TASK 14. SMOLT OUT-MIGRATION, 1990 - 1992

14.1 OBJECTIVE

The out-migration of chinook salmon was studied during the spring of 1990, 1991 and 1992 to determine the timing and number of smolts and fry migrating out of the Mokelumne River; to determine the age, size and physical condition of the migrants; and to identify the environmental variables influencing the migration patterns. During the study, the out-migration of steelhead rainbow trout released into the river from the MRFH was also examined.

14.2 METHODS

14.2.1 Woodbridge Dam Smolt Traps

14.2.1.1 1990 Study

The out-migration of chinook salmon smolts was monitored in the Mokelumne River at Woodbridge Dam during the late spring and early summer. A smolt trap was installed in the lower ladder at Woodbridge Dam by the CDFG (lower trap) and a fyke net was installed in the upper ladder (upper trap) (Figure 14-1). The lower trap was used to capture fish moving through the fish bypass pipeline from the mouth of the WID Canal in Lake Lodi. Fish screens (rotating drum, 4-mm mesh) are designed to prevent fish from entering the WID Canal during months when water is being diverted. Fish moving across the screen face are supposed to be drawn into the bypass and enter a 293 m long, 30 cm diameter pipe that deposits them into the trap in the lower fish ladder below the dam. Recent evaluation of fish screens and bypass operations indicate that there are inadequate flows across the face of the screens to efficiently attract all salmon smolts into the bypass (Vogel 1992).

The lower trap was installed in the upper pool (9A) of the lower ladder system at Woodbridge Dam (Figure 14-1) on 5 April and was operational until 28 July. The trap consisted of a capture unit and a holding unit. The capture unit was a rectangular, perforated metal box (3.4 m x 0.9 m x 0.9 m) that received water from the screen bypass (30-cm diameter) at the mouth of the WID Canal. A holding unit (0.6 m x 1.8 m x 1.2 m) installed perpendicular to the capture unit provided the smolts with some refuge from the current. The holding unit was constructed with a mesh front panel (6 mm) that allowed lampreys to escape. A sluice gate installed at the outflow from pool 9A was used to control the water level in the trap. By closing this gate, the trap was submerged in 2 m of water in order to prevent vandalism. To check the trap, the sluice gate was opened, which dropped the water level to 0.5 m in pool 9A. Throughout the study, the entire flow from the bypass into the lower fish ladder passed through the lower trap.

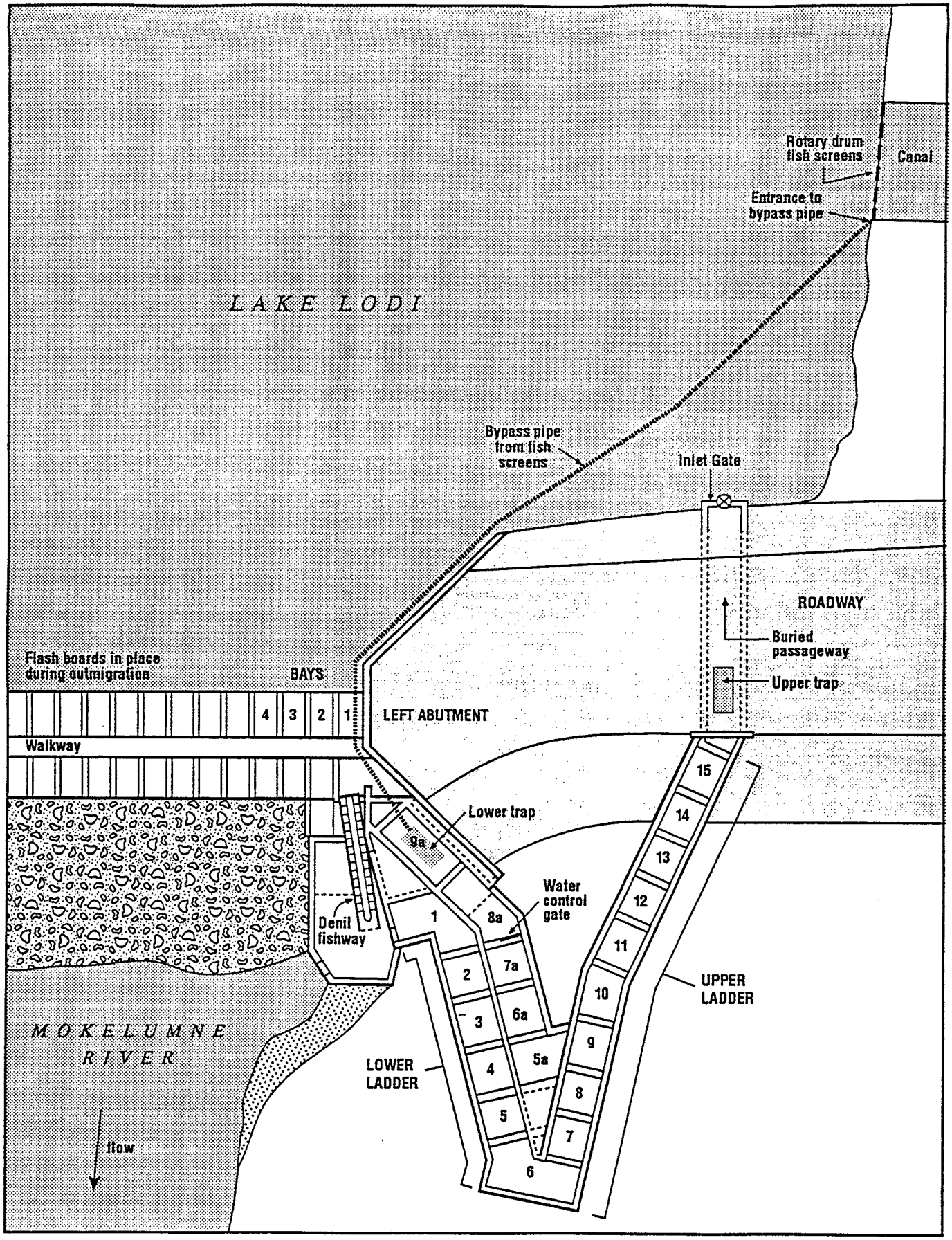

Figure 14-1. Plan view of Woodbridge Dam showing fish ladders and lower and upper smolt outmigration traps.

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In past years, it was assumed by CDFG that all out-migrating smolts left Lake Lodi via the bypass pipeline. However, during this investigation, it was determined that smolts avoid the screens entirely and move downstream through the upper fish ladder at Woodbridge Dam. To trap these fish, a modified fyke net (6.4 mm mesh) was installed in the upper fish ladder (upper trap) from 15 May to 9 July. The fyke net (4.6 m long x 1.8 m wide) was positioned across the 0.6 m^2 opening of the upper fish ladder at the dam (Figure 14-1) and baffles were placed across the exit of the chamber to reduce water velocity and minimize damage to fish held in the trap. Throughout the study, the entire flow through the upper fish ladder passed through this trap.

The traps were inspected three times a week until at least 100 smolts were captured. The trap was then checked daily until migration ended. The numbers and taxonomic classifications of all fish caught in the traps were recorded. When fewer than 100 salmon and trout were caught in a trap, the length and weight of all salmonids were measured. When large numbers of salmon and trout were captured (>100), data were collected from a random subsample (N=60-100 fish). Length (total and fork) was measured to the nearest millimeter; live weight to the nearest gram was obtained using a Pesola spring balance. Fulton condition factor (K) was calculated for all processed fish where w is the weight (g) of the fish and l is the total length (mm) of the fish:

$$K = \left[\frac{w}{l^3}\right] \times 100{,}000$$

The general condition of each fish was noted, as well as the presence of disease or parasites. Scales were collected from a subsample of chinook salmon and steelhead rainbow trout for age determination. Scales were mounted on microscope slides and viewed in a microfiche reader to determine age and growth (Jearld 1983).

In 1990, water was diverted into the WID Canal beginning 30 March. During the first week of April, the mean flow diverted into the WID Canal was 65 cfs, increasing to 227 cfs by late June and early July (Table 14.1). During this time, the percentage of total river flow diverted into the WID Canal increased from 75 percent in early April to approximately 90 percent during late June and July.

Water temperature at the trap locations was recorded when the traps were checked. Smolts were released immediately downstream from Woodbridge Dam when water temperatures were less than 18° C (prior to 1 May). During this time, all salmon and 90 percent of the trout were marked by injecting the fin rays with Alcian Blue dye (64 mg/ml) using a Panjet dental inoculator (Starkie 1975. Pitcher and Kennedy 1977) to study the movements of salmonids in the Lower Mokelumne River. By marking different fins on different days, the release dates of recaptured fish were determined. When the water temperature exceeded 18° C at Woodbridge Dam, all smolts were transported to the Delta. When temperatures in the Delta were less than 18° C, fish were released at Rio Vista. When temperatures exceeded 18° C at Rio Vista, the fish were released at Bennett's Marina in Rodeo. The fish were moved in an Eagar transporting tank (946 liter) with iced water (16° C) and aeration tanks. None of the smolts transported to the Delta were marked.

