Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon

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Abstract

Nonnatal rearing of juvenile chinook salmon (Oncorhynchus tshawytscha) was documented in several intermittent tributaries to the Sacramento River. Condition factors and length measurements of juvenile chinook captured in the intermittent tributaries were compared with those captured in the mainstem Sacramento River. The data suggests that juvenile chinook rearing in the tributaries grew faster and were heavier for their length than those rearing in the mainstem. Faster growing fish smolt earlier, and may enter the delta earlier in the year, before low water and pumping degrade rearing habitat. Optimal rearing conditions in the tributaries exist from approximately December through March. By April, conditions may be less favorable as temperatures rise to intolerable levels, and piscivorous fishes enter tributaries to spawn. Juvenile chinook entering the tributaries early in the year, such as winter and spring run, probably derive the most benefit from tributary rearing. Fall run, and especially the late-fall run, may be exposed to warmer than optimal temperatures, predation, and stranding. Documentation of nonnatal rearing is important for management of declining Sacramento River salmon populations. Actions may be necessary to protect intermittent stream habitat, and ensure adequate flows and habitat conditions for rearing.

Introduction

The Sacramento River produces four distinct races of chinook salmon (Oncorhynchus tshawytscha) : fall, late fall, winter, and spring. All races have declined substantially. 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 is the object of a current petition for inclusion on the endangered list. In an effort to reverse the decline of chinook salmon stocks, natural resource managers have focused on the maintenence and restoration of habitat in the Sacramento River and its larger tributaries (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Small, intermittent tributaries have generally been overlooked by fishery resource managers. While few of these tributaries serve as spawning habitat for chinook salmon, our research suggests they provide important rearing habitat , particularly for the imperiled winter and spring runs.

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.

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Researchers from California State University, Chico, have consistently captured wild and hatchery origin chinook salmon juveniles in small, intermittent tributaries of the Sacramento River where there are no records of spawning adults. Juvenile chinook may 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).

The objective of this study was to document various aspects of nonnatal rearing in intermittent tributaries of the Sacramento River. We estimated the spatial and temporal extent of nonnatal rearing. We also calculated the race distribution and growth rate of juvenile chinook rearing in tributaries. Additionally, the condition factors of juvenile chinook caught in tributaries were compared with those caught in the mainstem.

Methods

Sample sites were established on a number of intermittent tributaries: Mud Creek, Rock Creek, and Kusal Slough in Butte County; Stony Creek in Glenn county; and Toomes Creek, Thomes Creek, Red Bank Creek, Dibble Creek, and Blue Tent Creek in Tehama County. Two sample sites were established on the Sacramento River; one near the Red Bluff Diversion Dam in Tehama County, and one near Chico Landing in Butte County.

A 30 foot x 6 foot seine with 1/4 inch mesh was used to to capture fish. Juvenile chinook captured by seine were transferred to five-gallon buckets of clean water for immediate processing. Fish were anesthesized with tricane methanesulfonate (MS 222, brand name Finquel from Argent Chemical Company), measured on a plexiglass measuring board to the nearest 1.0 mm,.and weighed to the nearest 0.1 gram on an Ohaus field balance. A chamois cloth was used to blot and hold fish for weighing, as suggested by Anderson and Gutreuter (1983). After weighing, fish were placed in clean water and released immediately upon recovery from the affects of the anesthetic. Condition factors were calculated from the formula:

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

Adipose clipped fish were sacrificed and returned to the U.S. Fish and Wildlife Service for coded wire tag recovery and analysis. The daily length table generated by the California Department of Water Resources Environmental Services office (R. R. Johnson, et al., 1992), was used to identify run membership of juvenile chinook.

Water temperature at all sites was measured with a mercury thermometer during each sampling period. Onset "Datalogger" thermographs were established in Blue Tent, Dibble, and Red Bank Creeks. Turbidity was also measured in Blue Tent, Dibble, and Red Bank Creeks. Temperature and turbidity data for the Sacramento River at Red Bluff Diversion Dam were obtained from the Bureau of Reclamation Red Bluff Office.

Results

Extent and duration of non-natal rearing

Table 1 lists tributaries in which juvenile chinook were captured. Every tributary sampled contained juvenile chinook. Juveniles which entered tributaries apparently remained there for some time. Three lines of evidence support this conclusion: 1. Juvenile chinook were collected quite a distance upstream from the river (Thomes Creek - 11.5 km; Mud Creek - 13.1 km; Rock Creek - 17.4 km; Pine

Creek - 22.1 km). 2. When several sites in one tributary were sampled on the same day, the smallest juveniles were consistently found nearest the river , and juvenile size distribution upstream in the tributaries was quite different from that in or near the river (Fig. 1). 3. Modes of samples taken at the same site could be followed over time, as the juveniles grew until they reached 80 - 100 mm, the size at which most chinook smolt (Reimers and Loeffel, 1967; Ewing et.al., 1979; J.W. Johnson, et. al., 1992). Juvenile chinook larger than 100 mm were not present, except in rare cases when they were trapped in the tributary by low water.

Race Distribution

According to the daily length table, all four races of Sacramento River chinook were captured in nonnatal, intermittent tributaries at various times during the season (approximately December to May). Coded wire tags provided positive proof that winter and fall run were present (Table 1). Spring run and winter run were disproportionately abundant considering their scarcity in the Sacramento River system (see Fig. 5). In some cases, fish identified as spring run by the daily length table may actually have been fall run. The daily length table was developed from growth data collected in the Sacramento River, and fish may have grown faster in the tributaries than in the mainstem. For example, three juvenile chinook captured in Kusal slough identified as fall run by coded wire tag were categorized as spring run by the daily length table (Table 1). The apparent spring run juveniles observed in Thomes Creek on April 3, 1995 (Fig. 2) were probably fast growing fall run. However, in most cases (see examples in figures 3 and 4), misidentification of race due to faster growth in tributaries cannot explain the numbers of spring and winter run observed, as fall run have could not have grown fast enough from hatching until capture dates to to be misidentified as winter or spring run. Two additional factors suggest that most of the juvenile chinook identified as spring run were probably true spring run and not fast growing fall run. First, spring run were captured in greater numbers in tributaries located downstream of major spring run spawning streams (Fig. 5). Also, the proportion of spring run juveniles captured in tributaries decreased as the season advanced, as would be expected due to smolting and outmigration of true spring run fish (Fig. 6). If the apparent spring run fish were just fast-growing fall run, their proportion should have increased over the season as more growth time was available. Figure 7 summarizes race categories of juvenile chinook captured in nonnatal intermittent tributaries from 1990 to 1995. Relatively fewer spring and winter run were captured in 1990, 1991, and 1993, probably because sampling was initiated later in the season; after most winter and spring run had migrated out of the system.

