HABITAT USE, ABUNDANCE, TIMING, AND FACTORS RELATED TO THE ABUNDANCE OF SUBYEARLING CHINOOK SALMON REARING ALONG THE SHORELINES OF LOWER SNAKE RIVER RESERVOIRS

Final Completion Report

Projects:

Abundance of Subyearling Chinook Salmon in Little Goose Reservoir, Washington, Spring 1991 (# 14-16-0009-1559)

Abundance, Habitat, and Migration of Age-0 Chinook Salmon in the Lower Snake River Reservoirs With Emphasis on Little Goose Reservoir, Washington, 1992 (#14-16-0009-1579)

Presence, Abundance, and Habitat Utilization of Subyearling Chinook Salmon in the Lower Snake River Reservoirs With Emphasis on Little Goose Reservoir, Washington, 1993 (# 14-16-0009-1579, #98210-3-4037)

by

David H. Bennett

Tom Dresser, Jr.

and

Melissa A. Madsen

Department of Fish and Wildlife

University of Idaho

Moscow, Idaho 83844-1136

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Location: CSR
Species: Subyearling Chinook Salmon
Subject 1: Habitat
Subject 2: Abundance
Subject 3:

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ABSTRACT

A total of 331 subyearling chinook salmon was captured between 10 April through 15 July 1993 in Lower Granite Reservoir compared to 155 subyearling chinook salmon collected in Little Goose Reservoir about the same time. The estimated population size of subyearling chinook salmon in Lower Granite Reservoir peaked on 2 June 1993 at 6,346 fish whereas the estimated population abundance of subyearling chinook along the shoreline in Little Goose Reservoir peaked at 10,701 fish on 29 May 1993. Subyearling chinook salmon collected throughout Lower Granite Reservoir were associated with either sand (84%), sand/talus (6%), sand/cobble (5%), or rip-rap (5.5%) while those in Little Goose Reservoir exhibited a strong preference for sand substrates and high avoidance of talus and riprap. Rearing of subyearling chinook along the shoreline was about 96 days in 1993 and the overall rearing period was approximately 100 days, compared to 75 days in 1992 and 112 days in 1991. As in previous years, subyearling chinook salmon migrated from the shoreline when water temperatures reached approximately 16°C in 1993. Lower Monumental and Ice Harbor reservoirs were sampled for temporal and spatial comparisons of abundance of subyearling chinook salmon. Nineteen subyearling chinook were captured in Lower Monumental Reservoir during spring, and the highest abundance occurred on 13 June 1993. A total of 10 subyearling chinook salmon was collected in Ice Harbor Reservoir and the highest abundance occurred on 8 July 1993. Substrate analyses of largely shallow shoreline areas of Lower Granite and Little Goose reservoirs indicated the substrata were comprised of mainly finer materials. Substrata were generally < 25 mm and, based on laboratory analyses using the Bouyoucos method, were composed largely of fine sands and silts.

INTRODUCTION

Concerns for the depressed status of chinook salmon *Oncorhynchus tschawytscha* and listing as a threatened species in the Snake River system have initiated a myriad of research efforts. Efforts related to enhancing survival of downstream migrating juvenile salmon have been conducted for numerous years, especially in the Snake River, due to low abundance and high mortality. Giorgi (1991) reported predation, food supply, and fish quality in the Snake River upstream of Lower Granite Reservoir were possible explanations for low juvenile salmon survival to Lower Granite Dam.

The abundance of fall chinook salmon has been of recent interest in the Snake River because of low abundance and less knowledge of their life cycle than spring and summer chinook salmon. Recent research by the U.S. Fish and Wildlife Service has focused attention on spawning and rearing of fall chinook salmon in the flowing portions of the Snake River downstream of Hells Canyon Dam and the Clearwater River (William Conner, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication). Also, to gain a better understanding of fall chinook behavior, information has been applied from fall chinook salmon research conducted in the Hanford Reach of the Columbia River (Dauble et al. 1989; Becker 1970).

Historically, the lower Snake River was used as spawning and rearing habitat by fall chinook, although with dam construction and impoundment, general perception has been that a major loss of habitat has occurred. This perception may be erroneous, however, as Bennett et al. (1983) provided circumstantial evidence that fall chinook salmon may be spawning in the tailwater of Lower Granite Dam. Bennett and Shrier (1986) first reported subyearling chinook salmon were rearing in Lower Granite Reservoir and additional estimates of abundance and intensive habitat evaluations have been conducted by Bennett et al. (1988, 1990, 1993a, 1993b, 1994, 1995, 1997). Subyearling chinook salmon collected in Lower Granite Reservoir are believed to be largely progeny of adult fall chinook that have spawned upstream of the reservoir in the Snake and

Clearwater rivers (William Conner, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication). Electrophoresis samples have indicated a large proportion of subyearling salmon collected in the flowing portion of the Snake River were fall chinook, although some subyearlings sampled were spring chinook salmon (William Conner, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication). Subyearling spring chinook were generally collected in the thalweg of the river, while subyearling fall chinook were collected along the shoreline.

Fall chinook spawning in the tailwater of Lower Granite Dam has recently been found. Divers from the National Marine Fisheries Service examined several possible spawning areas in the Lower Granite Dam tailwater prior to the 1992 test drawdown, but failed to locate redds. Recently, an underwater videographer filmed high probability of use areas and located several redds (Dauble et al. 1994). Collection of small (< 40 mm) subyearling chinook salmon along the shoreline of Little Goose Reservoir in similar rearing habitat as that used upstream in Lower Granite Reservoir, and during a time when no salmon this size were collected at the Lower Granite Dam fish collection facilities, provides strong support for survival from this natural spawning immediately downstream of Lower Granite Dam. Subyearling chinook have been periodically collected in Little Goose Reservoir since 1979.

The purpose of this study was to estimate instantaneous abundance, quantify habitat characteristics, determine timing of migration of subyearling (fall) chinook salmon in Lower Granite and Little Goose reservoirs, and to assess their presence in Lower Monumental and Ice Harbor reservoirs. This report consolidates all of our research conducted on subyearling chinook salmon in the lower Snake River reservoirs during the period from 1987 through 1993.

OBJECTIVES

1. *To estimate abundance of subyearling (fall) chinook salmon in Lower Granite and Little Goose reservoirs;*

2. *To assess habitat preference and extent of utilization in Lower Granite and Little Goose reservoirs;*

3. *To assess timing and habitat characteristics when subyearling chinook salmon migrate from the shorelines of Little Goose Reservoir;*

4. *To assess distribution and factors that affect distribution of subyearling chinook salmon from shoreline to offshore areas in the lower Snake River reservoirs;*

5. *To assess the presence and abundance of subyearling chinook salmon in Lower Monumental and Ice Harbor reservoirs; and*

6. *To assess factors affecting abundance of subyearling chinook salmon in Lower Granite Reservoir.*

STUDY AREA

Four dams were constructed on the lower Snake River from 1961 to 1975. As indicated, habitat flooded by these dams was once considered spawning and rearing habitat for fall chinook salmon. Waters impounded from one reservoir extend upstream to the next dam; no free-flowing waters remain in this section of the lower Snake River.