Table 14.1. Mean weekly flows downstream of Woodbridge Dam and into the WID Canal during out-migration, 1990 -1992. Percentage of total river flow diverted into the WID Canal by week is also provided.

	WEEK ENDING	MEAN WEEKLY FLOW (cfs) BELOW WOODBRIDGE DAM (USGS Station #11325500)	MEAN WEEKLY FLOW (cfs) INTO WID CANAL (USGS Station #11325000)	PERCENTAGE OF TOTAL RIVER FLOW INTO WID CANAL
1990	29 March	21.9	0.0	0%
	05 April	22.0	65.1	75[1]
	12 April	20.7	89.7	81
	19 April	19.9	90.1	82
	26 April	21.4	93.9	81
	03 May	22.4	117.4	84
	10 May	24.4	159.3	87
	17 May	25.6	167.1	87
	24 May	26.6	167.3	86
	31 May	48.6	126.6	72
	07 June	22.6	67.4	75
	14 June	25.9	140.6	84
	21 June	25.7	197.1	88
	28 June	25.7	227.0	90
	05 July	25.6	227.1	90
	12 July	24.6	198.4	89
	19 July	24.6	199.1	89
	26 July	24.4	196.9	89
1991	29 March	74.1	0.0	0%
	05 April	35.1	0.0	0
	12 April	28.9	19.8	41[2]
	19 April	27.4	54.1	66
	26 April	30.6	56.6	65
	03 May	26.4	62.6	70
	10 May	25.7	98.0	79
	17 May	25.9	103.6	80
	24 May	27.1	103.9	79
	31 May	27.6	110.0	80
	07 June	28.1	123.6	81
	14 June	29.3	153.1	84
	21 June	27.3	191.0	88
	28 June	30.3	210.7	87
	05 July	33.7	187.0	85
1992	29 March	133.7	0.0	0%
	05 April	134.9	0.0	0
	12 April	145.4	53.1	27[3]
	19 April	104.7	55.1	35
	26 April	31.4	59.1	65
	03 May	27.4	132.6	83
	10 May	33.6	157.3	82
	17 May	32.7	154.7	83
	24 May	33.1	138.6	81
	31 May	33.6	129.0	79
	07 June	31.9	134.9	81
	14 June	35.1	152.6	81
	21 June	38.0	168.7	82
	28 June	37.4	149.9	80
	05 July	42.1	146.3	78

[1] Water was released into the WID Canal beginning 30 March 1990.
[2] Water was released into the WID Canal beginning 9 April, 1991.
[3] Water was released into the WID Canal beginning 6 April, 1992.

Midway through the out-migration period (17-18 May) the lower trap was checked every 2 hours for one 24-hour period to determine whether there was a diel cycle to out-migration.

14.2.1.2 1991 Study

The experimental methods used during the 1990 out-migration study were modified slightly for the 1991 out-migration study. In 1991, both traps were installed on 27 March and operated until 2 July. All smolts caught in the traps were tagged with coded wire tags (CWT, as outlined in Task 15), transported across the Delta, and released at Bennett's Marina in Rodeo because of high temperatures (>20° C) in the Mokelumne River below Woodbridge Dam.

During 1991, mean weekly flow diverted into the WID Canal ranged from 20 cfs in April to 211 cfs in June. The weekly percentage of total river flow diverted into the WID Canal ranged from 41 percent in April to 88 percent in June (Table 14.1). Flows in the river below Woodbridge Dam averaged less than 40 cfs after March.

In 1991, the 24-hour diel migration study was conducted 21-22 May.

14.2.1.3 1992 Study

In 1992, slight revisions were made in the experimental approach in order to improve smolt survival. The fyke net that had been used in the previous year in the upper ladder was replaced with a modified box trap. The trap (1.2 m x 1.2 m x 2.4 m) was positioned across the upstream opening of the ladder, and baffles were placed inside the trap to reduce water velocity. As in the 1991 study, all smolts caught in the traps were tagged with coded wire tags, and transported to Bennett Marina in Rodeo due to elevated temperature conditions (>20° C) below Woodbridge Dam.

In 1990 and 1991, a mesh size of 6 mm was used in the holding unit of the lower trap to allow lamprey to escape. In 1992, the mesh size in the holding unit was reduced to accurately quantify lamprey and salmon fry being captured in the trap. The lower and upper traps were installed on 1 and 16 April, respectively. Both traps remained operational until 1 July. Early in the out-migration study, water spilled over the top of Woodbridge Dam, potentially allowing smolts downstream passage without being captured in the traps. Because spillage was minimal and occurred early in the out-migration period when few smolts were being caught in the traps, it was assumed that 100 percent of the smolts were captured in 1992. By 16 April, there were no further spillage problems and the traps were completely functional.

Water from Lake Lodi was diverted into the WID Canal beginning 6 April. Mean weekly flow in the WID Canal increased from a minimum of 53 cfs in early April to a maximum of 169 cfs in June (Table 14.1). The percentage of total river flow diverted into the WID Canal

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increased from 27 percent in early April to approximately 80 percent throughout May and June. Flow below Woodbridge Dam was less than 55 cfs from late April through the end of the trapping operations (1 July).

During the diel migration study in 1992, both of the Woodbridge traps were checked at 2-hour intervals during a 32-hour period (30-31 May).

The total length and condition factor for young-of-year and yearling salmon were analyzed to compare intra-annual and inter-annual differences in size and condition over time. Additionally, the timing of the out-migration in each year was analyzed to identify potential environmental factors (flow and water temperature) influencing the timing of the out-migration.

14.2.2 Bruella Road Smolt Trap

In 1991, an experimental trap was installed upstream of Lake Lodi at Bruella Road to attempt to reduce smolt mortality in Lake Lodi by catching smolts before they entered the lake. A smolt trap was installed downstream of the fry traps on 12 March and operated until 7 May. The W-shaped trap was based on the design of a trap that was used on the Chemainus River, Vancouver, British Columbia (Conlin and Tutty 1979). Trap boxes were attached at both points where the panels converged at the base of the W. The trap boxes (1.2 m x 1.2 m x 2.4 m) had braced aluminum mesh with hinged lids open at the upstream end, where they were attached to the trap. Guard bars of 1.3 cm conduit were installed within the trap boxes to give the smolts refuge from potential predation. Sandbags were placed along the entire length of the panels to reduce scouring of the riverbed beneath the trap. The trap was checked and cleaned at least three times daily: early morning, mid-afternoon, and late at night. All fish were processed as described above for the Woodbridge traps. Other data such as water depth at the panels, temperature, ambient air temperature, weather and general comments were also recorded.

14.2.3 Bruella Road Fry Traps

14.2.3.1 1991 Study

To monitor the downstream movements of fry in the Mokelumne River, 12 fry traps were installed on 8 February, approximately 200 m downstream of Bruella Road above Lake Lodi. The traps consisted of a 1.8 m long 2-mm mesh net attached to a stainless steel external frame (0.9 m x 0.6 m x 0.9 m). A removable PVC trap cup (11.4 cm diameter, 30 cm long) was attached to the rear of the net to act as a live box for the fry. These traps were manufactured by Research Nets Inc., Bothell, Washington.

Fry traps were installed in two staggered rows across the river channel with the trap openings facing upstream. This placement enabled sub-sampling of the entire river channel. Sandbags were placed along the trap frames to secure them to the river bed. The traps were

checked three times daily: morning, evening, and late at night. The trap cup was detached and all fry were identified, counted, measured, weighed, and released. Water temperature, ambient air temperature, and general weather conditions were also recorded during each check. The traps were removed on 15 March.

14.2.3.2 1992 Study

In 1992, 11 fry traps were installed on 18 February approximately 250 m downstream from Bruella Road above Lake Lodi. To increase trap efficiency, the trap cups that were used as live boxes on the traps in 1991 were replaced with perforated aluminum canisters (1 m long x 0.3 m in diameter).

To reduce scouring of the sand substrate beneath the traps, each trap was placed on plastic sheeting (2 m x 3 m). The traps were secured to the river bottom with sandbags and 2.1 m steel posts were driven into the substrate. The traps were checked twice a day (morning and evening), and cleaned three times each day (morning, evening, and late at night).

Trap efficiency was calibrated by releasing three separate batches of marked fry. The caudal fin of each fry was marked with Alcian Blue dye using a Panjet dental inoculator. The first batch (N=500) was released 4 March, the second batch (N=862) on 11 March, and the third batch (N=682) on 17 March. Each batch of marked fry was released approximately 100 m upstream from the traps. All marked fry caught in the traps were measured and recapture rates were calculated. During the 4 March release, 700 unmarked fry were also accidentally released. To account for these unmarked fry in the traps, the daily catch total for naturally-produced fry for 5 March was adjusted using results from the mark-recapture study.

Trap efficiency was further evaluated by conducting three sets of flow velocity measurements near the trap openings (29 February, 9 March, and 19 March). During each survey, flow velocity was measured at three depths (20%, 60% and 80% of the total depth, measured from the surface) directly upstream (approximately 1.2 m) from each trap opening. Mean velocity at each trap was calculated by averaging the velocities from all three surveys at all three depths.