Relative Condition

The condition factor reflects the nutritional state or "well being" of an individual fish. During periods when fish have high energy intake, the growth of tissues and the storage of energy in the muscle and liver can cause an individual to have a greater-than-usual weight for a given length (Busacker, et al. 1990). Condition factors varied a great deal throughout the 1995 season, probably as a result of the enormous variation in flow volume and turbidity. High flows may have scoured out food resources (C.S.U. Chico Biology 359, unpublished class data, 1995). High turbidity may have affected feeding ability (see discussion for further details). However, with a few exceptions, fish in the tributaries were in as good or better condition than comparable-sized fish in the Sacramento River (Fig.8).

Growth Rates

Estimates of growth rates calculated for the Sacramento River using modal shifts correspond closely with the daily length table (see previous section). Growth rates estimated for Mud Creek, Kusal Slough, and Blue Tent Creek in 1995 were consistently higher than those estimated for the Sacramento River (Fig. 9). Growth rates estimated for juveniles captured in tributaries in previous years (Table 3) were comparable to the 1995 rates, except for Stony Creek in 1994; when fish were trapped in isolated pools. Coded wire tag data provides an independent confirmation of faster growth observed in tributaries. As mentioned previously, three marked fall run chinook captured in Kusal Slough on 3/10/95 were large enough to be classified as spring run (see Table 2).

Discussion

Faster growth and better condition of juvenile chinook rearing in tributaries may be explained by several physical and biological characteristics of intermittent tributaries, including relatively warm temperatures, diel temperature fluctuations, low turbidity, and lack of established predator populations.

Warmer temperatures earlier in the year may induce juvenile chinook to enter tributaries, and enhance the growth of those which remain for all or part of their rearing phase. Brett (1952) observed that growth of juvenile chinook was much better at 15 degrees C than at lower temperatures. Optimum growth at 15 C was also observed during temperature tolerance experiments conducted by the U.S. Fish and Wildlife Service in 1992 (Kurt Brown, personal communication). Tributary temperatures were closer to optimum for juvenile chinook than temperatures in the mainstem from February through April (Fig. 10). However, by late April or

May, average tributary temperatures were warmer than the reported optimum. Juvenile chinook which enter tributaries early in the year, such as winter and spring run, would encounter the most favorable temperatures.

The greater diel temperature fluctuations observed in small streams may also enhance the growth of juvenile chinook. Hokanson, et al. (1977) studied growth rates of rainbow trout at constant and fluctuating temperatures. Maximum growth was achieved with temperatures fluctuating four degrees C around a mean of 15 degrees C. Spigarelli et al.. (1982) studied the growth of brown trout in three different temperature regimes. One group was reared with a daily regular cycle of nine to 18 degrees C (mean of 12.5 degrees C), the second was reared at a constant 13 degrees C, and third group was maintained in an arrhythmic temperature regime of daily fluctuations and a gradual increase of daily mean temperatures (range four to 11 degrees C; 57 day mean 7.7 degrees C). The mean food consumption and weight gain per individual reared in the nine to 18 degrees C cycle were by far the best. Similar results have been reported for sockeye salmon (Brett, 1971; Biette and Geen, 1980), and various cyprinoids (Konstantinov and Zdanovich, 1986). Evidently, diurnally fluctuating temperatures promote more efficient conversion of temperature units to growth than do constant temperatures, presumably by stimulating greater food consumption (Behnke, 1992). The affects of diel temperature fluctuations on juvenile chinook have not been documented. However, diel fluctuations of tributary temperatures averaged about eight degrees C, and were similar to the fluctuations in Spigarelli's study (cited above) that produced the best fish growth. Diel temperature fluctuations in the mainstem Sacramento River averaged about two degrees C. (See Fig. 10).

Turbidity data were collected from January to May in Blue Tent, Dibble, and Red Bank Creeks. These tributaries were usually less turbid than the mainstem on the dates sampled (Fig. 11). No turbidity samples were taken in Mud Creek, Thomes Creek, or Kusal slough, but these tribuaries also appeared to be less turbid than the mainstem Sacramento river, and to clear up faster after storm events. Lower turbidity in the tributaries should be advantageous to juvenile chinook. Salmonids are sight feeders, and moderate levels of turbidity (24 Nephelotometric Turbidity Units for chinook salmon) are known to reduce feeding efficiency (Chapman and Bjornn, 1969). Scrivener, et al. (1994) concluded that stress from high sediment levels in the Fraser river during spring floods may induce juvenile chinook to move temporarily into Hawks Creek, a small, nonnatal tributary, in order to feed and clear their gills of sediment. Similar behavior may occur in Sacramento River chinook.

Because they are dry for months at a time, intermittent tributaries lack resident populations of large, piscivorous fishes. This is an obvious advantage to juvenile chinook. If less energy is expended on predator avoidance, more will be available for feeding and growth. However, later in the season (usually in April), adult squawfish move into tributaries to spawn, and may prey on juvenile chinook. Interface predators such as mergansers, egrets, herons, otters, and raccoons prey on fish in the shallow water of receding streams. Juvenile chinook which enter intermittent streams early (winter and spring run) and smolt before water levels recede have a better chance of avoiding predators.

Historically, juvenile chinook may have found favorable rearing conditions in shallow, protected backwaters and side channels once characteristic of the Sacramento River (Thompson, 1961). Although a few river reaches remain relatively natural, large sections have been rip-rapped and devegetated for erosion control and irrigation purposes, depleting chinook rearing habitat. While further studies are needed to detail the magnitude of tributary rearing, it seems evident that small, intermittent streams contribute to the overall habitat complexity of the river system,-and need to be considered in efforts to protect threatened species.

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[Table Captions]

Table 1. Tributaries in which juvenile chinook were observed. Coded wire tagged fish were recovered In those marked with an asterisk (*).

Table 2. Data from coded wire tagged juvenile chinook in 1995.

Table 3. Growth rates estimated for juvenile chinook rearing in Sacramento River Tributaries in former years.

[Figure Captions]

Figure 1. Selected examples of juvenile chinook size distribution at different sites within the same creek on the same date.

Figure 2. Juvenile chinook observed in Thomes Creek on April 3, 1995.

Figure 3. Juvenile chinook observed in Kusal Slough on April 3, 1995.

Figure 4. Juvenile chinook observed in Mud Creek on February 2, 1995.

Figure 5. Percent of winter, spring and fall chinook juveniles observed at two sites in the Sacramento River and in tributaries entering the river above and below Red Bluff.