Lower Granite Reservoir

Lower Granite Reservoir was formed by the construction of the Lower Granite Lock and Dam project in 1975 providing flood control, recreation, navigation, and electrical power generation (Bennett and Shrier 1986; Figure 1). Lower Granite Reservoir has a surface area of 3,602 ha (8,897 acres) with a mean depth of 16.6 m (54.4 ft). Lower Granite Dam is located at river mile (RM) 107.5 and the reservoir extends upstream in the Snake River to RM 148 (Snake River) and to RM 10 in the Clearwater River (U.S. Army

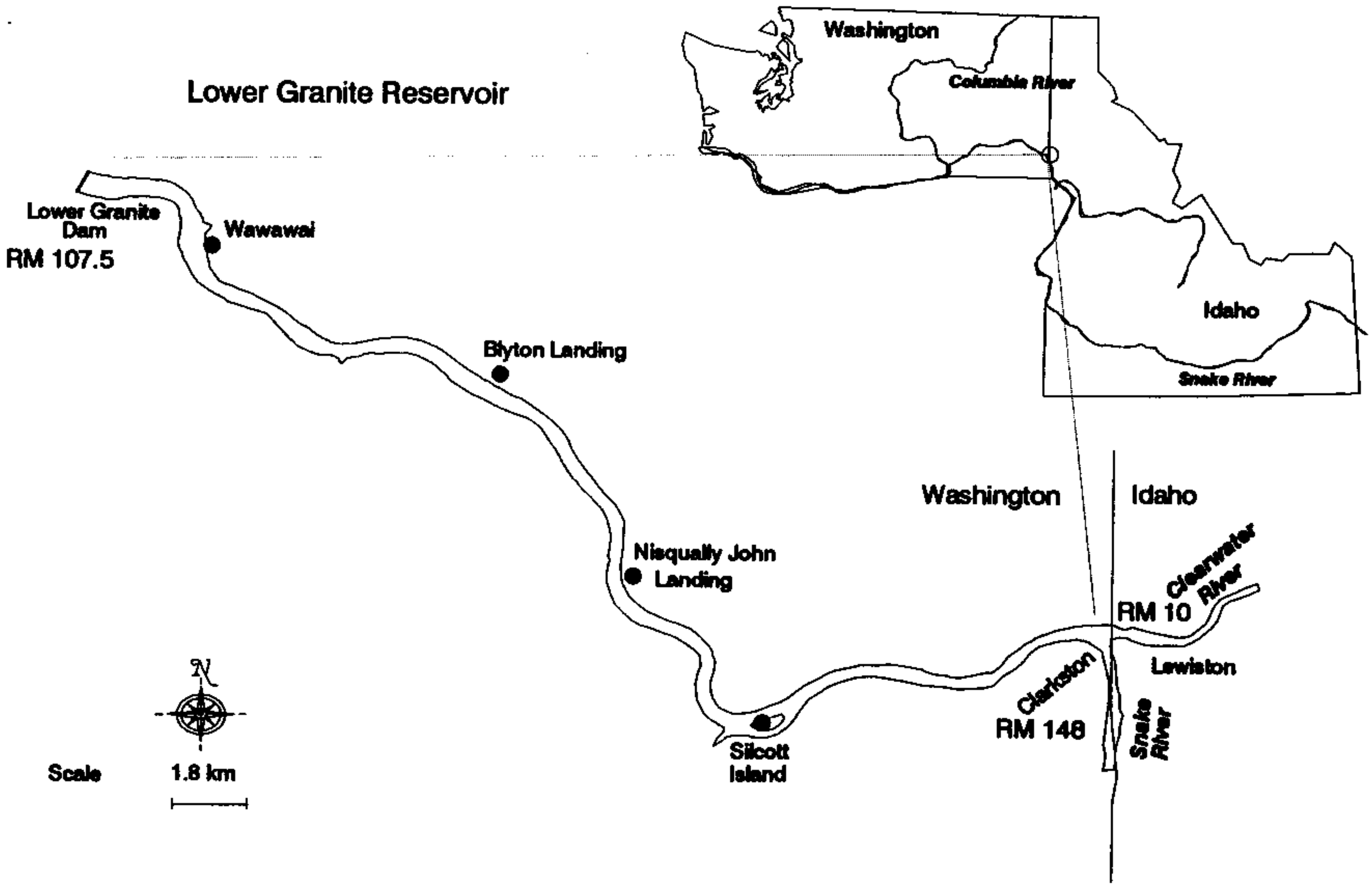

Figure 1. Lower Granite Reservoir, Idaho-Washington, sampled for subyearling chinook salmon. RM indicates river mile. Map modeled from the Mid-1980s System Description (U.S. Army Corps of Engineers 1977).

Corps of Engineers 1977). Substrata vary along the shoreline from rip-rap, mud, and sand beaches to steep basalt cliffs. Riparian vegetation in the upper-reservoir areas and at alluvial fans consists of short grasses, shrubs, and some cattails. In the lower sections of the reservoir, riparian vegetation is sparse as a result of the steep bathymetry and the 1.5-m (5-ft) water level fluctuations from reservoir operations. Aquatic macrophytes vary spatially and temporally and occur in localized areas throughout the reservoir (Bennett et al. 1997).

Lower Granite Reservoir was stratified by habitat type based on shoreline characteristics and location in the reservoir. We used a general classification of habitat; sand, sand-cobble, sand-talus, and rip-rap (Curet 1994). Sampling was allocated over these habitats.

Little Goose Reservoir

Little Goose Reservoir was formed by the construction of Little Goose Lock and Dam in 1970 and extends downstream from Lower Granite Dam at RM 107.5 to Little Goose Dam at RM 70.1 (Figure 2). The total surface area of the reservoir is 4,057 ha (10,017 acres) and the total length is 60 km (37.3 miles) with 142 km (88 miles) of shoreline. The width of the reservoir varies from 0.3 to 1.3 km (0.2 to 0.8 miles). Shoreline habitats vary from "natural" to man-altered by placement of rip-rap. The north shoreline is largely rip-rap and the south shoreline has been altered by livestock grazing and development activities.

We stratified Little Goose Reservoir by habitat type based on previous habitat assessments (Bennett et al. 1983) and aerial surveys conducted during the March 1992 test drawdown. Habitats were classified as rip-rap, talus, cobble, and sand. Previous surveys and collections of fall chinook salmon indicated the reservoir would be best divided into three reaches (Figure 2). Transects were then made along each 0.80-km (0.5-

