Progress Report:
Fisheries Investigations
in New River, Tributary to Trinity River,
Northern California.

FY 1993

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TABLE OF CONTENTS

LIST OF FIGURES iii

LIST OF TABLES vi

LIST OF APPENDICES vii

ACKNOWLEDGMENTS viii

ABSTRACT 1

INTRODUCTION 3

STUDY AREA 4

Description 4

History 6

Channel Morphology/Geology/Hydrology 7

MATERIALS AND METHODS 8

Stream Physical Measurements 8
Water Temperature Monitoring 8
Flows 9

Habitat Evaluations 9
Index Reaches 9

Population Trends 12
Summer Steelhead and Spring Chinook Counts 12
Spring and Fall Chinook Redd Counts 12
Resistance-board Weir 13
Juvenile Trapping 15

RESULTS AND DISCUSSION 18

Stream Physical Measurements 18
Water Temperature Monitoring 18
Flows 18

Habitat Evaluations 21
Index Reaches 21
Mainstem New River 21
YOY Steelhead-Mainstem New River 21
1+ steelhead-Mainstem New River 24
East Fork 24
YOY Steelhead-East Fork 24
1+ Steelhead-East Fork 29

Virgin Creek 29
YOY Steelhead-Virgin Creek 29
1+ Steelhead-Virgin Creek 30
Slide Creek 30
YOY Steelhead-Slide Creek 30
1+ Steelhead-Slide Creek 30

Population Trends 31
Summer Steelhead and Spring Chinook Counts 31
Spring and Fall Chinook Redd Counts 31
Resistance-board weir 38
Chinook 38
Steelhead 41
Coho 42
Juvenile Trapping 42
Chinook 44
YOY Steelhead 44
Steelhead Parr and Smolts 50

SUMMARY 57

REFERENCES 60

PERSONAL COMMUNICATIONS 63

APPENDICES 64

LIST OF FIGURES

Figure		Page
1.	Location of New River, a major tributary of the Trinity River, in northwestern California	5
2.	Map of juvenile salmonid index reach locations in New River, CA	11
3.	Overhead and lateral schematics of the floating resistance-board weir used to trap adult steelhead and chinook in New River (rkm 3.5)	14
4.	Lateral and overhead schematic of the rotary-screw trap used to trap emigrating juveniles in New River (rkm 3.75) from 1989-93	16
5.	New River daily mean water temperatures during FY 1993 compared to the 4-year mean of FY 1989-92	19
6.	New River mean monthly flow (at rkm 3.4) in cubic feet per second (cfs), during FY 1989-93 and FY 1960-69	20
7.	Mean densities (fish/m^3) of steelhead young-of-year (YOY) in the index reaches of New River and its major tributaries during 1990-93	22
8.	Mean densities (fish/m^3) of steelhead parr (1+) in the index reaches of New River and its major tributaries during 1990-93	23
9.	Mean densities (fish/m^3) and 95% confidence intervals of young-of-year (YOY) steelhead in the combined habitat types in the index reaches of New River and its major tributaries during 1990-93	25
10.	Mean densities (fish/m^3) and 95% confidence intervals of young-of-year (YOY) steelhead in each habitat type of the index reaches of the mainstem New River and its tributaries for the combined years of 1990-93	26
11.	Mean densities (fish/m^3) and 95% confidence intervals of steelhead parr for the combined habitat types in the index reaches of New River and its major tributaries during 1990-93	27

12. Mean densities (fish/m^3) and 95% confidence intervals of steelhead parr (1+) in each habitat type of the index reaches within the mainstem New River and major tributaries during 1990-93 28

13. Locations of spring chinook redds observed in New River snorkel surveys from 1988-93 35

14. Locations of fall chinook redds observed in New River snorkel surveys from 1988-93 36

15. The correlation between the number of adult spring chinook spawners observed during September snorkel surveys and the subsequent number of spring chinook redds counted during fall (October-December) snorkel surveys 37

16. Timing of the adult chinook and steelhead run in New River, based on numbers of fish trapped in the resistance-board weir (rkm 3.4) during the winter of FY93 39

17. Length-frequency histograms of adult chinook and steelhead trapped at the New River weir during FY93 .. 40

18. Juvenile chinook expanded daily emigrant estimates, based on New River rotary-screw trap catches during 1989-93 45

19. Juvenile chinook length-frequency histograms based upon rotary-screw trap catches during FY 1989-93 46

20. Juvenile chinook length-displacement relationships for emigrants caught in the rotary-screw trap (rkm 3.75) on New River during FY 1989-93 47

21. Steelhead young-of-year expanded daily emigrant estimate, based on New River rotary-screw trap catches during FY 1989-93 48

22. Expanded numbers of steelhead YOY, parr and smolt in relation to the river discharge and daily mean water temperature during FY 1993 49

23. Relationship between the number of adult steelhead counted during snorkel surveys and the number of emigrating progeny caught in the rotary-screw trap 51

24. Steelhead parr expanded daily emigrant estimates, based on New River rotary-screw trap catches during

FY 1989-93. Maximum daily water temperatures are presented on the second Y axis 52

25. Steelhead smolt expanded daily emigrant estimates, based on New River screw trap catches during FY 1989-93. Maximum daily water temperatures are presented on the second Y axis 53

26. Juvenile steelhead length-frequency histograms by month, based on rotary-screw trap catches during FY 1993 54

27. Mean fork lengths (± S.E.) of steelhead caught in the New River rotary-screw trap during Julian weeks 13-29 in FY 1993 55

28. Juvenile steelhead length-displacement relationships from emigrants caught in the rotary-screw trap (rkm 3.75) in New River during 1989-93 56

LIST OF TABLES

Table		Page
1.	Numbers of adult summer steelhead and spring chinook counted in New River and its major tributaries during September snorkel surveys from 1989-93	32
2.	Preliminary numbers of summer steelhead in northern California rivers from 1980-93	33
3.	California Department of Fish and Game (CDFG) spaghetti tag recoveries at the New River Weir (rkm 3.5)	41
4.	Summary of rotary-screw trap and late-season frame trap catches in New River, CA, from 1989 through 1993	43

LIST OF APPENDICES

Appendix	Page
A. Channel classification as described by Rosgen, 1985 ..	64
B. Habitat types and descriptions	66
C. List of Julian weeks and calendar dates	69

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ABSTRACT

Monitoring of adult and juvenile salmonids in New River continued for the fifth season during fiscal year (FY) 1993. Surveys of adult salmonids have indicated that spring and fall chinook (Oncorhynchus tshawytscha) runs are extremely low. A total of only 10 chinook redds were counted in FY93. Of these, three were believed to be spring chinook redds, the remainder fall chinook redds. The low spring chinook redd count reflects the low number of spring chinook adult spawners (2 adults, 15 jacks) that returned to New River in late FY92. A higher than average adult return (31) the following fall (FY93), however, produced the highest number of redds to date (53) in FY94.

Summer steelhead (Oncorhynchus mykiss) runs in New River are among the largest in California. The 1993 count of 368 adults was the third largest in California, following the Middle Fork Eel River (605 adults) and the North Fork Trinity River (604 adults). Annual counts have ranged from a low of 250 in 1980 to a high of 702 in 1991.

A resistance-board weir (rkm 3.5) was used to trap immigrating adult fall chinook and winter steelhead. A total of 29 steelhead and 31 chinook were trapped by the weir, prior to its destruction during storm flows on January 20.

Numbers of juvenile salmonids present in established index reaches were counted during the summer of 1993 and statistically compared with numbers obtained during similar surveys conducted over the previous three summers. Volumetric densities (fish/m^3) of young-of-year (YOY) steelhead in the main-stem of New River differed significantly ($P \leq 0.05$) among the four years of the study. However, there were no significant differences in the 1+ steelhead densities over the four years of the study. Both YOY and 1+ steelhead densities differed significantly ($P \leq 0.05$) among different habitat types. Highest mean densities of YOY steelhead were observed in side-channels (0.44 fish/m^3) and low-gradient riffles (0.45 fish/m^3). Lowest densities were found in corner pools (0.02 fish/m^3) and mid-channel pools (0.08 fish/m^3). Highest densities of 1+ steelhead were observed in step-runs (0.38 fish/m^3) and pocket-water (0.19 fish/m^3). Lowest densities were observed in corner pools (0.03 fish/m^3) and mid-channel pools (0.04 fish/m^3). No juvenile chinook were observed in New River index reaches during the snorkel surveys (July and August) in 1993.

A rotary screw trap (located at rkm 3.75) was used to trap emigrating salmonids during the months of March through July. These data were used to derive an index of total production in New River. The chinook abundance index (709) was lower in

FY93 than in any previous year. The steelhead abundance indices for YOY, parr, and smolts were lower than the previous 4-year averages, although the differences were not statistically significant.

Water temperature and flows have been monitored throughout the investigation. Flows in FY 1993 ranged from 0.6 to 530 cubic meters per second (cms). The mean daily temperatures reached 20.7°C in early August. No winter minimum temperature was recorded due to the loss of the thermograph.

INTRODUCTION

The Trinity River Basin has experienced substantial declines in anadromous fish stocks during recent years. It has been estimated that during the two decades between 1960 and 1980, populations of chinook salmon (Oncorhynchus tshawytscha), coho salmon (Oncorhynchus kisutch) and steelhead trout (Oncorhynchus mykiss) declined to about 20 percent of historic levels (USFWS, 1990). In 1963, the U.S. Bureau of Reclamation completed development of the Trinity River Division of the Central Valley Project. Construction of two dams enabled the storage of Trinity River water for regulated diversion through a trans-mountain aqueduct into the Sacramento River Valley. The dams blocked access to approximately 175 kilometers (km) of salmon and steelhead spawning and rearing habitat. In addition, the reduction in flows below the dam reduced habitat availability in the stretch of river which historically had supported the greatest concentration of spawning chinook salmon. Although the Trinity River Hatchery was constructed to mitigate for habitat losses, both salmon and steelhead populations have continued to decline (USFWS, 1994).

In addition to development associated with dam and road construction, countless other factors may have significant effects on salmonid populations. Ocean conditions such as food availability and natural and fishing mortality affect the return to fresh water. The quantity and quality of spawning, resting, and nursery habitats in fresh water are influenced by natural events (forest fires, droughts, landslides and floods), as well as human activities (construction, mining, logging, and water diversion). The combined effects of numerous factors have resulted in the widespread reduction of fishery resources within the Trinity Basin. The Trinity River Basin Fish and Wildlife Management Plan (TRBFWMP) has begun to address this problem by providing management options designed to restore salmonid populations and habitats to historic levels in the Trinity River and its large tributaries.

New River, a major tributary to the Trinity River, is a free-flowing river draining a relatively undisturbed watershed. Although gold mining operations (placer and lode) were numerous throughout the drainage in the past, mining is now limited primarily to small-scale suction-dredging operations. Logging has been moderate within the watershed. The upper watershed of New River received federal protection in 1984 by inclusion within the Trinity Alps Wilderness Area. Because intentional manipulations of the aquatic and riparian habitats have been minimal, New River appears to be a suitable index tributary to monitor changes in salmonid populations that are not associated with instream habitat improvement projects or watershed rehabilitation programs.

In 1988, the USFWS began a project, funded by the Trinity River Fish and Wildlife Restoration Act (TRFWRA) (P.L. 98-541), to identify the quantity, quality, and utilization of spawning and rearing habitats, relative production of natural stocks, and enhancement potential for chinook salmon in the basin. In 1989, the project scope was broadened to include all races of chinook and steelhead. Current studies include the assessment and monitoring of habitats used by juveniles and adults, adult counts, redd surveys, and monitoring of juvenile emigrants.

Although the abundance of summer steelhead in New River seems to have declined substantially since the turn of the century (Roelofs, 1983), the river still supports one of the larger populations in the state (USFWS, 1994a). According to the California Department of Fish and Game (CDFG), the statewide total number of natural summer steelhead ranges from 1,500 to 4,000 fish (Gerstung, pers. comm., 1993). The number of summer steelhead entering New River has ranged from approximately 250-700 individuals over the past decade (USFWS, 1994a).

Small, remnant populations of spring and fall chinook are also present in New River. These populations appear to be extremely low. CDFG estimates the total number of natural spring chinook statewide to be less than a few thousand individuals. The number of adult spring chinook observed during snorkel surveys in New River has ranged from a total of only 2 to 31 individuals over the past five years (USFWS, 1994). CDFG estimated the total natural fall chinook spawner escapement within the Trinity Basin to be 8,340 individuals during 1993 (Hubbell, 1994). Although the number of adult fall chinook returning annually to New River is unknown, the number of redds observed during snorkel surveys has ranged from one in 1989 to 25 in 1993.

STUDY AREA

DESCRIPTION

New River is a fifth-order tributary to the Trinity River in northern California. The 614 square kilometer (km^2) drainage is intermediate in size between the other two major tributaries, the North and South Forks of the Trinity River. The mouth of New River is located 140.1 river kilometers (rkm) from the ocean, and 70.2 rkm from the junction of the Trinity and Klamath rivers (Figure 1).

Access to most of the river is limited due to steep canyon walls, areas of private ownership, and inclusion of headwaters

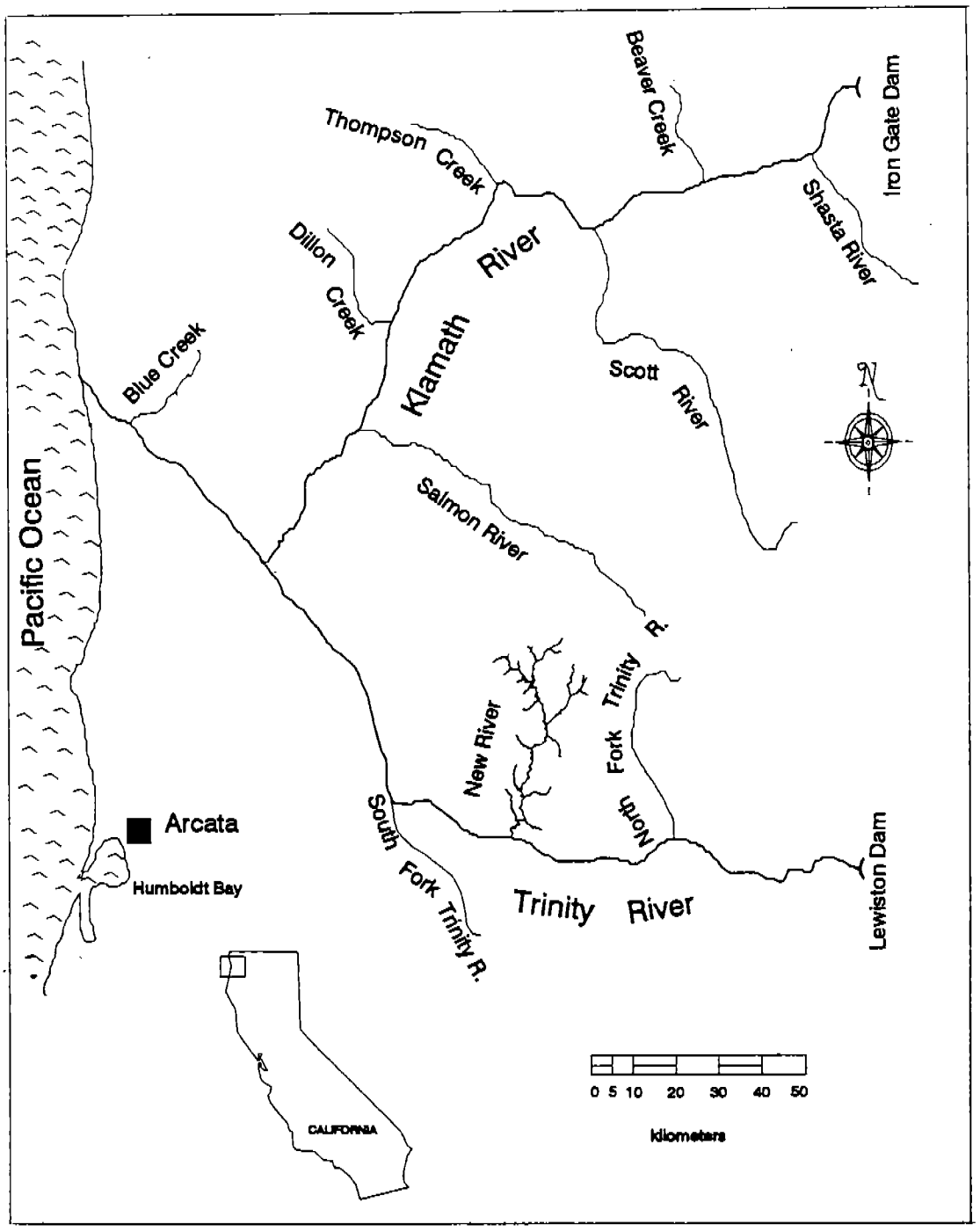

Figure 1. Location of New River, a major tributary of the Trinity River, in northwestern California.

in the Trinity Alps Wilderness Area, Shasta-Trinity National Forest. The main access roads to New River are State Highway 299 to Hawkins Bar, and the county road to Denny from Hawkins Bar. The Denny road parallels the river for approximately 27 km along the steep canyon walls. Access to the river is via privately owned land with the exception of two public campground areas (one near Denny and the other at rkm 18.5), and the county bridge at rkm 24.6. Beyond Denny, the road continues through National Forest land for approximately 5 km and then branches into short routes that end at the New River, Jim Jam, and East Fork trailheads. Only non-motorized access is allowed on the trails in the wilderness area.

There are numerous private landowners and mining claimants along the length of the river, however, the community of Denny is the only concentrated human population (25 - 50 residents). Most of the small-scale suction-dredging operations are located in the vicinity of Denny. The U.S. Forest Service (USFS) administers National Forest lands that cover the remainder of the basin.

Fishes of the New River Basin include spring and fall chinook salmon, steelhead trout (summer, and perhaps fall/winter races), rainbow trout (non-anadromous O. mykiss), very low numbers of coho salmon, speckled dace (Rhinichthys osculus), Klamath smallscale sucker (Catostomus rimiculus), and Pacific lamprey (Lampetra tridentata). An estimated 80.5 km of the New River drainage is accessible to adult steelhead and provides excellent nursery areas for the juveniles. Chinook salmon mainly utilize the lower 32 km of the New River main-stem.

HISTORY

Numerous gold mining operations (placer and lode) existed throughout the basin in the mid- to late-1800's. Gold was discovered in the area in 1848 and mining began in 1851. Mining activity began to wane in the 1870's, but was revitalized by a second gold rush in 1880. The second wave of mining lasted until the early 1900's. The last mining town, Old Denny (located near Slide Creek, rkm 14.3), was abandoned in 1920 (USFS, 1986).

Logging has been of moderate importance in the drainage. Approximately 20-25 percent of the watershed has been burned over or logged since 1950 (California Department of Water Resources, 1980). Numerous logging roads were constructed in the southeastern and central parts of the drainage, but do not provide river access.

The flood of 1964 greatly altered the riverbed of the main-

stem New River. In addition to washing away much of the riparian vegetation, the high bedload blanketed the channel with deep sediment deposits. The resultant lack of pools and streamside canopy elevated water temperatures and subsequently degraded the remaining habitat. The local state fishery biologist, J. Thomas (pers. comm., 1989) stated, "New River was like a sidewalk from the confluence of Virgin and Slide Creeks to the mouth" (a distance of nearly 35 km).

Historical records of anadromous fish runs are largely anecdotal. Local residents claim that streams and pools were "so black with fish you couldn't see the stream bottom". Fish stocking began in 1932 and continued sporadically until 1979. A discussion of the fish stocking history is presented in the FY 1991 Progress Report (USFWS, 1992).

In 1980, approximately 33.6 km of New River were placed in the National Wild and Scenic River System. Nearly 68% of the New River uppermost watershed is within the Trinity Alps Wilderness, which was designated in 1984. A system of trails within the Wilderness area provides access to Virgin Creek, Slide Creek, and the East Fork.

CHANNEL MORPHOLOGY/GEOLOGY/HYDROLOGY

From its headwaters on the southern slopes of the Salmon Mountains, New River flows in a southwesterly direction through deeply incised, V-shaped canyons. Elevation varies from a low of 213 m at the mouth to a high of 2,279 m in the headwaters. Overall gradient of the main-stem channel (37.2 km) is 1.2% (11.59 m/km or 61.2 feet/mile). Gradients of individual reaches, however, range from 0.6% (above rkm 3.5), to 2.6% (in the lower canyon below rkm 1.2). The average width of the channel is 9 m. The average depth is 1.1 m, but some pools are as much as 5.5 - 6.1 m deep. The pool to riffle ratio is 20:50 (Freese and Tayler, 1979). The primary sources of instream cover for fish are boulders, bedrock ledges, pool depth, and surface turbulence. Instream woody material and a well-developed riparian canopy of mature trees are absent throughout most of the river. The upslope overstory vegetation consists of Douglas-fir (Pseudotsuga menziesii), tan oak (Lithocarpus densiflora), big-leaf maple (Acer macrophyllum), digger pine (Pinus sabiniana), madrone (Arbutus menziesii), and California black oak (Quercus kelloggii). Understory riparian vegetation includes herbaceous shrubs, alders (Alnus sp.), and willows (Salix sp.).

The New River drainage is located in the Klamath Mountains Geomorphic Province. Sedimentary metamorphic rocks comprise 80% of the rock types of the New River drainage and igneous

rocks the remaining 20%. Predominant rock formations of the area are of the Rattlesnake Creek Plate type. Tectonic mixing is likely in this unit due to the highly variable rock compositions. The Ironside Mountain Batholith underlies the lower reaches of the river and the western side of the drainage into the headwaters. This area includes hornblende diorite which is known to be highly erodible (Young, 1978).

Boulder and bedrock streambanks are common throughout the system and bank slopes vary from 25 to 100 degrees. Exposed soil streambanks are rare and are mainly associated with logging, wildfires, and over-steepened slopes of fine-textured soils. Streambank landslides and recently dredged (placer mined) areas are the main sources of silt. Compaction of spawning gravels (by more than 30% silt content) is uncommon.

New River is predominantly a rain influenced basin and is characterized as hydrologically "flashy". Average annual precipitation ranges from 102-127 cm. The heaviest precipitation normally occurs between December and April. Typically, river flows peak in February or March. The United States Geological Survey (USGS) recorded New River flows at rkm 13.5 between June 1959 and September 1969. An extreme peak flow of nearly 1,300 cms (46,000 cfs) occurred during a "rain-on-snow event" on December 22, 1964. During this study (1989-1993) peak winter flows ranged from 270 cms to 540 cms (9,540-10,081 cfs). Mean summer and autumn (August through October) flows have ranged from 0.7 to 2.0 cms (25-71 cfs).

Three headwater tributaries to New River contain habitat suitable for salmonid spawning, resting, and rearing. The combined watersheds for these three tributaries comprise about half of the entire basin area. The East Fork covers 17% of the basin, Slide Creek and Virgin Creek each comprise 16%.

MATERIALS AND METHODS

STREAM PHYSICAL MEASUREMENTS

Water Temperature Monitoring

A Ryan Instruments TempMentor digital temperature recorder (Model #RTM) located at rkm 3.4 (near the mouth of Dyer Creek) was used to monitor stream temperature. The thermograph was anchored within a portable, 40 kg cement casing designed for camouflage and protection during high winter flows. Temperature data were recorded at 2-hour intervals and downloaded using RTM software. Maximum, minimum, and average daily temperatures were calculated from the raw data. An

ambient water temperature was also taken (at rkm 3.5) using a hand-held thermometer, whenever a field crew was at the site.

