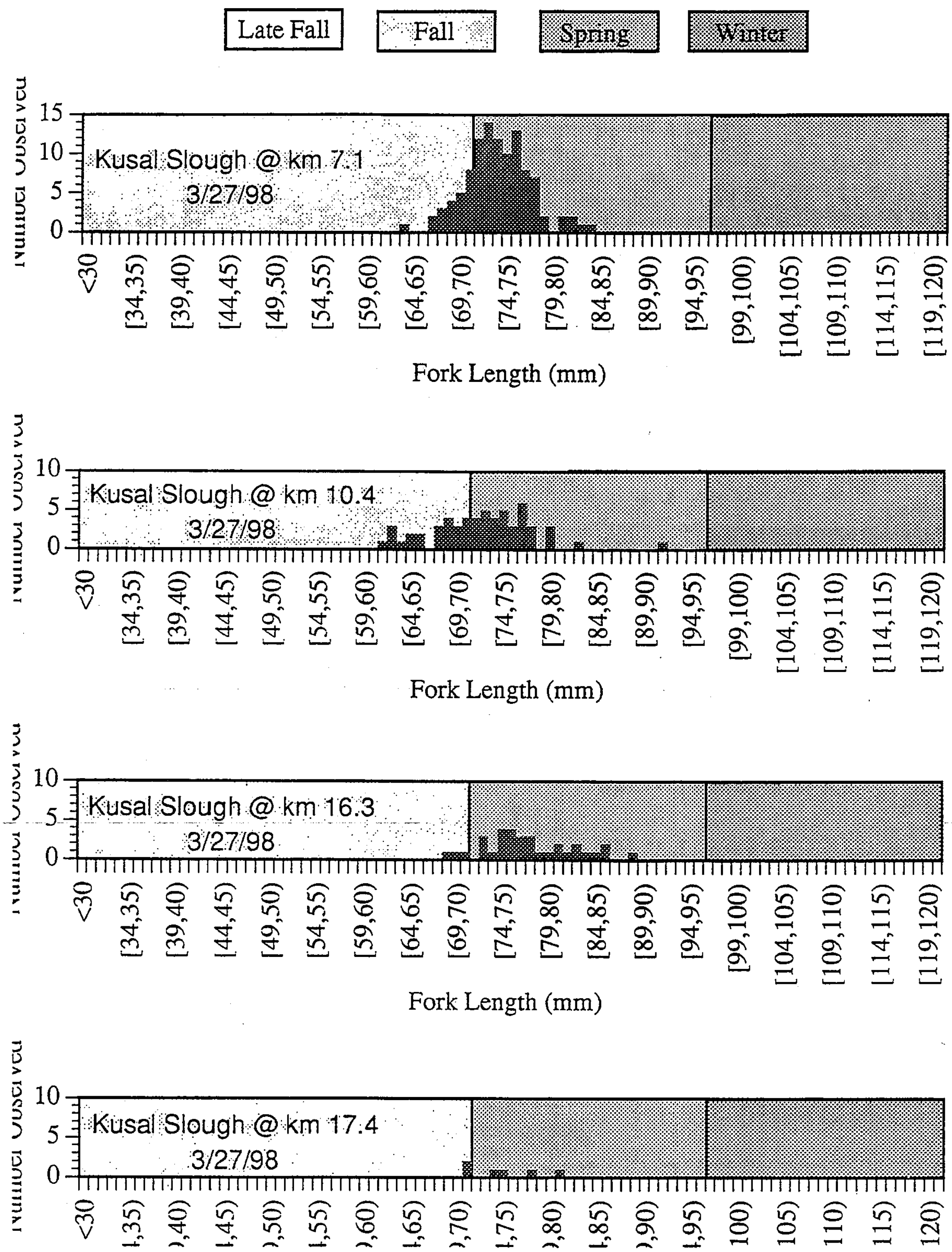


Figure 26. Size distribution of juvenile chinook observed in Rock Creek (Kusal Slough) in 1998.