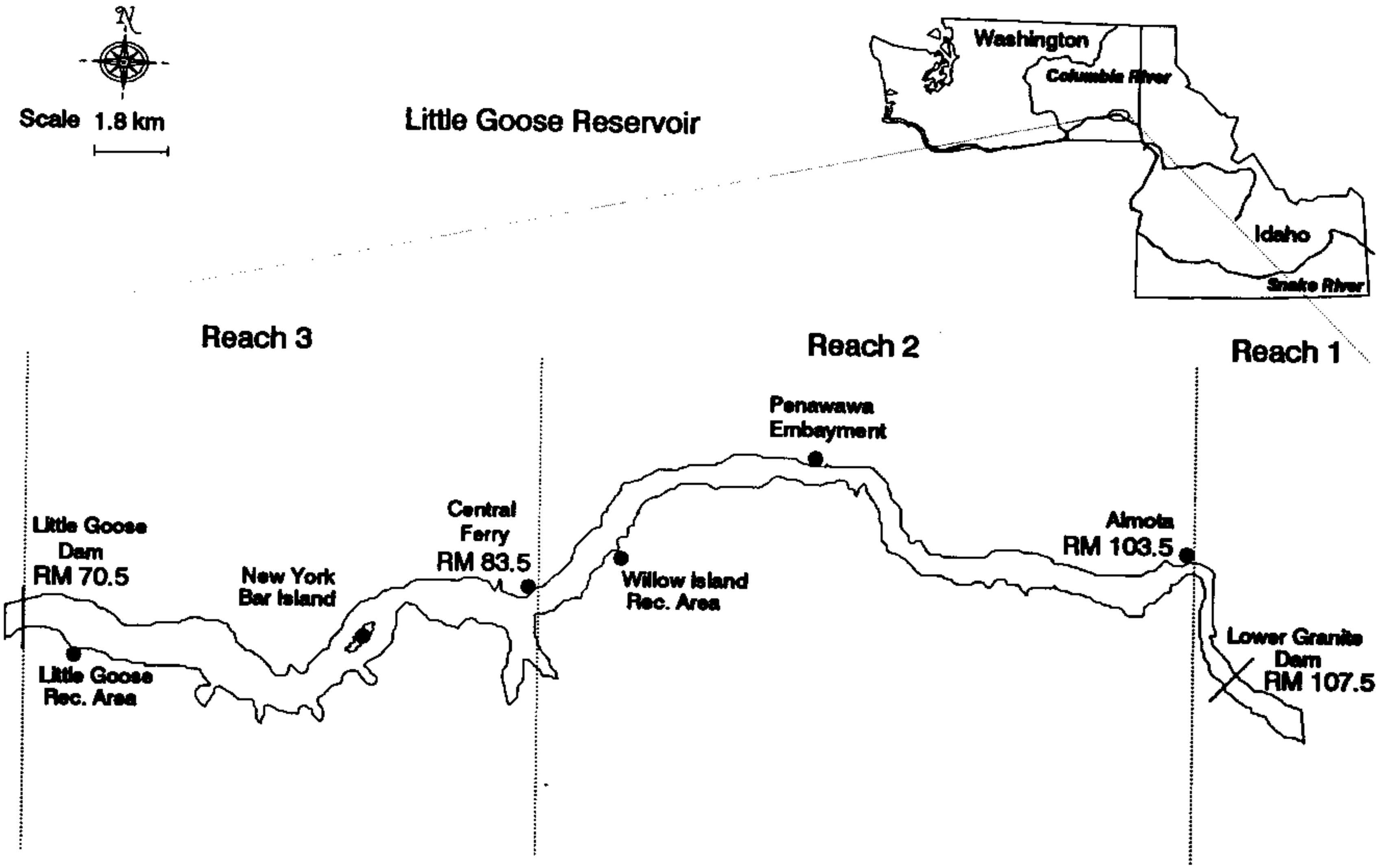

Figure 2. Three reaches in Little Goose Reservoir, Washington, sampled for subyearling chinook salmon during 1991, 1992, and 1993. RM indicates river mile. Map modeled from the Mid-1960s System Description (U.S. Army Corps of Engineers 1977).

mile) segment of the reservoir. Reach 1 extended from the tailwater of Lower Granite Dam (RM 107.5) downstream to Almota (RM 103.5). This reach was characterized by higher water velocities from Lower Granite Dam than Reaches 2 and 3 and substrata consisting primarily of rip-rap and cobble on the northern shoreline and sand and gravel on the southern shoreline. Reach 2 extended from RM 103.5 to approximately RM 83.5 at Central Ferry. Reach 3 extended from RM 83.5 to RM 70.5 at Little Goose Dam. Reaches 2 and 3 have a combination of four general habitat types: embayment, rip-rap shorelines, sandy shorelines, and talus slopes (Bennett et al. 1983). The northern shores in the mid and lower reaches were generally railroad rip-rap. Embayments were more common in the lower region.

Lower Monumental Reservoir

Lower Monumental Reservoir extends from RM 70.5 to RM 41.7 (Figure 3). The reservoir was formed in 1969 by the construction of the Lower Monumental Lock and Dam project. The project impounds water to Little Goose Lock and Dam and the total surface area is 2,667 ha (6,590 acres). Lower Monumental Reservoir averages < 0.6 km (0.4 miles) wide and is characterized by steep basalt cliffs and benches rising to > 305 m (> 1,000 ft) msl. Average depth is 17.4 m (57.2 ft) and two major tributaries, the Palouse and Tucannon rivers, enter the reservoir.

We stratified Lower Monumental Reservoir into three reaches. Reach 1 consisted of the upstream end of the reservoir from RM 70.5 downstream of Little Goose Dam to RM 66.5. Reach 1 was characterized by higher water velocities than other reaches in the reservoir. Reach 2 extended from RM 66.5 to RM 59. Reach 3 encompassed the lower portion of the reservoir from RM 59 to RM 41.7 at Lower Monumental Dam.

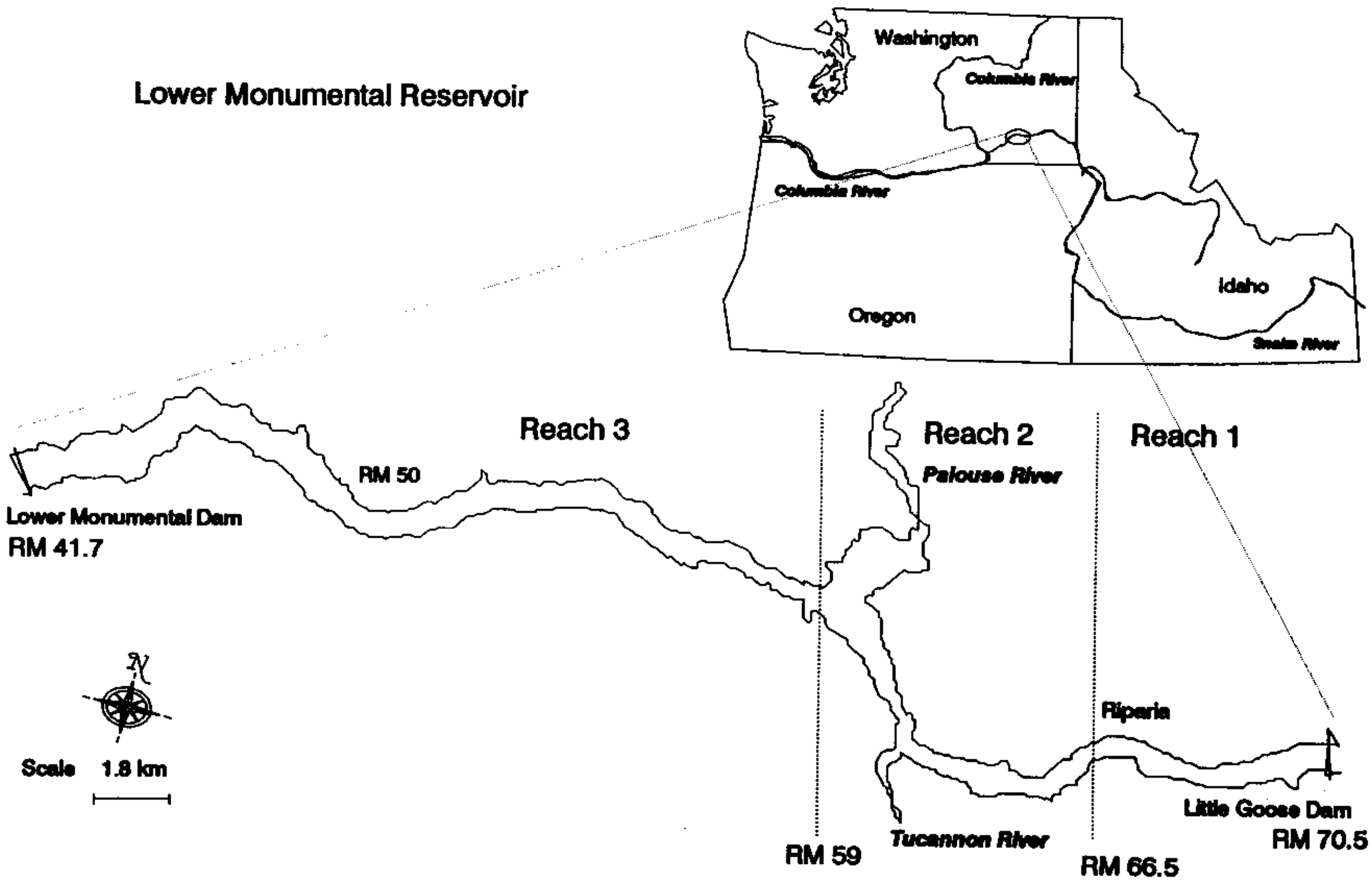

Figure 3. Three reaches in Lower Monumental Reservoir, Washington, sampled for subyearling chinook salmon during 1992 and 1993. RM indicates river mile. Map modeled after Mid-1980s System Description (U.S. Army Corps of Engineers 1977).