Traps were removed from the Bruella site on 29 March.

14.2.4 Ray Road Fry Traps

In order to monitor fry movement downstream from Woodbridge Dam, 11 fry traps were placed approximately 15 kilometers downstream from the dam on 30 March 1992. The trap operations and calibrations were conducted similarly to methods at the Bruella Road site. At the Ray Road site, calibration studies with marked fry were conducted on 31 March (N=424), 2 April (N=697) and 9 April (N=780). Trap velocity measurements were taken on 3 April, 4 April, and 14 April, approximately 1.2 m upstream from the trap openings. All traps were removed from the Ray Road site on 16 April.

14.3 RESULTS

14.3.1 Woodbridge Dam Smolt Traps

Numerous native and introduced fishes were captured in the Woodbridge traps during the out-migration studies in 1990, 1991 and 1992 (Table 14.2). The most abundant species counted in the traps during each year was chinook salmon. Rainbow trout, largemouth bass, sculpins and lamprey comprised substantial portions of the catch during individual years. Data underestimated the number of lampreys for two reasons: large numbers of lampreys were often caught in a short period of time, making counting difficult, and the lower trap was designed to allow lamprey to escape in 1990 and 1991. Other fishes captured included threadfin shad, golden shiner, hitch, crappie, perch, goldfish, carp, catfish, bass, and sunfish (Table 14.2).

14.3.1.1 Chinook Salmon

Timing and Abundance - In 1990, a total of 78,179 chinook salmon were trapped: 70,027 in the lower trap and 8,152 in the upper trap (fyke net). The fyke net was only operated between 15 May and 9 July, during the peak of the out-migration period. During this time, the fyke net comprised 11 percent of the total catch, but weekly catch rates varied between 1 and 32 percent of the total weekly catch (Table 14.3). The peak catch in the fyke net (32%) coincided with a substantial decrease in WID diversion rates and increased flows past Woodbridge Dam for the week ending 7 June. It appears that when diversion rates are high, most smolts are drawn toward the canal, but when diversion rates are low many smolts avoid the intake to the bypass pipeline located near the WID Canal intake.

In 1990, 62 percent of the salmon were caught in June and the rest in April (<1%), May (28%) and July (10%). Over 40 percent of the salmon were caught during a 2-week period (8-21 June) (Figure 14-2a). During the study, mean weekly flow below Camanche Dam ranged from 144 cfs (end of March) to 374 cfs (end of June).

In 1991, 31,025 out-migrating smolts were counted (Table 14.3). The catch in the upper trap comprised 24 percent of the total number of smolts caught. Peak out-migration in 1991 occurred in May, when over 80 percent of the total number of smolts were caught (Figure 14-2b). The salmon catch in June accounted for less than 10 percent of the total catch. Fifty percent of the out-migrating smolts were caught by 16 May.

Mean weekly flow and water temperature data during the 1991 out-migration study are illustrated in Figure 14-2b. Mean weekly flow measured at Camanche Dam ranged from 90 cfs at the beginning of April to 343 cfs by the end of June. Mean weekly water temperatures recorded at Mackville ranged from 13.2° C (in late April) to 16.8° C (in late July).

Table 14.2. Species trapped at Woodbridge Dam (lower and upper traps) during out-migration, 1990-1992.

NUMBER OF INDIVIDUALS	1990	1991	1992
<100	Pacific lamprey[1] (*Lampetra tridentata*) Carp (*Cyprinus carpio*) Minnow (Family: *Cyprinidae*) Golden shiner (*Notemigonus crysoleuces*) Channel catfish (*Ictalurus punctatus*) Catfish (*Ictalurus* spp.) White crappie (*Pomoxis annularis*) Green sunfish (*Lepomis cyanellus*) Bluegill (*Lepomis macrochirus*) Redear sunfish (*Lepomis microlophus*) Sunfish (*Lepomis* spp.) Bass (*Micropterus* spp.)	Carp (*Cyprinus carpio*) Goldfish (*Carassius auratus*) Golden shiner (*Notemigonus crysoleuces*) Blue catfish (*Ictalurus furcatus*) White catfish (*Ameiurus catus*) Brown bullhead (*Ameiurus nebulosus*) Catfish (*Ictalurus* spp.) Crappie (*Pomoxis* spp.) Warmouth (*Lepomis gulosus*) Bluegill (*Lepomis macrochirus*) Sunfish (*Lepomis* spp.) Bigscale logperch (*Percina macrolepida*) Perch (Family: *Percidae*) Tule perch (*Hysterocarpus traski*)	Pacific lamprey[1] (*Lampetra tridentata*) Carp (*Cyprinus carpio*) Goldfish (*Carassius auratus*) Golden shiner (*Notemigonus crysoleuces*) Hitch (*Lavinia exilicauda*) Channel catfish (*Ictalurus punctatus*) Catfish (*Ictalurus* spp.) Black crappie (*Pomoxis nigromaculatus*) Crappie (*Pomoxis* spp.) Pumpkinseed (*Lepomis gibbosus*) Warmouth (*Lepomis gulosus*) Sunfish (*Lepomis* spp.) Smallmouth bass (*Micropterus dolomieui*) Bigscale logperch (*Percina macrolepida*) Perch (Family: *Percidae*) Tule perch (*Hysterocarpus traski*)
100-1,000	Threadfin shad (*Dorosoma petenense*) Sculpin (*Cottus* spp.)	Sculpin (*Cottus* spp.)	Rainbow trout (*Oncorhynchus mykiss*) Green sunfish (*Lepomis cyanellus*) Bluegill (*Lepomis macrochirus*) Bass (*Micropterus* spp.) Sculpins (*Cottus* spp.)
1,000-10,000	Rainbow trout (*Oncorhynchus mykiss*) Largemouth bass[2] (*Micropterus salmoides*)	Pacific lamprey[1] (*Lampetra tridentata*) Rainbow trout (*Oncorhynchus mykiss*) Largemouth bass[2] (*Micropterus salmoides*)	Largemouth bass[2] (*Micropterus salmoides*)
>10,000	Chinook salmon (*Oncorhynchus tshawytscha*)	Chinook salmon (*Oncorhynchus tshawytscha*)	Chinook salmon (*Oncorhynchus tshawytscha*)

[1]Predominantly ammocoetes; note that trap design results in underestimation of lampreys.
[2]Predominantly fry

Table 14.3. Summary of all chinook salmon trapped weekly in the lower and upper traps at Woodbridge Dam during out-migration in 1990 (6 April - 28 July), 1991 (27 March - 2 July), and 1992 (1 April - 1 July).

WEEK ENDING		LOWER TRAP		UPPER TRAP		TOTAL
		N	%	N	%	
1990	29 March	-	-	-	-	-
	05 April	-	-	-	-	-
	12 April	5	100%	-	-	5
	19 April	7	100	-	-	7
	26 April	65	100	-	-	65
	03 May	1,293	100	-	-	1,293
	10 May	2,869	100	-	-	2,869
	17 May	3,441	78	997	22%	4,438
	24 May	6,734	86	1,122	14	7,856
	31 May	6,567	86	1,080	14	7,647
	07 June	6,085	69	2,802	31	8,887
	14 June	16,264	91	1,522	9	17,786
	21 June	13,877	97	373	3	14,250
	28 June	7,023	98	177	2	7,200
	05 July	4,119	98	76	2	4,195
	12 July	692	99	3	1	695
	19 July	531	100	-	-	531
	26 July	382	100	-	-	382
	2 August	73	100	-	-	73
1990 TOTAL		**70,027**	**89%[1]**	**8,152**	**11%[1]**	**78,179**
1991	29 March	7	22%	25	78%	32
	05 April	35	65	19	35	54
	12 April	46	23	153	77	199
	19 April	324	85	57	15	381
	26 April	577	88	82	12	659
	03 May	1,252	74	443	26	1,695
	10 May	4,053	81	971	19	5,024
	17 May	6,563	73	2,465	27	9,028
	24 May	4,583	75	1,512	25	6,095
	31 May	4,430	84	827	16	5,257
	07 June	1,124	68	532	32	1,656
	14 June	456	78	126	22	582
	21 June	180	68	83	32	263
	28 June	32	60	21	40	53
	05 July	27	57	20	43	47
1991 TOTAL		**23,689**	**76%**	**7,336**	**24%**	**31,025**
1992	29 March	-	-	-	-	-
	05 April	0	-	-	-	0
	12 April	0	-	-	-	0
	19 April	5	42%	7	58%	12
	26 April	186	38	298	62	484
	03 May	561	30	1,324	70	1,885
	10 May	3,719	40	5,530	60	9,249
	17 May	4,707	34	9,040	66	13,747
	24 May	2,324	16	12,414	84	14,738
	31 May	2,435	29	5,971	71	8,406
	07 June	4,769	58	3,464	42	8,233
	14 June	4,438	51	4,243	49	8,681
	21 June	1,764	47	1,970	53	3,734
	28 June	543	71	223	29	766
	05 July	27	47	31	53	58
1992 TOTAL		**25,478**	**36%**	**44,515**	**64%**	**69,993**

[1]Percentages based on weeks when both the upper trap and lower trap were functional.