Flows

A staff-gage was installed at rkm 3.4 in 1990. Gage heights were recorded on a daily basis whenever a field crew was at the site. The gage-height/flow relationship established in 1990 (USFWS, 1991) was used to determine the discharge for the varying gage heights recorded.

$$Y = \{10^{[1.35 + 3.05(\log X+1)]}\}-1$$

X = gage height (ft), Y = discharge (cfs)

River discharge was measured using a Price AA current meter and top-setting rod. Discharge measurements were taken at 1.5 m intervals across a transect line (rkm 3.5) at the recommended depths for the calculation of total stream flows. Discharge measurements taken at various gage heights during 1993 confirmed that the regression equation above was valid.

A crest gage (2.5 cm diameter polyethylene tubing) was used to determine peak storm flows. The crest gage was attached to the staff gage with the bottom end submerged in the water. Prior to storm flows, fine burnt cork shavings were placed inside the tubing top and washed down to the meniscus. The raising and lowering of the water level left a cork mark on the inside tubing indicating the peak flow height. Stage of the crest gage was recorded after storm waters receded.

HABITAT EVALUATIONS

Index Reaches

Approximately 65.8 km of New River and its tributaries have been classified as seven different channel geomorphic types and 25 standard habitat types (USFWS, 1990, 1992). After assessing the habitat type information collected from 1988 - 1990, permanent index reaches were established in 1990 for long-term monitoring of juvenile abundance and possible changes in habitat types. Approximately 15 km of four headwater streams that may contain anadromous fish habitat have not been classified because of difficult access for surveyors and the scarcity of low to moderate gradient reaches with sufficient flow to attract spawning salmonids.

All the habitat types identified within the main-stem and major tributaries are proportionally represented in the index reaches. Index reaches were chosen based on geomorphic characteristics, the proportional representation of habitat

types, and the accessibility and location of tributaries. As a result, 14 index reaches were designated in the New River system (Figure 2). Eight index reaches are in the main-stem, one in East Fork, two in Slide Creek, and the remaining three are in Virgin Creek. Three reaches are located within a B1 channel type, three are within a C1 channel type, and four each are in B2 and B3 channel types (a description of channel types is presented in Appendix A). Index reaches were marked for the duration of the study by the use of flagging and metal tags on trees. Lengths of index reaches range from 125 to 720 m, for a combined total length of 4,286 m. Index reaches comprise 7% of the 65.8 km of main-stem and headwater channels that have had habitats classified.

All index reaches were snorkeled during August (August 9-13, 17-19, and 24) by teams of two to four people to count numbers of juvenile chinook and steelhead remaining in the system. Teams began snorkeling at the downstream end of an index reach in order to minimize disturbance to fish. Total numbers of fish, classified by species and age class (YOY, 1+, 2+), were tallied at upstream ends of individual habitat units. Snorkelers proceeded upstream until they reached the upper end of the index. Snorkelers recorded water visibility and estimated the accuracy of their counts for each index reach. Diver calibration (Hankin and Reeves, 1988) was practiced wherever each diver could clearly see both banks. Using this method, each diver snorkeled the unit and counted all fish observed. All divers then compared counts to ascertain accuracy.

Snorkel surveys of juvenile salmonids have been completed in mid- to late-summer every year since 1989. Since most emigrating salmonids have left the drainage by this time, the surveys provide an estimate of the numbers of juveniles that may overwinter in the system. Summer water flows are low and stable and water temperatures are highest (18-24°C) at this time. Hillman et al. (1992) found that snorkel counts were most accurate at temperatures above 14°C. He determined that at temperatures below 14°C most counts revealed only half the number of fish present. At temperatures below 9°C less than 20% of the fish present were observed.

Physical measurements were taken at designated transect points (downstream end, 1/4 length, 1/2 length, 3/4 length, upstream end) for each habitat unit within the index. Stream widths were measured with a range-finder at each transect point. Depths were measured across each transect from the right bank edge, 1/4 width, 1/2 width, 3/4 width, and the left bank edge using a stadia rod. Maximum depths and mean unit lengths were also recorded. Additional information obtained included the percent of total cover, the dominant/subdominant cover type, and the dominate/subdominate substrate. Cover types include

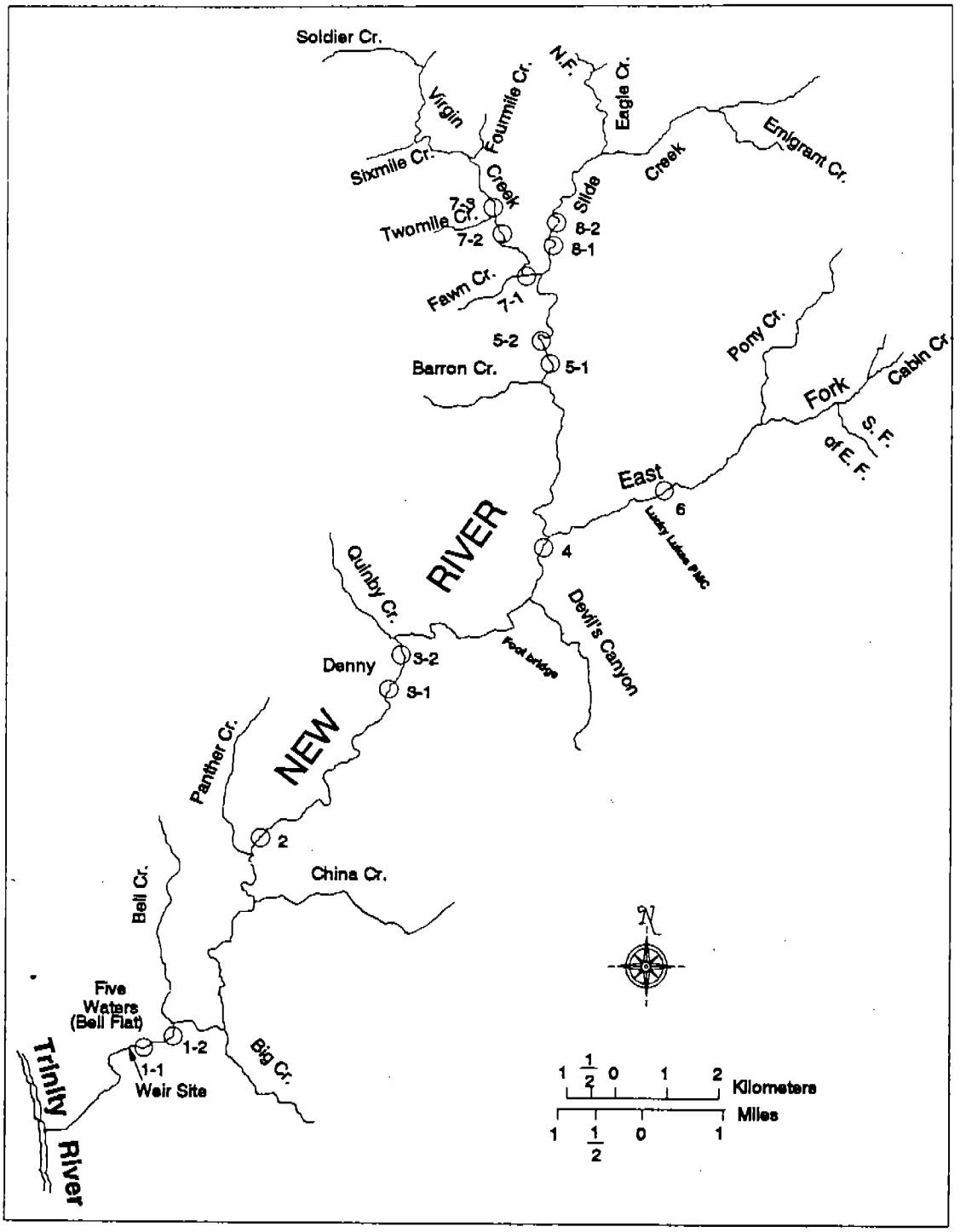

Figure 2. Map of juvenile salmonid index reach locations in New River, CA.

bank, small woody material (<10 cm diameter), large woody material, terrestrial vegetation, surface turbulence, boulders, bedrock ledges and depth. Types of substrate include bedrock, boulder (>30 cm), cobble (8-30 cm), gravel (.5-8 cm), sand (1 mm to 0.5 cm), and fines (sands, silts, and clays).

The average density of fish (fish/m^3) in each habitat type was determined separately for YOY, 1+, and 2+ steelhead and chinook in the main-stem New River, Virgin Creek, Slide Creek, and the East Fork. Densities were calculated by volume rather than area to better compare fish use of habitat types over a range of depths. Two-factor analyses of variance (ANOVAS) were used to determine if fish densities differed significantly ($P \leq 0.05$) among years (1990 through 1993) or among different habitat types. If significant differences were observed between years, a Tukey's test was used to determine which years differed.

POPULATION TRENDS

Summer Steelhead and Spring Chinook Counts

Snorkel surveys for steelhead and spring chinook adults were conducted from July 26 through August 4, and from September 7 to 16, 1993. The survey included the entire main-stem of New River (mouth to rkm 34.7), Virgin Creek (Soldier Creek confluence to the mouth), Eagle Creek (North Fork confluence to the mouth), Slide Creek (Eagle Creek confluence to the mouth), and the East Fork (South Fork confluence to the mouth). All habitat units within these sections were snorkeled by experienced observers in teams of two. Numbers of summer steelhead and spring chinook along with their location and the habitat type were recorded. All of the river that could be expected to be used by chinook was surveyed. Any steelhead adults that were already upstream of the surveyed reaches would not have been observed.

Spring and Fall Chinook Redd Counts

Four redd surveys were conducted on the main-stem New River (confluence of Virgin and Slide Creeks to the mouth of New River) from October 19-20, November 1-6, 14-17, and 25-29. A partial survey, of the lower canyon only (rkm 3.4 to the mouth), was completed on December 4. The habitat unit type, redd location within unit, redd size (length, mean width, depth of pit, depth of mound), apparent age of redd, adjacent water depth, mean stream width, and substrate size (large cobble 15-30 cm, small cobble 8-15 cm, large gravel 3.5-8 cm, small gravel 0.5-3.5 cm, and fines < 0.5 cm) were recorded at each redd location. The age of redds was categorized as

"fresh", 2 weeks to one-month old, or greater than one-month old. Age determination was based upon the relative amount of algae on rocks, and the distinctness of the pit and mound.

Resistance-board Weir

The status of natural winter steelhead within the Trinity basin has been difficult to assess. Snorkel surveys are impractical due to high flows and turbid water during the winter months. Therefore, a fish weir was installed in New River to trap winter steelhead (and fall chinook) immigrating upstream to spawn.

A floating resistance-board weir (Figure 3) was chosen because of the "flashy" nature of New River. Components for this type of weir can be fabricated at a reasonable cost using standard materials, and can be easily removed from the river upon completion of the project. Floating weirs are designed to withstand a wide range of flows and debris loads by submerging during high water velocities and/or increased bedloads. Once submerged, the bedload is carried downstream over the weir by the velocity of the water. The weir re-emerges when the buoyancy of the weir pickets plus the uplift provided by the planing boards (resistance boards) exceed the drag forces of the bedload, water velocity, and gravity. Thus, floating weirs provide a barrier to fish migrating upstream, while allowing downstream passage of rootwads, branches, mobilized bedload and other debris.

Several criteria were important in selecting the weir site: accessibility, a relatively flat gravel streambed within a straight run of river, a constrained channel both upstream and downstream of the weir-site, normal high-water river depths of less than one meter, an available campsite nearby, and a total channel width of less than 50 m. A suitable location was selected at rkm 3.5.

During the summer of 1991, abutments were built to anchor the weir on either side of the river. The left bank abutment is a wooden frame (2.5 m high by 4.5 m long) attached to a bedrock face with steel pins glued horizontally into the bedrock. The right bank abutment is built of gabions, filled with rubble, and faced with a wooden frame (2.5 m high by 4.5 m long). Both abutments have vertical channel steel stanchions (50 cm by 250 cm web size) to which the weir foundation rails are secured.

The streambed at the site was leveled with a tracked bulldozer before the weir foundation was placed at right angles to the channel. The foundation was constructed of 1.1 m long sections of heavy steel rail (45 kg/m) bolted end-to-end to make one continuous rail foundation. Each end of the rail

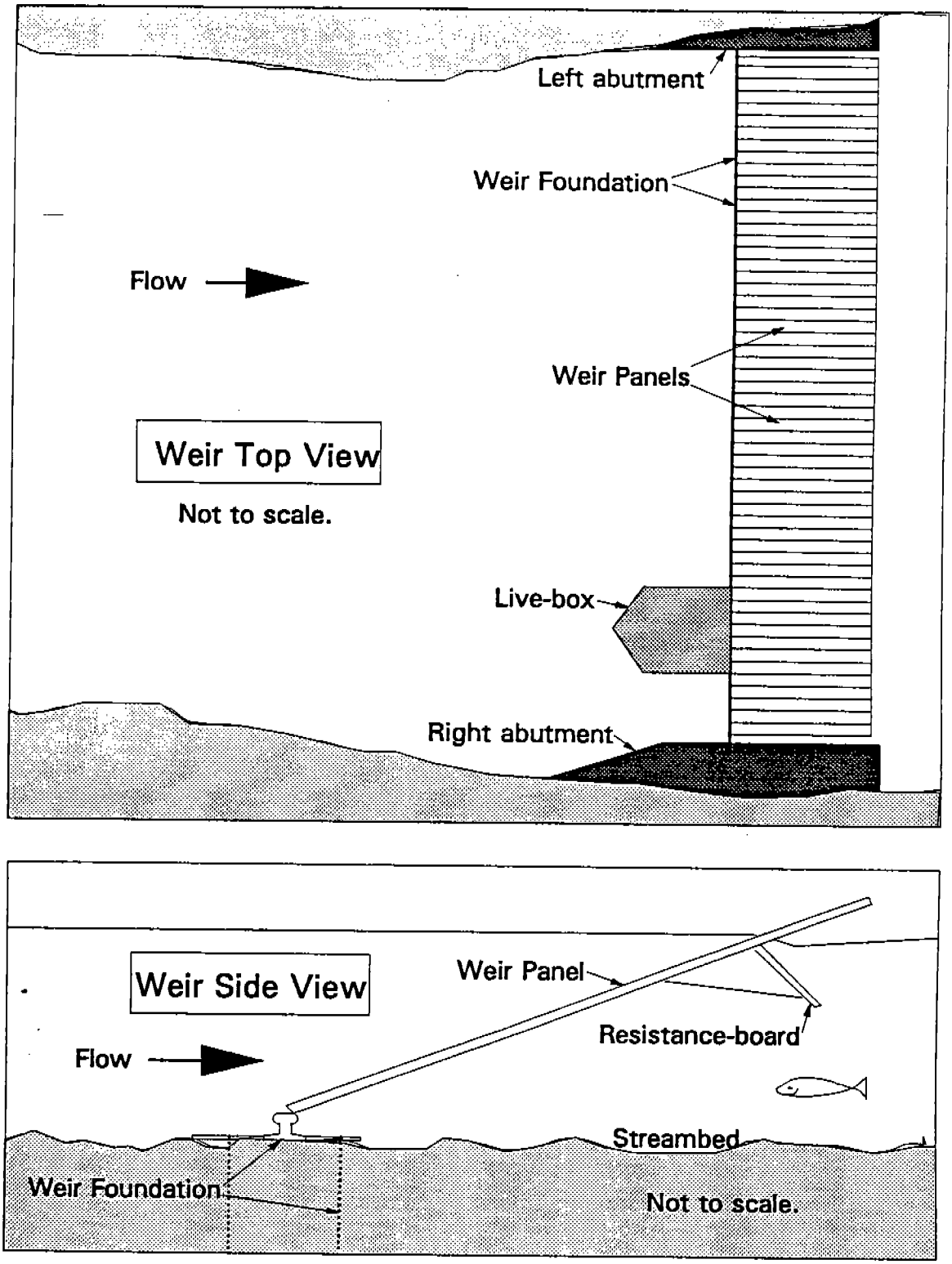

Figure 3. Overhead and lateral schematics of the floating resistance-board weir used to trap adult steelhead and chinook in New River (rkm 3.5).

foundation was bolted to the base of an abutment. Alternating rail sections were anchored with pairs of large steel tabs (0.2 m^2). Steel pins (1.5 m lengths of #6 steel rebar) were driven through the steel tabs to secure the rail foundation to the streambed. To minimize scour, chain-link fencing was placed under the rail foundation on the left half of the channel, along the section of foundation expected to receive the most energy at high flows.

A wire cable (9.5 mm diameter) was secured along the top of the foundation rail to provide an attachment for the bottom (upstream) edge of the weir panels. Weir panels were 1.2 m wide by 4.6 m long, and were made of water-tight lengths of heavy-walled PVC pipe (2.5 cm diameter) held together with wooden cross-pieces. Width of spacing between pipes was no more than 3.2 cm. To augment the positive buoyancy provided by the air trapped in the sealed pipes, each weir panel was fitted with a "planing-board". This fixed resistance-board is designed to provide additional lift as water flows through the panels.

Fish immigrating upstream to the weir were directed into a 10 m^3 livebox. Trapped fish were sampled each morning. Species were identified and sexed, external characteristics (existing tags, fin clips, scars, missing scales, condition of fish, etc.) were noted, and fork lengths and scale samples were taken. All fish were marked with a 6 mm diameter caudal fin punch before they were released above the weir. Additional data collected included time of sampling, weather, ambient air and water temperature, river stage, rainfall, and lunar cycle.

Scale samples from adult salmonids were cleaned and imprinted upon cellulose acetate using a hydraulic press equipped with heating elements. Age analyses of the scale impressions were conducted by two independent readers using a microfiche reader. A third reader aged the scale impression whenever there were discrepancies in the two original analyses. Scales not aged confidently after the third reading were excluded from the age analyses.

Juvenile Trapping

A rotary-screw trap (Figure 4) was used to trap emigrating juvenile salmonids. The "screw" is comprised of a fiberglass spiral vane enclosed in a funnel-shaped metal framework (cone) that is covered with galvanized hardware-cloth (6 mm rectangular mesh size). The cone is oriented with the large opening (trap mouth) facing upstream into the current. The spiral vane rotates to overcome the drag created by the current. When a fish enters the cone, the rotating vanes prevent escape and direct the fish into a live box (1.4 m^3)

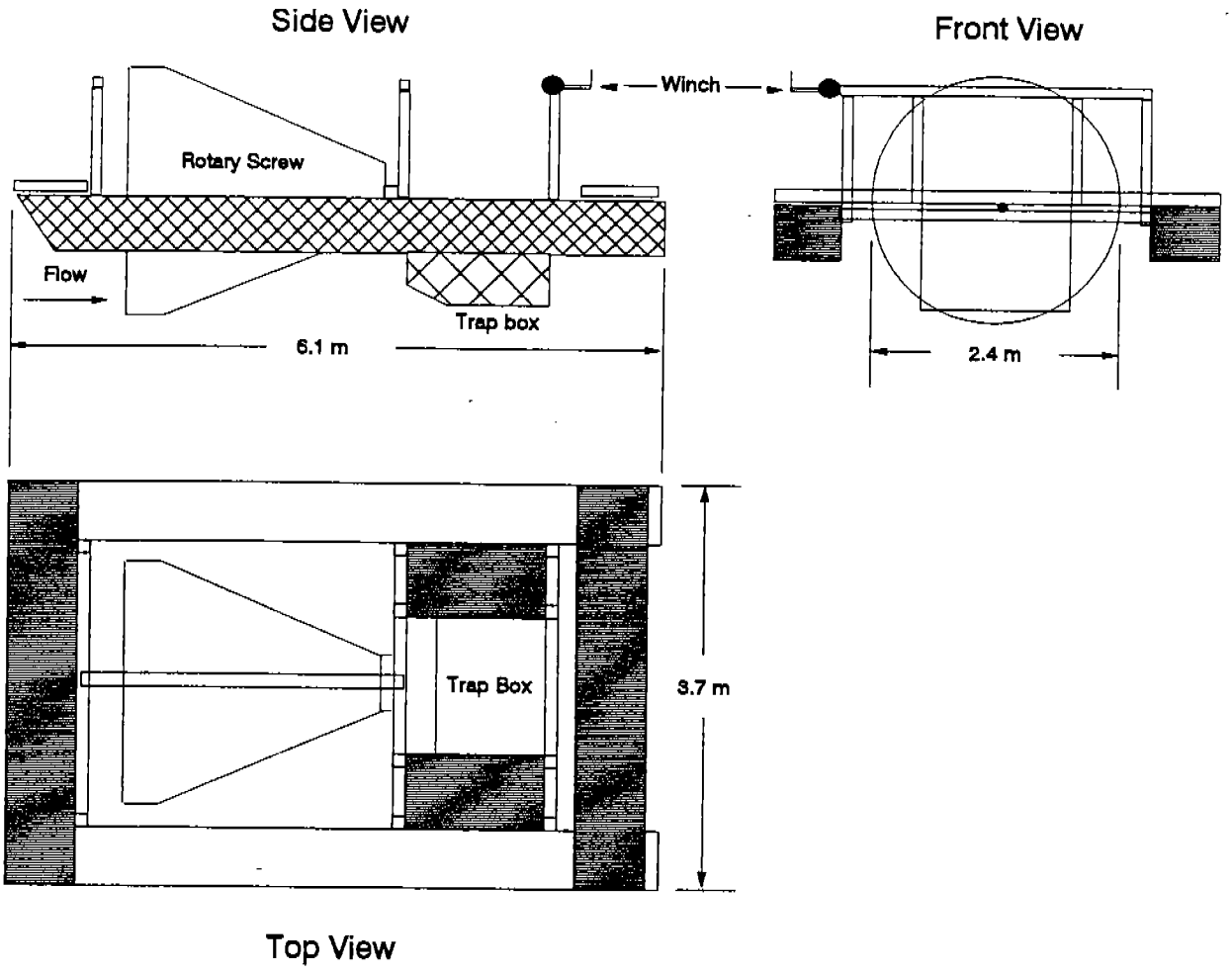

Figure 4. Lateral and overhead schematic of the rotary-screw trap used to trap emigrating juveniles in New River (rkm 3.75) from 1989-93.

at the small end of the cone. Small-sized floating debris are automatically removed from the live-box by a rotating, studded cylinder located across the rear of the live-box. The trap mouth has a diameter of 2.44 m, and can sample an area of 2.34 m^2 at maximum operating depth (1.22 m). Two 6.1 m long pontoons support the cone and live-box, and provide flotation and a walkway. Three hand-crank winches allow each end of the cone and the live-box to be raised clear of the water for maintenance or to remove fish from the live-box. Wooden walkways across the front and rear of the trap allow access to the winches and live-box. The floating trap is moored to trees and steel posts.

The screw-trap has been operated at the same location (rkm 3.75) since April, 1989. During 1993, the trap operated from March 29 through August 2, after which flows became too low to provide effective rotation of the screw. Rotations of less than 3 revolutions per minute (rpm) are insufficient to prevent escapement from the mouth of the cone. The screw trap was checked daily when operating.

All fish captured were identified to species, degree of development (YOY, parr, and smolt), and enumerated. Separation into parr and smolt categories was based upon the presence or absence of parr marks, of silvery coloration, of a black caudal-fin margin, and on the looseness of scales. Lengths and volumetric displacements were taken from random samples of up to 50 fish of each development stage of each species. Scale samples (for age determinations) were taken from up to 25 juvenile steelhead each day. Fish were also examined externally for any symptoms of disease or parasites.

The velocity of water entering the cone was measured at the center, and right and left sides of the cone with a Price AA current meter and top-setting rod. Flow volume through the trap was calculated by multiplying the flow velocity at the trap mouth by the area of the trap mouth in the water. The percentage of total river flow sampled was then calculated by dividing the flow through the trap by the total river flow. For the purposes of calculating total numbers, emigrating fish were assumed to be equally distributed across the 8 to 13 m wide river at the trap location (top to middle of a fast run below a narrow riffle).