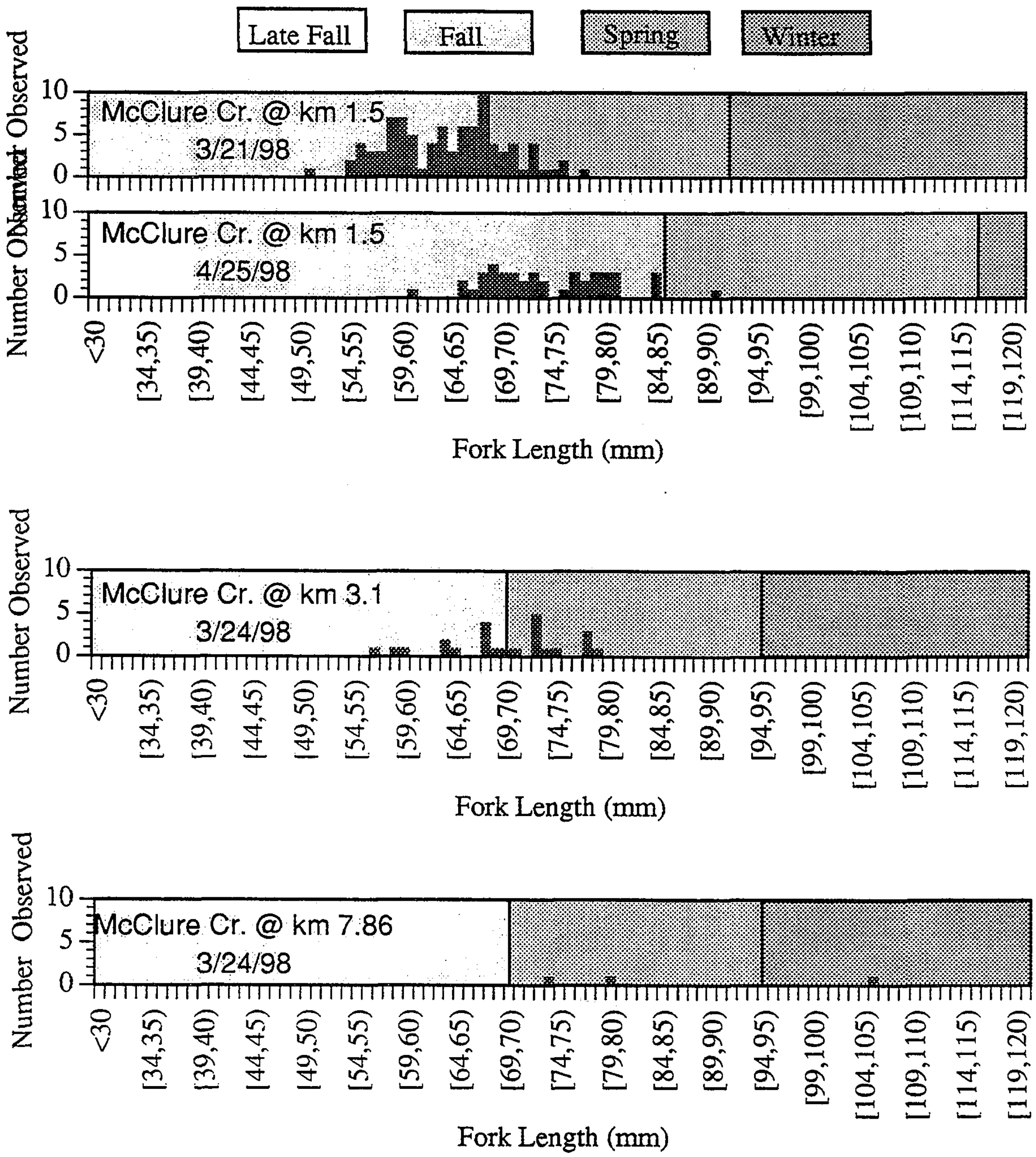


Figure 27. Size distribution of juvenile chinook observed in McClure Creek in 1998.