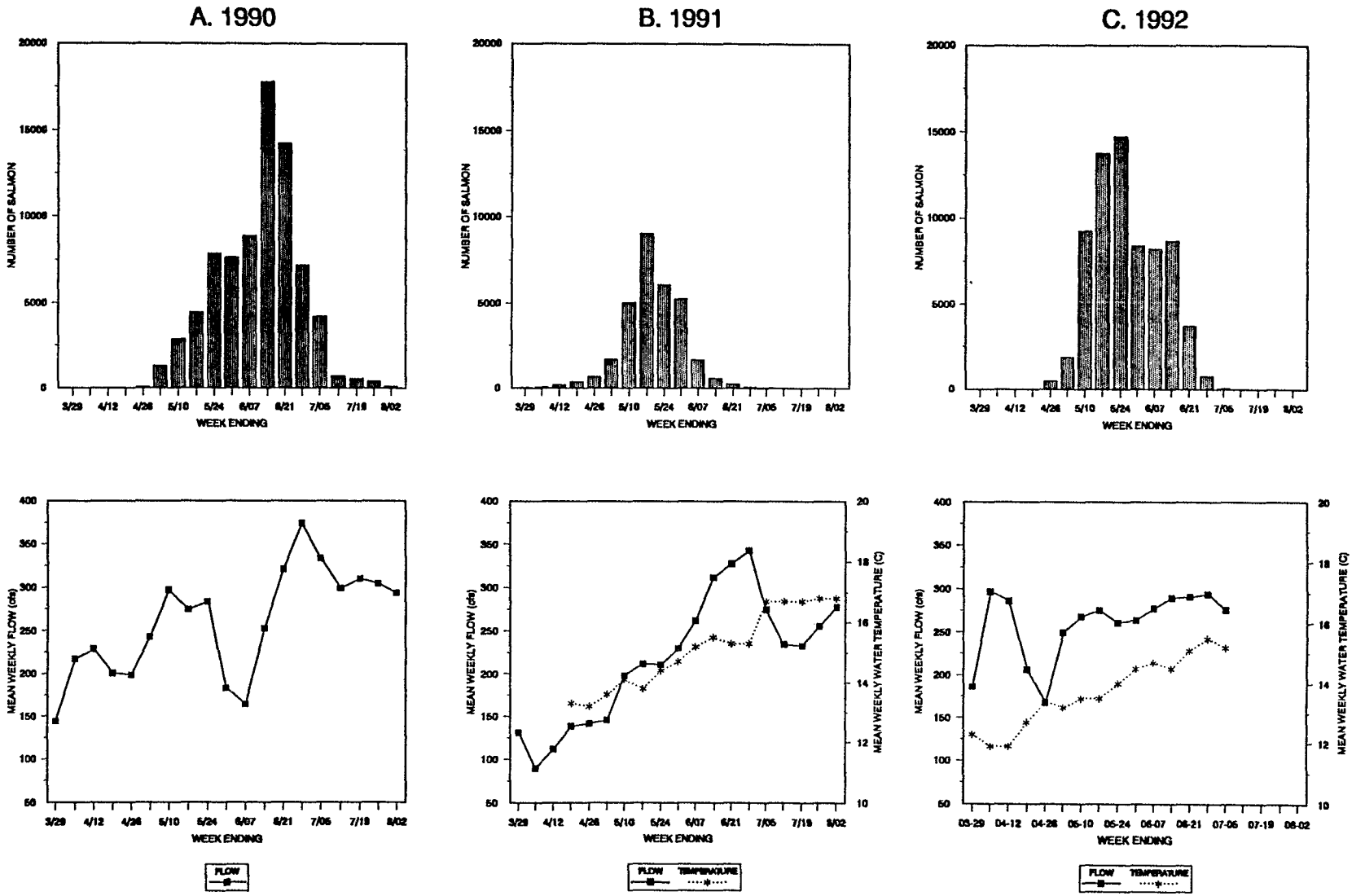

Figure 14-2. Timing and abundance of salmon out-migration in relation to flow at Camanche Dam (USGS Station #11323500) and temperature at Mackville (EBMUD datapod) (where available) for A) 1990 (5 April-28 July), B) 1991 (27 March-2 July), and C) 1992 (1 April-1 July).

In 1992, a total of 69,993 chinook salmon were captured in the Woodbridge traps (Table 14.3). The catch in the upper trap comprised 64 percent of the total number of smolts caught. Sixty-seven percent of the total catch occurred during May, and 31 percent in June (Figure 14-2c). Only about 1 percent of the salmon were caught during April (N=774). During the 1992 out-migration period, mean weekly flows below Camanche Dam fluctuated between 168 cfs and 297 cfs. Mean weekly temperature at Mackville increased from 11.9° C in early April to 15.5° C in late June.

Age Classes - A bimodal distribution of lengths of out-migrating salmon was observed in all three years (Figure 14-3). Scale analysis of several salmon collected in 1990 verified that these fish belonged to two distinct age classes. Salmon larger than 141 mm TL had one annuli, while no annuli were present in fish smaller than 136 mm TL. Based on length-frequency distribution and scale analysis, all salmon 140 mm TL or less were classified as young-of-year (YOY) (0+) fish, and salmon over 140 mm TL were classified as yearling (1+) fish.

Young-of-Year. Young-of-year salmon accounted for over 95 percent of the salmon caught during each of the three years. Each year, approximately 90 percent of 0+ salmon were between 95 and 125 mm (Figure 14-3, Table 14.4).

The mean length of out-migrating smolts was relatively consistent during the out-migration periods each year (Figure 14-4), indicating size-dependent movement. In 1990, there was a significant difference ($p < 0.05$) in the total length of YOY salmon caught in April and July compared to the lengths of YOY salmon caught in May and June based on Student-Newman-Keuls (SNK) multiple comparison analysis. In 1991 and 1992, there was no significant difference in the lengths of the monthly catch ($p > 0.05$). Although the mean length per year differed less than 3 mm between years (Table 14.4), there was a significant decrease in length from 1990 to 1992 according to the results of SNK multiple comparison ($p < 0.05$). The condition factor of YOY salmon in 1991 was significantly higher than YOY sampled in 1990 or 1992 (Table 14.4).

1+ Age Class. Yearling salmon (1+ age class) comprised less than 5 percent of the salmon sampled in each of the study years (1990=44 fish, 1991=115 fish; 1992=44 fish). In 1990, the peak catch of 1+ fish occurred during the fourth week of May (30%). In 1991 and 1992, most of the 1+ fish were measured by the end of April (82% in 1991, 70% in 1992). Since no samples were collected during the winter months, the precise timing or size of the downstream migration of yearling salmon could not be determined.

According to the SNK multiple comparison, there was a significant difference between the lengths of 1+ fish among years ($p < 0.05$), but no significant difference ($p > 0.05$) between the condition factor of 1+ fish during the three year study (Table 14.5).