The total numbers of fish emigrating past the trap site on a daily basis were extrapolated from the daily capture rate and percent flow sampled. On days not sampled, the number of juvenile salmonid emigrants was estimated using the average catch and river flow on the two days prior to, and the two days following, the non-trapping periods. The duration and magnitude of peak immigration were determined for juvenile chinook and steelhead. Because emigrating fish are not

randomly distributed (an assumption of the model), and sampling periods were non-random and discontinuous, calculated estimates of fish numbers are only indices of total production and should not be interpreted otherwise.

Juvenile length-displacement relationships were determined from log-transformed linear regression analyses. The slopes were compared statistically using an analysis of covariance. Tukey tests were used to test for differences between each pair of slope values. Length-frequency histograms, and average length-at-date relationships were derived for both juvenile chinook and steelhead.

RESULTS AND DISCUSSION

STREAM PHYSICAL MEASUREMENTS

Water Temperature Monitoring

High winter river flows dislodged the thermograph, resulting in the loss of all digital temperature data collected between October 6, 1992 and April 7, 1993. Temperatures were taken occasionally during that period with a hand-held thermometer.

The lowest temperature recorded with the hand-held thermometer was 5.0°C on January 12. However, the data are not available to determine the minimum daily temperature. The highest daily mean temperature (20.7°C) (Figure 5) and the two-hour maximum (23.7°C) were recorded on August 7, 1993.

Near-normal snow pack, rainfall, and runoff from late October onward, contributed to normal spring and summer water temperatures, compared with the USGS average (USGS, 1970). Although late summer mean water temperatures (at rkm 3.4) exceeded the optimum range for steelhead (10-15°C; Barnhart 1986) temperatures were substantially lower than the mean for the previous four years (Figure 5). Both adults and juveniles probably seek thermal refugia (deeper pools, cool-water seeps, etc.) when water temperatures exceed the optimum range.

Flows

The New River mean monthly water flows for FY 1993 (October 1, 1992 - September 30, 1993) exceeded the mean monthly flows recorded by USGS during the non-drought years of the 1960's (Figure 6). The crest gage at rkm 3.3 indicated a peak flow of 540 cms (19,081 cfs) on January 20, 1993. The minimum flow, 0.62 cms (22 cfs), occurred during early October, 1992. The mean annual peak flow for the ten years of USGS record, excluding the extreme flood of December, 1964, was 195 cms

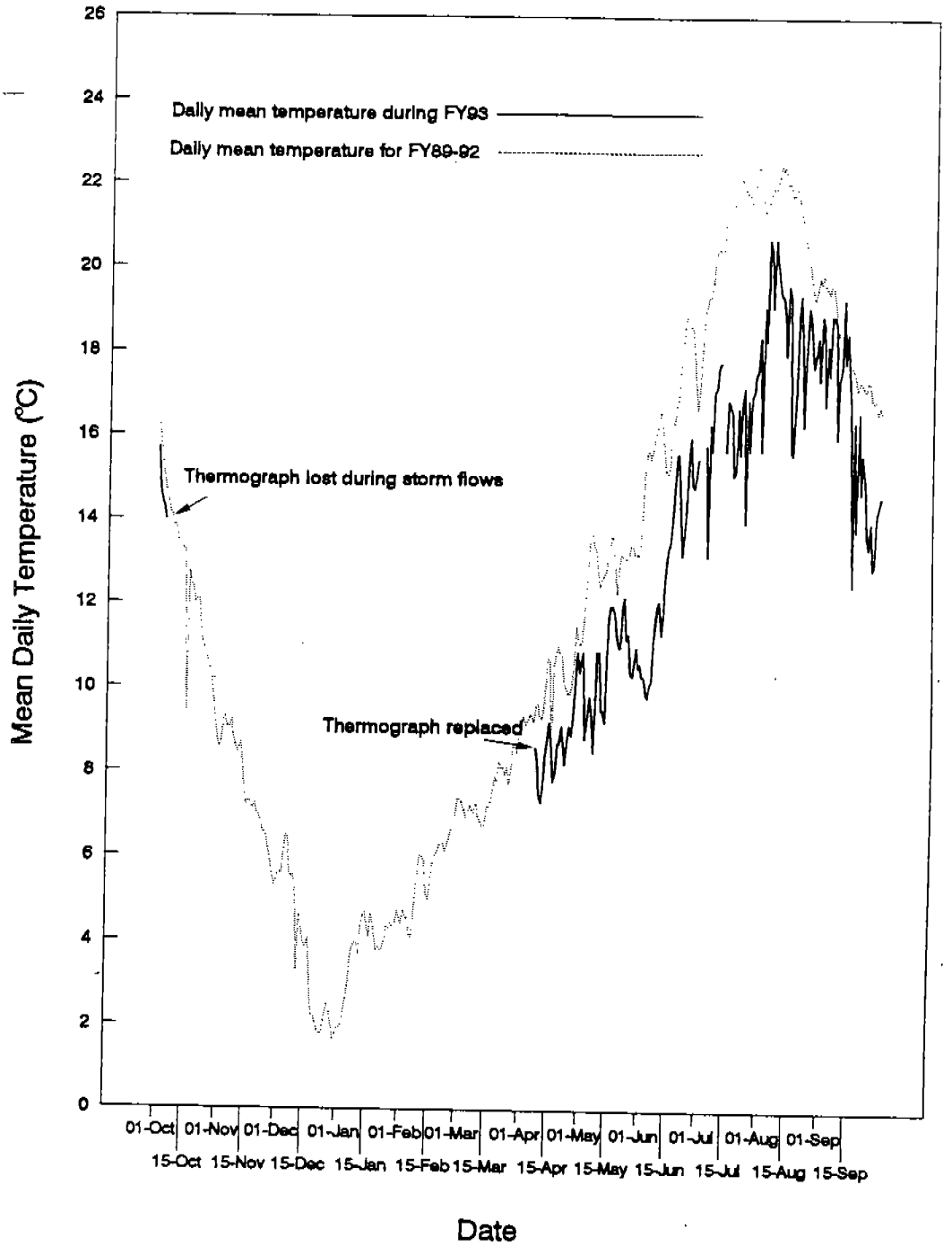

Figure 5. New River daily mean water temperatures during FY 1993 compared to the 4-year mean of FY 1989-92.

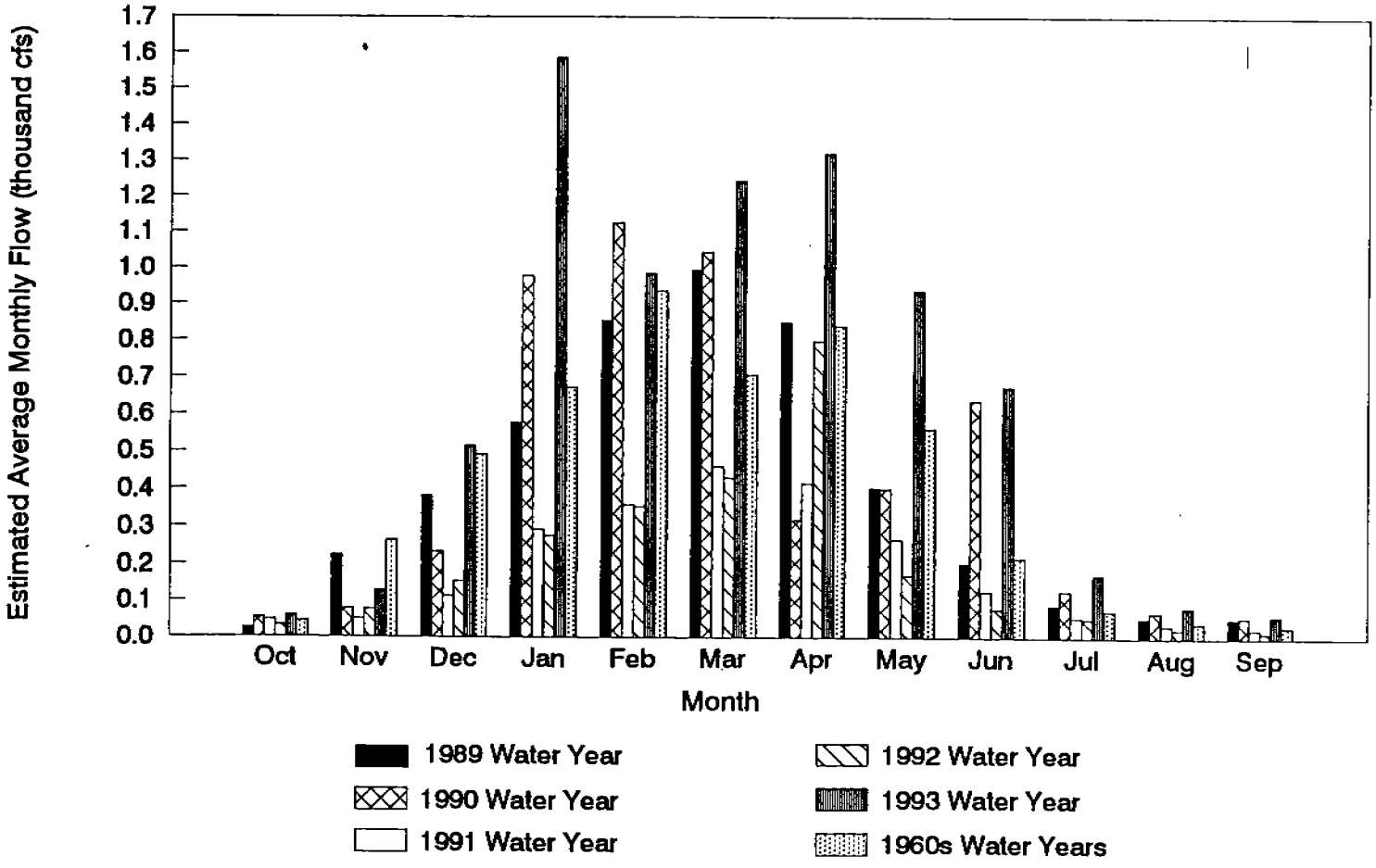

Figure 6. New River mean monthly river flow (at rkm 3.4) in cubic feet per second (cfs) during FY 1989-93 and FY 1960-69.

(6,890 cfs). The mean minimum flow was 0.65 cms (23 cfs). Flow information from this study is not directly comparable to data from the USGS record, since the USGS gage was located 10.2 km further up-stream. The difference in drainage areas between the two gages is approximately 26% (448 vs. 605 km^2).

HABITAT EVALUATIONS

Index Reaches

Measurements of index-reach volumes allowed comparison of conditions in 1993 with the lower-flow conditions of previous years. Index surveys have been conducted in early August each year at mainstem-river stages (at rkm 3.4) that have varied from 0.8 to 2.6 cms (2.6 cms in 1990, 2.1 cms in 1991, 0.8 cms in 1992, and 2.6 cms in 1993). The volume of the aggregated main-stem sites in 1993 did not increase substantially over the 3-year average. However, the volume of the combined East Fork index reaches exhibited a 13.9% increase, while Slide Creek index-reach volumes increased by 30.6% and Virgin Creek indices experienced a 4.2% increase in volume.

No juvenile chinook were observed during index-reach surveys in 1993. Only three YOY chinook had been observed in 1992.

The mean densities of YOY steelhead in nearly every habitat type were lower in 1993 than in previous years (Figure 7). The low densities might be attributed to a relatively poor adult return coupled with high winter flows (that may have damaged redds). The mean densities of 1+ steelhead, however, have not varied significantly ($P > 0.05$) throughout the previous four years (Figure 8). The relatively static densities of fish in this age class may indicate that the numbers that overwinter in the system may be limited by the carrying capacity of the environment.

Fish densities generally differed significantly among the various habitat types. These differences likely reflect preferred feeding sites within habitat units. By the time of surveys in late-July/early-August, YOY steelhead are large enough (estimated mean fork length of 60 mm) to be feeding in moderate velocities. Various sizes of juvenile steelhead were observed in swifter water, including riffles and runs.

Mainstem New River

The eight index reaches in the mainstem New River represent 10 different habitat types (described in Appendix B) in 69 separate units, and span a total length of 3028 m (Figure 2).

YOY steelhead-Mainstem New River. The mean density and 95%

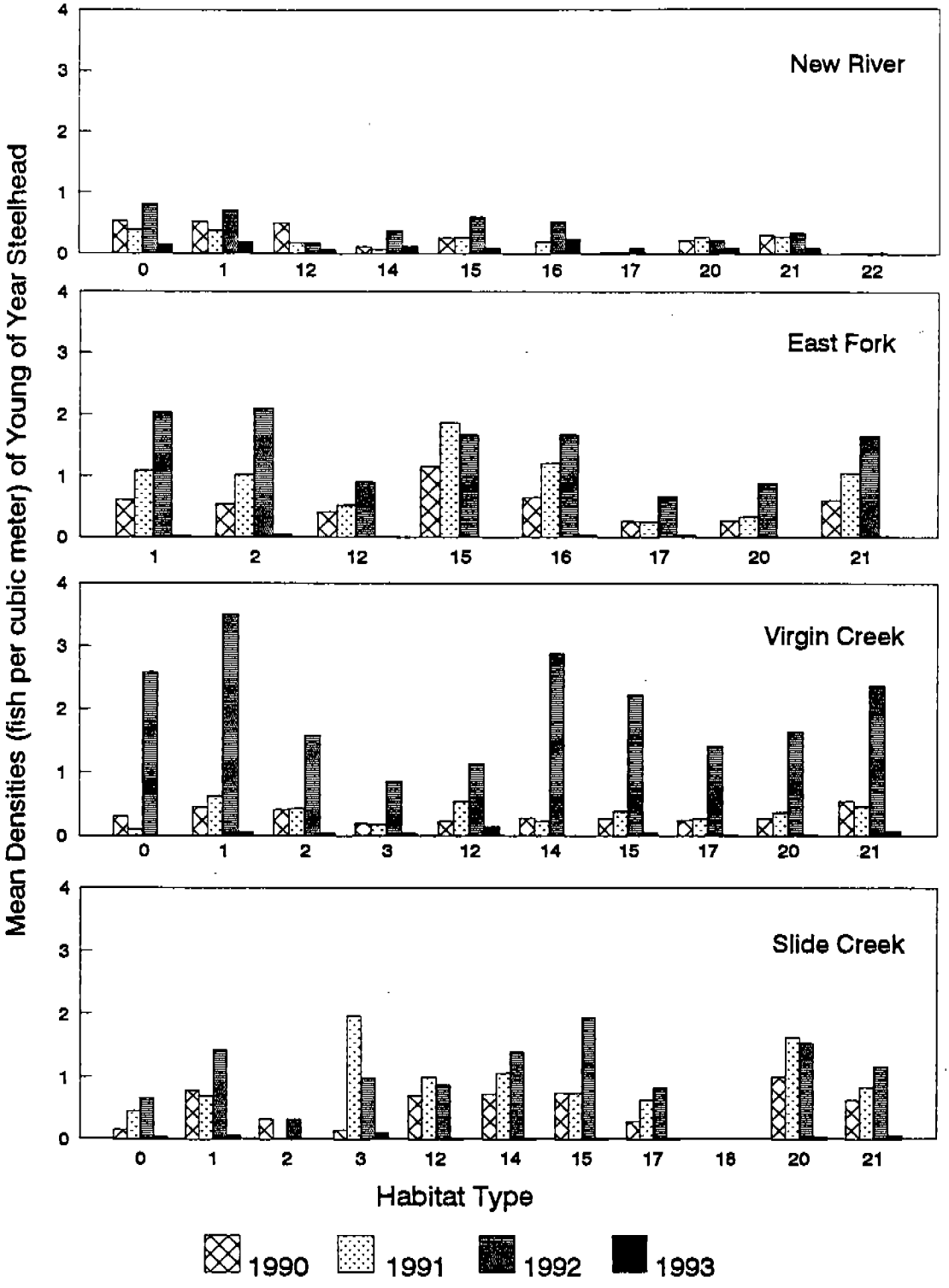

Figure 7. Mean densities (fish/m^3) of steelhead young-of-year (YOY) in the index reaches of New River and its major tributaries during 1990-93. Habitat type descriptions are presented in Appendix B.

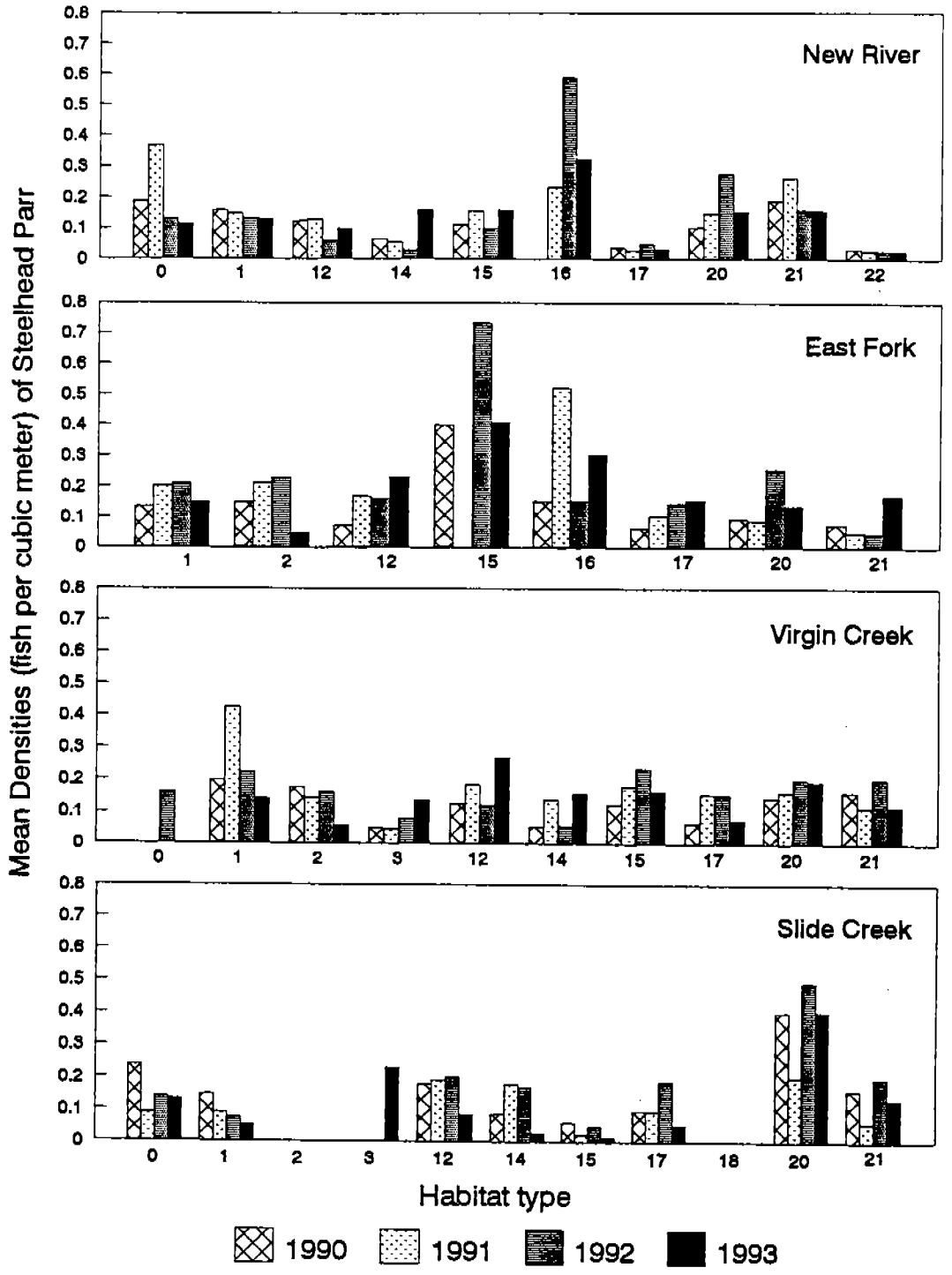

Figure 8. Mean densities (fish/m^3) of steelhead parr (1+) in the index reaches of New River and its major tributaries during 1990-93. Habitat type descriptions are presented in Appendix B.

confidence interval of YOY steelhead (all index reaches combined) for 1993 is compared with previous years (1990-1992) in Figure 9. The mean density in 1993 (0.12 $\pm$ 0.12 fish/m^3) was significantly lower ($P < .0001$) than in any previous year. The low juvenile density corresponds to the low number of adult spawners (272) the previous fall. The greatest mean density (0.38 $\pm$ 0.36 fish/m^3) occurred in 1992, reflecting the large number of adult spawners (702) in 1991.

The mean densities and 95% confidence intervals of YOY steelhead in each habitat type for the combined years of 1990-1993 are presented in Figure 10. Significant differences in fish densities were observed among the 10 different habitat types ($P < .0001$). The highest mean densities occurred in low-gradient riffles (0.45 $\pm$ 0.32 fish/m^3) and side channels (0.44 $\pm$ 0.43). The lowest densities occurred in corner pools (0.02 $\pm$ 0.01 fish/m^3) and mid-channel pools (0.08 $\pm$ 0.19 fish/m^3). The majority of juveniles within pools were observed in the head and tail-out areas, while few YOY steelhead were observed in the deep-pool area.

1+ Steelhead-Mainstem New River. The mean density and 95% confidence interval of 1+ steelhead (all index reaches combined) for 1993 is compared with previous years (1990-1992) in Figure 11. The mean density in 1993 (0.12 $\pm$ 0.09 fish/m^3) was not significantly different from the density in any previous year ($P = 0.92$).

The combined mean densities of 1+ steelhead in each habitat type for 1990-1993 are presented in Figure 12. Significant differences in fish densities were observed among the 10 different habitat types ($P < .0001$). The highest mean densities occurred in step runs (0.38 $\pm$ 0.18 fish/m^3) and pocket-water (0.19 $\pm$ 0.17) while the lowest densities occurred in corner pools (0.03 $\pm$ 0.02 fish/m^3) and mid-channel pools (0.04 $\pm$ 0.04 fish/m^3).

Habitat conditions remained relatively stable from 1990 through 1993. However, placer mining operations in indices 3-2 and 4-0 (Figure 2) altered some of the flat-water habitats by "punching holes" in the gravel streambeds. This created small pools and adjacent spoil-piles. Higher flows in 1993 resulted in the reclassification of a mid-channel pool and adjacent pocket water to a lateral-scour pool and a run. A high-gradient riffle was changed to a step-run in 1993.

East Fork

The single index reach on the East Fork of New River is comprised of nine habitat types (see Appendix B) in 13 separate units and extends for a length of 295 m (Figure 2).