Ice Harbor Reservoir

Ice Harbor Reservoir was formed in 1961 by construction of the 30.4-m (100 ft) high Ice Harbor Lock and Dam at RM 9.7. The reservoir extends upstream to Lower Monumental Lock and Dam at RM 41.7 (Figure 4). Ice Harbor Reservoir averages 0.6 km (0.4 miles) wide with shorelines of basalt cliffs and benches rising to about 305 m (1,000 ft) msl. Mean depth is 14.5 m (48.6 ft). No major tributaries enter Ice Harbor Reservoir.

Ice Harbor Reservoir was stratified into three reaches. Reach 1 consisted of the upstream end of the reservoir from RM 41.7 to RM 35.2. Reach 1 was characterized by higher water velocities than other reaches in Ice Harbor Reservoir. Reach 2 extended from RM 35.2 to RM 27. Reach 3 consisted of the downstream end of the reservoir from RM 27 to RM 9.7 at Ice Harbor Dam.

METHODS

Fish Collections

Lower Granite, Little Goose, Lower Monumental, and Ice Harbor reservoirs were sampled to assess the presence and abundance of subyearling chinook salmon (Table 1). Sampling in Lower Granite and Little Goose reservoirs was generally conducted from April to July, whereas Lower Monumental and Ice Harbor reservoirs were sampled from June to August. Sampling was continued in all reservoirs until no juvenile chinook salmon were collected on two consecutive efforts.

Beach seining was the principal collection method using established methods (Bennett et al. 1988) for temporal and spatial comparisons of fish abundance. Seines were set parallel to the shoreline at a distance of 15.2 m (50 ft). Ropes, each 15.2 m (50 ft) long attached to the brails on the end of the seine, were pulled simultaneously to sample an area equivalent to 454 m^2 (1,482 ft^2) or 227 m^2 (744 ft^2) depending on the

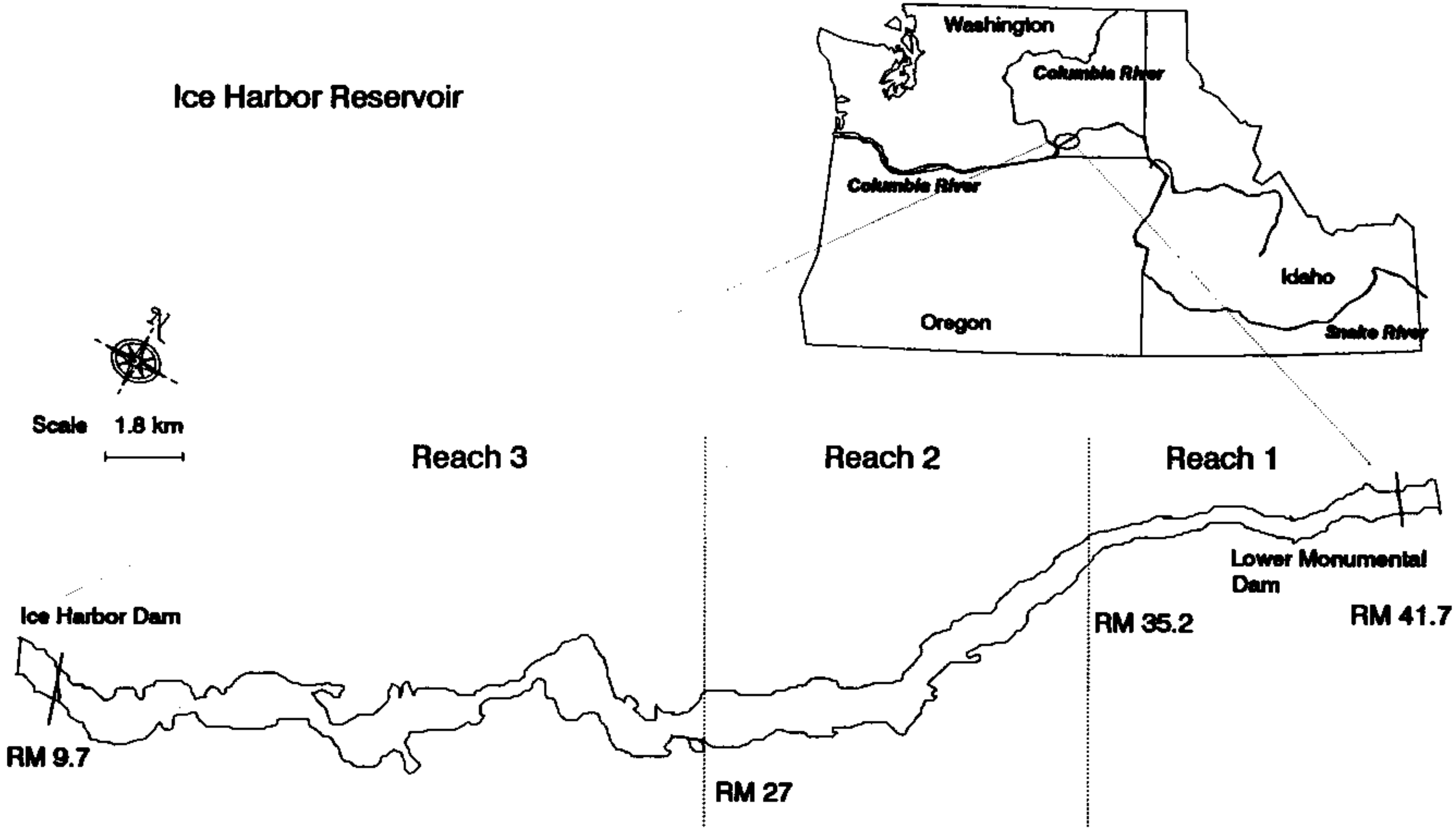

Figure 4. Three reaches in Ice Harbor Reservoir, Washington, sampled for subyearling chinook salmon during 1992 and 1993. RM indicates river mile. Map modeled from Mid-1980s System Description (U.S. Army Corps of Engineers 1977).

Table 1. Sampling efforts by reservoir, date, and gear for subyearling chinook salmon from 1987 through 1993 in lower Snake River reservoirs.

Reservoir	Year	Month	Gear
Lower Granite	1987	April–June	beach seine, purse seine, electrofishing
	1988	April–July	beach seine, electrofishing
		May–August, October November, February	bottom trawl, purse seine
		June–August	surface trawl
	1989	April–July	beach seine, electrofishing
		April–June	surface trawl
	1990	April–July	beach seine, electrofishing
		April–June	surface trawl
	1991	April–July	beach seine, electrofishing
		April–June	surface trawl
	1992	April–July	beach seine, electrofishing
		April–June	surface trawl
	1993	April–July	beach seine, electrofishing
Little Goose	1991	May–July	beach seine
	1992	May–July	beach seine
	1993	May–July	beach seine
Lower Monumental	1992	early June	beach seine
	1993	July–August	beach seine
Ice Harbor	1992	late June	beach seine
	1993	July–August	beach seine

beach seine used. Prior to 4 May, we used a 15.25 m x 2.4-m (50 ft x 8-ft) beach seine consisting of 0.32-cm (0.1-inch) knotless nylon mesh to ensure that small subyearling chinook salmon did not escape. After 4 May, a 30.5 m x 2.4-m (100 ft x 8-ft) beach seine consisting of 0.64-cm (0.25-inch) knotless nylon mesh was used. Each sampling effort consisted of 60 to 65 randomly selected beach seine hauls based on a stratified design for each reservoir. All beach seine collections were conducted during the day.