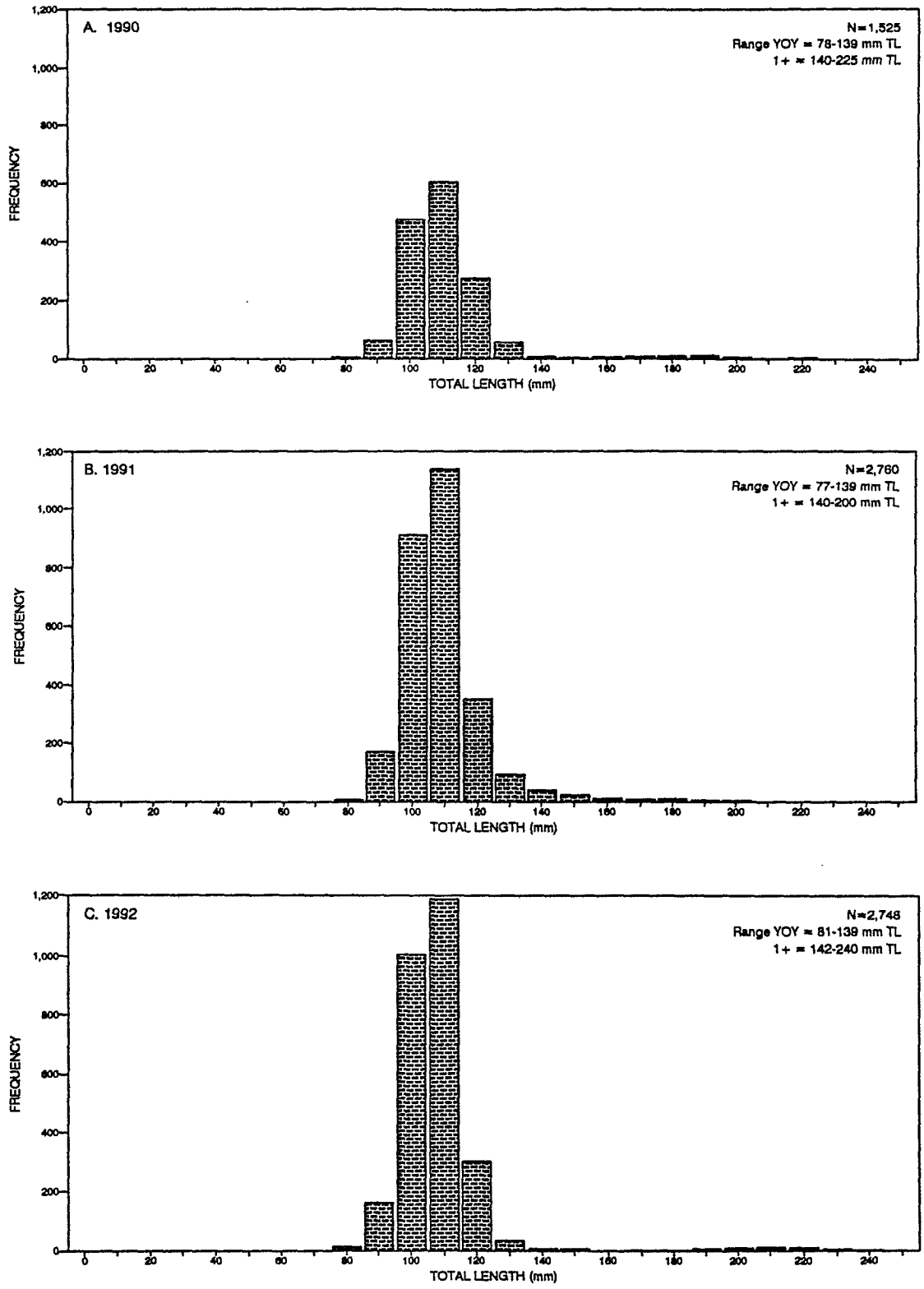

Figure 14-3. Length frequency distribution of out-migrating chinook salmon trapped at Woodbridge Dam from A) 1990, B) 1991, and C) 1992.

Table 14.4. Weekly mean condition factor (K[TL]) and total length of young-of-year salmon (≤ 140 mm TL) trapped at Woodbridge Dam during out-migration, 1990-1992.

WEEK ENDING		N	MEAN K(TL)	SD	N	MEAN TOTAL LENGTH (mm)	SD
1990	05 April	-	-	-	-	-	-
	12 April	2	0.70	0.03	2	92.0	2.8
	19 April	4	0.70	0.02	4	104.3	8.1
	26 April	56	0.76	0.08	56	112.8	6.8
	03 May	137	0.73	0.09	139	113.6	9.0
	10 May	76	0.76	0.06	77	108.1	10.8
	17 May	148	0.77	0.09	151	106.9	10.7
	24 May	114	0.79	0.07	114	107.5	10.5
	31 May	133	0.78	0.07	133	109.7	7.9
	07 June	155	0.80	0.08	155	105.1	8.1
	14 June	133	0.76	0.08	133	106.3	7.2
	21 June	137	0.85	0.07	137	109.4	7.6
	28 June	155	0.84	0.06	155	109.3	6.6
	05 July	136	0.84	0.06	136	111.7	7.7
	12 July	78	0.82	0.06	78	114.4	7.2
	19 July	-	-	-	-	-	-
	26 July	-	-	-	-	-	-
	02 Aug	11	0.77	0.10	11	120.8	3.8
1990	**OVERALL**	**1,475**	**0.79**	**0.08**	**1,481**	**109.3**	**8.9**
1991	05 April	4	0.94	0.10	4	104.8	23.5
	12 April	85	0.88	0.09	85	108.5	7.3
	19 April	105	0.84	0.09	126	105.8	8.9
	26 April	154	0.84	0.07	159	110.3	8.2
	03 May	175	0.83	0.13	189	110.1	8.5
	10 May	236	0.84	0.07	250	104.7	8.1
	17 May	373	0.84	0.09	383	107.1	8.4
	24 May	371	0.84	0.09	377	107.5	8.2
	31 May	291	0.84	0.07	293	107.5	7.2
	07 June	257	0.88	0.08	260	108.2	7.2
	14 June	338	0.85	0.08	342	110.0	11.6
	21 June	169	0.86	0.07	170	110.9	10.2
	28 June	47	0.89	0.07	48	109.0	7.4
1991	**OVERALL**	**2,605**	**0.85**	**0.08**	**2,686**	**108.1**	**8.9**
1992	05 April	-	-	-	-	-	-
	12 Apr	-	-	-	-	-	-
	19 Apr	3	0.97	0.07	4	111.3	13.1
	26 Apr	134	0.85	0.07	134	105.9	7.8
	03 May	275	0.80	0.07	275	104.3	7.2
	10 May	276	0.81	0.08	278	105.5	7.0
	17 May	310	0.79	0.06	315	107.3	7.1
	24 May	279	0.77	0.08	279	104.8	8.4
	31 May	278	0.79	0.09	279	104.7	8.0
	07 June	280	0.78	0.06	280	104.9	7.3
	14 June	279	0.78	0.07	280	108.0	6.6
	21 June	278	0.80	0.07	279	110.8	6.3
	28 June	274	0.79	0.07	274	112.0	7.1
	05 July	26	0.83	0.07	27	112.4	8.1
1992	**OVERALL**	**2,692**	**0.79**	**0.07**	**2,704**	**106.9**	**7.7**

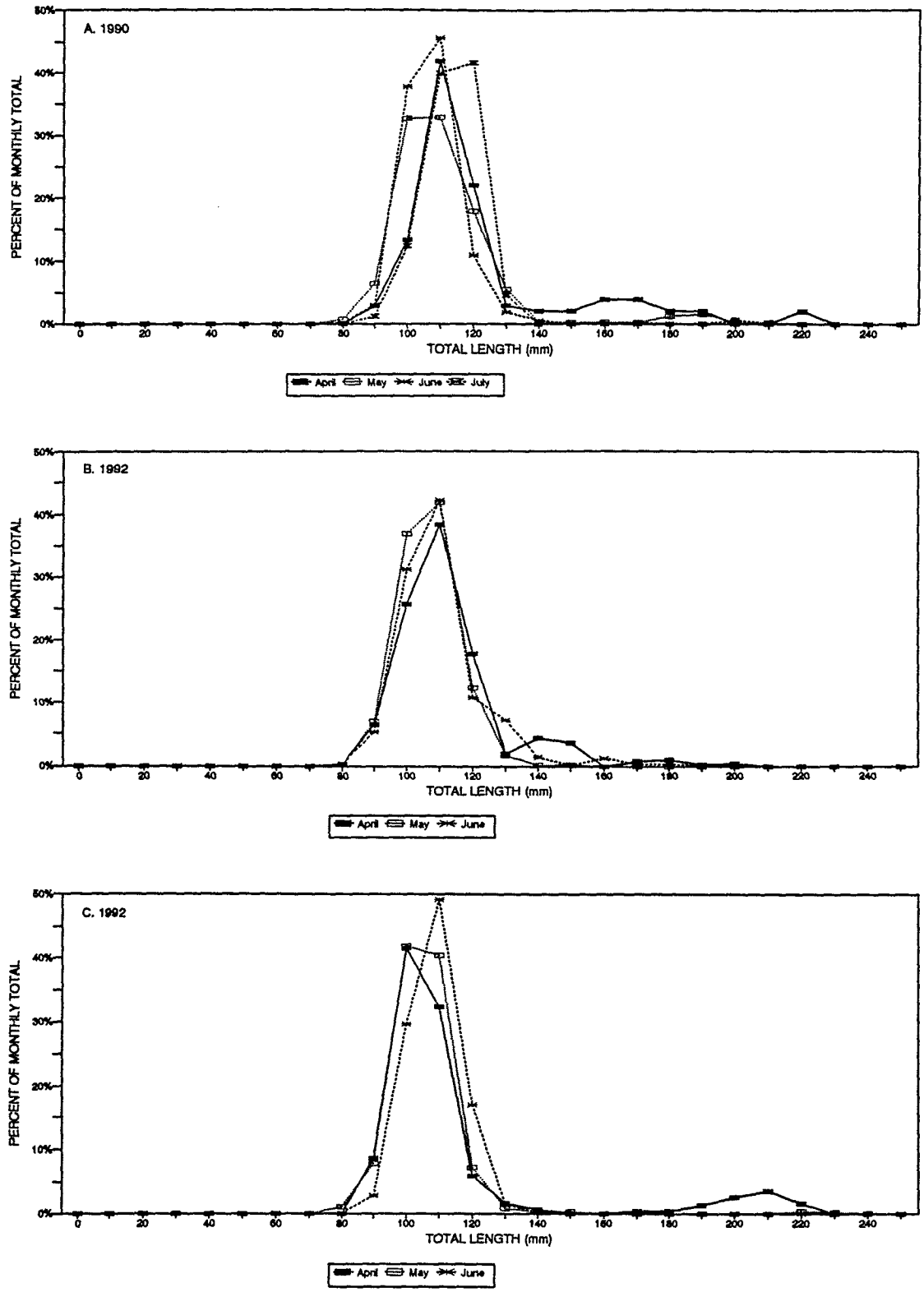

Figure 14-4. Length frequency distribution of salmon caught at Woodbridge Dam by month during out-migration studies in A) 1990, B) 1991, and C) 1992.