Figure 6. Temporal distribution of chinook races observed in intermittent tributaries entering the Sacramento River between Red Bluff and Willows.

Figure 7. A breakdown into races of chinook juveniles observed in different years. (Lower numbers of spring and winter chinooks captured prior to 1994 can be attributed to a sampling regime which started later in the season, thereby missing most representatives of these races).

Figure 8. Condition factors for juvenile chinook in 1995. Each symbol represents the mean of two or more fish within a 10 mm size range. Open circles indicate Sacramento River sites; dots indicate tributary sites .

Figure 9. Growth rate estimates for juvenile chinook rearing in the Sacramento River and intermittent tributaries in 1995.Table 4. Growth rates estimated for juvenile chinook rearing in Sacramento River Tributaries in former years.

Figure 10. Examples of tributary temperature fluctuation with comparable data from the river.

Figure 11. Turbidities measured on selected dates in 1995.

Table 1.

WEST SIDE OF RIVER		EAST SIDE OF RIVER	
CREEK	USGS QUAD	CREEK	USGS QUAD
Stony*	Chico	Big Chico*	Chico
Thomes*	Vina	Mud*	Chico
Elder*	Los Molinos	Rock*	Chico
Red Bank	Red Bluff East	Pine*	Ord Ferry
Reeds	Red Bluff East	Toomes*	Vina
Brickyard	Red Bluff East	Dye	Los Molinos
Blue Tent*	Red Bluff East	Ash	Ball's Ferry
Dibble	Red Bluff East		
Anderson	Ball's Ferry		

Table 2.

Capture Date	Release Date	Capture Site	Release Site	Fork Length	Tag Code	Known Race	Race Based on Size
2/23/95	1/26/95	Dibble Creek	Bonnyview Boat Ramp	83	5111004	W	W
2/23/95	1/26/95	Dibble Creek	Bonnyview Boat Ramp	73	5111009	W	S
2/23/95	1/26/95	Dibble Creek	Bonnyview Boat Ramp	93	5111202	W	W
3/5/95	1/26/95	Stony Creek	Bonnyview Boat Ramp	91	5111115	W	W
3/5/95	1/26/95	Stony Creek	Bonnyview Boat Ramp	104	5111015	W	W
3/26/95	3/10/95	Mud Creek	Red Bluff Diversion Dam	64	5111205	F	F
3/26/95	3/10/95	Mud Creek	Red Bluff Diversion Dam	67	5111205	F	F
4/3/95	1/26/95	Thomes Creek	Bonnyview Boat Ramp	102	5111010	W	W
4/17/95	3/10/95	Kusal Slough	Red Bluff Diversion Dam	86	5111205	F	S
4/17/95	3/10/95	Kusal Slough	Red Bluff Diversion Dam	84	5111204	F	S
4/17/95	3/10/95	Kusal Slough	Red Bluff Diversion Dam	83	5111205	F	S
5/7/95	4/24/95	Toomes Creek	Battle Creek	68	5111208	F	F
5/7/95	4/24/95	Kusal Slough	Battle Creek	78	5111208	F	F
5/7/95	4/24/95	Kusal Slough	Battle Creek	81	5111208	F	F
5/7/95	4/24/95	Kusal Slough	Battle Creek	73	5111204	F	F

Table 3.

Site	Period	Rate (mm/day)
Kusal Slough at W. Sac.	Mid March, 94	0.6
Mud Creek at W. Sac.	Mid March, 94	0.6
Mud Creek at W. Sac.	Mar 23 - Apr 8, 94	0.63
Chico Creek near Mud	Mar 25 - Apr 8, 94	0.86
Mud Creek at W. Sac.	Late March, 90	0.8
Mud Creek at W. Sac.	Early April, 90	1.4
Mud Creek at W. Sac.	Mid April, 90	0.7
Stony Creek at TNC	Mar 2 - Apr 10, 94	0.41

Figure 1.

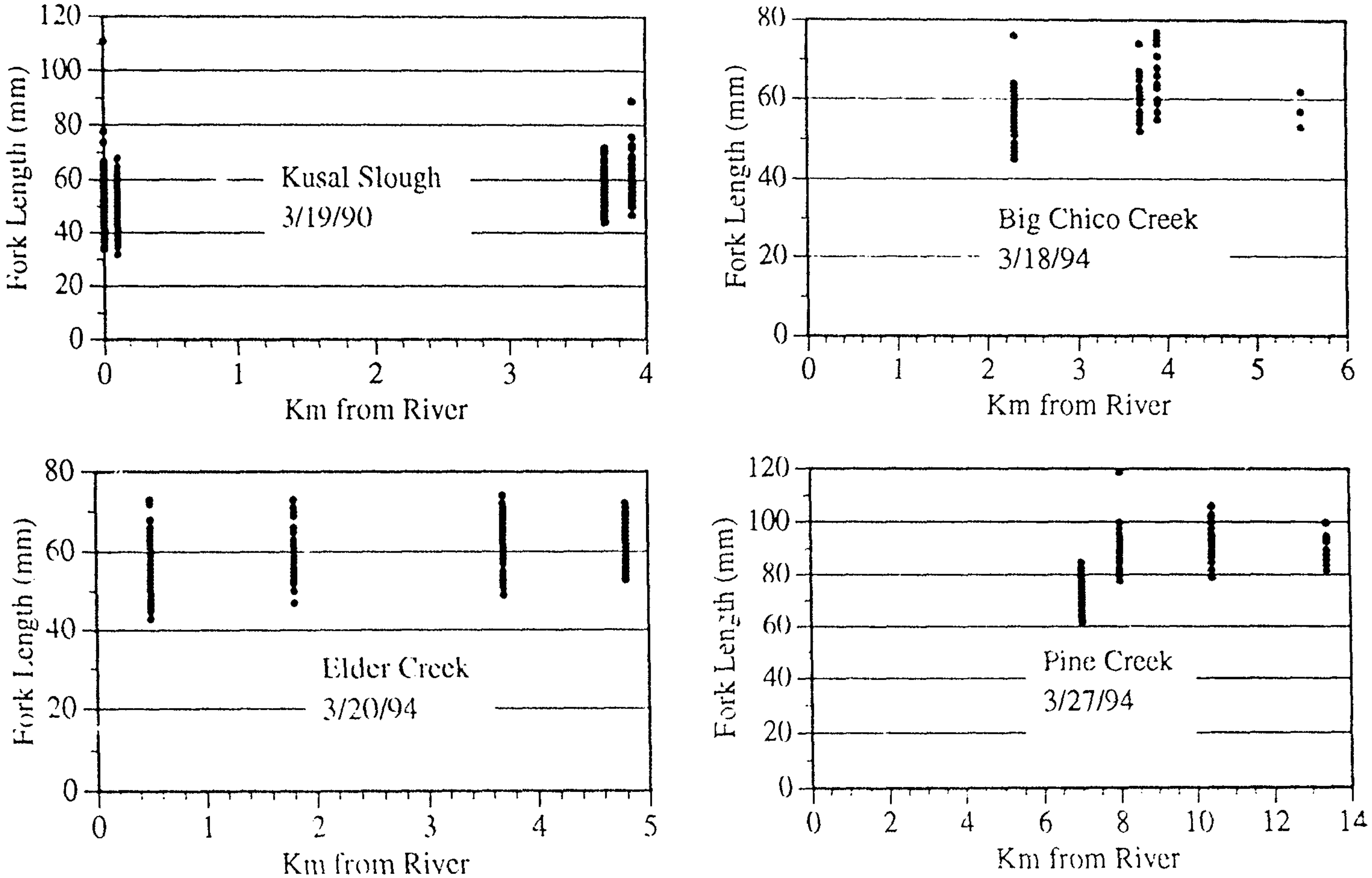
Kusal Slough
3/19/90
Big Chico Creek
3/18/94
Elder Creek
3/20/94
Pine Creek
3/27/94
Fork Length (mm)
Km from River