In 1992, surface, mid, and bottom trawling were conducted in areas of open water in Lower Granite Reservoir to assess the presence of subyearling chinook salmon 3 weeks after subyearlings disappeared from the shoreline of the reservoir. Sampling was conducted during the day and night to record diel movements. The principal time of movement of outmigrating juvenile salmonids occurs at night (Sims and Miller 1977; Mains and Smith 1964; Smith 1974; Dauble et al. 1989). In the Hanford Reach (approximately RM 329) of the Columbia River, the principal movement patterns of subyearling chinook salmon occurred just after darkness (2200 to 2400 h) throughout the river cross section, but the highest concentrations occurred near shore (< 9 m; Dauble et al. 1989). In other years, surface and bottom trawling was conducted during the daytime (Bennett et al. 1990). Daytime purse seining was also conducted in 1987 and 1988 (Bennett et al. 1988, 1990). We also sampled at night along the shoreline of Lower Granite Reservoir using boat mounted electrofishing techniques. Effort was variable among years (Bennett et al. 1990, 1993a, 1993b, 1994, 1995, 1997).

Measurements and Tag Interrogation

All subyearling chinook salmon collected were enumerated, measured to nearest millimeter (total length, TL) and interrogated for the presence of a passive integrated transponder (PIT tag) in 1992 and 1993 emplaced by U.S. Fish and Wildlife Service

(William Conner, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication).

Size was the principal criterion used to identify subyearling chinook from other juvenile chinook salmon in the reservoirs. The approximate minimum size of yearling chinook salmon migrating through the lower Snake River reservoirs in the early spring is approximately 80 mm based on our analysis of length frequency distributions for spring and summer chinook from tributaries throughout Idaho. We used a conservative maximum length of 75 mm during April and May and 85 mm during June to ensure yearling chinook were not included in the samples. These lengths have been considered conservative (Ed Buettner, Idaho Department of Fish and Game, Lewiston, Idaho, personal communication; William Conner, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication) and, therefore, estimates of abundance are probably conservative.

Population Estimates

When sampling intensity allowed, we estimated shoreline abundance from our collections by habitat type in Lower Granite and Little Goose reservoirs and calculated 95% bounds on our estimates based on methods presented by Scheaffer et al. (1986). Stratified random sampling was also conducted in the three reaches of Lower Monumental and Ice Harbor reservoirs.

The mean number of subyearling chinook salmon was estimated by:

$$\bar{y} = \sum_{i=1}^{n} \frac{y_i}{n}$$

where: y_i = total subyearling chinook salmon in the ith haul, and

n = total number of hauls in each reservoir stratum.

The variance associated with this estimate was calculated as:

$$V(\bar{y}) = \left((N-n)/N\right)\left(\frac{s^2}{n}\right)$$

where:

$$s^2 = \sum_{i=1}^{n} (y_i - \bar{y})^2 / n-1$$

N = total number of possible sampling units (maximum number of seine hauls along the shoreline) in each habitat type, and

n = number of samples (hauls) taken.

A 95% bound (β) (α=0.05) was placed on this estimate by

$$\beta = 1.960\sqrt{V(y)}.$$

A total reservoir subyearling chinook salmon population estimate was calculated by summing each of the estimates from the various reservoir strata (Scheaffer et al. 1986):

$$\hat{T} = \sum_{i=1}^{L} (N_i y_i)$$

where: $N_i y_i$ = the population estimates for each reservoir stratum.

The associated variance (V(T)) of this total population estimate was calculated by:

$$V(T) = \sum_{i=1}^{L} N^2 i\left(\frac{N_i - n_i}{N_i}\right)\left(\frac{s^2 i}{n_i}\right).$$

A 95% bound (ß) (α=0.05) was placed on this estimate by:

$$\beta = 1.960\sqrt{V(y)}$$

Habitats and Substrata

We related subyearling abundance to habitat information of water temperatures and substrata. Jacobs Utilization Index was used to determine habitat selected and distribution of subyearling chinook salmon in Lower Granite Reservoir (Jacobs 1974). The index graphically depicts habitats selected and avoided with a score of 1 indicating strong selection and -1 indicating strong avoidance of a given habitat. We assessed the influence of water temperature on the time of outmigration. Shoreline substrate was noted and related to substrate in deeper water. A Mach I echosounder was used to obtain depth profiles to assess habitat availability at various water levels.

Shoreline and Pelagic Abundance

To estimate the duration of shoreline and pelagic rearing of subyearling chinook salmon, we examined the number of days between the first capture and last capture along the shoreline. Duration of pelagic rearing was determined as the number of days between the last date of shoreline collection and peak collection at Lower Granite Dam.

Sediment Analyses

We collected substrate samples throughout Lower Granite and Little Goose reservoirs with emphasis on habitats where subyearling chinook salmon were collected. Substrate samples were collected with Ponar or Shipek dredges and analyzed for particle size distribution and organic matter content.

Substrate samples were dried at 105°C (221°F) for 72 hours. Samples were separated by dry sieving into nine categories: 50.0 mm, 25 mm, 12.5 mm, 9.5 mm, 6.3 mm, 4.75 mm, 3.35 mm, 2.0 mm, and < 2.0 mm. Because fine sediments were caked, samples were crushed manually before sieving. After sieving, the weight (g) of each substrate size category was measured.

Fifty grams of soil < 2.0 mm from each sample were dried in crucibles at 105°C for 12 hours, cooled, and weighed to measure the oven dried weight. Samples were then placed in the incinerator at 500°C (1,022°F) for 8 hours and cooled. Samples were then rehydrated and redried at 105°C for 12 additional hours, cooled, and weighed to measure the rehydrated oven dry weight. Percent organic matter was determined by:

$$OW = (OVW - RHD)/TW;$$

where: OW = organic weight,
OVW = oven dry weight,
RHD = rehydrated oven dry weight, and
TW = total weight of the sample.

Particle size analysis was determined by the Bouyoucos method (Bouyoucos 1962). Forty grams of soil < 2.0 mm was placed in a 600-ml beaker, mixed with 100 ml of 5% hexametaphosphate and 250 ml of deionized water, and allowed to soak for 12 hours. Soil samples were then mixed with an electric blender for 5 minutes, placed into a sedimentation cylinder, and filled to the 1 liter mark. Temperatures of the soil solutions were recorded to correct readings to 19.5°C (67.1°F). Cylinders were then stoppered and shaken for 1 minute. Immediately following the 1 minute shaking period, the soil hydrometer was placed in the solution and readings were recorded at 40 seconds and 2 hours.

We used the following formulas to calculate percent sand, silt, and clay:

$$\%\ clay = \frac{2\ hour\ corrected\ reading}{40\ grams} \times 100$$

$$\%\ silt = \frac{40\ second\ corrected - 2\ hour\ corrected}{40\ grams} \times 100$$

$$\%\ sand = 100\% - (\%\ Silt + \%\ Clay).$$

Growth

Growth of subyearling chinook was determined by a model fit by a weighted regression analysis weighing each point by the number of fish.