Table 14.5. Yearly mean condition factor and total length of 1+ salmon (>140 mm) trapped at Woodbridge Dam during out-migration, 1990-1992.

	1990			1991			1992		
	N	MEAN	SD	N	MEAN	SD	N	MEAN	SD
Condition factor	42	0.78	0.07	112	0.80	0.06	44	0.80	0.07
Total length (mm)	44	179.4	19.5	115	157.4	13.1	44	199.5	26.54

14.3.1.2 Out-migration Timing

Relationship between Out-migration Timing and Flow or Water Temperature - The relationships between the daily out-migration of juvenile salmon at Woodbridge Dam and daily flow or daily temperature were analyzed using Autoregressive Integrated Moving Average (ARIMA) time series analysis. Univariate ARIMA analysis was conducted to identify the potential relationships between daily counts of out-migrants. Bivariate ARIMA analysis was conducted to determine if flow or temperature (input variables) influence the daily number of smolts out-migrating (output variable). The results of these analyses are presented in Table 14.6.

Table 14.6. A summary of univariate ARIMA analyses of daily out-migrant counts at Woodbridge Dam, and bivariate ARIMA analyses between daily flow and daily temperature (input variables) to daily out-migrant counts (output variable). Time-lag indicates the delay between input and output variables (number of days).*

		ARIMA ANALYSIS DAILY OUT-MIGRANT COUNTS		
		UNIVARIATE	BIVARIATE	
YEAR	PERIOD COVERED	R^2	R^2	TIME-LAG
			DAILY FLOW	
1990	16 April - 9 July	0.58	0.63	t-1
1991	27 March - 2 July	0.38	- -	- -
1992	16 April - 10 June	0.54	0.62	t-4
			DAILY TEMPERATURE	
1990	NA	NA	NA	NA
1991	19 April - 2 July	0.34	0.42	t-3
1992	16 April - 2 July	0.60	- -	- -

* Two hyphens (-) indicate no significant bivariate relationship.
NA indicates not available.

The results of univariate ARIMA analyses show that the count of out-migrants on one day was autocorrelated with the count on the previous days (Table 14.6). The results of the bivariate ARIMA analyses indicate significant relationships between the daily counts and flow in 1990 and 1992; however, the relationship was not significant in 1991. In 1990, there was a significant correlation between the count of out-migrants on one day and flow on the day before. In 1992, there was a significant relationship between out-migrant counts on one day and flow from four days earlier. Additional bivariate analyses indicate a significant relationship between out-migration counts and water temperature three days earlier in 1991 (Table 14.6). Temperature data was not available for 1990, and there was no significant causal relationship between out-migrant counts and temperature in 1992.

These analyses indicate that flow and temperature have little effect on the number of smolts out-migrating past Woodbridge Dam based on the limited improvement in significance ($R^2 < 0.1$) between univariate and bivariate analyses.

Diel Patterns - During the diel migration studies, the smolt catch per year ranged between 987 fish (in 1992) and 1,543 fish (in 1990). During all three years, the peak catch occurred between 0400 and 1000 hrs (1990= 66%, 1991= 72%, and 1992= 79%) (Figure 14-5). Only about 2 percent of the smolts were caught during darkness (2200-0400 hours) in each year.

During the diel migration studies of 1990-1992, the water temperature fluctuated a maximum of 1.5° C during the 24-hour monitoring period and did not appear to influence catch rate.

14.3.1.3 Steelhead Rainbow Trout

There has not been a significant steelhead rainbow trout run in recent years (Meyer 1982, CDFG 1991). It is speculated that most of the steelhead rainbow trout caught in the Woodbridge traps were probably reared in the MRFH and stocked in the Mokelumne River below Camanche Dam. The behavior and condition of these stocked trout was not necessarily typical of wild steelhead.

Approximately 4,000 steelhead rainbow trout were caught in the Woodbridge traps in 1990 (4,196) and 1991 (4,026) (Table 14.7). In 1992, there were no steelhead rainbow trout planted in the Mokelumne River until after the conclusion of the salmon out-migration, and only 174 steelhead rainbow trout were caught in the Woodbridge traps. In 1990, the peak catch occurred in April (Figure 14-6). In 1991 and 1992, the peak catch also occurred in May (Figure 14-6).

The percentage of trout caught in the upper trap was similar to the percentage of salmon caught in the upper trap during the same period (Table 14.7; 1990=11%, 1991=36%, and 1992=60%).

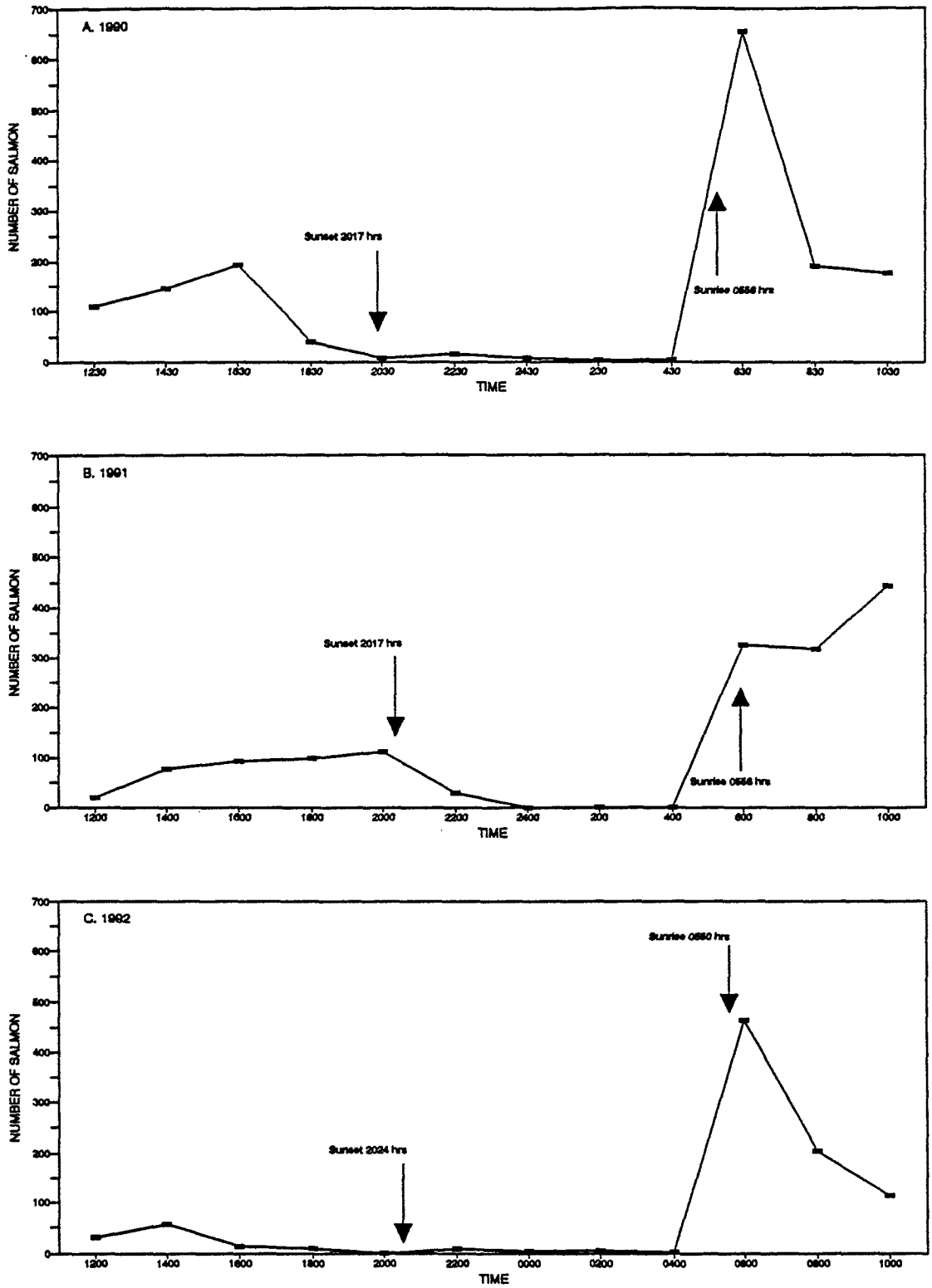

Figure 14-5. Diel migration rates of salmon smolts at the Woodbridge smolt trap during out-migration studies in A) 1990 (17-18 May), B) 1991 (21-22 May), and C) 1992 (30-31 May).

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Table 14.7. Weekly number and mean total length of steelhead rainbow trout trapped at Woodbridge Dam during out-migration, 1990-1992. Due to small sample size in 1992, weekly means were not calculated.