Figure 2

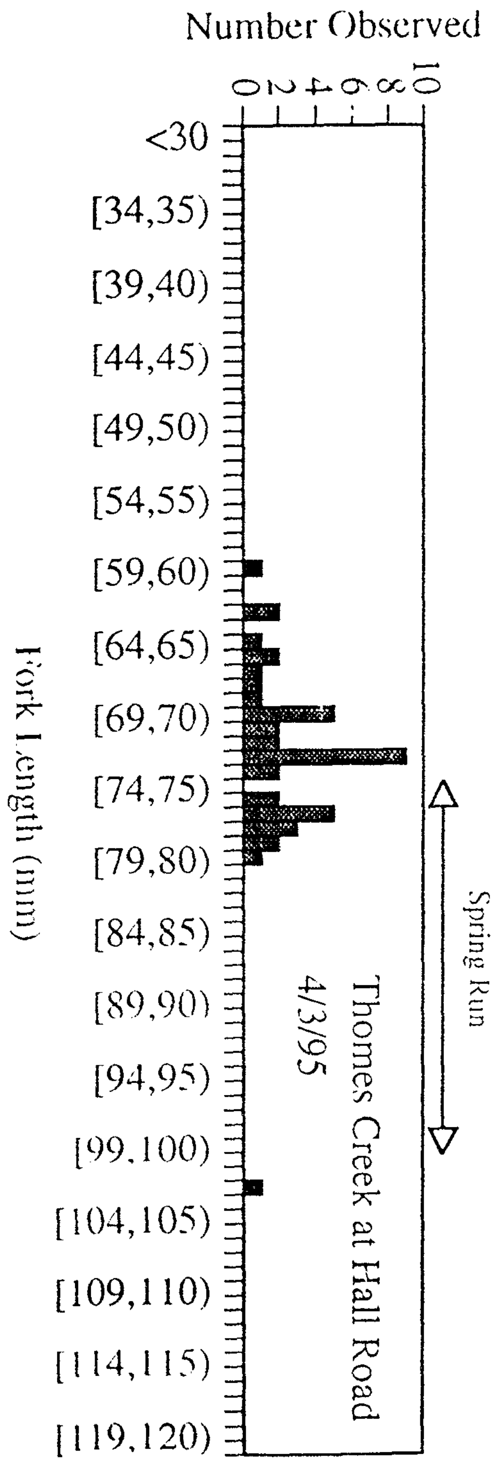

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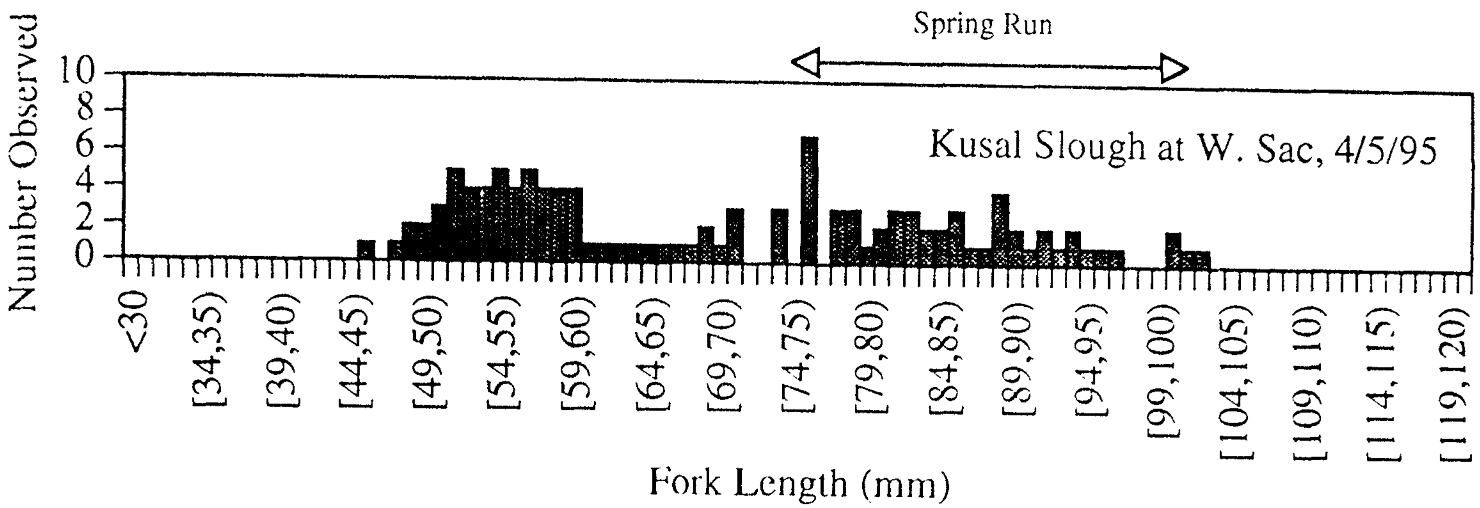
Figure 3.