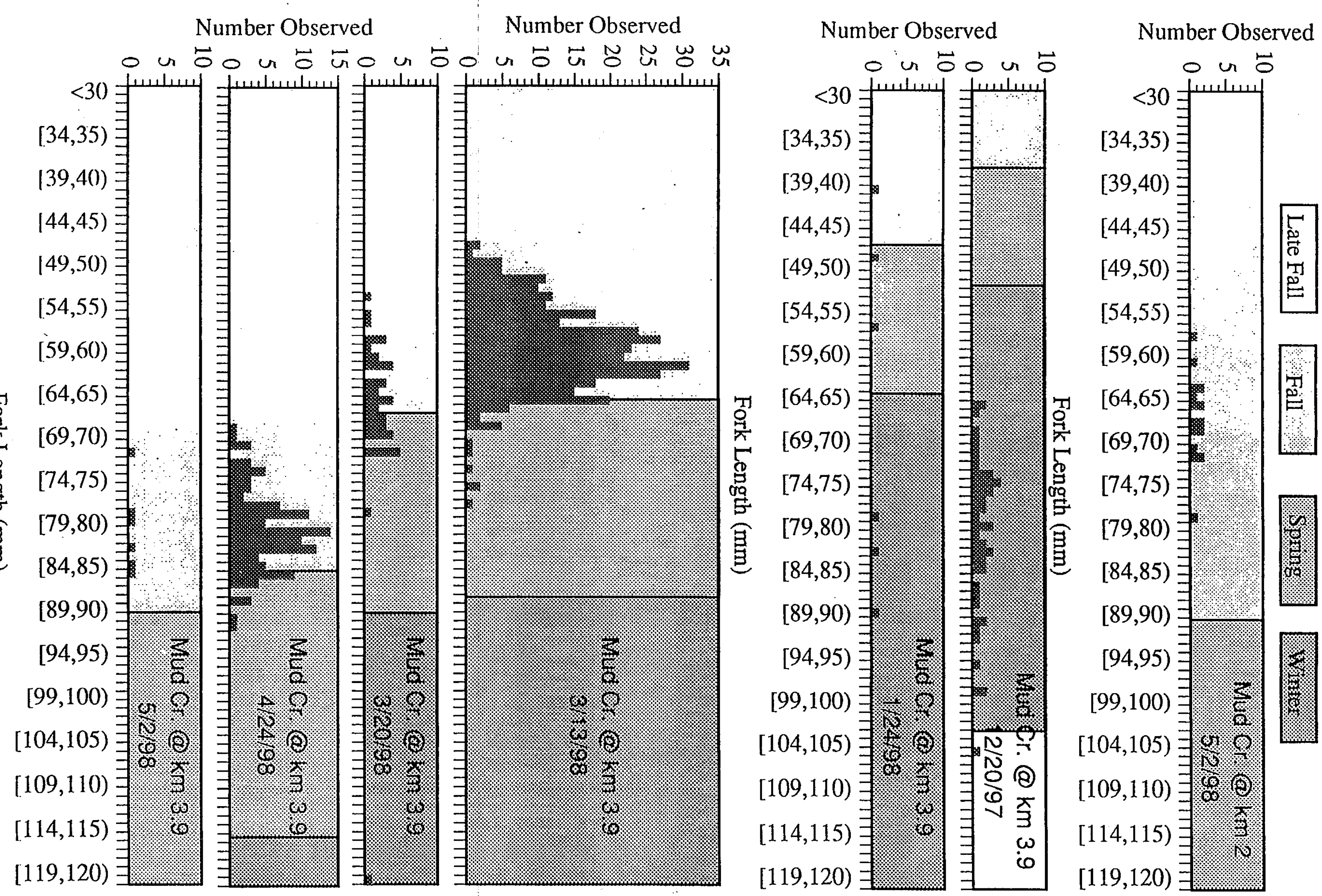


Figure 28. Size distribution of juvenile chinook observed in Mud Creek in 1998.