WEEK ENDING		NUMBER CAUGHT					TOTAL LENGTH		
		BOX TRAP N	%	FYKE NET N	%	TOTAL	N	MEAN (mmTL)	SD
1990	29 Mar	-	-	-	-	-	-	-	-
	05 Apr	-	-	-	-	-	-	-	-
	12 Apr	504	100%	-	-%	504	187	265.0	22.7
	19 Apr	820	100		-	820	134	263.9	23.7
	26 Apr	571	100	-	-	571	173	270.7	22.6
	03 May	631	100	-	-	631	135	274.4	26.1
	10 May	338	100	-	-	338	35	272.3	26.6
	17 May	269	88	36	12	305	60	277.8	25.4
	24 May	236	91	24	9	260	30	280.6	25.3
	31 May	197	86	31	14	228	46	298.4	25.5
	07 Jun	224	88	32	12	256	54	290.3	23.6
	14 Jun	54	96	2	4	56	30	280.8	37.4
	21 Jun	73	95	4	5	77	30	300.6	23.0
	28 Jun	33	97	1	3	34	11	301.1	27.0
	05 Jul	35	92	3	8	38	13	301.7	50.6
	12 Jul	7	78	2	22	9	4	305.0	19.4
	19 Jul	26	100	-	-	26	-	-	-
	26 Jul	31	100	-	-	31	-	-	-
	2 Aug	12	100	-	-	12	9	-	39.1
1990 TOTAL		**4,061**	**97%**	**135**	**3%**	**4,196**	**953**	**274.9**	**27.6**
1991	29 Mar	9	11%	75	89%	84	83	247.7	38.6
	05 Apr	113	39	175	61	288	280	249.7	38.4
	12 Apr	58	31	130	69	188	162	240	33.3
	19 Apr	251	74	89	26	340	192	236.7	31.5
	26 Apr	265	58	194	42	459	221	240.8	36.6
	03 May	148	46	174	54	322	196	236.1	25.1
	10 May	328	72	128	28	456	110	236.7	26.8
	17 May	557	83	111	17	668	111	240.9	32.0
	24 May	252	65	138	35	390	113	248.3	28.2
	31 May	201	59	140	41	341	103	236.1	35.0
	07 Jun	114	64	65	36	179	143	230.2	46.4
	14 Jun	76	83	16	17	92	63	228.2	48.4
	21 Jun	102	81	24	19	126	74	251.9	33.4
	28 Jun	53	93	4	7	57	14	237.8	45.5
	05 Jul	35	97	1	3	36	-	-	-
1991 TOTAL		**2,562**	**64%**	**1,464**	**36%**	**4,026**	**1,869**	**240.6**	**35.6**
1992	05 Apr	-	-	-	-	-	NOT CALCULATED		
	12 Apr	0	-	-	-	-			
	19 Apr	2	100%	0	0%	2			
	26 Apr	5	17	24	83	29			
	03 May	4	22	14	78	18			
	10 May	16	64	9	36	25			
	17 May	16	64	9	36	25			
	24 May	7	23	24	77	31			
	31 May	9	47	10	53	19			
	07 Jun	8	53	7	47	15			
	14 Jun	2	29	5	71	7			
	21 Jun	0	-	1	100	1			
	28 Jun	0	-	2	100	2			
	05 Jul		-	-	-	0			
1992 TOTAL		**69**	**40%**	**105**	**60%**	**174**	**44**	**283.4**	**64.4**

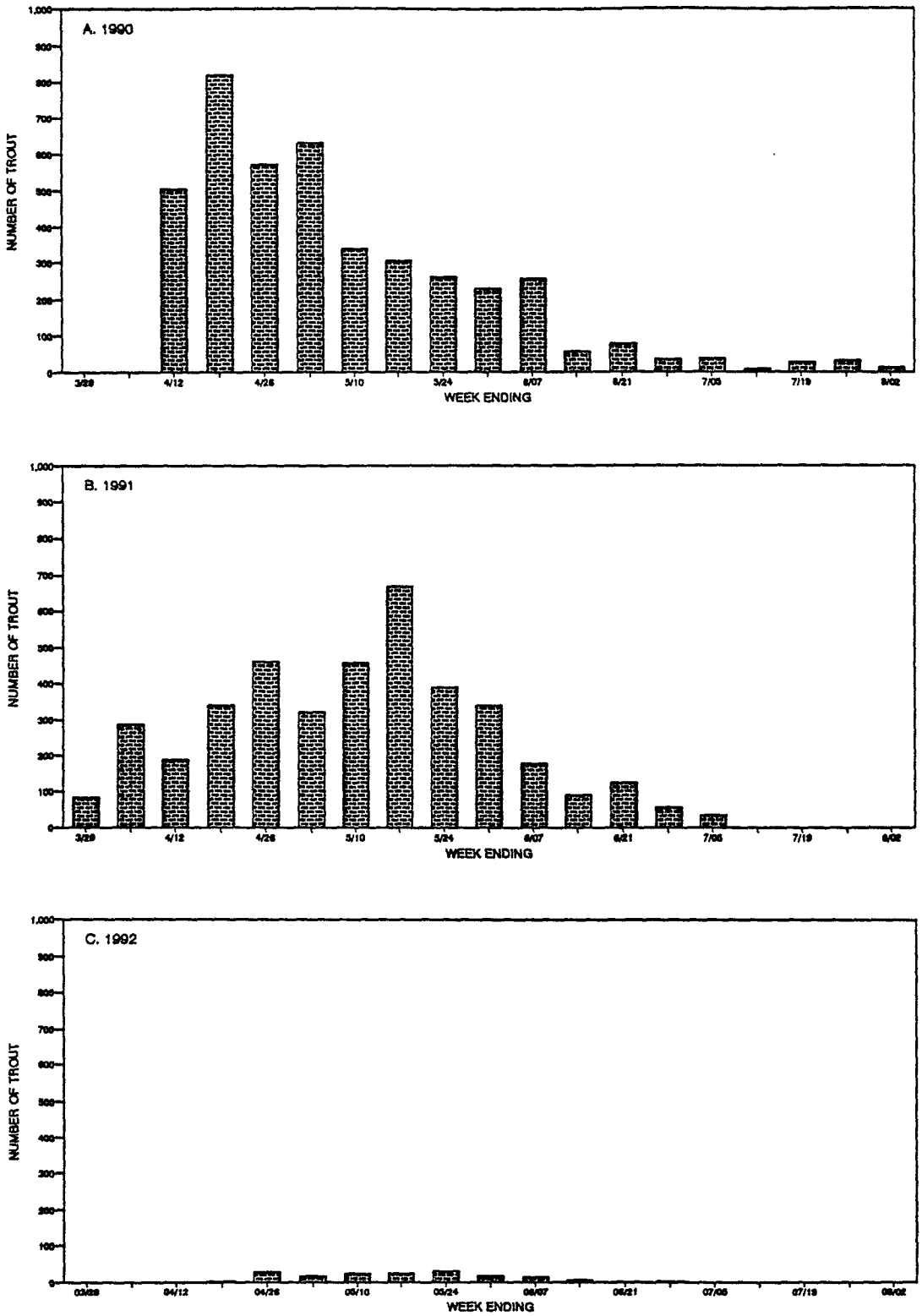

Figure 14-6. Timing and abundance of steelhead rainbow trout collected at Woodbridge Dam during out-migration studies in A) 1990, B) 1991, and C) 1992.

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During the 3-year study, the mean length per year ranged from 240.6 mm TL (in 1991) to 283.4 mm TL (in 1992).

14.3.2 Bruella Road Smolt Traps

In 1991, the Bruella Road smolt trap was removed on 7 May because the trap would not withstand the increased flows scheduled from Camanche Dam. During high flows in early and late April, panels on the trap were blown out, making the trap inefficient.

14.3.3 Bruella Road Fry Traps

In 1991, most of the fry captured in the fry traps near Bruella Road were suckers (n=82); only two salmon fry were caught.

In 1992, a total of 1,122 salmon fry were caught in the Bruella fry traps between 19 February and 29 March. There were three major peaks in the daily catch rates, with the greatest peak occurring in early March (Figure 14-7). There was a negative relationship ($r^2=0.62$, $p< 0.05$) between water temperature and the timing of the fry out-migration, but no correlation between river flow and the timing of fry out-migration ($r^2=0.1$, $p> 0.10$). Most fry were caught in the middle of the river channel, and there was a significant relationship ($r^2= 0.85$, $p< 0.05$)) between mean velocity and fry caught in the traps (Figure 14-8).

The mark-recapture studies indicate that 16.6 percent (N=3, 95% CI = 9.7-26.3%) of the fry passing downstream were captured in the fry traps (Table 14.8). Therefore, the estimated total number of salmon fry migrating past Bruella Road during trapping operations was 6,759 fish (range of 4,266-16,261 fry).

14.3.4 Ray Road Fry Traps

In 1992, the Ray Road fry traps were operated from 30 March through 16 April. During calibration studies, 5 percent (N=3, SD=3.33) of the marked salmon fry released upstream of the fry traps were captured in the traps. No wild salmon were caught during trapping operations.