Spring Run
Kusal Slough at W. Sac, 4/5/95
Number Observed
10
8
6
4
2
0
<30
[34,35)
[39,40)
[44,45)
[49,50)
[54,55)
[59,60)
[64,65)
[69,70)
[74,75)
[79,80)
[84,85)
[89,90)
[94,95)
[99,100)
[104,105)
[109,110)
[114,115)
[119,120)
Fork Length (mm)

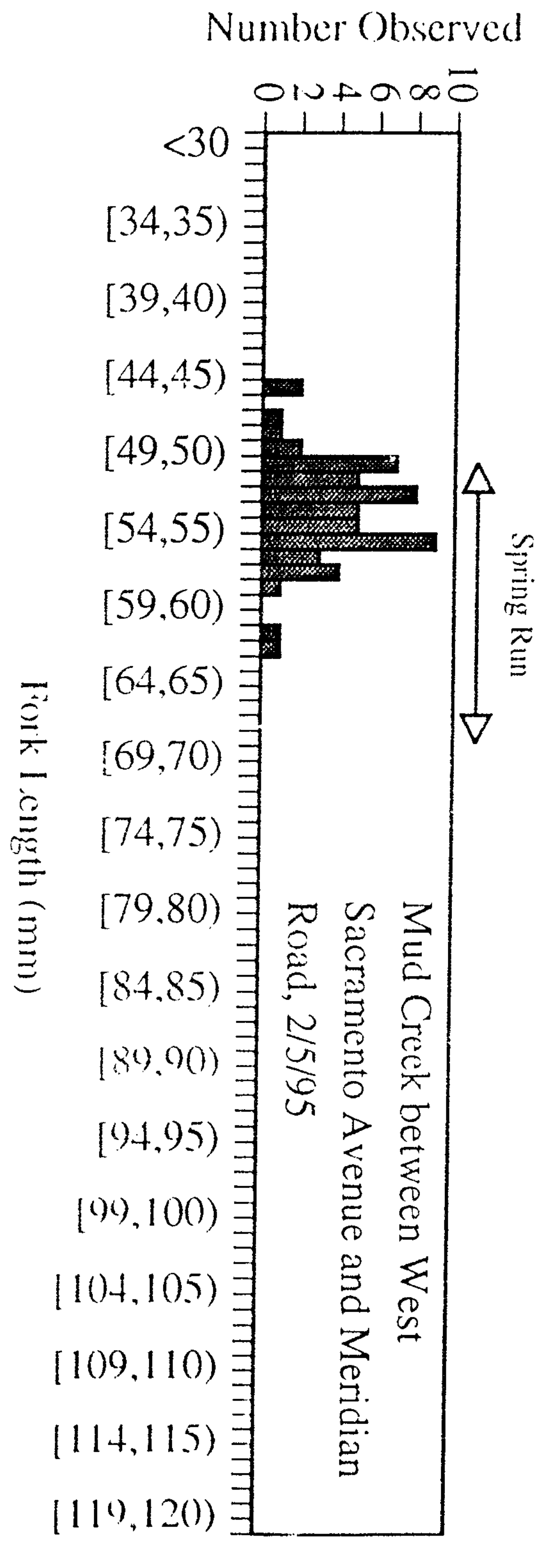

Number Observed
0
2
4
6
8
10
<30
[34,35)
[39,40)
[44,45)
[49,50)
[54,55)
[59,60)
[64,65)
[69,70)
[74,75)
[79,80)
[84,85)
[89,90)
[94,95)
[99,100)
[104,105)
[109,110)
[114,115)
[119,120)
Fork Length (mm)
Mud Creek between West
Sacramento Avenue and Meridian
Road, 2/5/95
Spring Run

Figure 4

Figure 5.

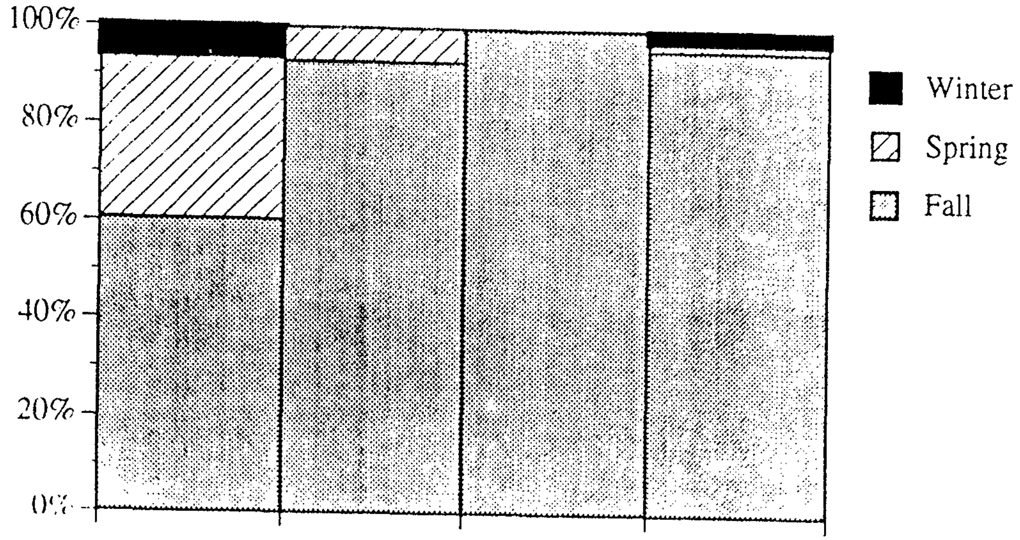


Figure 6.