YOY Steelhead-East Fork. Mean densities and 95% confidence

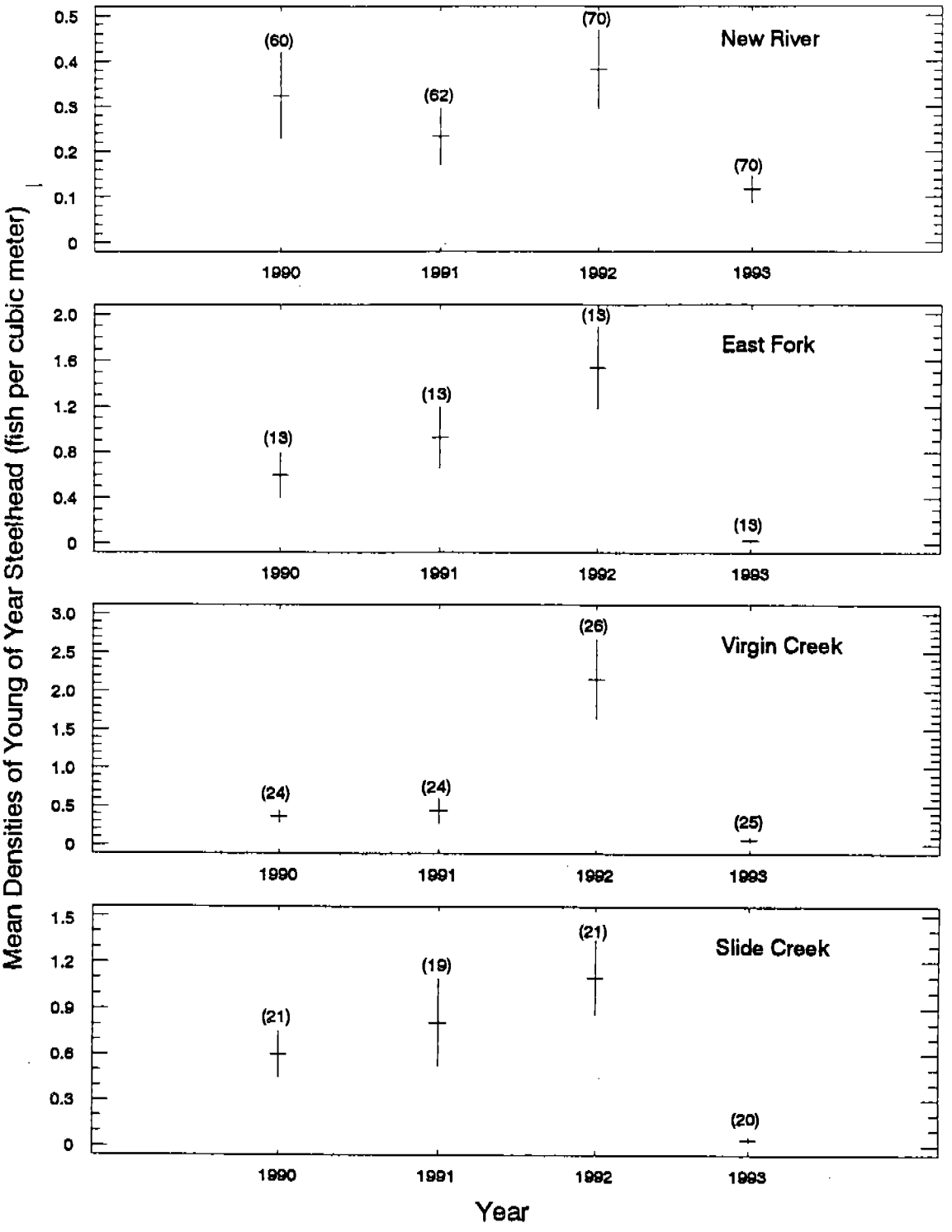

Figure 9. Mean densities (fish/m^3) and 95% confidence intervals of young-of-year (YOY) steelhead in the combined habitat types in the index reaches of New River and its major tributaries during 1990-93. Sample sizes are in parentheses.

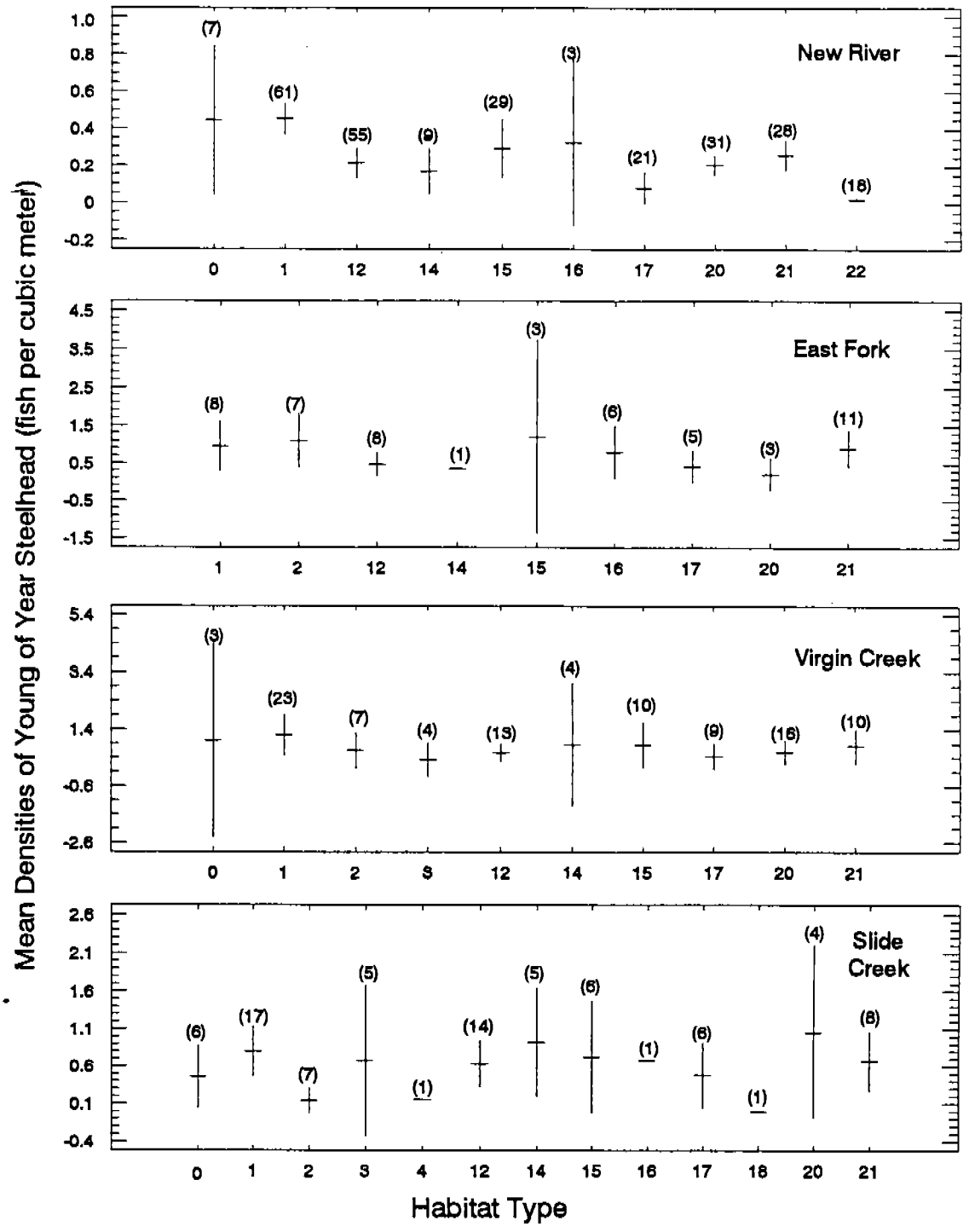

Figure 10. Mean densities (fish/m^3) and 95% confidence intervals of young-of-year (YOY) steelhead in each habitat type of the index reaches of the mainstem New River and its tributaries for the combined years of 1990-93. Sample sizes are in parentheses.

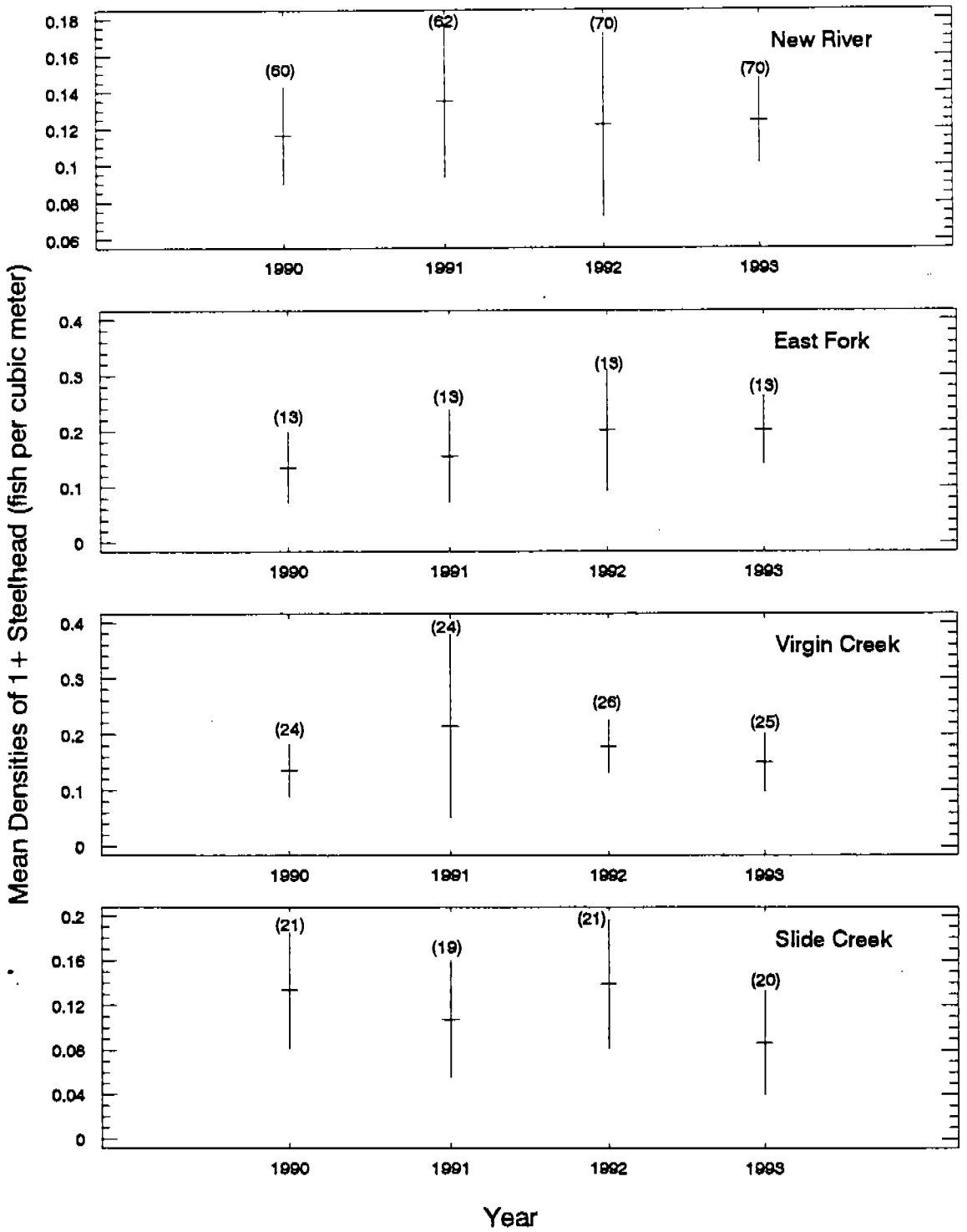

Figure 11. Mean densities (fish/m^3) and 95% confidence intervals of steelhead parr (1+) for the combined habitat types in the index reaches of New River and its major tributaries during 1990-93. Sample sizes are in parentheses.

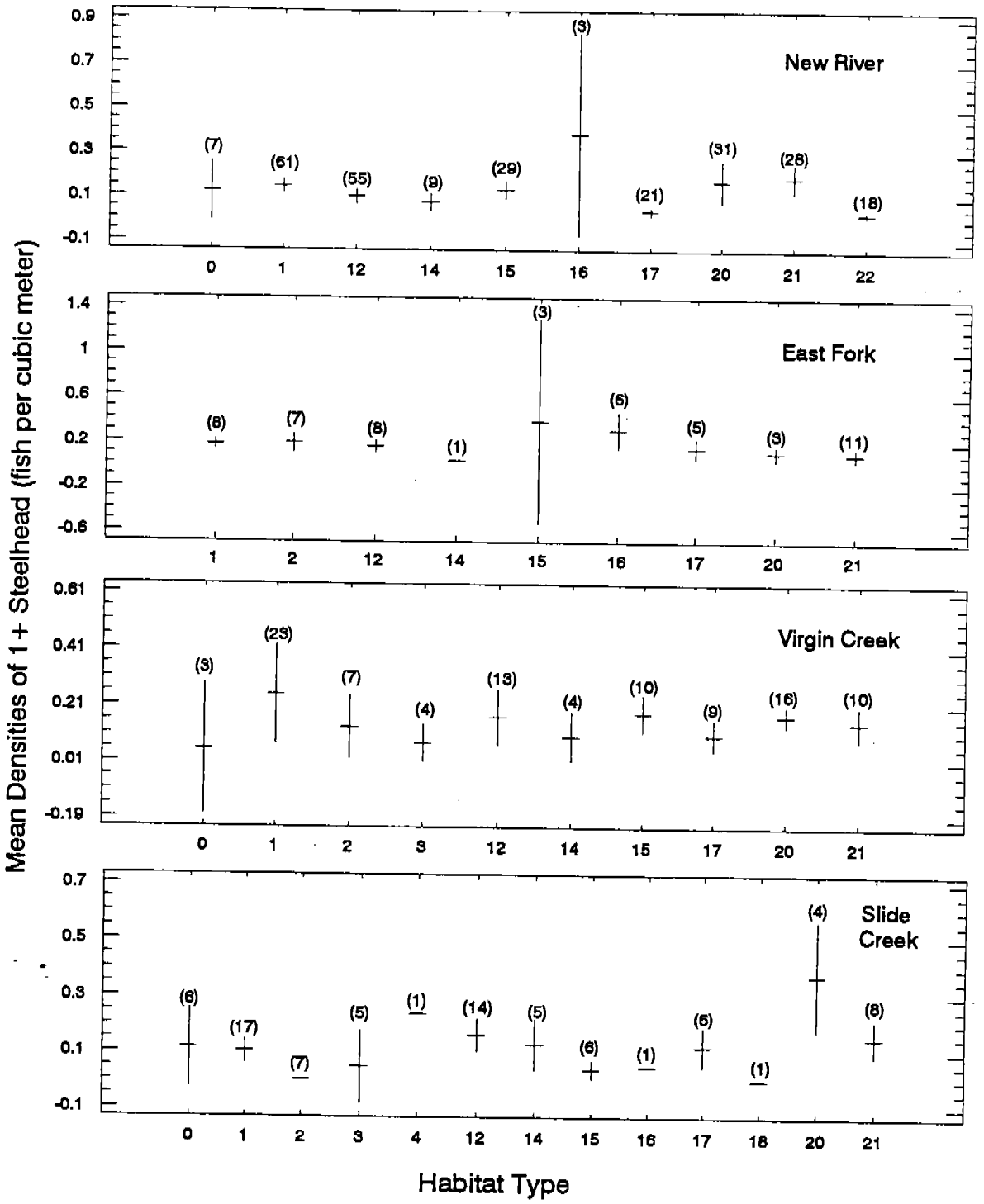

Figure 12. Mean densities (fish/m^3) and 95% confidence intervals of steelhead parr (1+) in each habitat type of the index reaches within the mainstem New River and major tributaries during 1990-93. Sample sizes are in parentheses.

intervals of YOY steelhead in the East Fork for 1990 through 1993 are presented in Figure 9. The mean density in 1993 (0.03 ± 0.02 fish/m^3) was significantly lower than in any previous year ($P < .05$). The highest mean density (1.54 ± 0.58 fish/m^3) occurred in 1992.

There were also significant differences ($P = 0.0009$) in the combined mean densities of YOY steelhead (1990 - 1993) among the different habitat types (Figure 10). The lowest densities were observed in a glide (0.34 fish/m^3), and in lateral-scour pools (0.21 ± 0.17 fish/m^3). Highest densities were observed in runs (1.18 ± 1.02 fish/m^3) and riffles (1.08 ± 0.78 fish/m^3).

1+ steelhead-East Fork. Mean densities of 1+ steelhead in the East Fork during 1993 are compared with densities of previous years in Figure 11. The density during 1993 (0.20 ± 0.10 fish/m^3) was not significantly different ($P = 0.56$) from the mean densities in any of the previous years.

There were significant differences in mean densities ($P = 0.009$) among the various habitat types during the four years of the study (Figure 12). The lowest densities were observed in a glide (0.03 fish/m^3) and in pocket-waters (0.09 ± 0.08 fish/m^3). The highest densities were observed in runs (0.38 ± 0.36 fish/m^3) and in step-runs (0.31 ± 0.15 fish/m^3).

Habitat changes over the past four years have been minimal. The glide observed in 1990 was retyped as pocket-water in 1992 and 1993 due to the movement of boulders. A mid-channel pool was changed to a lateral-scour-boulder pool due to additional scour and a high-gradient riffle was reclassified as a step-run.

Virgin Creek

There are 3 index reaches on Virgin Creek, with a total length of 543 m. (Figure 2). A total of 10 different habitat types (see Appendix B) are represented within 26 units.

YOY steelhead-Virgin Creek. The mean density and 95% confidence interval of YOY steelhead for 1993 is compared with the mean densities of the previous three years in Figure 9. The mean density in 1993 (0.07 ± 0.09 fish/m^3) was significantly lower ($P < .0001$) than in 1992, but did not differ from previous years. The highest density (2.16 ± 1.28 fish/m^3) occurred in 1992.

Differences in YOY mean densities within the 10 different habitat types (Figure 10) were not significantly different ($P = 0.07$). Lowest densities were observed in cascades (0.32 ± 0.37 fish/m^3) and in mid-channel pools (0.44 ± 0.58 fish/m^3).

Highest densities were observed in low-gradient riffles (1.20 ± 1.66 fish/m^3) and in side-channels (1.00 ± 1.37 fish/m^3).

1+ steelhead-Virgin Creek. The mean density and 95% confidence interval of 1+ steelhead during 1993 is compared with previous years in Figure 11. The 1993 mean density (0.15 ± 0.12 fish/m^3) was not significantly different (P = 0.67) from densities observed in 1990 through 1992. The highest mean density of 1+ steelhead in Virgin Creek (0.21 ± 0.38 fish/m^3) occurred in 1991.

Mean densities of 1+ steelhead within the 10 different habitat types (Figure 12) were not significantly different (P = 0.76). The highest densities (0.25 ± 0.40 fish/m^3) were observed in low-gradient riffles and in runs (0.19 ± 0.09 fish/m^3). Lowest densities occurred in side-channels (0.05 ± 0.09 fish/m^3) and in cascades (0.08 ± 0.04 fish/m^3).

The streambed in index 7-1 near Fawn Creek (Figure 2) had been altered by dredge mining in both 1991 and 1992. However, no additional alterations were recorded in 1993. A side-channel identified during 1992 no longer existed in 1993, due to the higher flows.

Slide Creek

There are two index reaches on Slide Creek. A total of 12 different habitat types (see Appendix B) in 21 units are represented. The total length of the index units is 420 m (Figure 2).

YOY steelhead-Slide Creek. The mean density and 95% confidence interval of YOY steelhead for 1993 is compared with mean densities from the previous three years in Figure 9. The mean density in 1993 (0.04 ± 0.04 fish/m^3) was significantly lower (P < 0.0001) than in previous years. The highest density (1.10 ± 0.53 fish/m^3) occurred in 1992.

Mean YOY densities within the 10 different habitat types (Figure 10) differed significantly (P = 0.009) over the four years of the study. The lowest densities occurred in an edgewater area (0 fish/m^3) and in high gradient riffles (0.14 ± 0.18 fish/m^3). The highest densities were observed in lateral-scour pools (1.06 ± 0.72 fish/m^3) and glides (0.92 ± 0.58 fish/m^3).

1+ steelhead-Slide Creek. The mean density of 1+ steelhead in 1993 (Figure 11) was not significantly different (P = 0.34) from the mean densities in previous years (1990 - 1992). The mean density observed in 1993 (0.09 ± 0.10 fish/m^3) was the lowest of the four years of the study. The highest density (0.14 ± 0.12 fish/m^3) occurred in 1992.

Combined mean densities (1990 - 1993) in each of the different habitat types (Figure 12) were significantly different ($P < 0.0001$) from one another. Lowest mean densities were observed in high-gradient riffles (0 fish/m^3) and in an edgewater area (0 fish/m^3). Highest mean densities occurred in lateral-scour pools (0.37 $\pm$ 0.12 fish/m^3) and in a secondary-channel pool (0.24 fish/m^3).

The side channel observed in 1992 was changed to edgewater in 1993 due to the higher flows. Habitat changes have been minimal over the four years of the study.

POPULATION TRENDS

Summer Steelhead and Spring Chinook Adult Counts

A total of 368 adult summer steelhead, 59 "half-pounder" steelhead, and 31 adult spring chinook were observed from September 7-16, 1993 (Table 1). Previous September counts of steelhead have ranged from 272 in 1992 to 702 in 1991 (Table 2). The lowest count of steelhead (250) in New River was reported by CDFG in 1981.

Snorkel surveys are conducted in September each year since previous surveys have indicated that salmonids immigrate into New River throughout August and early September. A summer survey of adult salmonids (July 26 to August 4) counted a total of 255 adult steelhead, 53 "half-pounders", and 10 chinook.

Although steelhead are regularly observed in the tributaries, as well as the mainstem, neither juvenile nor adult chinook have been observed in the tributaries during this study (1988-1993).

Spring and Fall Chinook Redd Counts

Because redd surveys are conducted from October to December each year, the redd counts for FY94 correspond with the adult counts for FY93 presented above. Therefore, results of the redd surveys for both FY93 and FY94 are presented below.

A total of 10 chinook redds were identified in FY93 (mid-October to early-December, 1992). Eighteen chinook (including 15 jacks) had been counted during adult surveys completed in September 1992. Three of the chinook redds were observed in the upper mainstem on November 6, 1992. The timing and location of these redds indicate that they were probably made by spring chinook. Spring chinook spawn in the mainstem Trinity River from early September through mid-

Table 1. Numbers of adult summer steelhead and spring chinook counted in New River and its major tributaries during September snorkel surveys from 1989-93. CHN=spring chinook, STH=summer steelhead

Location	1989		1990		1991		1992		1993 - first survey		1993 - second survey	
	CHN	STH	CHN	STH	CHN	STH	CHN	STH	CHN	STH	CHN	STH
VIRGIN CREEK Soldier Ck. to Four Mile Ck. (4.0 km)	0	10	0	10	0	40	0	0	0	35	0	5
Four Mile Ck. to Confluence Pool (4.2 km)	0	5	0	2	0	7	0	2	0	15	0	28
SLIDE CREEK N.F. Eagle Ck. to Mouth of Eagle Ck. (2.7 km)	0	7	0	20	0	8	0	0	0	8	0	6
Mouth of Eagle Ck. to Confluence Pool (4.2 km)	0	14	0	18	0	6	0	0	0	6	0	1
EAST FORK Mouth of South Fork to Lucky Lukes PMC (4.1 km)	No Survey	No Survey	0	8	0	3	0	0	0	16	0	1
Lucky Lukes PMC to Mouth of East Fork (4.6 km)	No Survey	No Survey	0	2	0	0	0	0	0	2	0	0
NEW RIVER Confluence Pool to Barron Creek (3.7 km)	0	104	1	31	0	74	0	44	0	74	0	82
Barron Creek to East Fork Confluence (4.4 km)	1	116	0	18	0	82	0	0	7	27	10	51
East Fork Confluence to Footbridge Area (3.6 km)	5	177	0	50	0	93	0	73	2	42	0	39
Footbridge Area to Denny Campground (5.4 km)	1	73	3	46	0	167	1	65	0	22	4	46
Denny Campground to Panther Creek (4.6 km)	3	50	0	17	0	16	0	12	0	16	11	57
Panther Creek to Bell Flat (8.8 km)	1	23	2	60	1	109	8	52	1	33	1	60
Bell Flat to Mouth of New River (3.3 km)	6	108	7	61	1	97	9	24	0	12	5	51
TOTAL (57.6 km)	17	687[1]	13	343	2	702	18[2]	272	10	308[3]	31	427[4]

[1] Count includes 32 half-pounders. [2] 15 chinook believed to be jacks. [3] Count includes 53 half-pounders. [4] Count includes 59 half-pounders.

Table 2. Preliminary numbers of summer steelhead in northern California rivers from 1980 - 1993, () = estimated, NS = No Survey, ND = No Data, (Gerstung pers. comm., 1993).