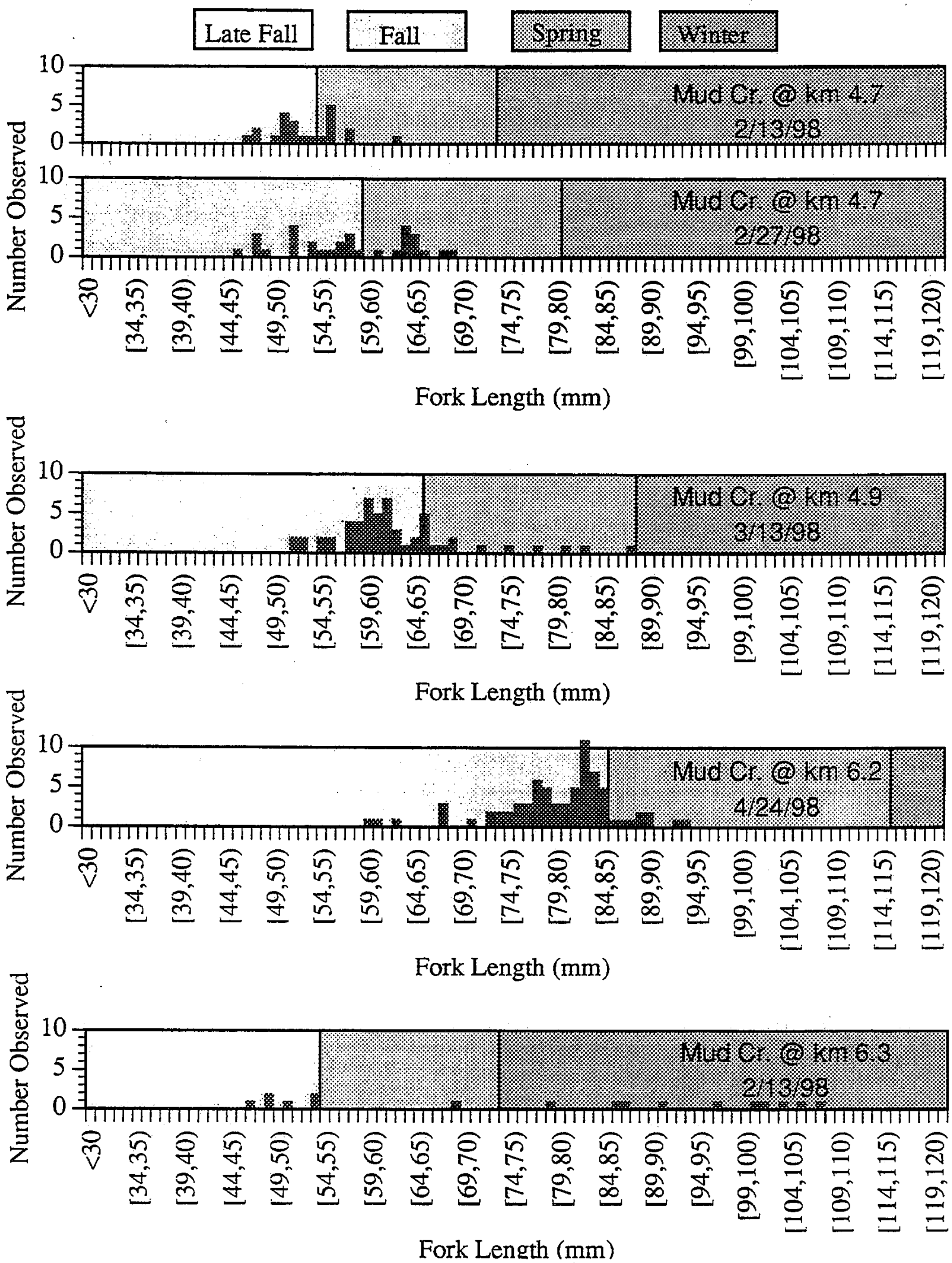


Figure 28 (Cont.). Size distribution of juvenile chinook observed in Mud Creek in 1998.