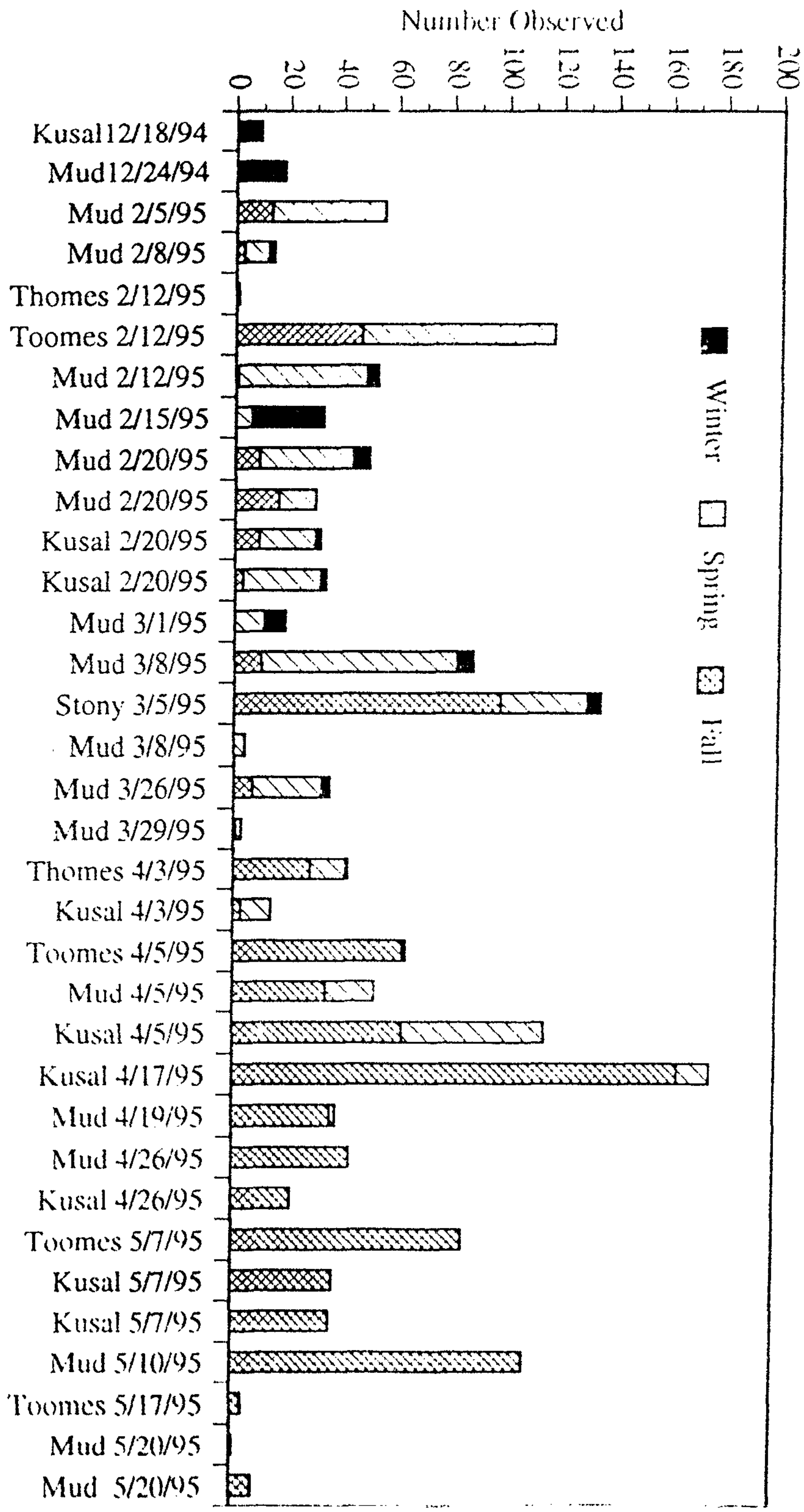


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Figure 7.