Stream	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
New River	368	272	702	343	687	204 (350)	NS	NS	NS	335 (340)	NS	114 (300)	236 (250)	320 (355)
M.Fk. Eel	605	516	691	449	726	711	1550	1000	1463	1524	666	1051	1600	1052
Van Duzen	NS	0	31 (38)	4 (5)	42 (49)	52	NS	NS	58	13 (16)	8	7 (8)	25	31
S.Fk. Trinity	42	29	9 (43)	66	37	30	NS	73 (100)	3 (20)	8 (30)	NS	26	NS	NS
N.Fk. Trinity	604	369	825-1037	554	347 (600)	624	36 (300)	NS	57 (112)	179	160	193 (210)	219	456
Canyon Creek	24	6	3	15	NS	32	NS	NS	10	20	3	20	3	6
Bluff Creek	31	23	49	14	14	33	59	73	6	26	11	37	16	17
Bluff Creek (late)	77	ND	ND	77	44	40	41	ND	17	22	12	57	41	20
Camp Creek	0	ND	0	3	7	0	1	0	NS	0	NS	NS	NS	2
Red Cap Creek	9	6	2	7	23 (33)	25 (35)	29 (40)	NS	18	10	12	45	NS	10
Dillon Creek	77	NS	88	74	294 (320)	38 (60)	77	NS	NS	200	300-500	295	194	236 (268)
Clear Creek	64	47	76	91	920	678 (838)	512	428 (458)	162 (222)	156 (167)	257 (275)	610	270 (300)	241 (251)
Indian Creek	28	27	8	12	154	41	NS	NS	NS	NS	NS	5 (17)	NS	1 (7)
Elk Creek	24	22	72	31	150 (188)	63	31	NS	NS	58	NS	249	47	90
Salmon	44	ND	21	15	13	128	NS	NS	NS	NS	NS	120	NS	36
N.Fk. Salmon	16	16	17	12	17	8 (32)	4 (19)	6 (28)	8 (37)	NS	NS	41	13 (60)	69
S.Fk. Salmon	47	59	26	21	11 (66)	155 (200)	20 (84)	13 (78)	9 (54)	NS	NS	223	10 (60)	166
Wooley Creek	49	17	25	73 (76)	234 (244)	379 (481)	280 (291)	NS	290 (307)	92 (96)	78	353	245 (269)	165 (177)
S.Fk. Smith	4	8	13	8 (10)	4 (6)	12 (16)	NS	NS	NS	NS	NS	5 (7)	0 (3)	
N.Fk. Smith	0	ND	0	NS	NS	NS	NS	NS	NS	NS	2	NS	0	0
M.Fk. Smith	5	13	11	21	1	2	NS	NS	NS	NS	2			
Mad River	48	34	66 (76)	33 (47)	20 (28)	60 (85)	18 (22)	134 (188)	52 (71)	134 (188)	31 (40)	167	6 (50)	2 (16)
Redwood Creek	8	5	15	14	0	8	15	44	44	44	7	3	16	

November, although peak spawning usually occurs in late September to early October (Zuspan, pers. comm., 1992). The total of three spring chinook redds observed in FY93 is the lowest recorded during this project (10 redds in FY89, 14 in FY90, 7 in FY91, and 3 in FY92) (Figure 13).

Another 7 chinook redds were observed after November 14. All of these redds were located in the lower 3.5 rkms of the river. Two of the redds were being guarded by adult chinook and several chinook were observed in the vicinity of other redds. The timing and location of these redds would indicate that they are probably fall chinook redds (Figure 14). Spawning of fall chinook in the mainstem Trinity River usually peaks in early to mid-November (Zuspan, pers. comm., 1992).

Unsafe snorkeling conditions (due to winter storms and high river flows), prevented the continuation of fall chinook spawning surveys beyond December 4, 1992. The scouring of the river bed by high water flows also made it difficult to distinguish redds from natural hydraulic gravel movement.

Redd surveys during the fall of 1993 (FY94) were initiated in late October and continued through November. The relatively high number of spring chinook adults (31) observed in September, 1993 corresponded with the highest number of chinook redds (53) observed to date. A total of 28 redds were counted in late October. These are believed to be primarily spring chinook (Figure 13), although seven redds were located in the lower 3.4 rkms of the river and may have been made by early arriving fall chinook. Another 25 redds were counted between November 14-30. Based on the timing, these are probably all fall chinook redds (Figure 14).

The near-normal rainfall and resultant cool summer water temperatures during 1993 may have facilitated the upstream passage of spring chinook adults. The adult spring chinook count (31) and redd count (28) were the highest recorded to date.

Regression analysis indicates that the relationship between adult spring chinook counts in September and the subsequent number of spring chinook redds is highly significant (r^2 = 0.95, $P < 0.05$)(Figure 15) in spite of several factors that could introduce error: (1) It is unlikely that snorkelers observe all fish, (2) some fish may enter New River between the mid-September adult surveys and the October-December spawning surveys, and (3) some pre-spawning mortality (due to poaching, disease, thermal stress, etc.) probably occurs. Because redd surveys are often hampered by fall storms, the regression equation may be used to estimate redd numbers during those years when redd surveys are impractical.

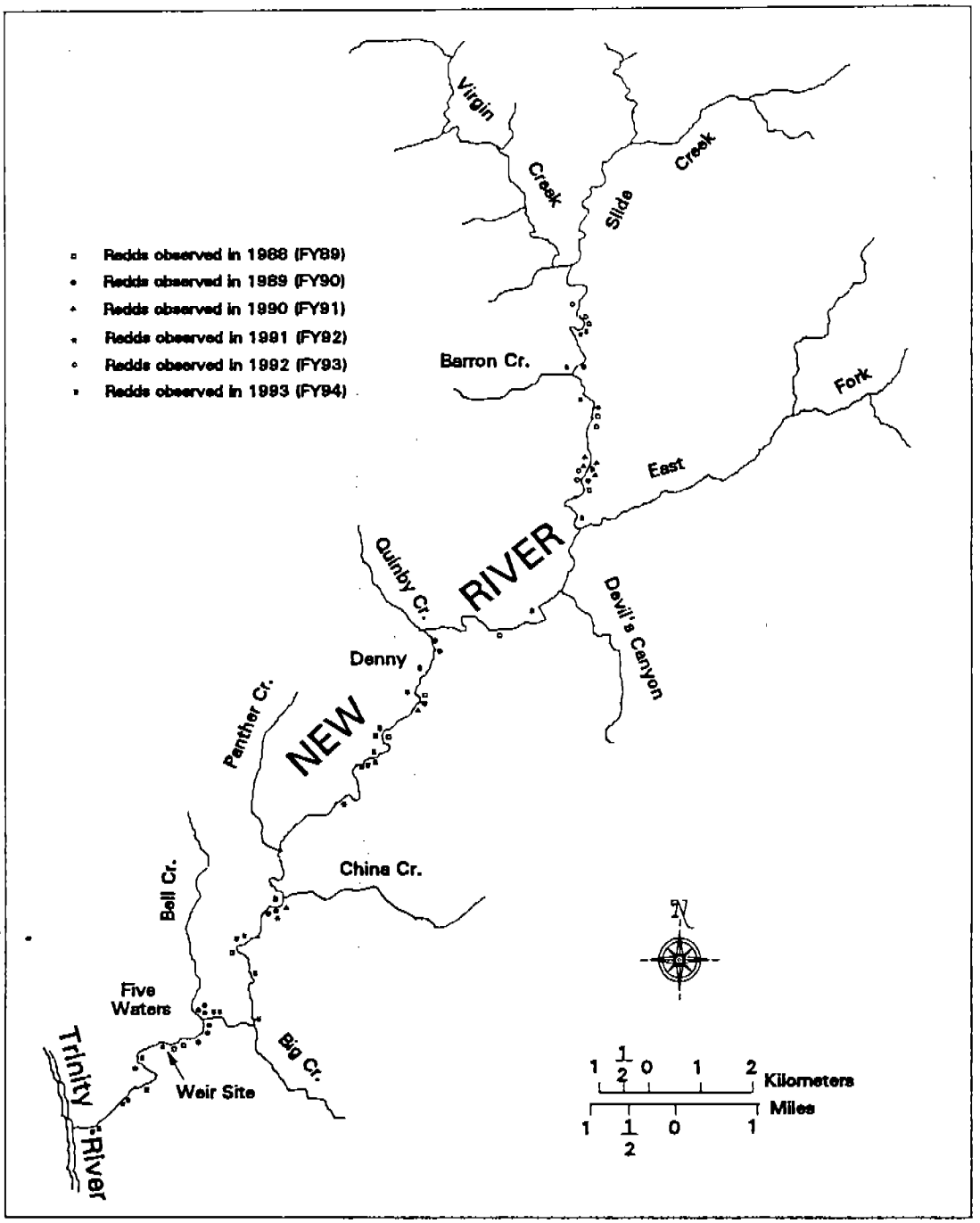

Figure 13. Locations of spring chinook redds observed in New River snorkel surveys from 1988-93.

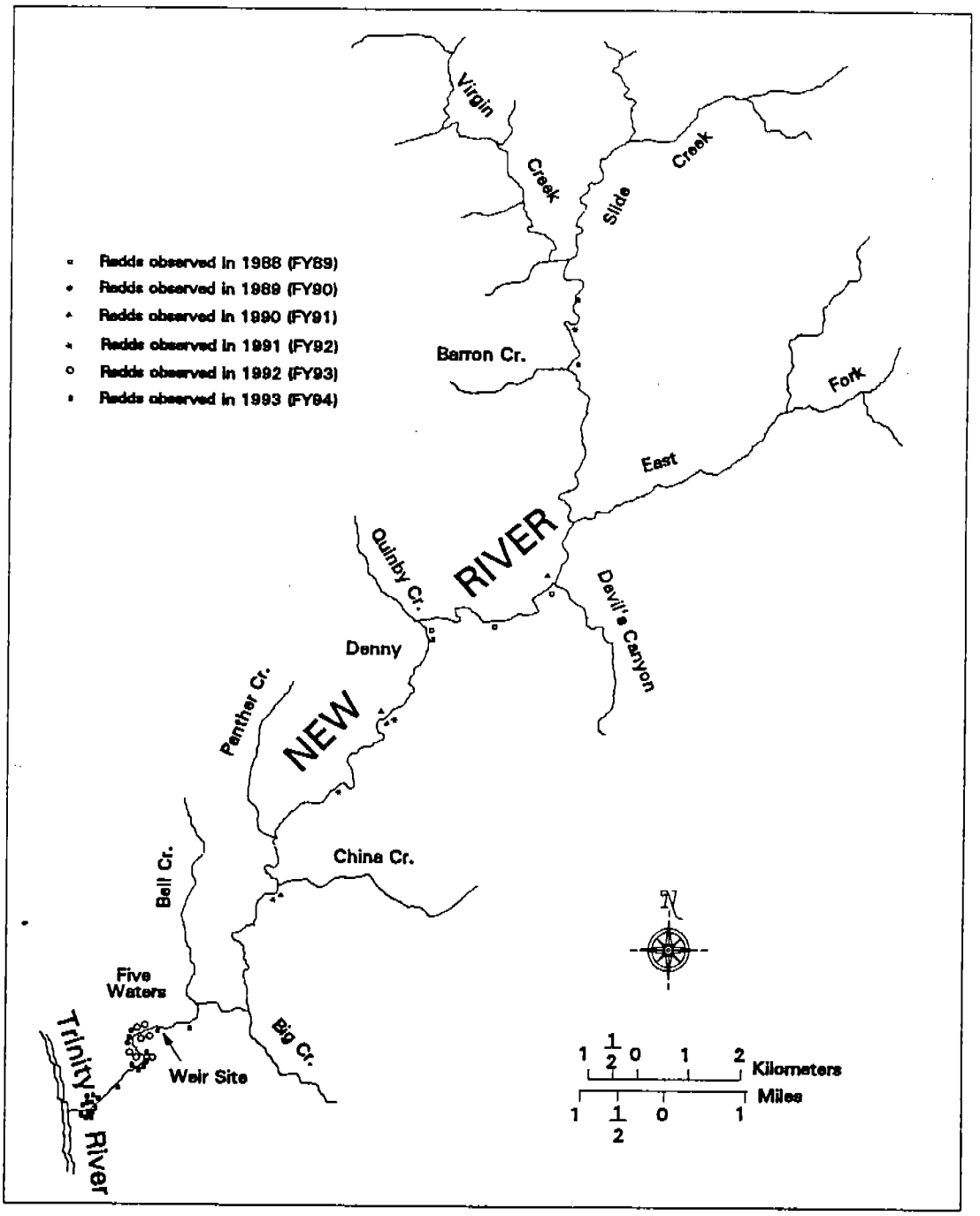

Figure 14. Locations of fall chinook redds observed in New River snorkel surveys from 1988-93.

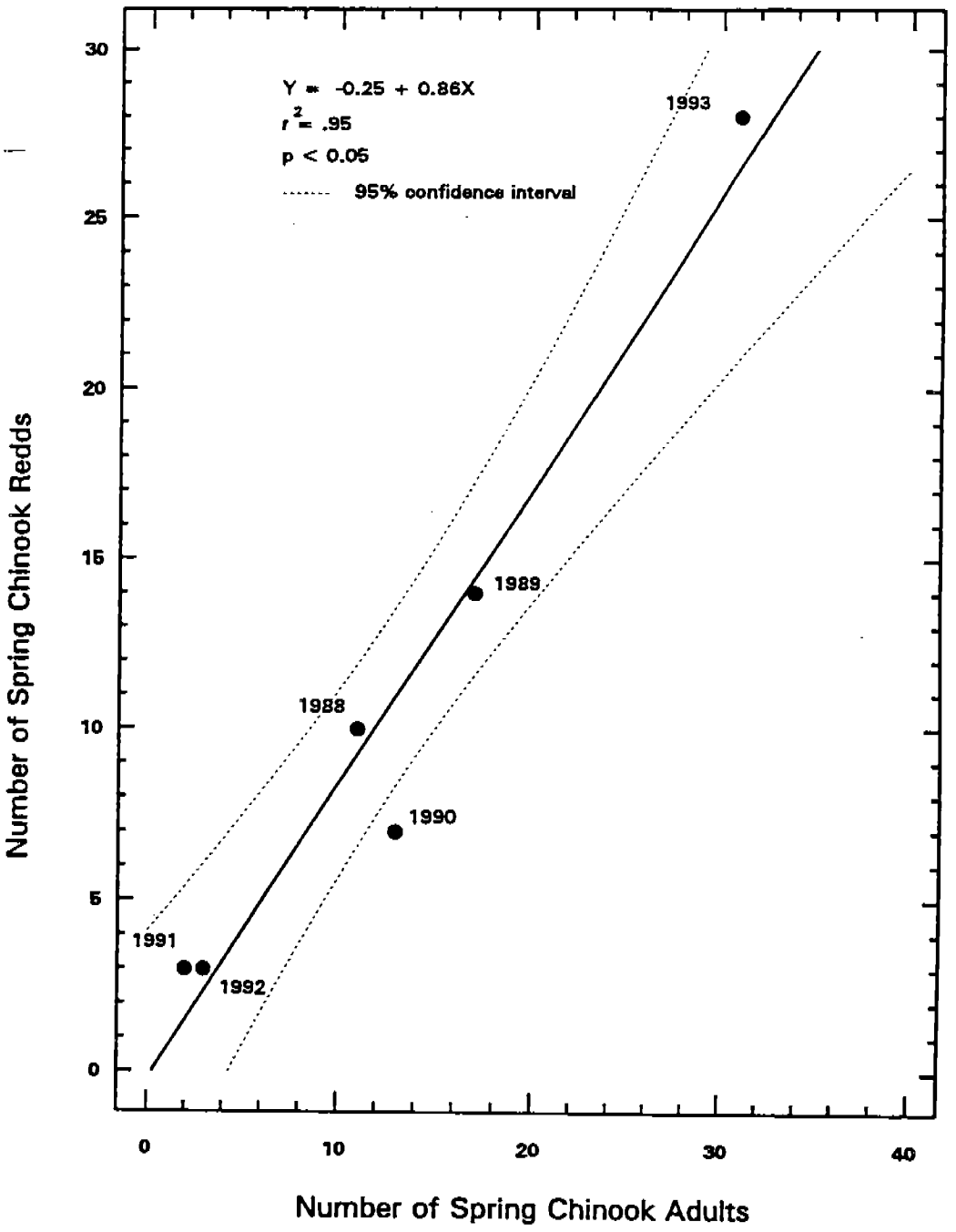

Figure 15. The relationship between the number of adult spring chinook spawners observed during September snorkel surveys and the subsequent number of spring chinook redds counted during fall (October-December) surveys.

Resistance-Board Weir

The weir was operated from October 19, 1992 until January 20, 1993, when it was destroyed by flood waters from a severe southerly storm. Heavy rainfall on top of an accumulated snowpack increased the flow from 14.4 cms to 263.7 cms (509-9,318 cfs) over the course of several hours. The cable that anchored the panels to the foundation snapped when the flow exceeded 193.0 cms (6,820 cfs). It was not possible to repair the damage to the weir until flows subsided the following summer.

During the months of operation, high river flows (25 - 38 cms, depending on the amount of accompanying debris) caused the weir panels to sink. It is unknown if adult fish moved upstream over the pickets during the periods when the weir was submerged.

Although migrating fish are stimulated to move during periods of higher flows and are able to dart past brief obstructions, several studies have indicated that adult salmonids tend to move upstream after storm flows begin to subside (Shapovalov and Taft, 1954; Thompson, 1972). According to Thompson (1972), reported in Pauley et al (1986), the maximum water velocity that allows successful migration of steelhead is 2.4 m/s. Another study reported a maximum water velocity of 2.51 m/s for anadromous salmonids passing through a 10 m long culvert (Kay and Lewis, 1970). Mean water velocities in New River during periods of weir submergence (derived from staff-gage readings), ranged from 1.8 to 2.6 m/s. Therefore, it is possible that fish may have passed over the submerged weir, at least at the lower velocities. However, even during periods of submergence the panels are elevated at an angle off of the river bottom. This may be sufficient to direct migrating adults into the live box.

Chinook. A total of 31 chinook adults were trapped at the weir between October 27 and November 24, 1992. The peak catch (2 adult chinook and 10 jacks) occurred on October 30 (Figure 16). Chinook fork lengths ranged from 40 to 95 cm (mean 51.5 ± 13.1 cm). A length-frequency histogram revealed that the modal frequency was 45 cm (Figure 17). Scale samples revealed that 23 of the chinook (74.2%) were age 2, a total of five (16.1%) were age 3, and three (9.7%) were age 4. The good condition of these fish indicated that they were probably all fall chinook.

Adult snorkel surveys indicate that fall chinook begin entering the New River drainage in late October. Some remain in the lower 3 rkm and spawn below the weir site (Figure 14). Others probably remain in the lower 3 rkm until fall storms increase the river flow. During 1993, high water accompanied

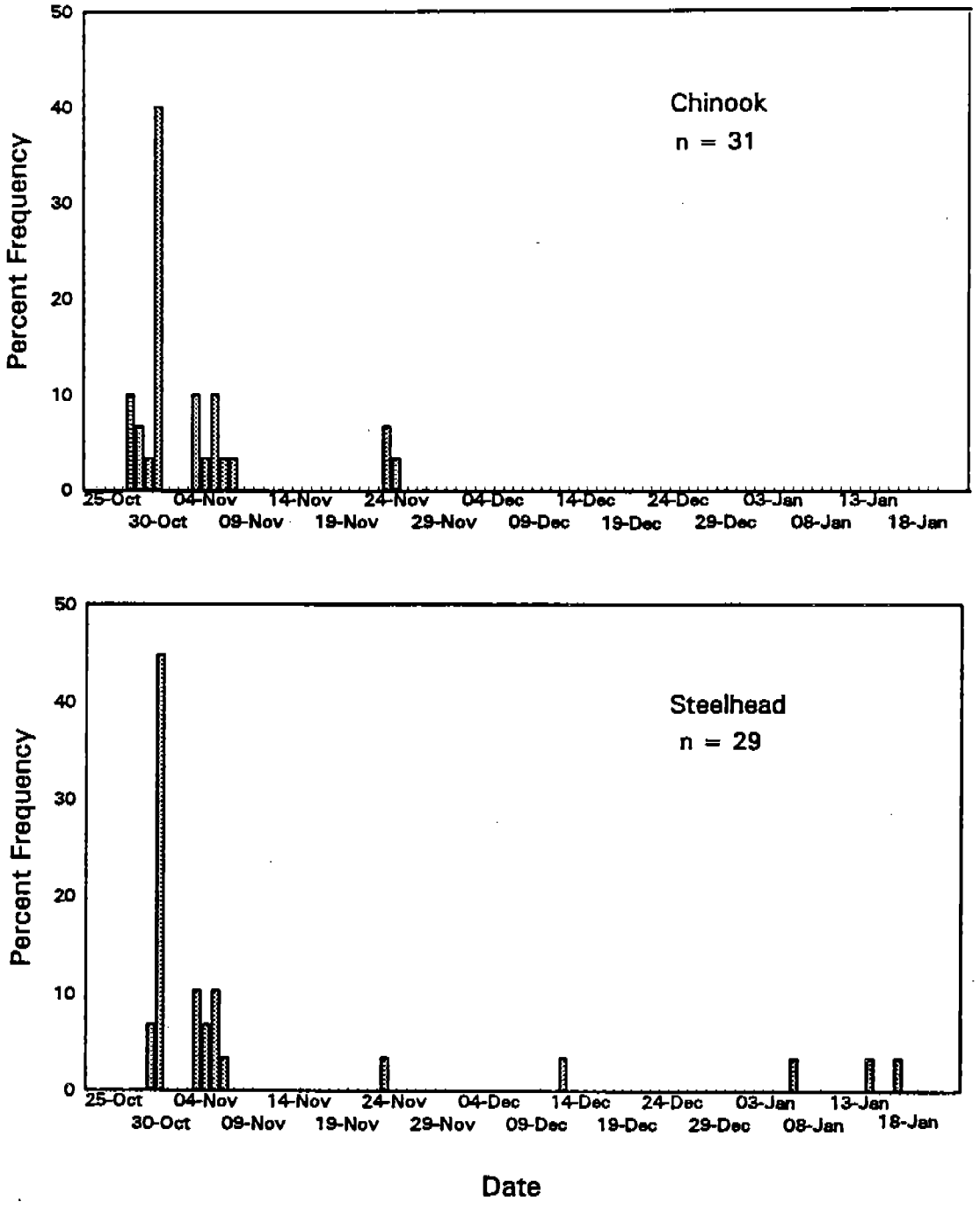

Figure 16. Timing of the adult chinook and steelhead run in New River, based on numbers of fish trapped in the resistance-board weir (rkm 3.5) during the winter of FY93.