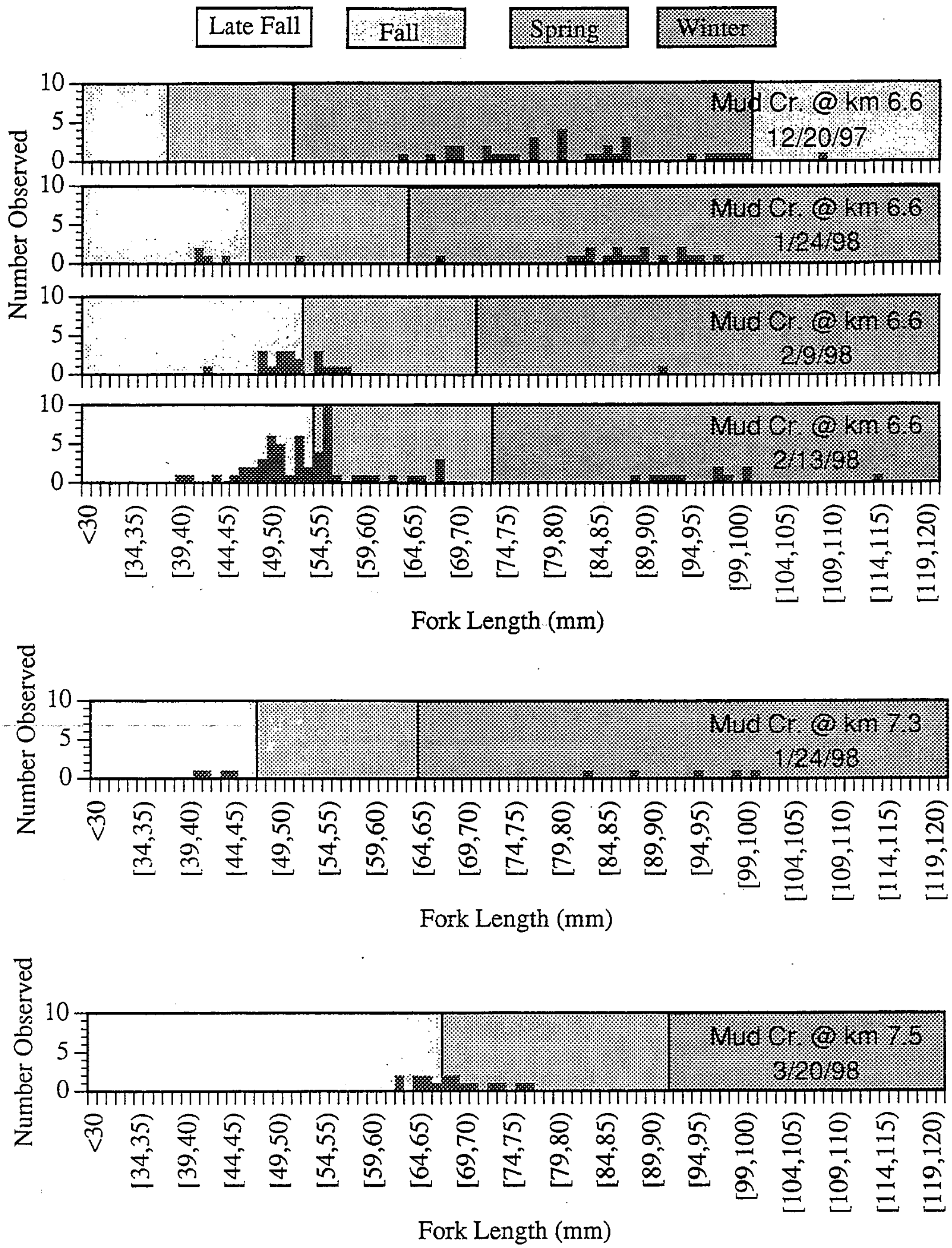
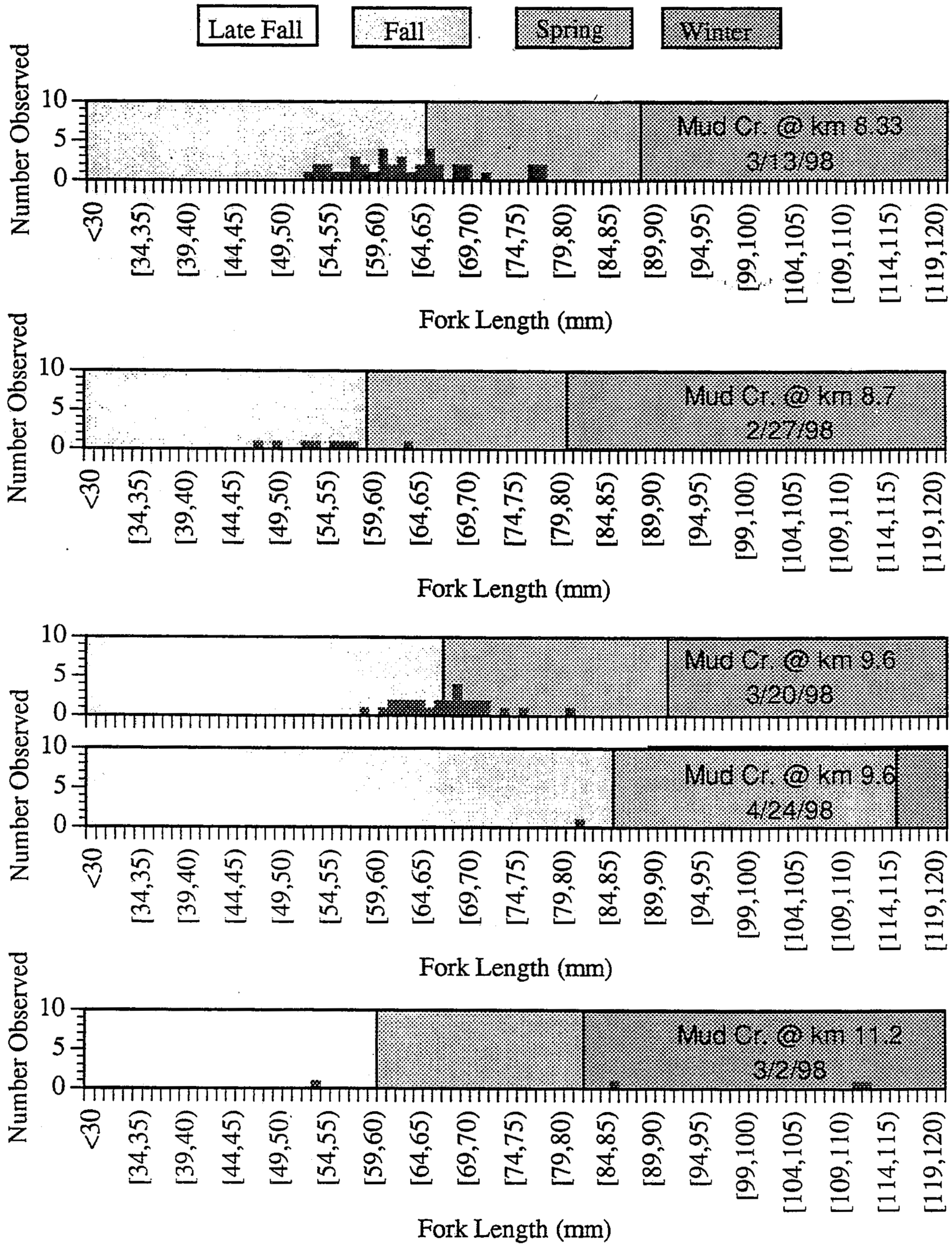