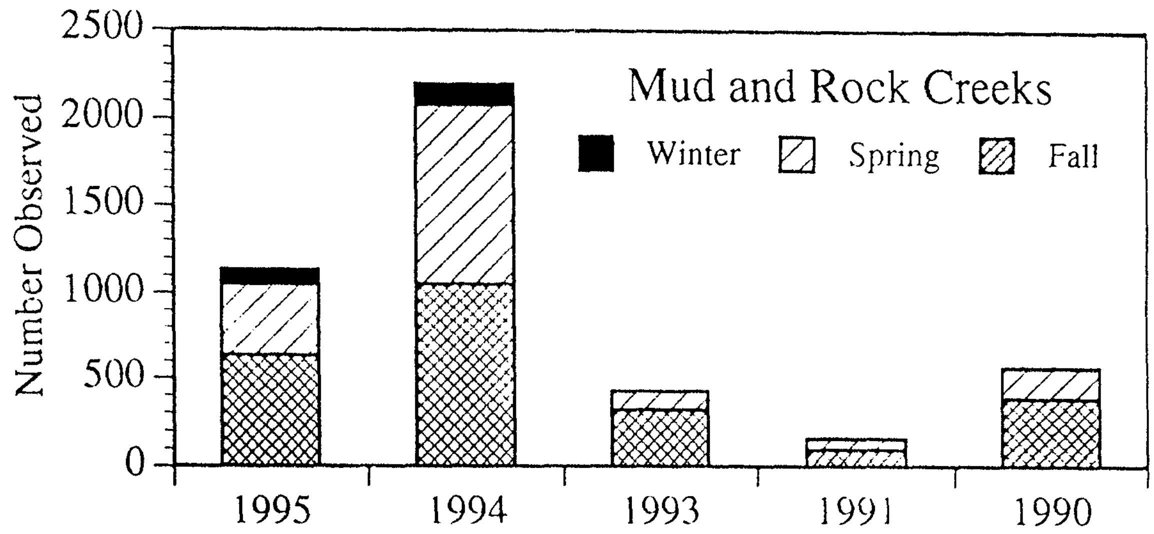
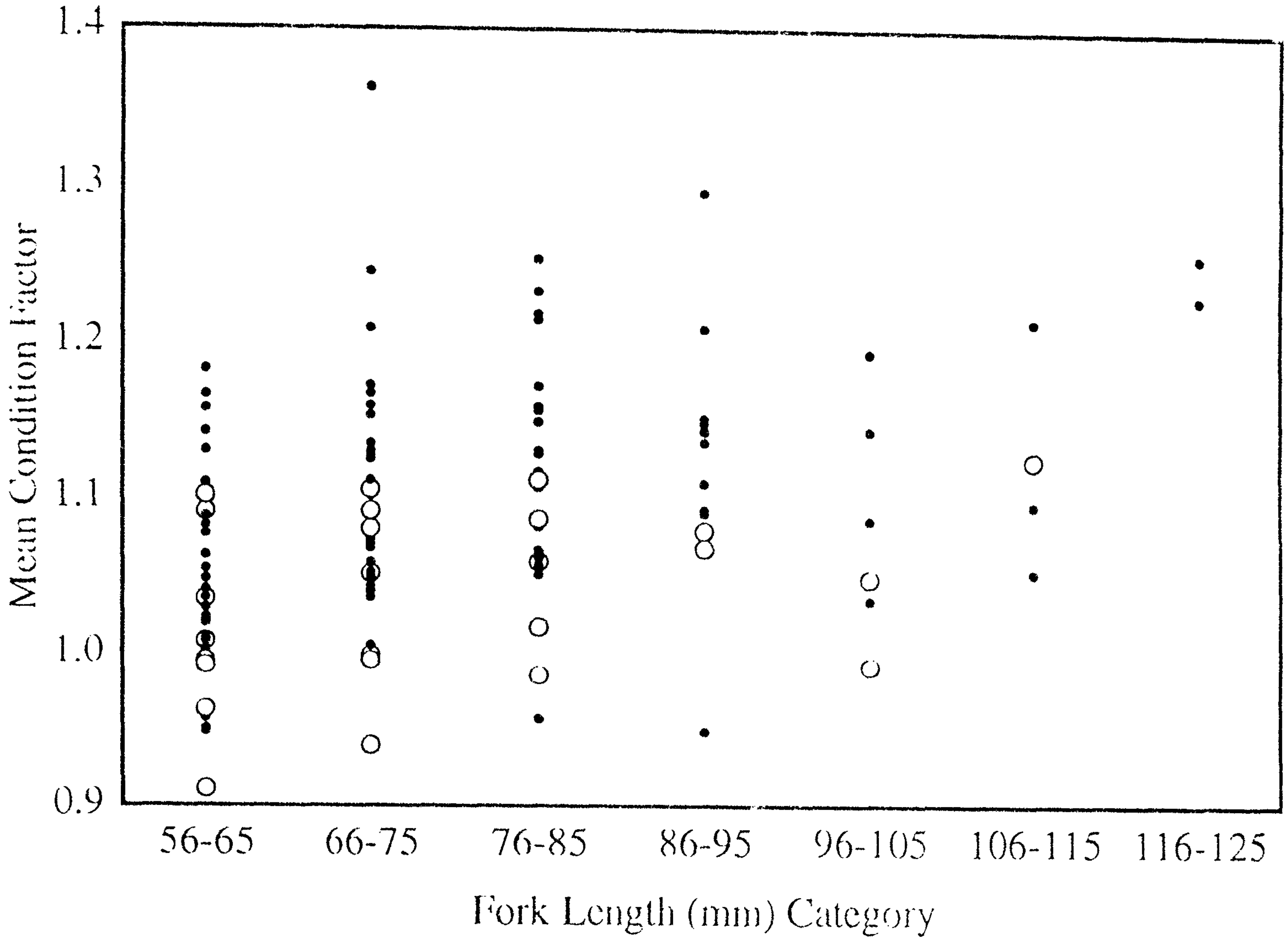
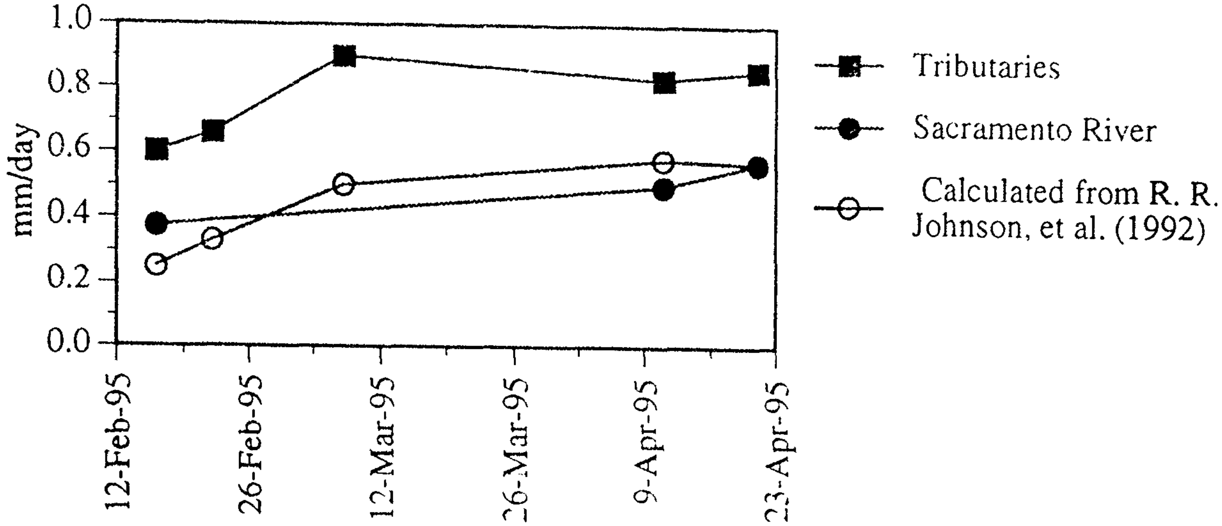