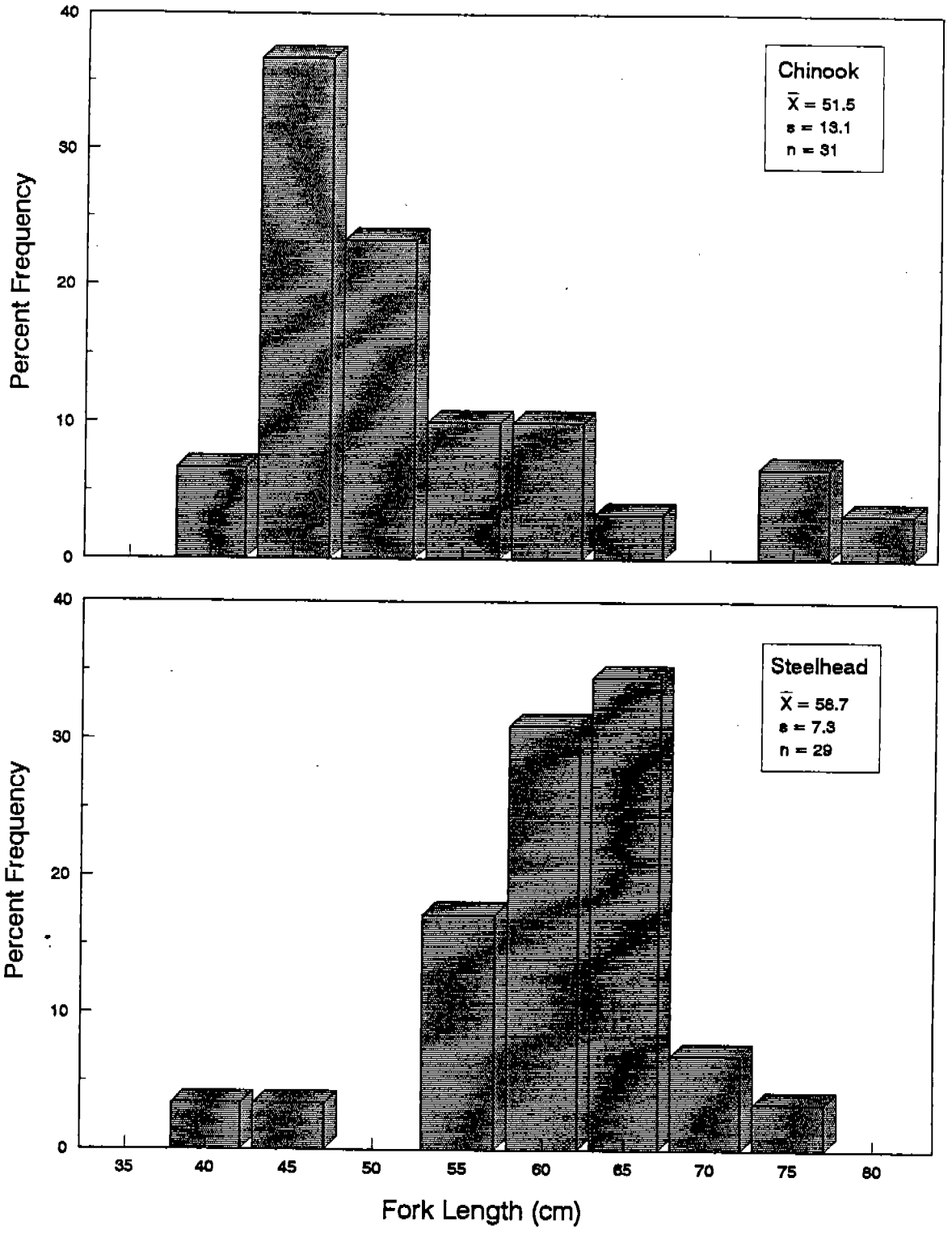

Figure 17. Length-frequency histograms of adult chinook and steelhead trapped at the New River weir during FY93.

by floating leaves caused the weir to submerge for a total of 42 hours between December 9 and 12, allowing an unknown number of chinook to move upstream past the weir site. Some small-sized age 2 (jack) chinook were observed passing through the panels.

In addition to the chinook trapped in the live box, a total of 17 chinook carcasses washed up on the weir panels and 11 more were found in the vicinity of the weir. The deteriorated condition of recovered carcasses made it difficult to distinguish a caudal-fin mark (6 mm diameter hole punch) so it is unknown how many of these were sampled and marked while alive at the weir. Scale samples from 21 of the carcasses revealed that 12 (57.1%) were age 2, a total of 2 (9.5%) were age 3, and 7 (33.3%) were age 4.

The ranges of fork lengths by age class were determined for the 52 chinook (including carcasses) that were aged from scales. Fork lengths of age 2 chinook ranged from 38 - 55 cm, age 3 chinook ranged from 59 - 73 cm, and age 4 chinook ranged from 68 - 95 cm.

Only one chinook was tagged with a California Department of Fish and Game (CDFG) spaghetti tag. This fish had been tagged at the CDFG Willow Creek weir on October 13 and was recovered at the New River weir on October 30 (Table 3).

Table 3. CDFG spaghetti tag recoveries at the New River weir (rkm 3.5). U = unknown, M = male, F = female.

Tag Code	Recovery Date	Species	Fork Length	Sex	Tagging Agency	Tagging Location	Tagging Date
R006189	10/30/92	Chinook	53 cm	U	CDFG	Willow Cr.	10/13/92
R004010	10/30/92	Steelhead	62 cm	U	CDFG	Willow Cr.	10/20/92
W005349	10/30/92	Steelhead	62 cm	M	CDFG	Willow Cr.	10/20/92
W005158*	10/30/92	Steelhead	56 cm	M	CDFG	Willow Cr.	10/06/92
R006020	10/30/92	Steelhead	58 cm	F	CDFG	Willow Cr.	09/04/92
W005477	12/24/92	Coho	64 cm	M	CDFG	Willow Cr.	0.004

* Tag code W005158, difficult to read last number.

Steelhead. A total of 29 steelhead adults were trapped at the weir from October 29 to January 6. Nearly half of these were trapped on October 30 (Figure 16). Smaller numbers were trapped sporatically through early January. Fork lengths

ranged from 36 - 71 cm (mean 58.7 ± 7.3). The modal frequency was 65 cm (Figure 17). Of the 20 steelhead that were aged, only 1 was age 3 (5.0%), 14 were age 4 (70.0%), and 5 were age 5 (25.0%). All but one fish (4-year old) had reared in freshwater for two years. At least four fish (two 4-year olds and two 5-year olds) had spawned previously.

The steelhead captured at the weir from October to December are probably a mix of fall and late-arriving summer races. Four adult steelhead were tagged with CDFG spaghetti tags (Table 3). Transit times between weirs (a distance of 26.9 km) varied from 10 to 56 days for the four tagged steelhead. Only one steelhead was trapped in December (December 12). This fish was described as "bright" and in good condition and may represent the beginning of the winter run. Three more steelhead were trapped in January prior to the loss of the weir. Most of the winter steelhead run would be expected to arrive in late January to March, based on the timing of returns to the Trinity Hatchery.

Coho. Two male coho salmon carcasses (41 and 64 cm fork lengths) were collected at the weir on December 24. Although one of the coho had been tagged in Willow Creek 61 days previously (Table 3), the actual transit time between weirs is unknown. It is unknown whether these fish passed over the weir panels during a period of weir submergence or whether they moved upstream prior to October 19, when the weir-trapping began. It appears likely that both fish were strays from the Trinity River since no coho adults or juveniles have been observed in previous years of the project. Neither female coho nor redds were observed during FY93, so it is unknown if any coho spawned successfully.

Juvenile Trapping

The rotary screw trap was operated for 83 nights between March 29 and August 2, 1993. A total of 104 YOY chinook, 817 YOY steelhead, 1,231 steelhead parr, 253 steelhead smolts and one sub-adult ("half-pounder") steelhead were trapped (Table 4).

The number of fish captured provides an abundance index of juvenile emigrants. Indices of daily abundance, compared between years, show a wide variation in emigration timing and magnitude. Some of the factors that may influence the timing of emigration include length of photo-period, water temperature, and timing of storms and high flows. The numbers of emigrants are affected not only by the number of spawners, but by numerous physical and biotic factors as well.

The fraction of the total river flow that is sampled by the screw trap influences the daily index estimate. Although indices are flow-adjusted, more reliable estimates are

Table 4. Summary of rotary-screw trap and late-season frame trap catches in New River, CA, from 1989 through 1993. YOY = young-of-year

	1989	Steelhead			Chinook	
Month	Number of nights sampled	YOY	Parr	Smolt	YOY	Yearling
MAR	0					
APR	13	0	67	3	4	0
MAY	18	2	662	173	55	0
JUN	21	140	364	22	375	0
JUL	7	46	6	2	61	0
AUG	0					
SEP	0					
OCT	0					
NOV	0					
1989 Totals=	**59**	**188**	**1,099**	**200**	**495**	**0**
	1990					
MAR	0					
APR	23	1	4,669	1,349	25	0
MAY	26	31	645	231	341	0
JUN	24	297	50	7	350	0
JUL	18	201	29	3	106	0
AUG	3	0	0	0	0	0
SEP	13	28	4	0	0	0
OCT	10	6	0	0	0	0
NOV	4	9	0	0	0	0
1990 Totals=	**121**	**573**	**5,397**	**1,590**	**822**	**0**
	1991					
MAR	6	0	20	47	0	1
APR	19	0	390	234	1	1
MAY	18	1	551	256	105	2
JUN	19	221	157	17	420	0
JUL	15	1	2	0	10	0
AUG	9	1	0	0	1	0
SEP	10	15	9	0	0	0
OCT	4	1	0	1	0	0
NOV	0					
1991 Totals=	**100**	**240**	**1,129**	**555**	**537**	**4**
	1992					
MAR	0					
APR	7	0	1,423	446	0	5
MAY	13	741	529	337	53	0
JUN	17	911	41	8	67	0
JUL	9	847	44	2	1	0
AUG	0					
SEP	0					
OCT	0					
NOV	0					
1992 Totals=	**46**	**2,499**	**2,037**	**793**	**121**	**5**
	1993					
MAR	2	0	39	10	0	0
APR	18	1	300	75	0	0
MAY	23	7	488	134	4	0
JUN	17	122	276	22	53	0
JUL	21	681	128	12	47	0
AUG	2	6	0	0	0	0
SEP	0					
OCT	0					
NOV	0					
1993 Totals=	**83**	**817**	**1,231**	**253**	**104**	**0**

achieved by increasing the percentage of flow sampled. Flows in 1993 were higher than in any preceding year of the study, resulting in a reduction in the fraction of river flow sampled by the screw trap. An average of 22% of the river volume was sampled throughout the trapping season this year, compared with 34% for 1990, 44% for 1991, and 41% for 1992.

Chinook. YOY chinook were first trapped on May 20, their numbers peaked in mid-June, and diminished by August 1. The abundance index estimate of 709 YOY chinook for the entire season is lower than the value from any previous trapping year (Figure 18). A correspondingly low number of spawners had been observed in the fall and winter of 1992 (3 adult chinook and 15 jacks). The absence of any juvenile chinook observed during index surveys in late-July suggests that few YOY chinook remained to overwinter in New River. No older juvenile chinook (1+ or 2+) were trapped during 1993 (Table 4), nor were any observed in juvenile snorkel surveys.

The chinook length frequency histogram for 1993 was distinctly bimodal, unlike those of the previous four years (Figure 19).

The length-displacement relationship for 1989-93 is presented in Figure 20. The length-displacement relationship can be used as a measure of condition. A slope of 3.0 or more indicates that the fish become heavier for a given length as they grow. The slope of the log-transformed linear regression for fish trapped in 1993 was 2.93 (n=88). Although this indicates that the fish were slightly leaner than average, the slope for 1993 did not differ significantly from the previous four years ($P > 0.05$).

YOY steelhead. The first YOY steelhead (mean fork length = 29 mm) was observed on April 30 (Figure 21). The number of emigrating YOY steelhead peaked in mid-July, although a smaller peak occurred in late June. Two distinct peaks were also observed in 1992, but they occurred earlier in the season (prior to July 1). Peak emigration in 1993 occurred slightly later than in any previous year. Water temperatures remained cooler longer during the summer of 1993, and may have been a factor in the late emigration.

The magnitude and timing of the steelhead YOY emigration may be influenced by the river discharge as well as the daily mean water temperature (Figure 22). The largest pulse of YOY emigrants occurred at a mean daily water temperature of 16.8° (maximum temperature of 18.8° C). River discharge had declined to 200 cfs.

The estimated number of emigrating YOY steelhead was substantially lower than for the previous year, but was comparable to estimates for 1990 and 1991 (Figure 21). The

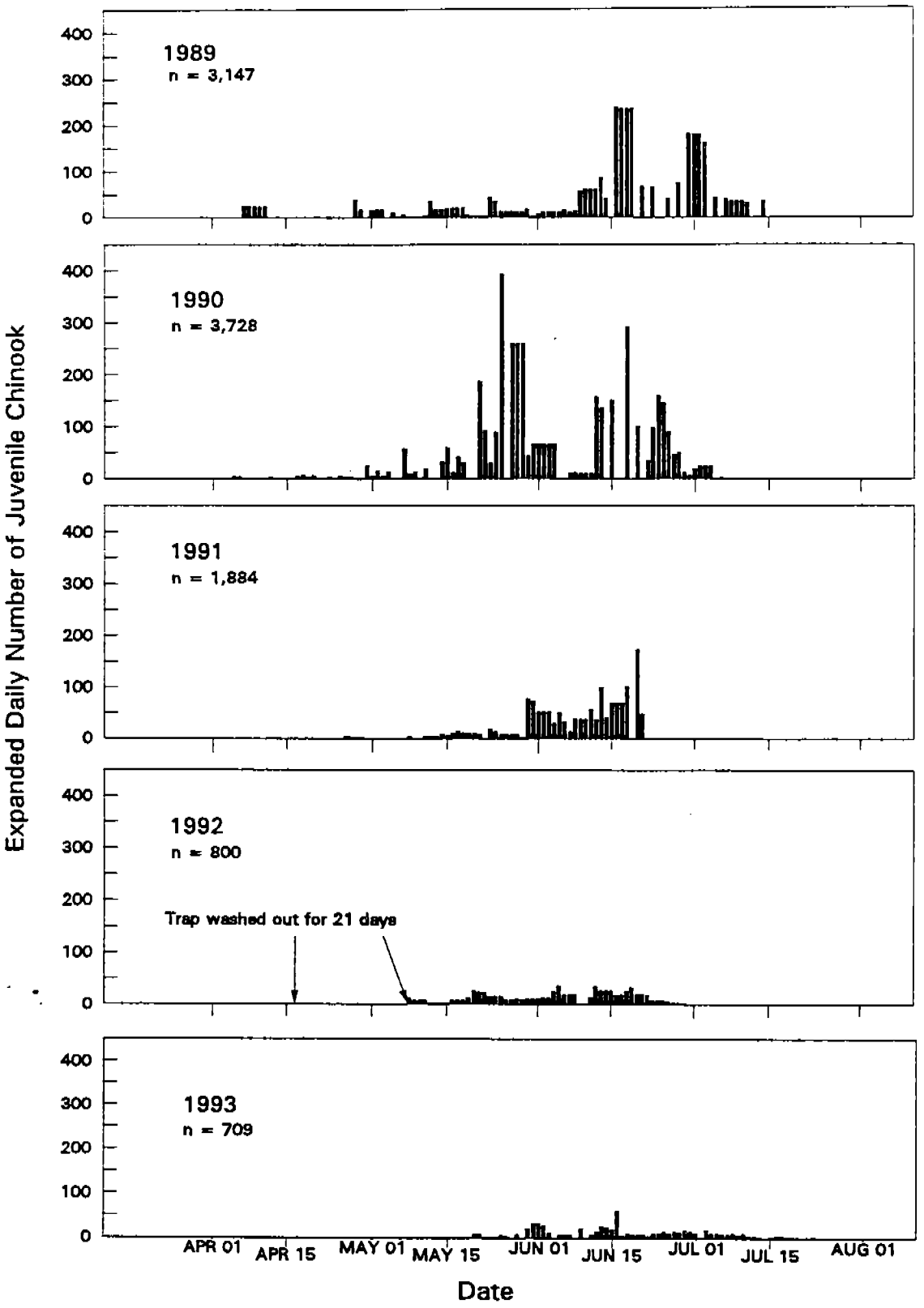

Figure 18. Juvenile chinook expanded daily emigrant estimates, based on New River rotary-screw trap catches during 1989-93.

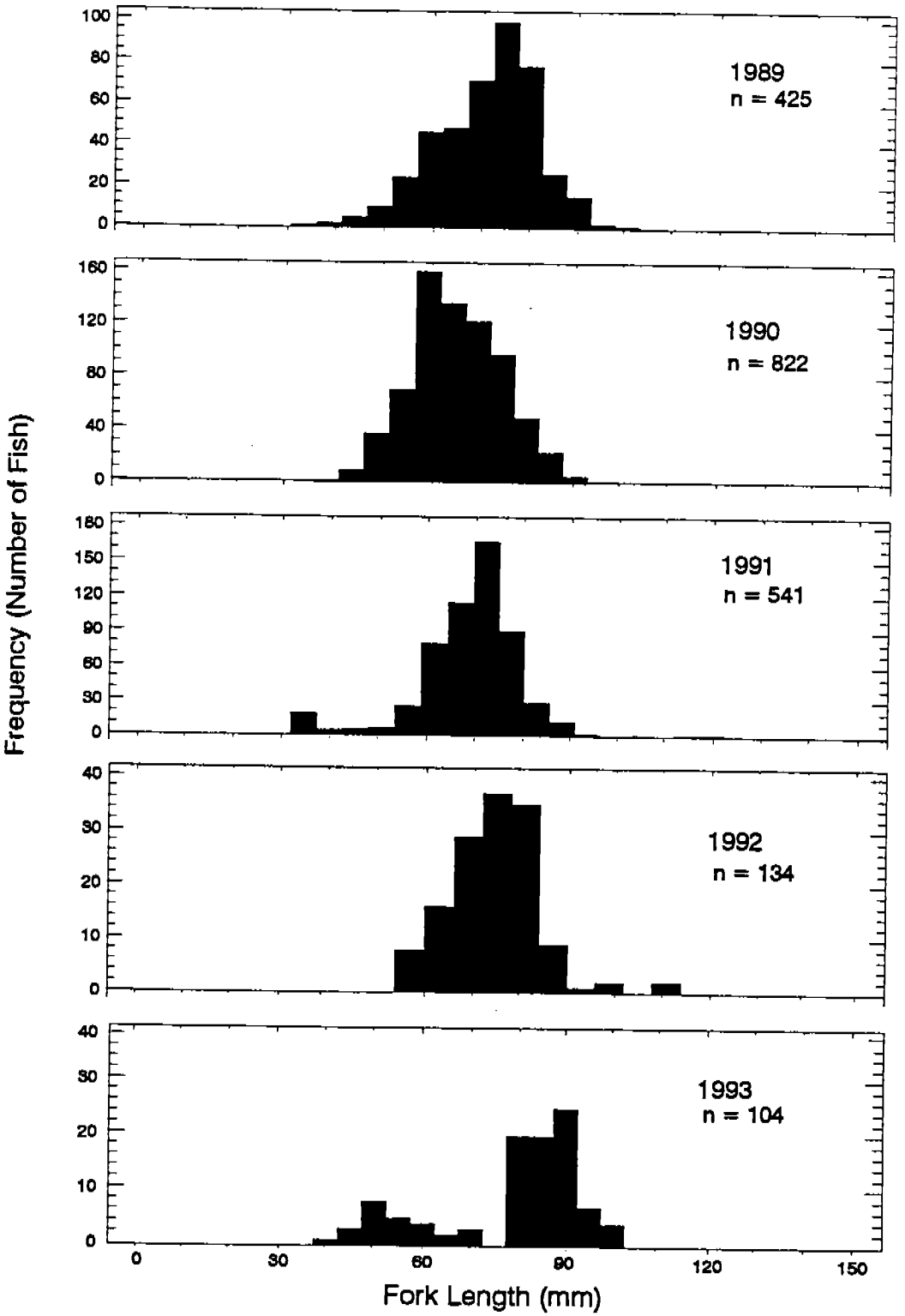

Figure 19. Juvenile chinook length-frequency histograms based on rotary-screw trap catches during FY 1989-93.

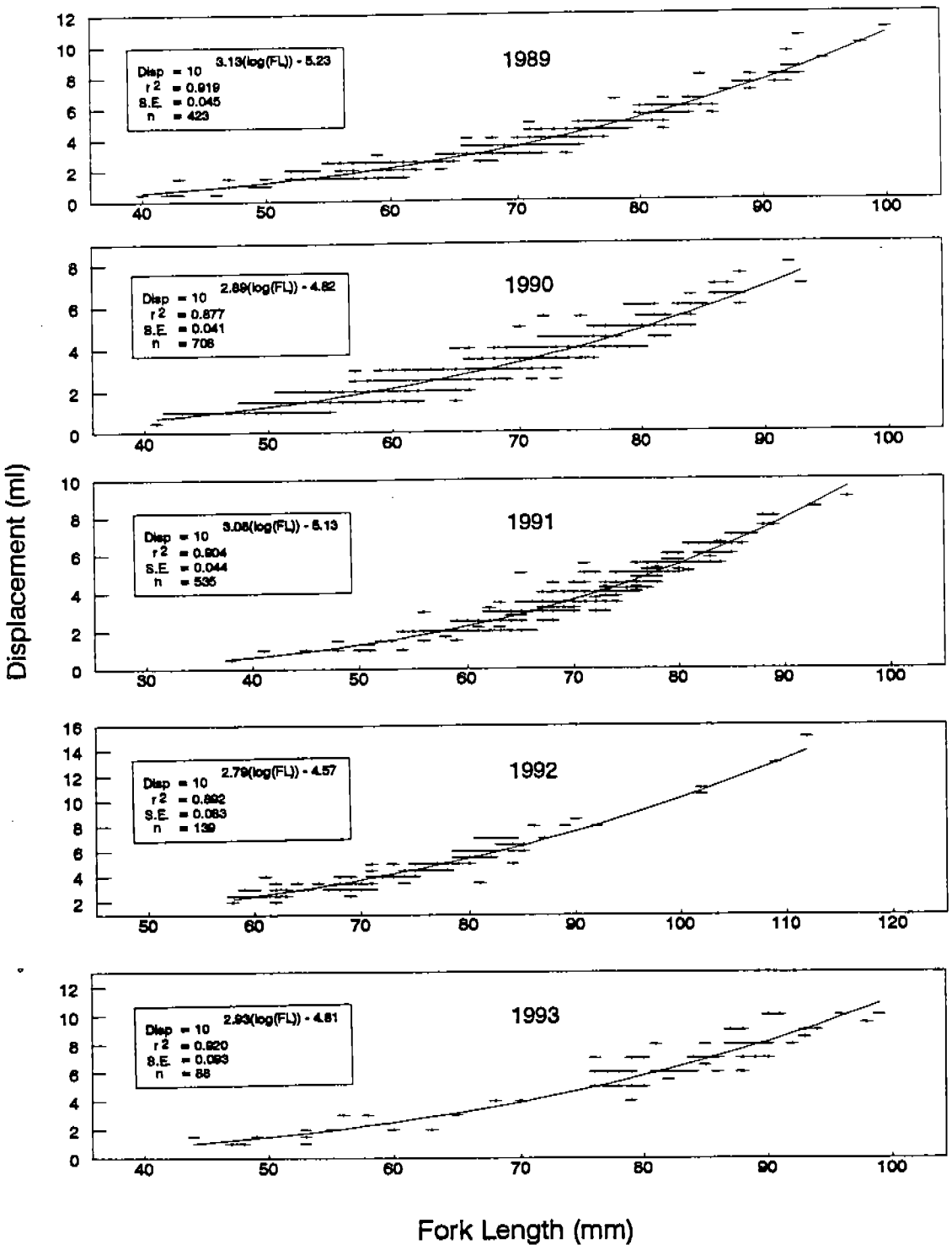

Figure 20. Juvenile chinook length-displacement relationships for emigrants caught in the rotary-screw trap (rkm 3.75) on New River during FY89-93.