Figure 28 (Cont.). Size distribution of juvenile chinook observed in Mud Creek in 1998.



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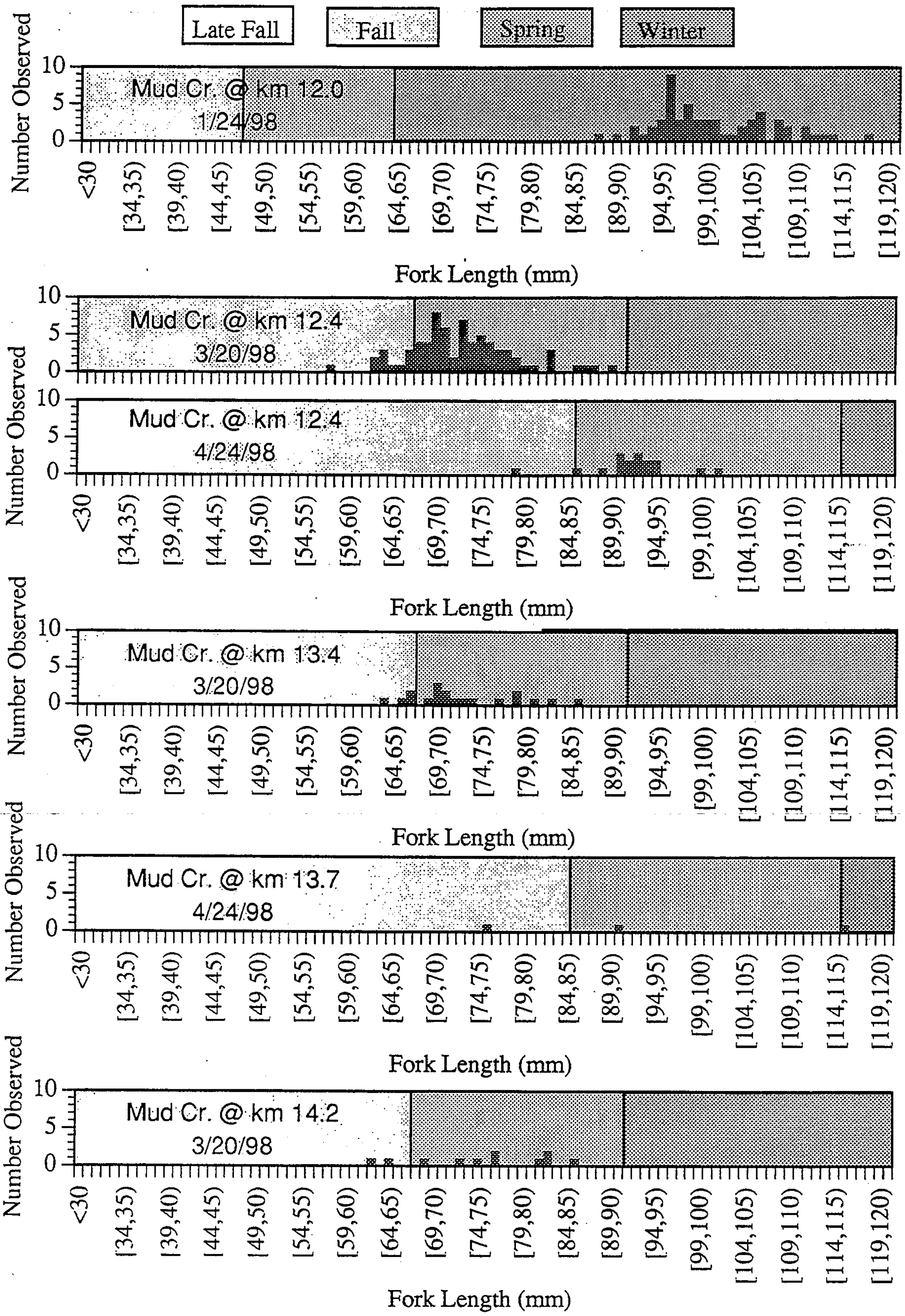