Mud and Rock Creeks
Winter
Spring
Fall
Number Observed
2500
2000
1500
1000
500
0
1995
1994
1993
1991
1990

Figure [illegible].

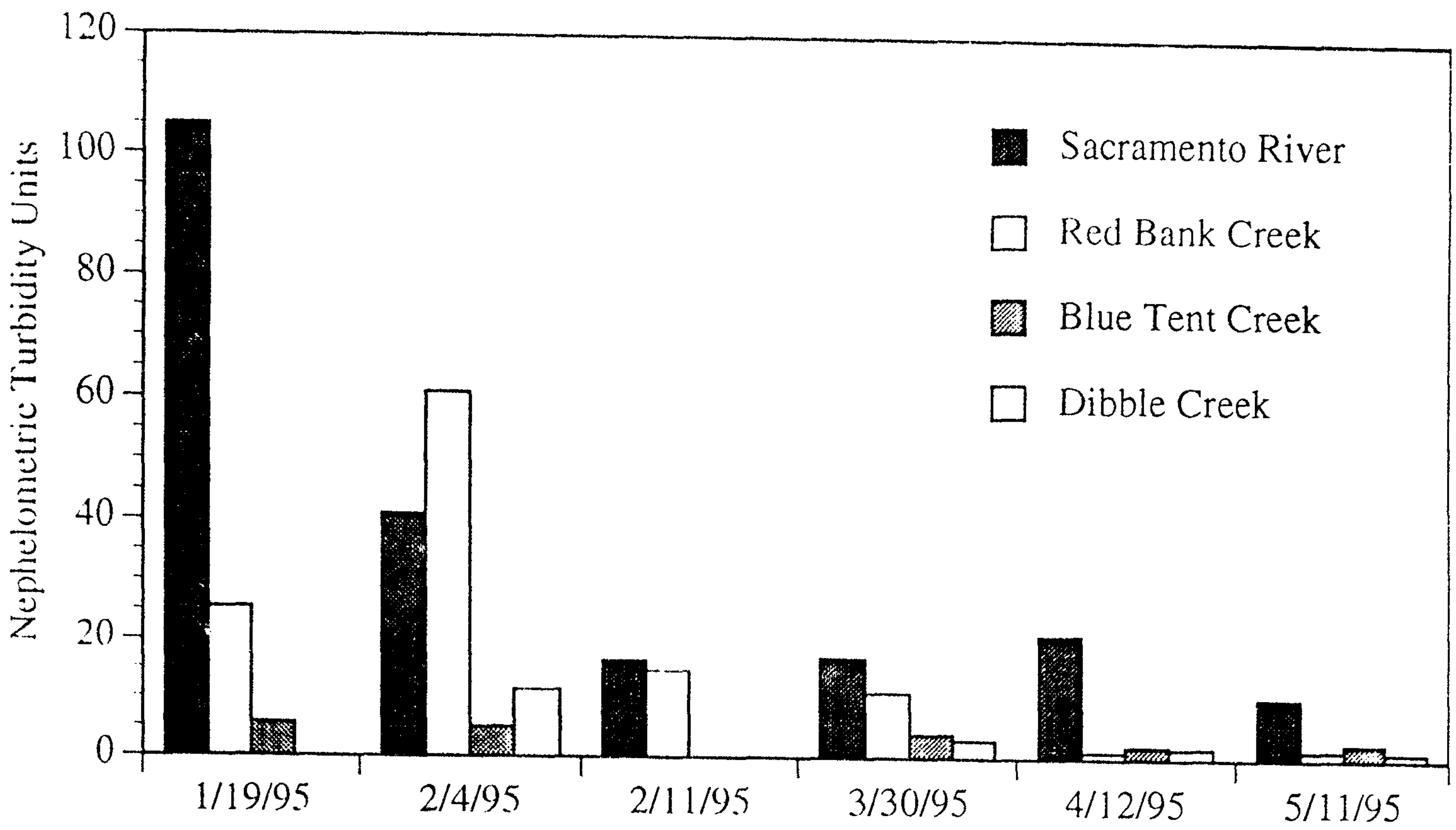


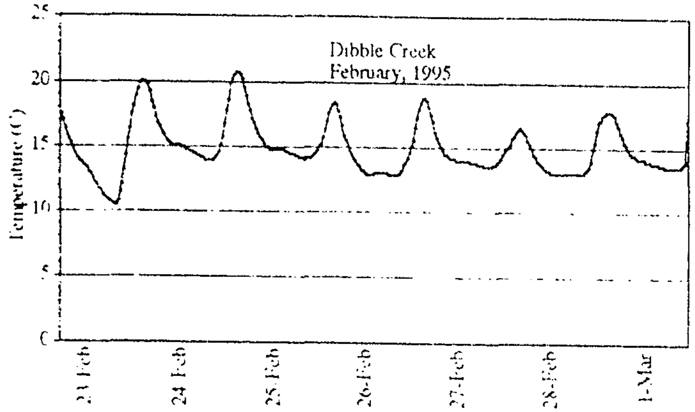
Mean Condition Factor
1.4
1.3
1.2
1.1
1.0
0.9
56-65
66-75
76-85
86-95
96-105
106-115
116-125
Fork Length (mm) Category

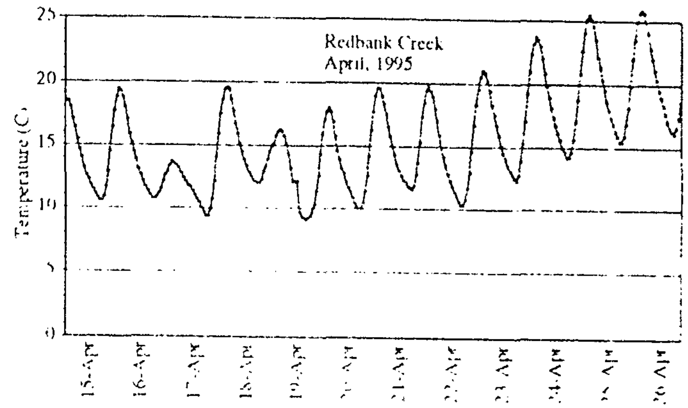
Figure 9.

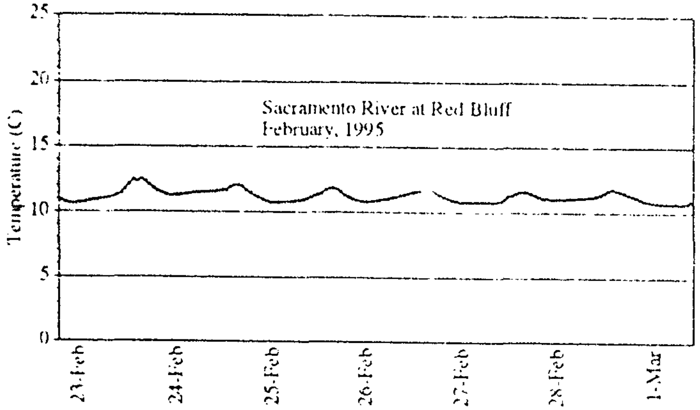


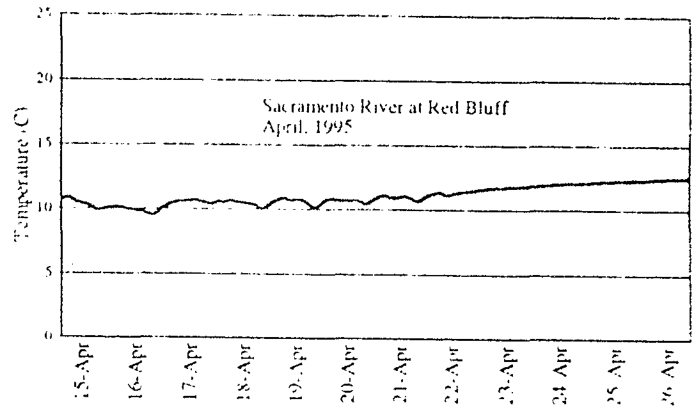
mm/day
1.0
0.8
0.6
0.4
0.2
0.0
12-Feb-95
26-Feb-95
12-Mar-95
26-Mar-95
9-Apr-95
23-Apr-95
Tributaries
Sacramento River
Calculated from R. R. Johnson, et al. (1992)


120
100
80
60
40
20
0
Nephelometric Turbidity Units
Sacramento River
Red Bank Creek
Blue Tent Creek
Dibble Creek
1/19/95
2/4/95
2/11/95
3/30/95
4/12/95
5/11/95


Dibble Creek
February, 1995
Temperature (C)
0
5
10
15
20
25
23-Feb
24-Feb
25-Feb
26-Feb
27-Feb
28-Feb
1-Mar


Redbank Creek
April, 1995
Temperature (C)
0
5
10
15
20
25
15-Apr
16-Apr
21-Apr
26-Apr


Sacramento River at Red Bluff
February, 1995
Temperature (C)
0
5
10
15
20
25
23-Feb
24-Feb
25-Feb
26-Feb
27-Feb
28-Feb
1-Mar


Sacramento River at Red Bluff
April, 1995
Temperature (C)
10
20
15-Apr
16-Apr
17-Apr
18-Apr
19-Apr
20-Apr
21-Apr
22-Apr
23-Apr
24-Apr
25-Apr
26-Apr

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