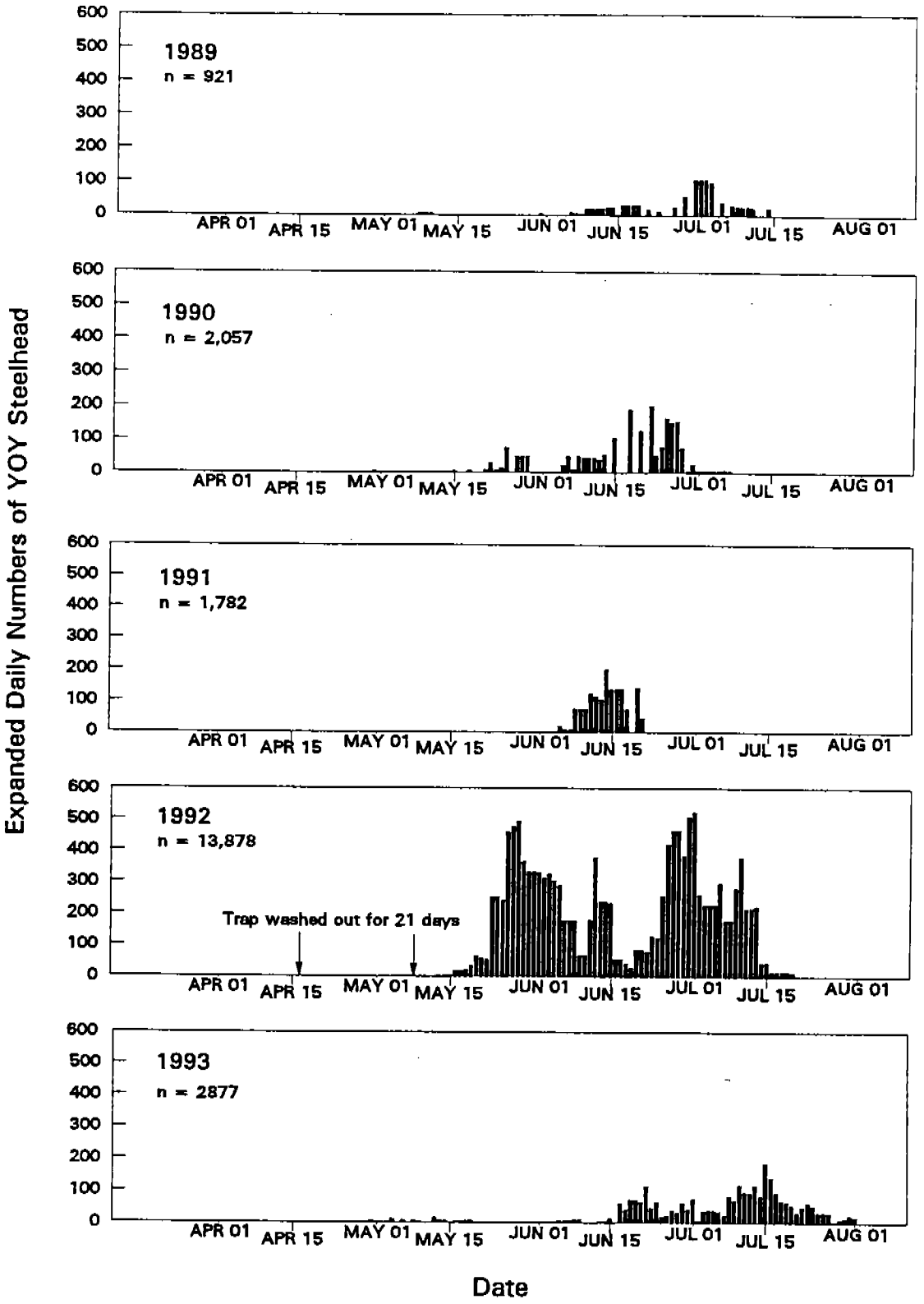

Figure 21. Steelhead young-of-year expanded daily emigrant estimates, based on New River rotary-screw trap catches during FY 1989-93.

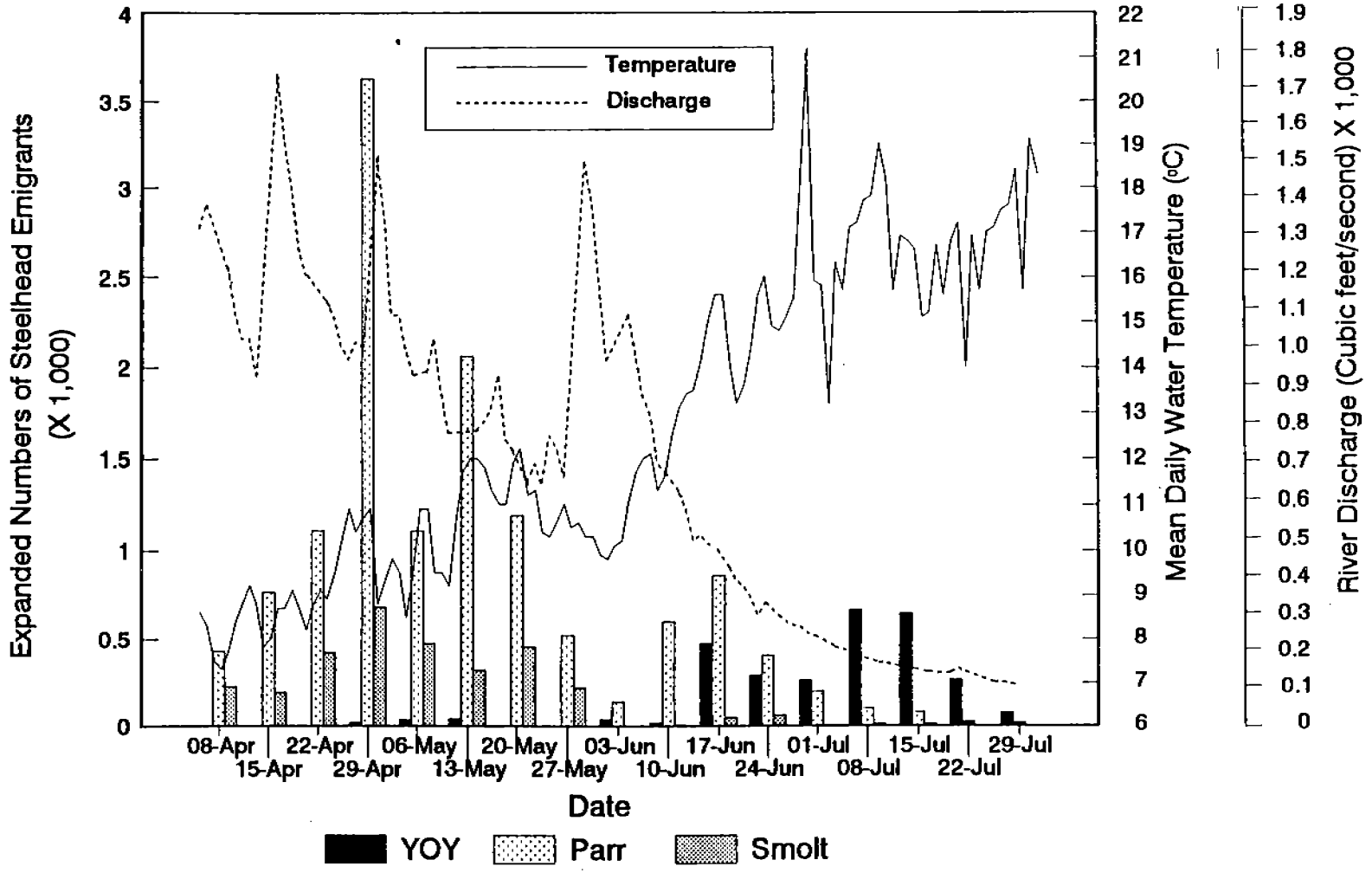

Figure 22. Expanded numbers of steelhead YOY, parr and smolts in relation to the river discharge and daily mean water temperature during FY 1993.

number of summer steelhead spawners in 1992 (272) and in 1990 (343) were low, corresponding with the low number of progeny in each of the subsequent years (2,877 in 1993 and 1,782 in 1991). However, this was not the case in 1989, when a relatively high number of summer steelhead spawners (687) produced a relatively low number of YOY emigrants (2,057) the following year. Numbers of emigrating YOY progeny are influenced not only by the number of spawners, but by numerous other factors such as the stability of flows during incubation, the overall volume of rearing habitat available, food availability and depredation rates. Even though September counts of adult steelhead (Table 1) do not include numbers of fall or winter steelhead, they have roughly corresponded to total estimates of emigrating YOY steelhead during the following spring and summer (Figure 23). In the future, numbers of fall and winter steelhead, provided by use of the weir, should produce a better relationship between adult and YOY numbers.

Steelhead parr and smolts. A few steelhead parr and smolts were trapped in the first days of screw trap operation, suggesting that they may have begun to emigrate prior to installation of the trap. Numbers peaked in early May, with very few caught after June 1 (Figures 24 and 25).

There appears to be a relationship between timing of peak emigrations of steelhead parr and smolts and daily maximum water temperatures, based on screw trap catches from 1989 to 1993 (Figures 24 and 25). Maximum daily temperatures of 10°-12°C were associated with peak emigration of steelhead parr and smolts in each of the five years.

Monthly length-frequency histograms for March 29 through August 2 are presented in Figure 26. Scale samples were age-analyzed for those fish whose fork lengths did not fall within a distinct age class in the length frequency histogram. A total of 210 scale samples, taken from fish with fork lengths ranging between 70 and 211 mm, were analyzed. Weekly mean fork lengths (± S.E.) are shown in Figure 27. Mean fork lengths for YOY steelhead ranged from 27 mm (Julian week 23) to 62 mm (Julian week 31), 1+ steelhead ranged from 86 mm (Julian week 13) to 130 mm (Julian week 31), and 2+ steelhead ranged from 140 mm (Julian week 26) to 186 mm (Julian week 24).

Volumetric measurements of 1,346 fish were taken during 1993. A log-transformed linear regression of the length-displacement relationship yielded a slope value of 2.84 for 1993 (Figure 28). This value did not differ significantly from values obtained in the previous three years, but did differ significantly ($p \leq 0.05$) from the value obtained in 1989.

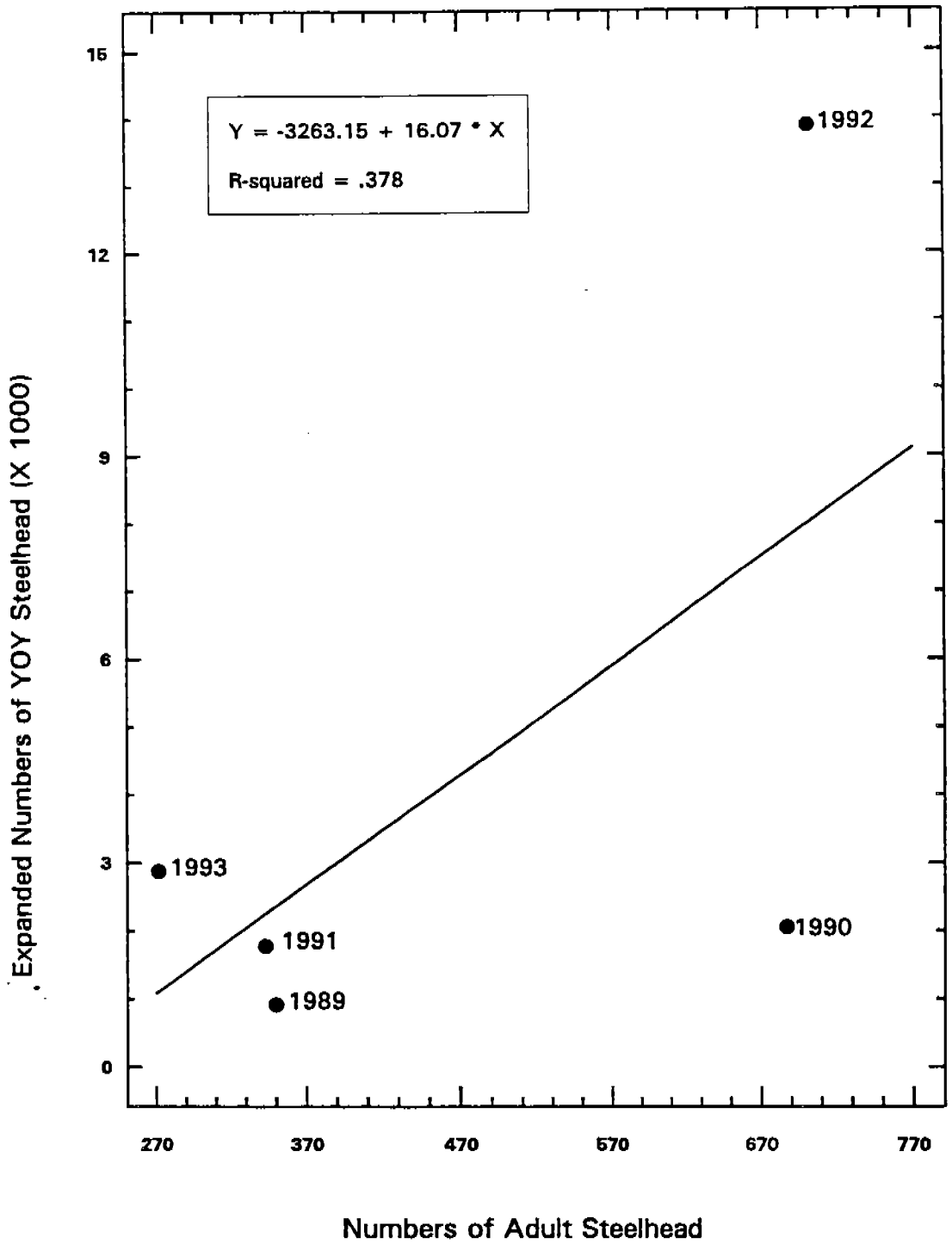

Figure 23. Relationship between the number of adult steelhead counted during snorkel surveys and the number of emigrating progeny caught in the rotary-screw trap.

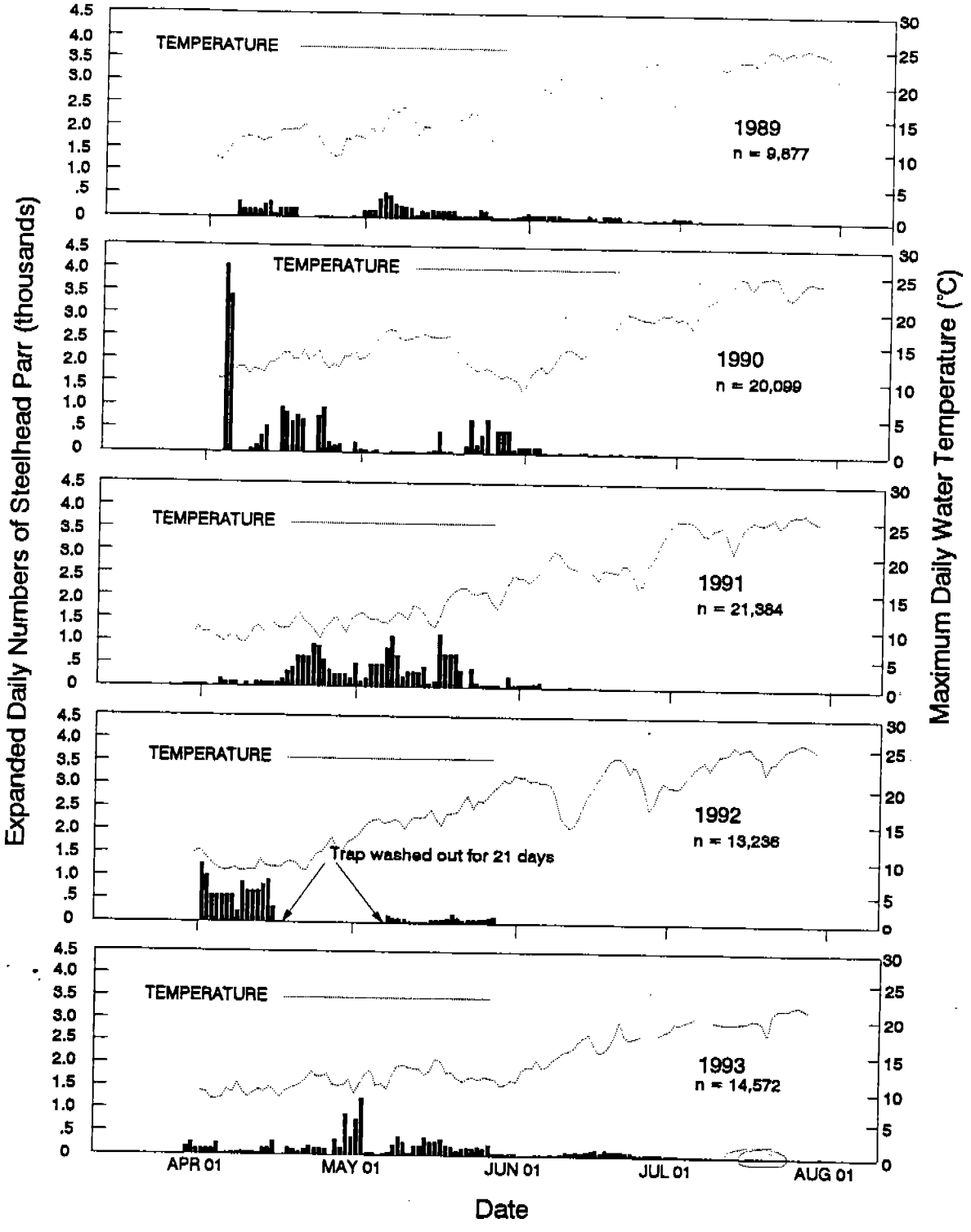

Figure 24. Steelhead parr expanded daily emigrant estimates, based on New River screw trap catches, 1989-93. Maximum daily water temperatures during the trapping season are presented on the second Y axis.

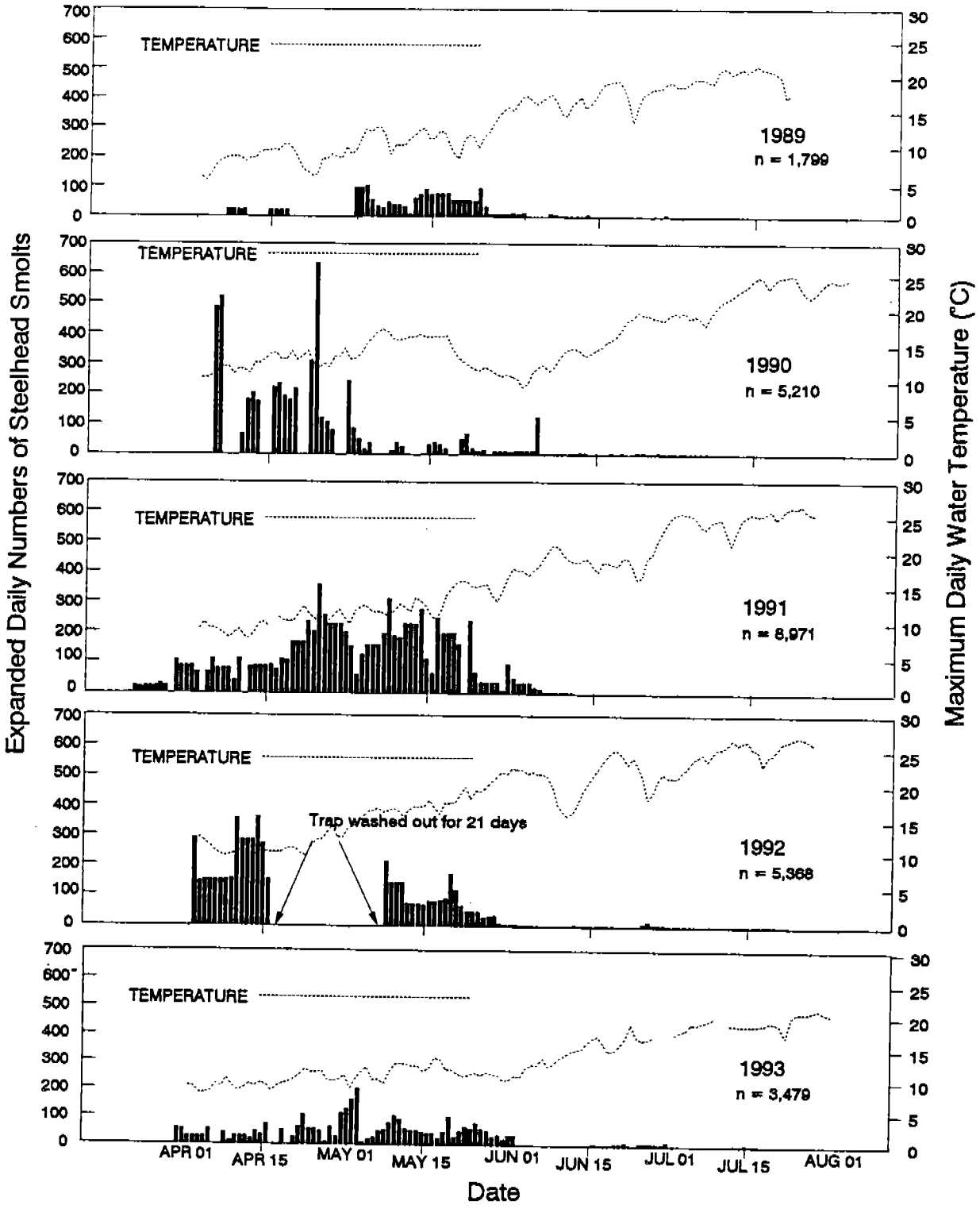

Figure 25. Steelhead smolt expanded daily emigrant estimates, based on New River screw trap catches during 1989-93. Maximum daily water temperatures during the trapping season are presented on the second Y axis.

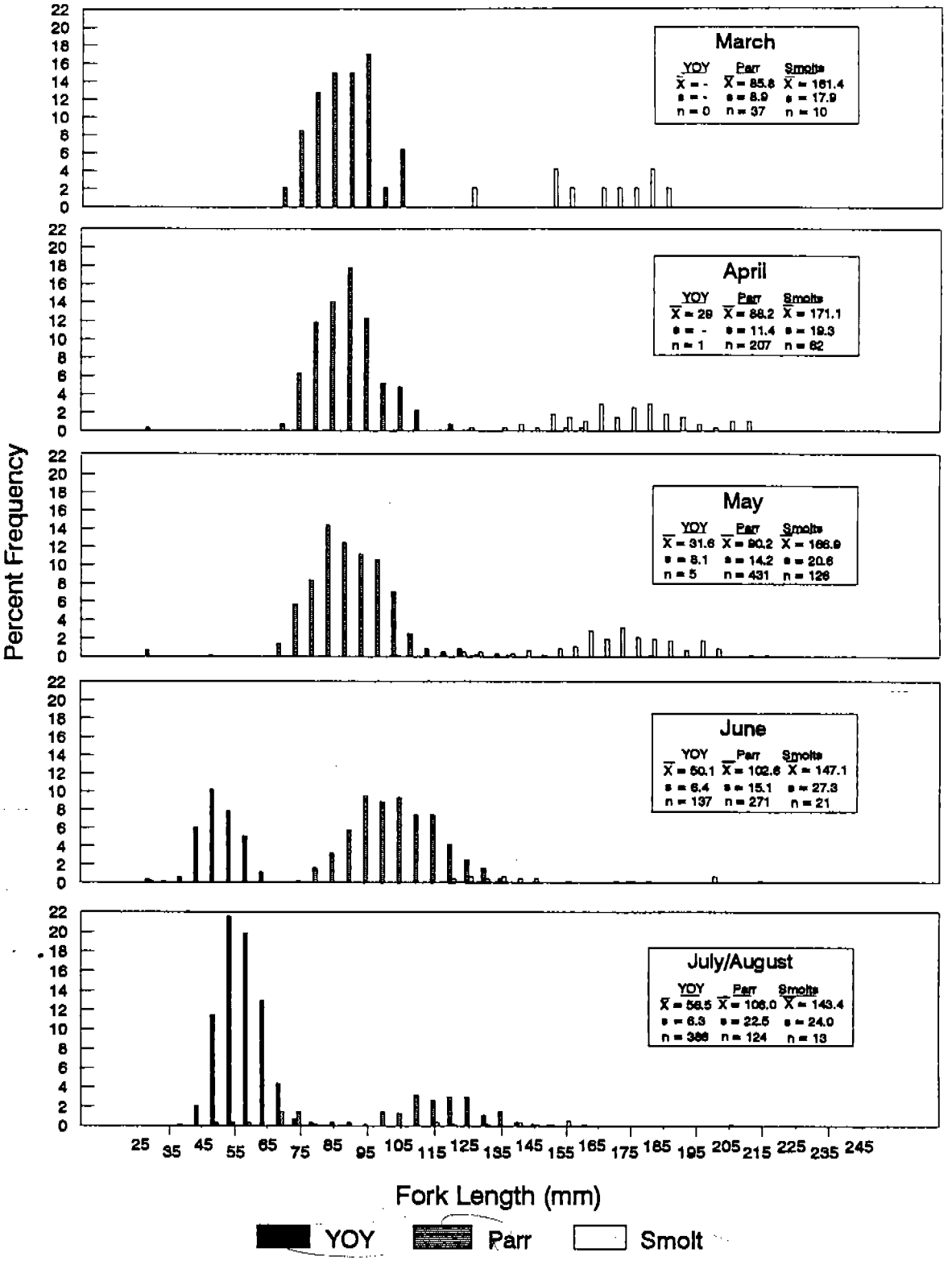

Figure 26. Juvenile steelhead length-frequency histograms by month, based on New River screw trap catches during FY 1993.