Figure 28 (Cont.). Size distribution of juvenile chinook observed in Mud Creek in 1998.

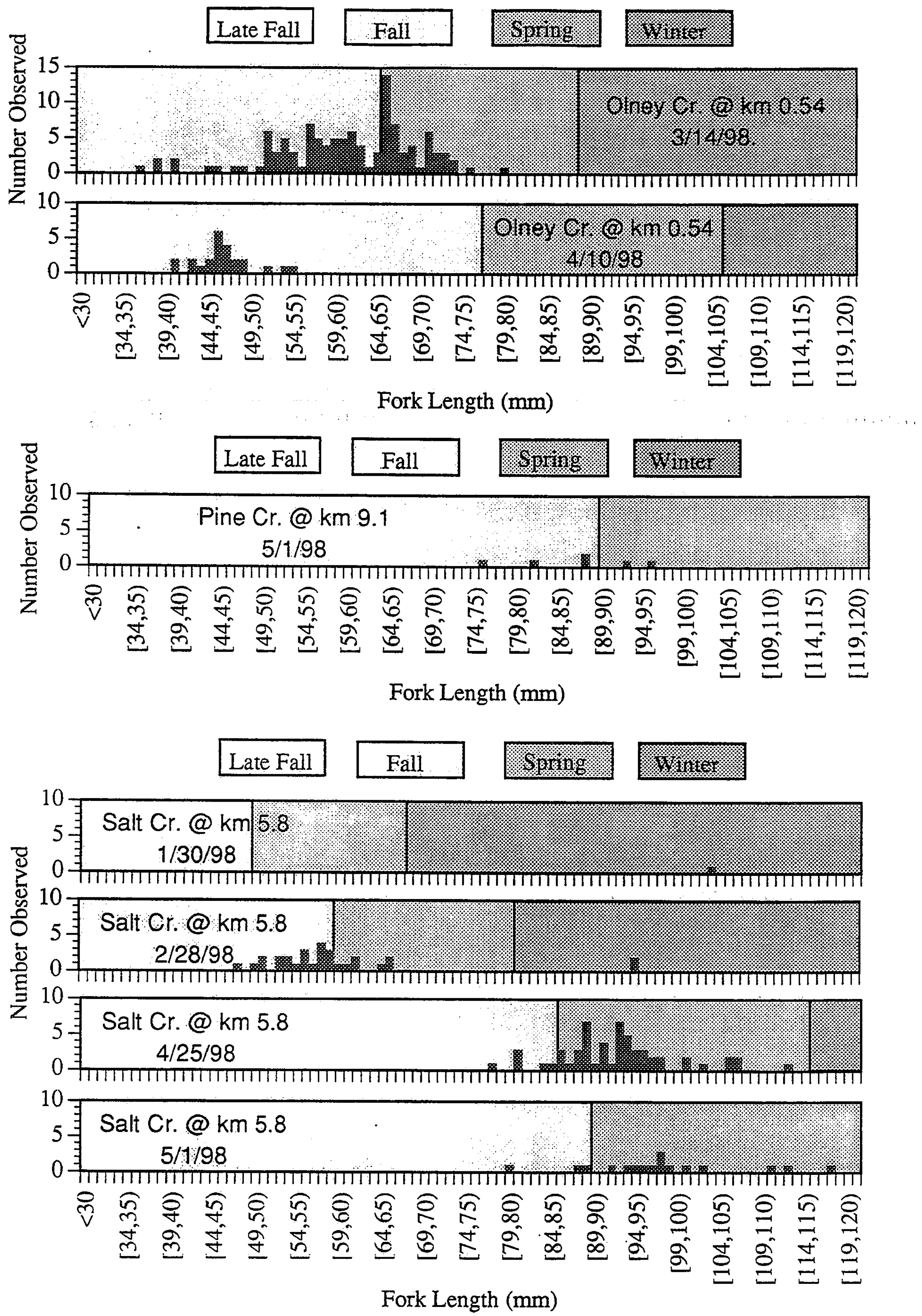

Figure 29. Size distribution of juvenile chinook observed in Olney, Pine and Salt Creeks in 1998.