Abundance of Predators

Potential predators were collected in Lower Granite Reservoir from 1991 to 1993 by gill netting, electrofishing, and beach seining (Bennett et al. 1993a, 1993b, 1995, 1997).

Eight horizontal, multifilament gill nets 68.6 m x 1.8 m (225 ft x 6 ft) consisting of three graded panels with bar measurements of 3.8, 4.4 and 5.1 cm (1.5, 1.75, and 2.0 inches; Webb et al. 1987) were fished in Lower Granite Reservoir. Gill nets were set perpendicular to the shoreline and fished on the bottom for approximately 3 hours of daylight and 3 hours of dark for a total of 6 hours. Gill nets were checked every 2 hours to avoid destructive sampling to salmonids and other fishes.

A 30.5 m x 2.4-m (100 ft x 8-ft) beach seine with a 2.4-m^3 (8-ft^3) bag constructed of 0.64-cm (0.25-inch) mesh was used to sample fish along the shoreline. Beach seining was employed at semiweekly intervals during the daytime in April, May, and June and at monthly intervals during July, August, September, and October. Three seine hauls were conducted at each location sampled. Standardized beach seine hauls were made by setting the seine parallel and approximately 15.2 m (50 ft) from shore with attachment lines and then drawing the seine perpendicular toward the shoreline.

Nighttime electrofishing was conducted by paralleling the shoreline, and effort generally consisted of three periods of 5 minutes at each location. Electrofishing was conducted semimonthly during April, May, and June. A constant output of 400 volts at 3-5 amps was found to adequately stun fish without causing mortality or visual evidence of injury.

All potential predators captured were measured to total length to the nearest millimeter. During 1992, stomach contents from all potential predators were collected. Stomach samples were examined in the laboratory and diagnostic bones were used to identify prey fishes and determine live fork lengths (Hansel et al. 1988). Losses of subyearling chinook to predators were based on stomach analysis of smallmouth bass and northern squawfish. We used the same for our field collections.

Numbers of Adult Fall Chinook Salmon

Numbers of adult fall chinook salmon crossing Lower Granite and Little Goose dams were retrieved from Annual Fish Passage Reports (U.S. Army Corps of Engineers 1986, 1989, 1990, 1991, 1992, 1993). The number of adults enumerated at the fish ladders the year prior to the collection of subyearlings enumerated was used as an index of potential spawners. The difference between the number of adults passing Little Goose Dam and those passing Lower Granite Dam was used as an index of potential spawners in Little Goose Reservoir.

RESULTS

Lower Granite Reservoir

Timing and Abundance

1987, 1990 through 1993.—Subyearling chinook salmon have generally been sampled along the shoreline of Lower Granite Reservoir from mid- to late April through May and as late as the latter part of July. Peak catches in 1987 and 1992 occurred at similar times in mid-May, although 176 subyearling chinook were collected in 1992 compared to about 100 in 1987 (Figure 5). In contrast, peak catches along the shoreline occurred during late May in 1991, early June in 1990, and mid-June in 1993. The highest peak catches of subyearling chinook salmon occurred in 1992. In 1992, the majority of

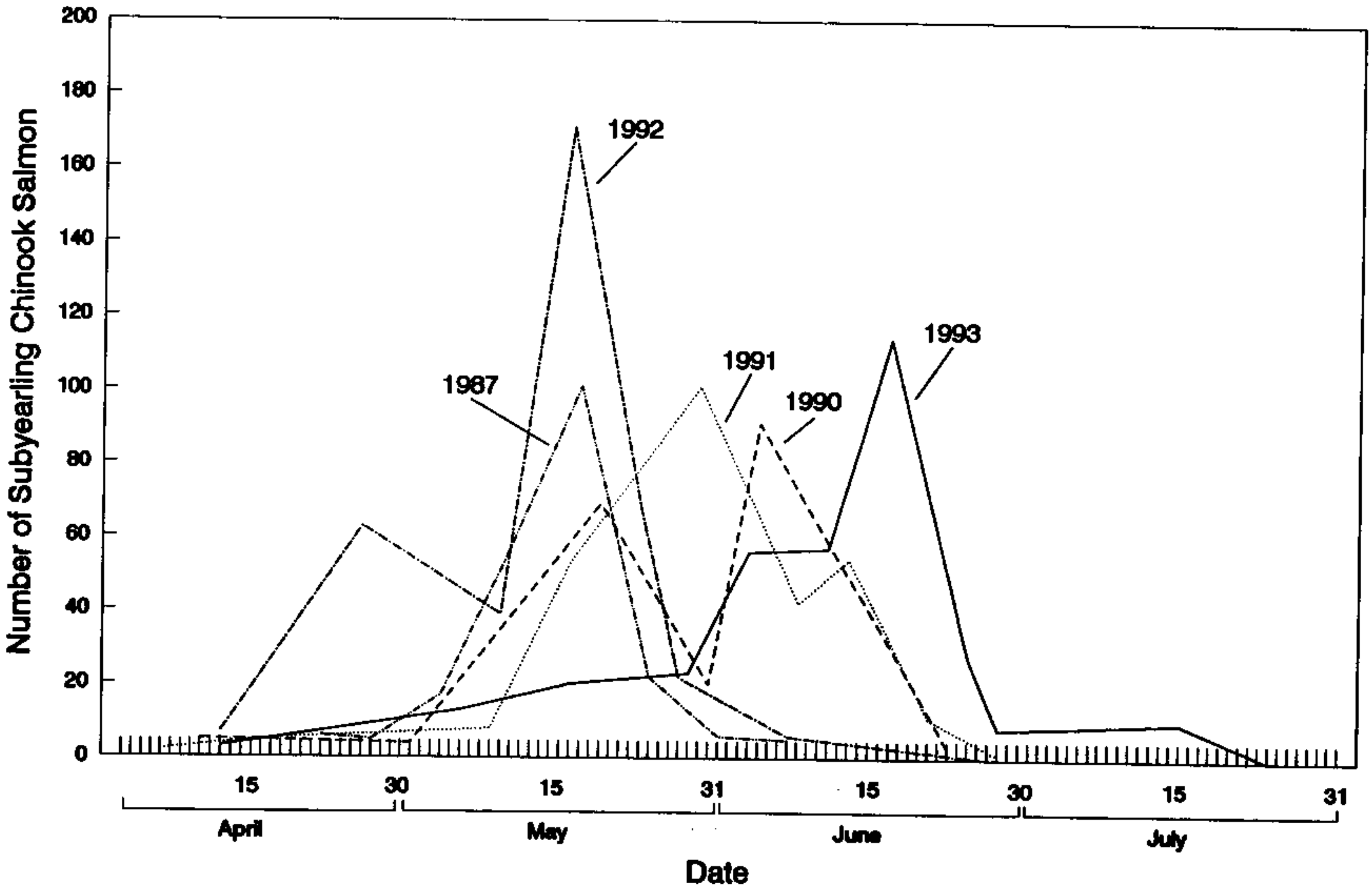

Figure 5. Annual comparisons of shoreline abundance of subyearling chinook salmon sampled during 1987, 1990, 1991, 1992, and 1993 in Lower Granite Reservoir.

fish were collected within a few weeks, although numbers before and after the peak of abundance were low.

In 1992, we estimated the population abundance of subyearling chinook salmon along the shoreline on 10 May at 4,460 (+/-4,812 at 95% C.I.) in Lower Granite Reservoir (Figure 6). Population estimates from 24 April and 16 May 1992 exceeded 4,000 and 3,000 subyearling chinook, respectively.