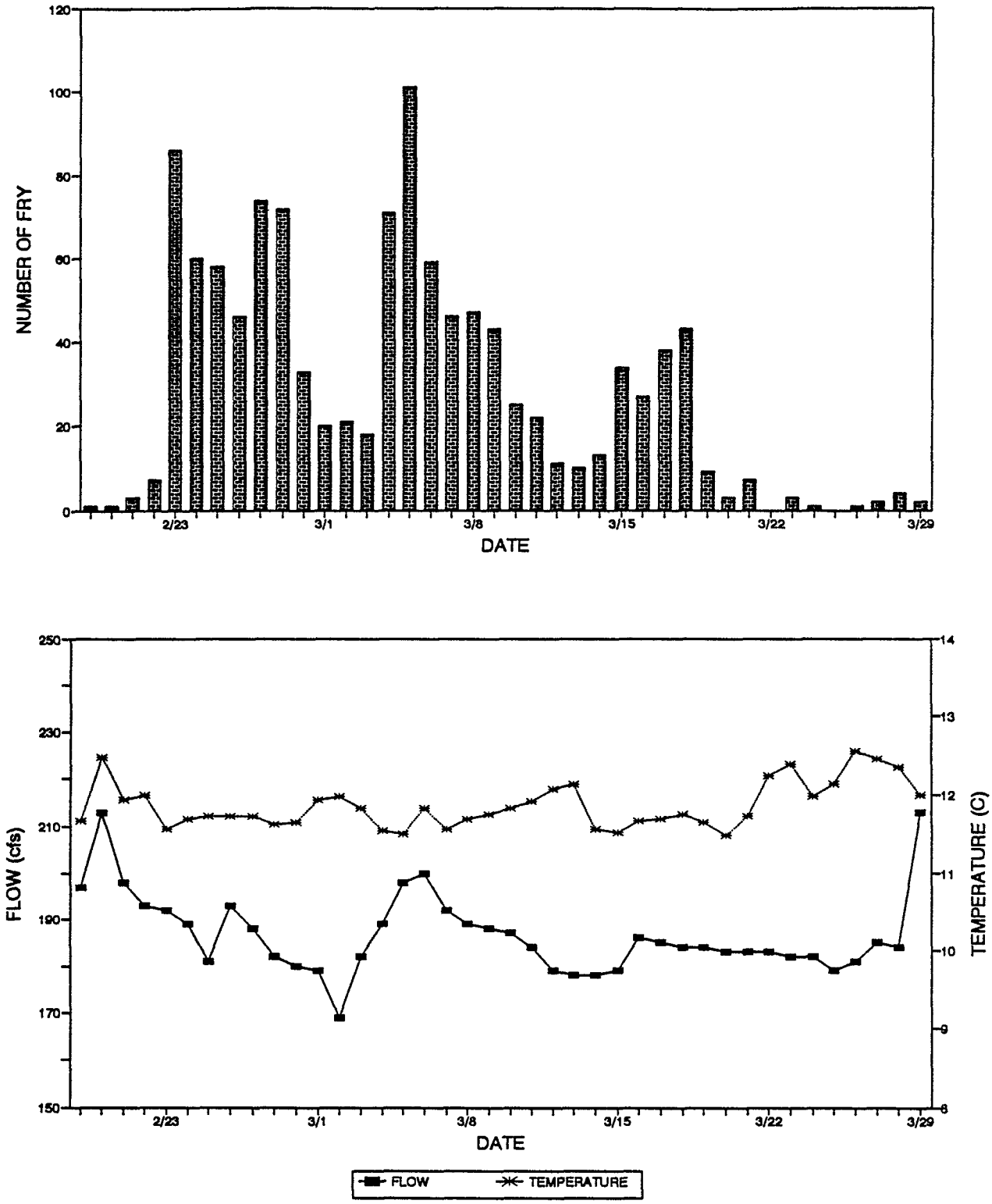

Figure 14-7. Timing and abundance of the 1992 salmon fry out-migration in relation to flow at Camanche Dam (USGS Station #11323500) and temperature at Mackville (EBMUD datapod).

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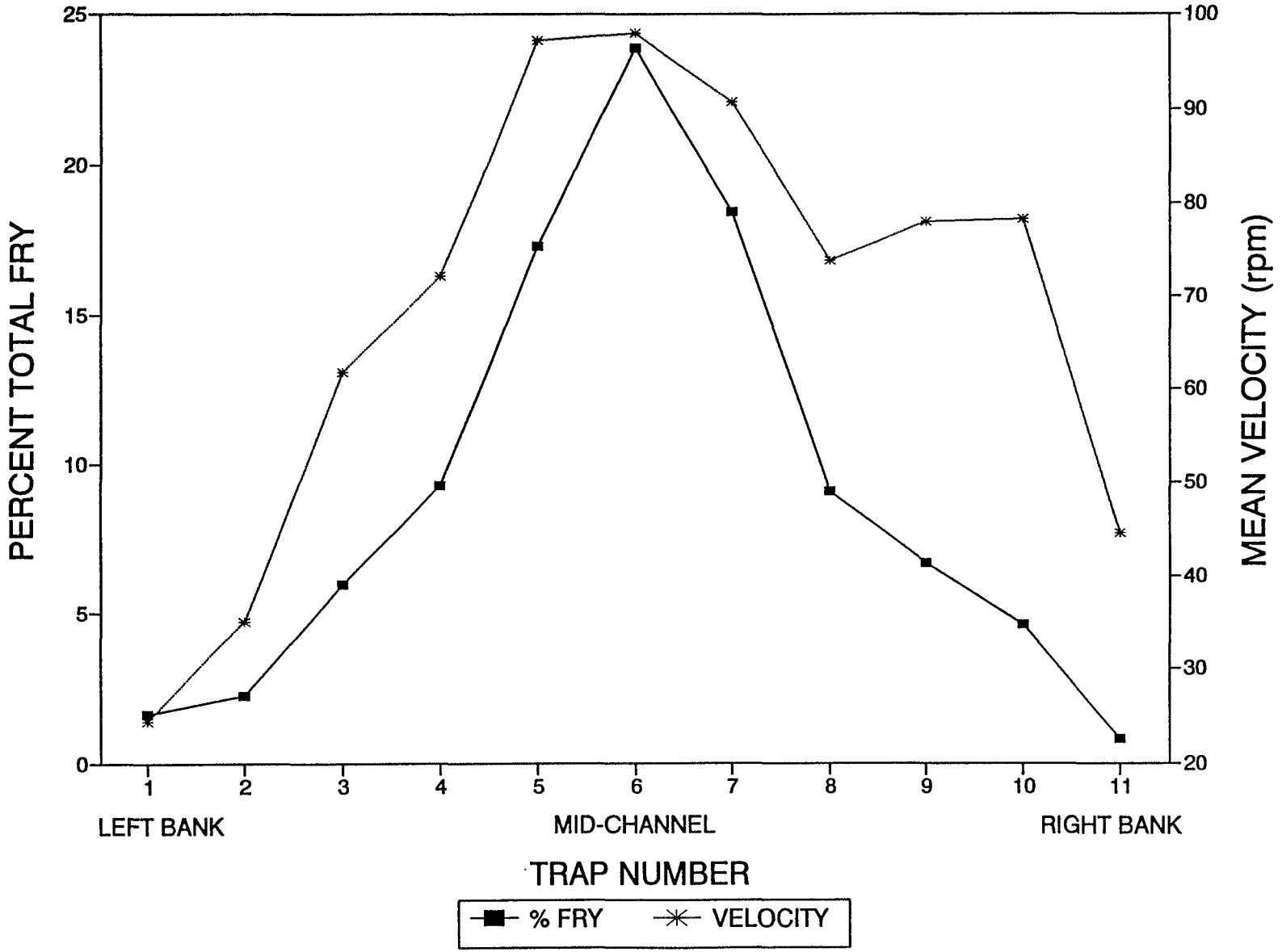

Figure 14-8. The percent of the total fry catch and mean velocity at each trap at Bruella Road, February - March 1992.

Table 14.8. Summary of mark-recapture studies of chinook salmon fry at the Bruella Road and Ray Road fry traps, March and April 1992.

	BRUELLA ROAD FRY TRAPS			RAY ROAD FRY TRAPS		
BATCH NUMBER	1	2	3	1	2	3
Date of release	4 Mar	11 Mar	17 Mar	31 Mar	2 Apr	9 Apr
Number released	500	862	682	424	697	780
Number recaptured	102	144	86	37	16	31
Recapture rate	20.4%	16.7%	12.6%	8.7%	2.3%	4.0%
Mean recapture rate:		16.6 %			5.0%	
Standard Deviation:		3.9%			3.3%	
95% CI:		9.7 - 26.3%			-3.3 - 13.3%	
Total wild fry in traps (19 Feb - 29 Mar)		1,122			0	
Estimated wild fry at Bruella Road:		6,759			NA	
Range:		4,266 - 16,621			NA	