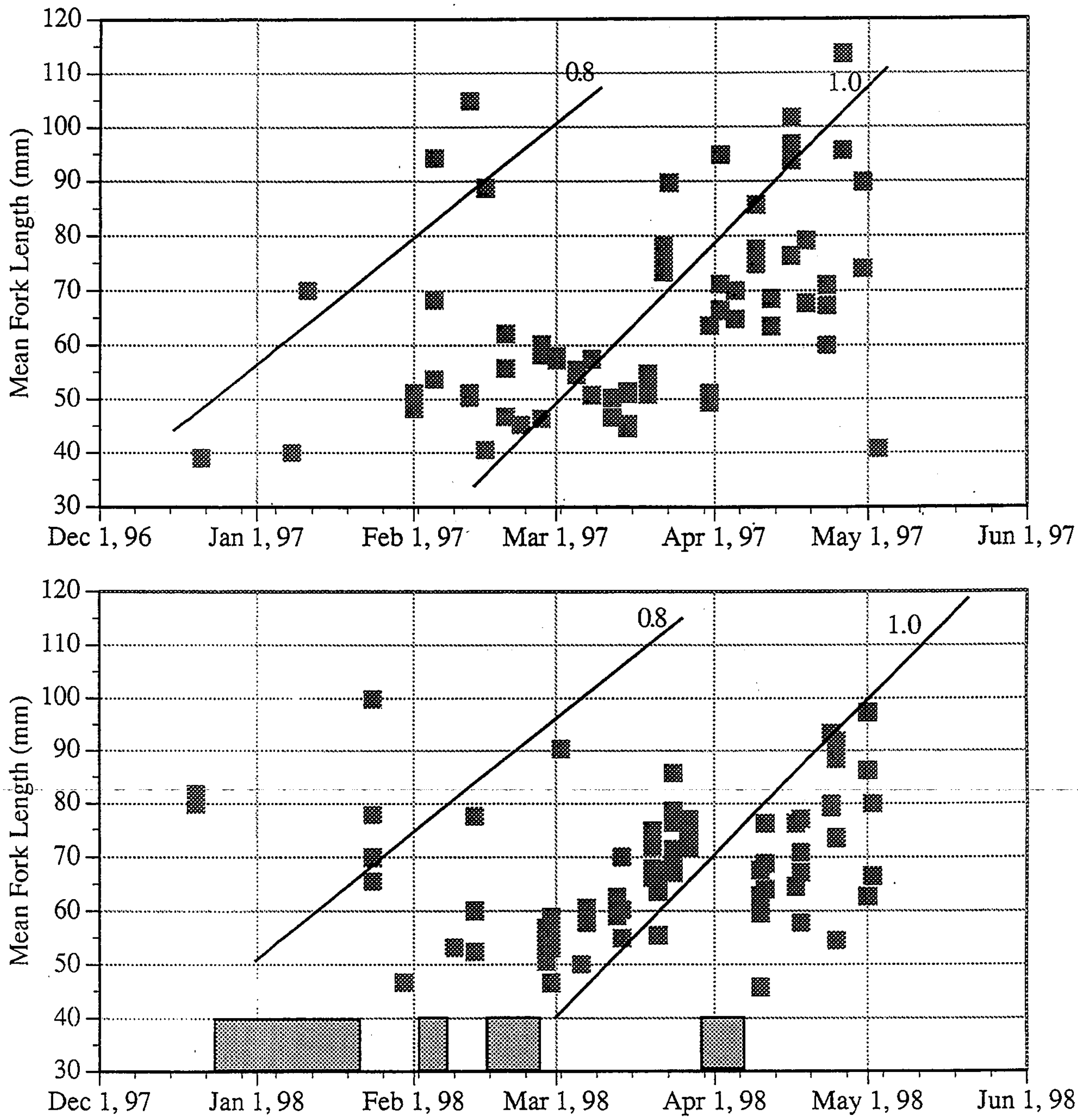

Figure 30. Change in juvenile chinook fork length in all tributaries through the 1997 and 1998 sampling season. The lines show hypothetical growth rates of 0.8 mm/day and 1.0 mm/day. The rectangles in 1998 show times when water was too high for sampling.