1993. —A total of 331 subyearling chinook salmon was captured by daytime beach seining from 10 April to 15 July 1993 in Lower Granite Reservoir. Peak catches along the shoreline in 1993 did not correspond to the estimated peak population of subyearling chinook. No subyearling chinook salmon were collected in littoral areas after 15 July 1993. The estimated population size of subyearling chinook salmon peaked on 2 June 1993 at 6,346 (+/- 4,262 at 95% C.I.) in Lower Granite Reservoir (Figure 7). The highest catch/effort by beach seining in 1993 occurred on 16 June.

Our population estimates of subyearling abundance along the shoreline were considerably higher in 1993 than in 1992 (Figure 7). Highest abundance exceeded 6,300 fish, although numbers before and after peak abundance were about 2,000. Ninety-five percent confidence intervals generally ranged from 30 to 50% of the estimated abundance.

Shoreline Habitation

The overall rearing period of subyearling chinook salmon in Lower Granite Reservoir has generally varied from about 75 to 112 days in 1987 and 1990 through 1993. During 1993, the rearing period was 100 days compared to 75 days in 1992 and 112 days in 1991 (Figure 8). Although the duration of rearing was similar, littoral rearing of subyearling chinook was 96 days in 1993, 48 days in 1992, and 84 days in 1991 (Curet 1994). Pelagic rearing during 1993 was 4 days compared to 27 and 28 days for 1992 and 1991, respectively.

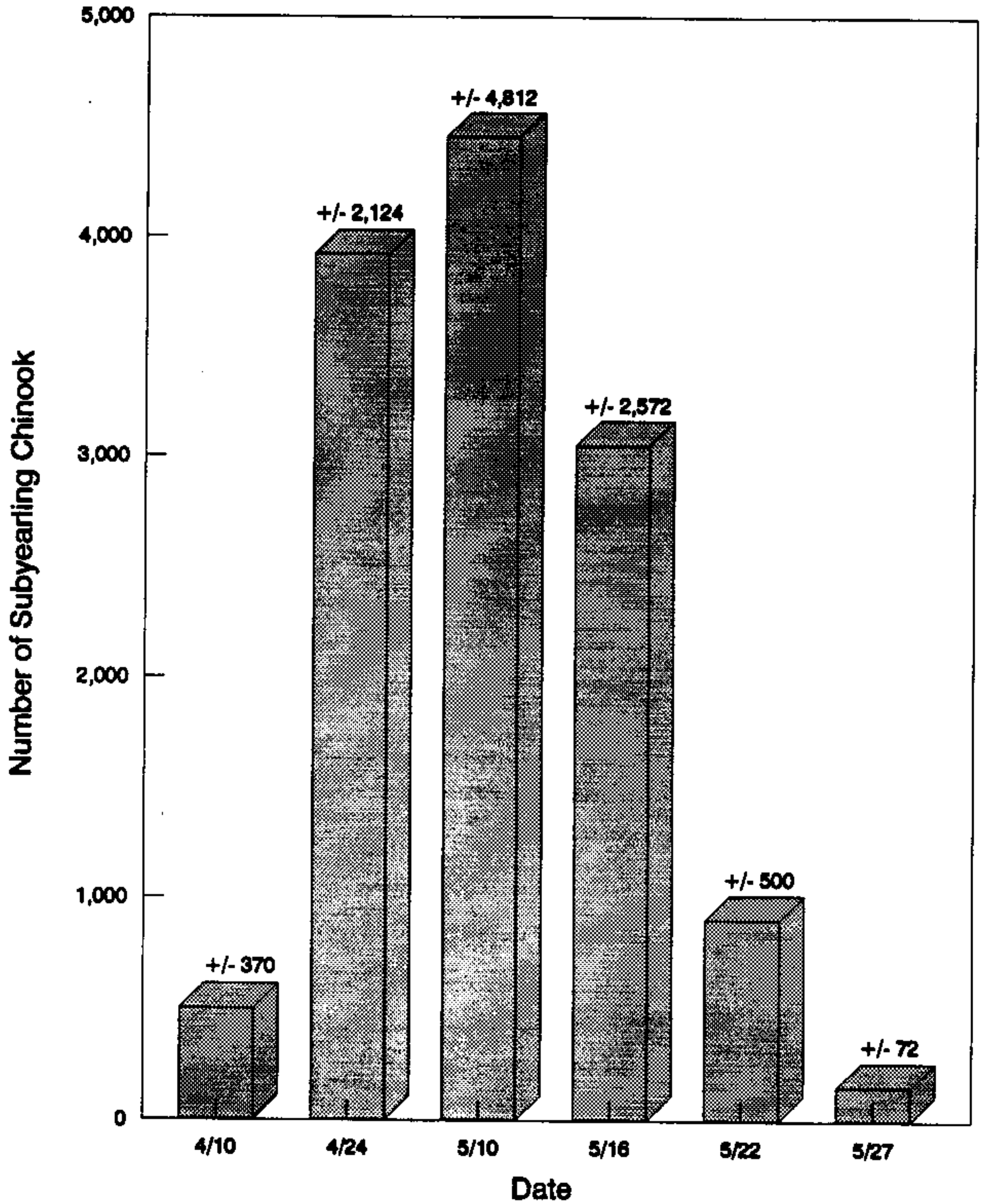

Figure 6. Population estimates of subyearling chinook salmon by date using stratified random samples (4/10 and 5/10 estimated using simple random samples) during 1992 in Lower Granite Reservoir. Confidence intervals were calculated using 95% bounds.