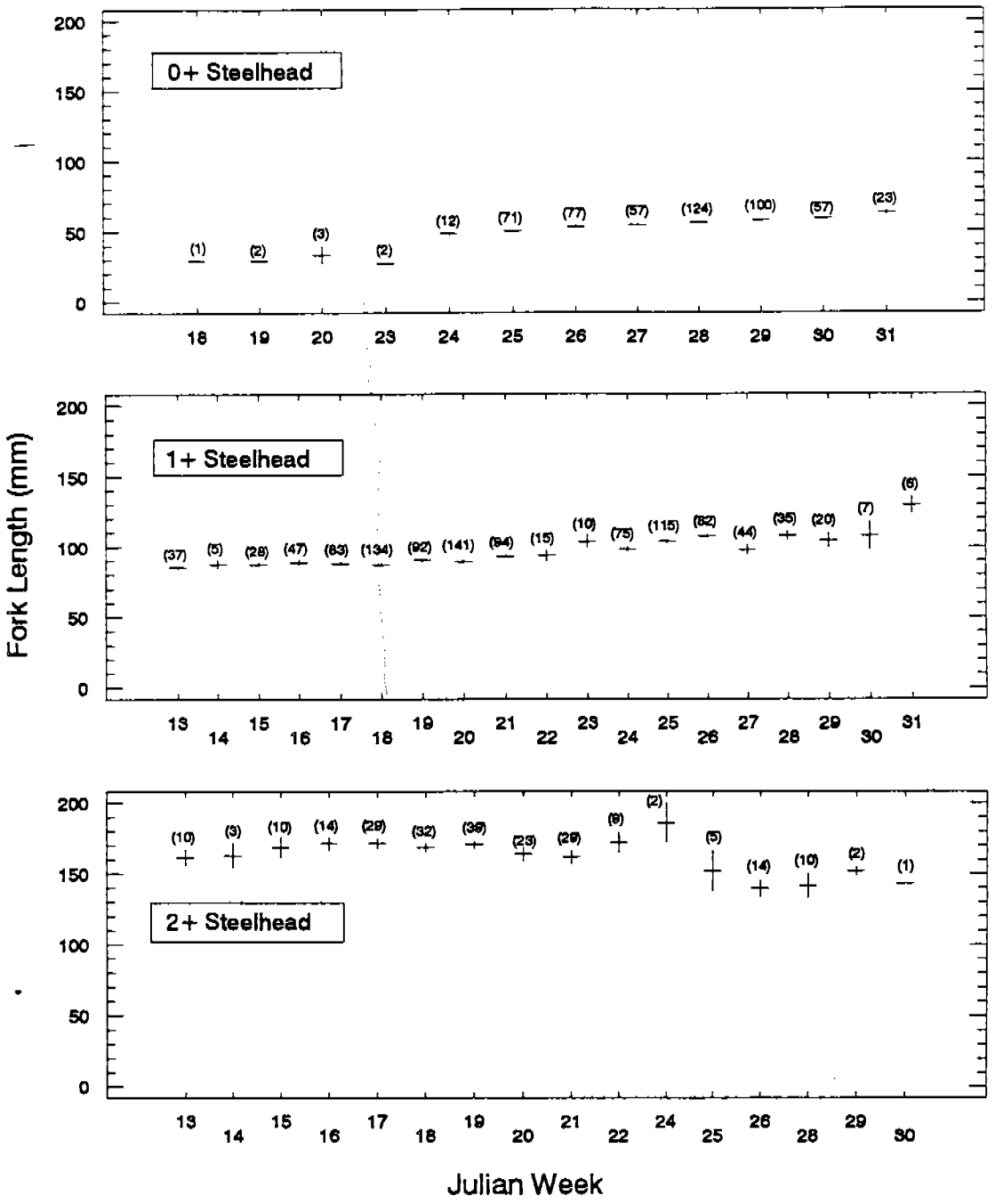

Figure 27. Mean fork lengths (± S.E.) of steelhead caught in the New River rotary-screw trap during Julian weeks 13-29 in FY 1993. Sample sizes are in parentheses. (Appendix C provides a list of Julian weeks and the corresponding calendar dates.)

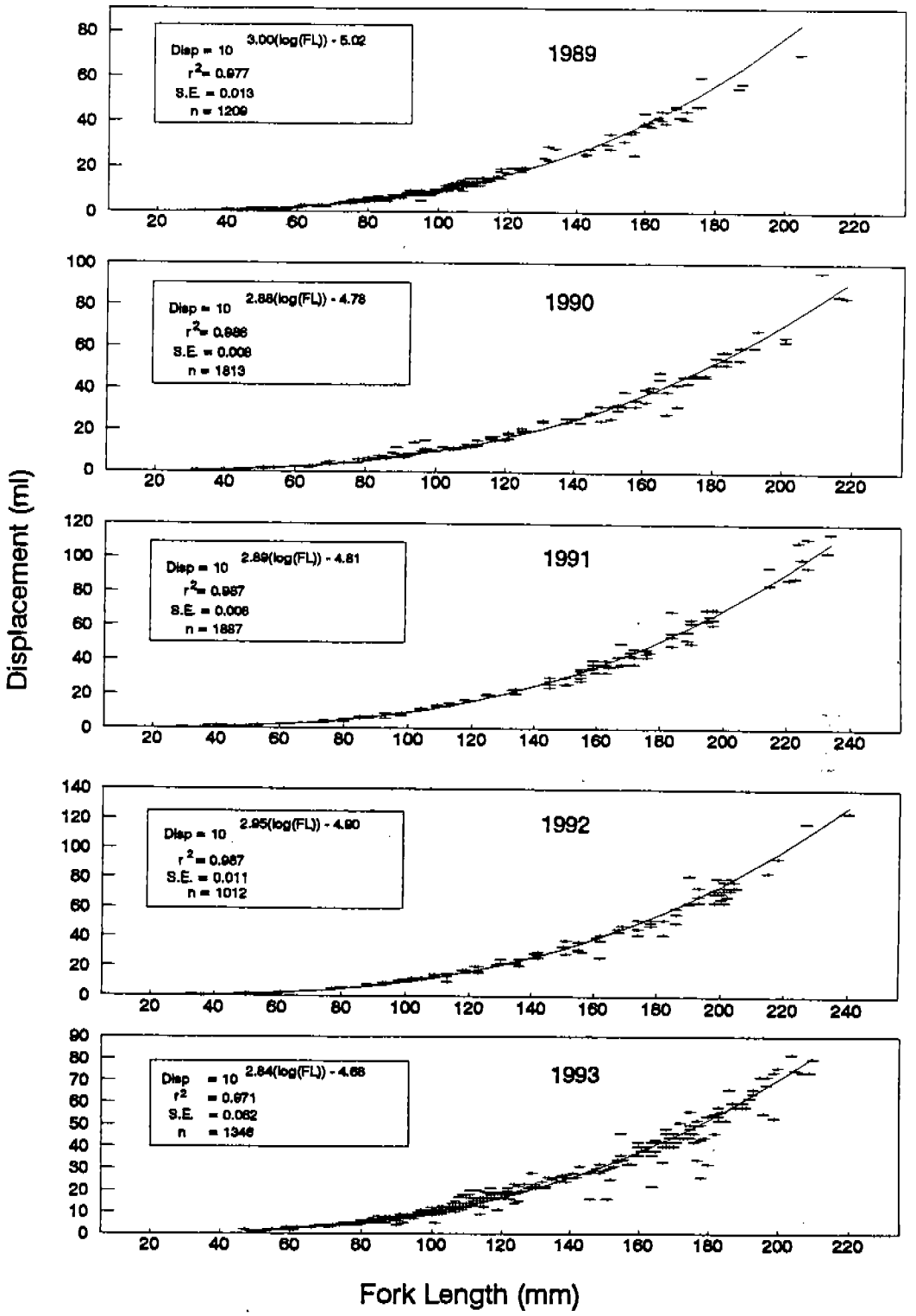

Figure 28. Juvenile steelhead length-displacement relationships from emigrants caught in the rotary-screw trap (rkm 3.75) on New River during 1989-93.

Juvenile salmonids appeared to be in good condition throughout the trapping season. Mortality rates were negligible (less than 0.1%) from trapping operations. No external diseases were observed, although puncture wounds from birds were observed on a few YOY steelhead and chinook.

SUMMARY

More than 80 km of high-quality steelhead spawning and rearing habitat are available in New River. Consequently, the numbers of summer steelhead are among the highest in the state (Table 2). During 1993, a total of 368 adult steelhead were observed during fall snorkel surveys, compared to a high of 702 individuals in 1991 and a low of 250 in 1982. Because snorkel surveys are not feasible during high winter flows, the numbers of fall and winter steelhead using the drainage are uncertain. A resistance-board weir was installed and operated during the winter of 1992-93 to trap immigrating fall and winter races of steelhead. However, high winter flows destroyed the weir in mid-January after only 29 steelhead had been trapped. The number of fall and winter steelhead adults will be estimated when the renovated weir is operated during the winter of 1993-94.

The chinook population in New River appears to be very low. A survey of potential spawning habitat in the main-stem New River revealed that an estimated 1,442 to 2,351 spawning chinook pairs could potentially spawn in New River (USFWS, 1991). However, a redd survey conducted in the fall of 1992 (FY 1993) identified only 10 chinook redds. Three of these were believed to be spring chinook redds. A total of three spring chinook adults and 15 jacks had been counted during the preceding adult spawner surveys. Another 31 adults, all believed to be fall chinook, were trapped at the weir during late October and November. However, snorkel surveys located only seven redds that were identified as fall chinook redds. A total of 31 spring chinook adults were counted during the subsequent spawner surveys in September of 1993. Snorkel surveys identified a total of 28 spring chinook redds during the following months. This was the largest number of adults and redds counted during this study (1989-93). Increased river discharge (Figure 6) and decreased water temperatures (Figure 5) during the summer may have facilitated the movement of spring chinook into New River. An additional 25 redds were counted in mid- to late-November. All of these were believed to be fall chinook redds. This was also the largest number of fall chinook redds counted to date (1989-93).

A rotary-screw trap was used to capture emigrating juvenile salmonids at rkm 3.75 for the fifth season during 1993. An average of 23% (a range of 4% - 77%) of the total stream flow

was sampled by the screw trap. A total of 104 YOY chinook, 0 age 1+ chinook, 817 YOY steelhead, 1,231 steelhead parr, and 253 steelhead smolts (Table 3) were trapped during the 83 nights of operation (March 29 to August 2).

Based upon the time of first appearance of fry in the rotary-screw trap catches, emergence of chinook from the spawning gravel is estimated to occur in late February. Steelhead emergence probably occurs in April and May. Juvenile emigrant trapping over the last five years has indicated that peak emigration of juvenile chinook occurs between mid-May and late June. Emigration of steelhead parr and smolts occurs throughout the early trapping season. The peak in 1993 occurred in early May.

The 1993 abundance index estimate for emigrating YOY steelhead (2,877) was much less than in 1992 (13,878), but was comparable to other sampling years (Figure 21). The number of emigrating juveniles is determined by numerous factors including the run size of the adult spawners, the stability of river flows during incubation, food availability and depredation rates. In this case, low numbers of summer steelhead spawners the previous winter (272), coupled with high, scouring flows during spawning and incubation may have been the most influential factors.

The relative contribution of summer and fall/winter steelhead spawners is still unknown. However, future trapping of fall and winter steelhead at the weir site combined with adult snorkel surveys should provide relative numbers of each race, and enable a better correlation between estimated adult numbers and YOY abundance index estimates.

Most juvenile steelhead emigrate from New River as parr (1+) (Figure 24). However, scale samples taken from returning adults indicated that 95% had spent their first two years of life in freshwater. Therefore, suitable down-stream rearing habitats in the Trinity and Klamath rivers may be critical to the continued success of the New River population.

The abundance index estimate for emigrating YOY chinook (709) was 12% lower than in 1992, and was the lowest estimate to date (1989-93). There had been a correspondingly low number of spring chinook spawners (3 adults, 15 jacks) the previous fall.

Juvenile snorkel surveys of designated index reaches have been undertaken in late summer every year since 1990. No juvenile chinook were sighted during the 1993 surveys. The mean density (fish/m^3) of YOY steelhead in the mainstem, and in each of the tributaries, was significantly lower in 1993 than in any previous year (Figure 9). This is probably

attributable to the low number of adult spawners the previous winter coupled with the high river flows during spawning and incubation.

In contrast to the variable densities of the YOY steelhead, the mean density of steelhead parr (1+) in the mainstem, and in the tributaries, has not differed significantly during the four years of the study (Figure 11). Because most of the steelhead that remain in the system at the time of the surveys will overwinter in the system and emigrate during the following season, the constant densities may indicate that all habitats suitable for overwintering parr are being utilized each year. All juveniles that are not occupying suitable habitats emigrate out of the system earlier in the summer.

Mean densities of YOY and 1+ steelhead differed significantly among the various habitat types identified in the mainstem, East Fork and Slide Creek index reaches over the four years of the study (Figures 10 and 12). Over the past four years, mean densities of YOY steelhead in the mainstem index reaches were highest in low-gradient riffles and side-channels and lowest in corner pools and mid-channel pools. Mean densities of 1+ steelhead were highest in step-runs and pocket-water areas and lowest in corner pools and mid-channel pools. The surprisingly low densities of YOY and 1+ steelhead in mainstem pools probably results from the large cubic volumes of most of the pools. Juveniles tend to occur in the shallower tail-out areas of pools, not in the deep, mid-pool area. However, the entire volume of the pool is used in calculating the density (fish per cubic meter). Conversely, the highest mean densities have been found to occur in habitats that are relatively shallow and have a low volume (riffles and runs).

The mean densities of YOY and 1+ steelhead in the Virgin Creek index reaches have not differed significantly ($P > 0.05$) among the 10 identified habitat types over the four years of the study.

Long term monitoring of the index reaches should provide additional information on habitat preferences and population trends in New River. New River has not been subjected to any major restoration projects and lies within a relatively undisturbed watershed. Because the system has been manipulated in a minimal way relative to other northern California rivers, it appears to have potential as an index tributary to monitor salmonid population trends that are not associated with habitat restoration or watershed rehabilitation projects.

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APPENDIX A. Channel classification as described by Rosgen 1985.

Stream Type	Gradient (%)	Dominant Particle Size of Channel Materials	Channel Entrenchment Valley Confinement
A1	4-10	Bedrock	Very deep; very well confined
A1-a	10+	Same as A1	
A2	4-10	Large & small boulders w/mixed cobbles	Same as A1
A2-a	10+	Same as A2	
A3	4-10	Small boulders, cobbles, coarse gravels, some sand.	Same as A1
A3-a	10+	Same as A3	
A4	4-10	Predominantly gravel, sand, and some silts.	Same as A1
A4-a	10+	Same as A4	
A5	4-10	Silt and/or clay bed and bank materials.	Same as A1
A5-a	10+	Same as A5	
B1-1	1.5-4.0	Bedrock bed:banks are cobble, gravel, some sand.	Shallow entrench-ment; moderate confinement
B1	2.5-4.0 (X=3.5)	Predominately small boulders and very large cobble.	Moderate entrench-ment; moderate confinement
B2	1.5-2.5 (X=2.0)	Large cobble mixed w/small boulders and coarse gravels	Moderate entrench-ment; moderate confinement
B3	1.5-4.0 (X=2.5)	Cobble bed w/mixture of gravel and sand. Some small boulders	Moderate entrench-ment; well confined
B4	1.5-4.0 (X=2.0)	Very coarse gravel w/cobbles, sand and finer materials	Deeply entrenched; well
B5	1.5-4.0 (X=2.5)	Silt / clay	Deeply entrenched; well confined.
B6	1.5-4.0	Gravel w/few cobbles and w/noncohesive sand and finer soil.	Deeply entrenched; slightly confined

			Stream type
C1-1	1.5 or less (X=1.0)	Bedrock bed, gravel sand or finer banks.	Shallow entrenchment; partially confined.
C1	1.0-1.5 (X= 1.3)	Cobble, coarse gravel bed, gravel, sand banks.	Moderate entrenchment; well confined.
C2	0.3-1.0 (X=0.6)	Large cobble bed w/mixture of small boulders and coarse gravel.	Moderate entrenchment; well confined.
C3	0.5-1.0 (X=0.8)	Gravel bed w/mixture of small cobble and sand.	Moderate entrenchment; slightly confined.
C4	0.1-0.5 (X=0.3)	Sand bed w/mixture of gravel and silt. No bed armor.	Moderate entrenchment; slightly confined.
C5	0.1 or less (X=0.05)	Silt clay w/mixture of medium to fine sand, no bed armor.	Moderate entrenchment; slightly confined.
C6	0.1 or less (X=0.05))	Sand bed w/mixture of silt and some gravel.	Deeply entrenched; unconfined.
D1	1.0 or greater (X=2.5)	Cobble bed w/mixture of coarse gravel, sand, and small boulders.	Slightly entrenched; no confinement.
D2	1.0 or less (X=1.0)	Sand bed w/mixture of small to medium gravel and silt.	Slightly entrenched; no confinement.
F1	1.0 or less	Bedrock bed w/few boulders, cobble and gravel.	Total confinement.
F3	1.0 or less	Cobble/gravel bed with locations of sand in depositional sites.	Same as F1
F4	1.0 or less	Sand bed with smaller amounts of silt and gravel.	Same as F1
F5	1.0 or less	Silt/clay bed and banks with smaller amounts of sand.	Same as F1

APPENDIX B. Habitat types and descriptions.

CODE	HABITAT TYPE	DESCRIPTION
0	Side Channel (SCH)	Less than half the flow in a parallel channel.
1	Low-Gradient Riffle (LGR)	Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient <4%, substrate is usually cobble dominated.
2	High-Gradient Riffle (HGR)	Steep reaches of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively high. Gradient is >4%, and substrate is boulder dominated.
3	Cascade (CAS)	The steepest riffle habitat, consisting of alternating small waterfalls and shallow pools. Substrate is usually bedrock and boulders.
4	Secondary-Channel Pool (SCP)	Pools formed outside of the average wetted channel width. During summer, these pools will dry up or have very little flow. Mainly associated with gravel bars and may contain sand and silt substrates.
5	Backwater Pool formed by Boulder (BwBo)	Found along channel margins and caused by eddies around obstructions such as boulders, rootwads, or woody debris. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.
6	Backwater Pool formed by Root-wad (BwRw)	
7	Backwater Pool formed by Log (BwL)	
8	Trench/Chute (TRC)	Channel cross sections typically U-shaped with bedrock or coarse-grained bottom flanked by bedrock walls. Current velocities are swift and the direction of flow is uniform. May be pool-like.
9	Plunge Pool (PLP)	Found where stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring out

a depression; often large and deep. Substrate size is highly variable.

10 Lateral-Scour Pool formed by Log (LsL)
Formed by flow impinging against one streambank or against a partial channel obstruction. The associated scour is generally confined to <60% of wetted channel width. Channel obstructions include rootwads, woody debris, boulders and bedrock.

11 Lateral-Scour Pool formed by Root-wad (LsRw)

12 Lateral-Scour Pool formed by Bedrock (LsBk)

13 Dammed Pool (DPL)
Water impounded from a complete or nearly complete channel blockage (debris jams, landslides or beaver dams). Substrates tend toward smaller gravels and sand.

14 Glides (GLDA)
A wide uniform channel bottom. Flow with low to moderate velocities, lacking pronounced turbulence. Substrate usually consists of cobble, gravel and sand.

15 Run (RUN)
Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrates are gravel, cobble and boulders.

16 Step-Run (SRN)
A sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.

17 Mid-Channel Pool (MCP)
Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.

18 Edgewater (EGW)
Quiet, shallow area found along the margins of the stream, typically associated with riffles. Water velocity is low and sometimes lacking. Substrates vary from cobbles to boulders.

19 Channel-Confluence Pool (CCP)
Large pools formed at the confluence of two or more channels. Scour can be due to plunges, lateral obstructions or scour at the channel

intersections. Velocity and turbulence are usually greater than those in other pool types.

20 Lateral-Scour Pool formed by boulder (LsBo)
Formed by flow impinging against boulders that create a partial channel obstruction. The associated scour is confined to <60% of wetted channel width.

21 Pocket-Water (POW)
A section of swift flowing stream containing numerous boulders or other large obstructions which create eddies or scour holes (pockets) behind the obstructions.

22 Corner Pool (CRP)
Pools formed at a sharp bend in the channel. These pools are common in lowland valley bottoms where stream banks consist of alluvium and lack hard obstructions.

23 Step Pool (STP)
A series of pools separated by short riffles or cascades. Generally found in high gradient, confined mountain streams dominated by boulder substrate.

24 Bedrock-Sheet (BRS)
A thin sheet of water flowing over a smooth bedrock surface. Gradients are highly variable.

APPENDIX C. List of Julian weeks and calendar dates.

Julian week	Calendar date		Julian week	Calendar date	
	start	end		start	end
01	Jan 01	Jan 07	27	Jul 02	Jul 08
02	Jan 08	Jan 14	28	Jul 09	Jul 15
03	Jan 15	Jan 21	29	Jul 16	Jul 22
04	Jan 22	Jan 28	30	Jul 23	Jul 29
05	Jan 29	Feb 04	31	Jul 30	Aug 05
06	Feb 05	Feb 11	32	Aug 06	Aug 12
07	Feb 12	Feb 18	33	Aug 13	Aug 19
08	Feb 19	Feb 25	34	Aug 20	Aug 26
09	Feb 26	Mar 04	35	Aug 27	Sep 02
10	Mar 05	Mar 11	36	Sep 03	Sep 09
11	Mar 12	Mar 18	37	Sep 10	Sep 16
12	Mar 19	Mar 25	38	Sep 17	Sep 23
13	Mar 26	Apr 01	39	Sep 24	Sep 30
14	Apr 02	Apr 08	40	Oct 01	Oct 07
15	Apr 09	Apr 15	41	Oct 08	Oct 14
16	Apr 16	Apr 22	42	Oct 15	Oct 21
17	Apr 23	Apr 29	43	Oct 22	Oct 28
18	Apr 30	May 06	44	Oct 29	Nov 04
19	May 07	May 13	45	Nov 05	Nov 11
20	May 14	May 20	46	Nov 12	Nov 18
21	May 21	May 27	47	Nov 19	Nov 25
22	May 28	Jun 03	48	Nov 26	Dec 02
23	Jun 04	Jun 10	49	Dec 03	Dec 09
24	Jun 11	Jun 17	50	Dec 10	Dec 16
25	Jun 18	Jun 24	51	Dec 17	Dec 23
26	Jun 25	Jul 01	52	Dec 24	Dec 31