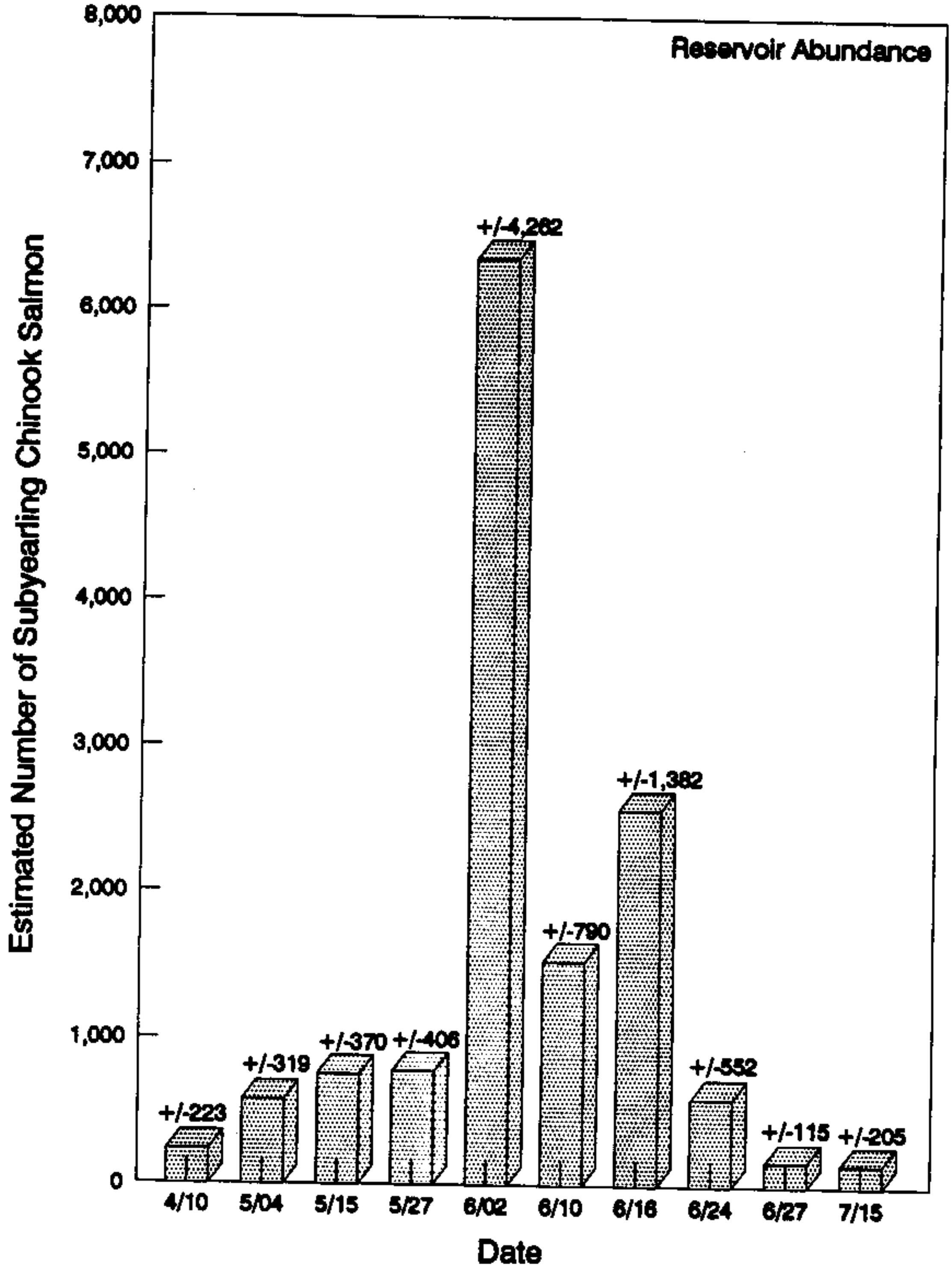

Figure 7. Population estimates of subyearling chinook salmon by date during 1993 in Lower Granite Reservoir. Estimates were calculated by stratified random sampling. Confidence intervals were calculated with 95% bounds.

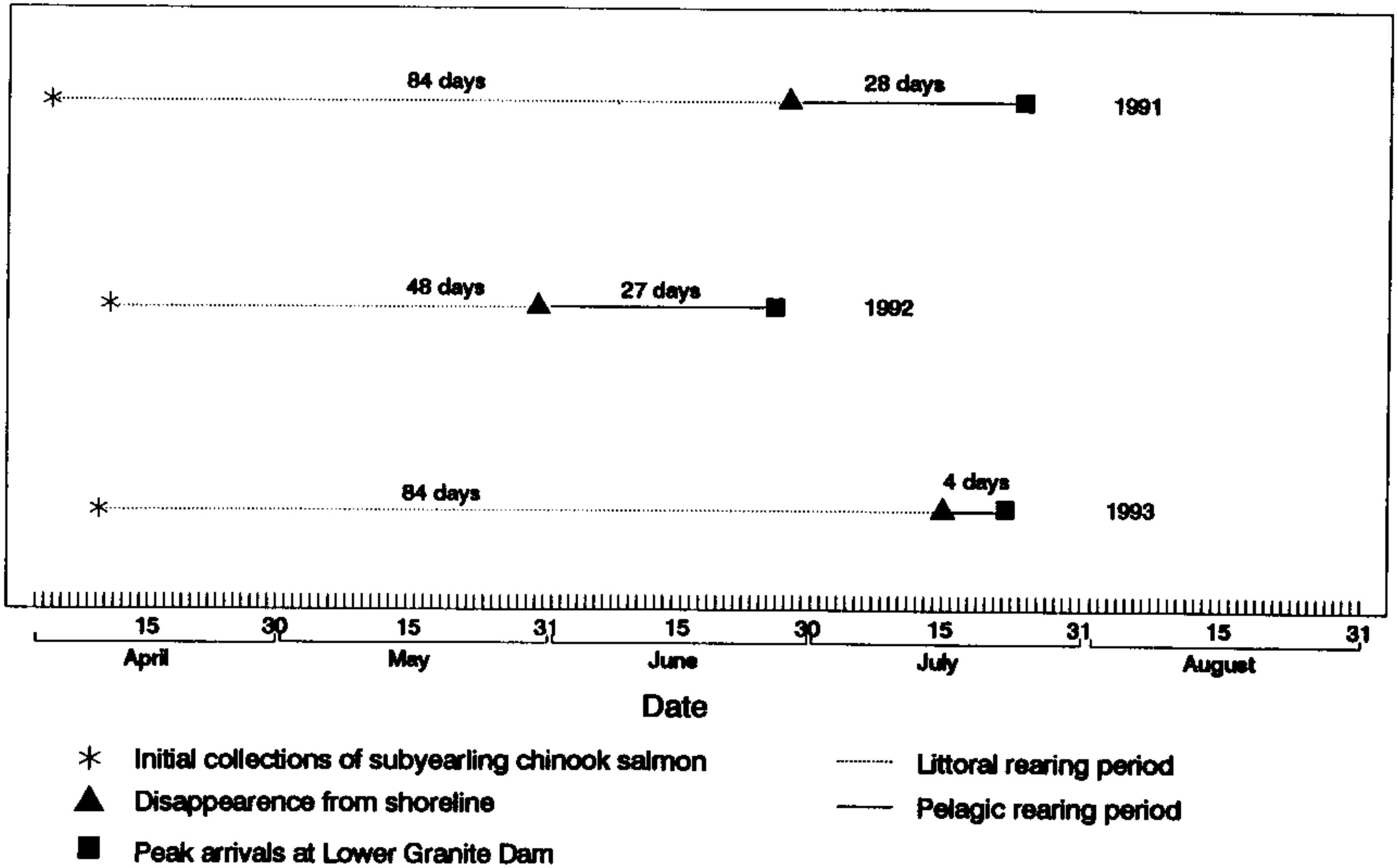

Figure 8. Estimated overall, shoreline, and open water rearing periods of subyearling chinook salmon during 1991, 1992, and 1993 in Lower Granite Reservoir.

Although rearing periods of subyearling chinook varied among years, the water temperatures at which shoreline migration occurred were similar. Water temperatures during 1987 and 1990 through 1993 indicate subyearlings migrate from the shoreline consistently once shoreline water temperatures are > 18°C (64.4°F; Figure 9). Dates when 18°C temperatures occurred in Lower Granite Reservoir varied about 50 days from late May (1992) to mid-July (1993).

Habitat Use

Habitat use of subyearling chinook salmon collected during 1990 through 1993 by beach seining from Lower Granite Reservoir was compared using the Jacobs Utilization Index (Jacobs 1974; Figure 10). Subyearling chinook salmon rearing along the shoreline of Lower Granite Reservoir exhibited a strong preference for sand substrate for all years. In spring 1993, subyearling chinook showed a weaker preference for sandy shorelines and exhibited a moderate avoidance of cobble/sand and talus/sand. We found a strong avoidance of rip-rap habitat for years 1990 through 1992 whereas during 1993 a moderate avoidance was found.

Substrate Analyses

Substrate analyses of sediment sampled from the south side of Lower Granite Reservoir at RMs 138.75 and 138.5 showed predominantly material > 25 mm both at 1 (3.3 ft) and 3 m (9.8 ft) depths; Figure 11). In comparison, substrata on the north side of the reservoir at RM 135.0 N (north) at 1, 2, and 2.5 m depths were predominantly fine sand with silt comprising > 30% (Figure 12). Organic content was about 5% at this site. Similar results were found at RMs 134.5 N and 134.0 N at 1 and 3 m depths with particles largely < 2.0 mm (Figure 13). On the south side of the reservoir at RMs 133.0 and 133.25, particles were predominantly > 25 mm (Figure 14). Downstream at RMs

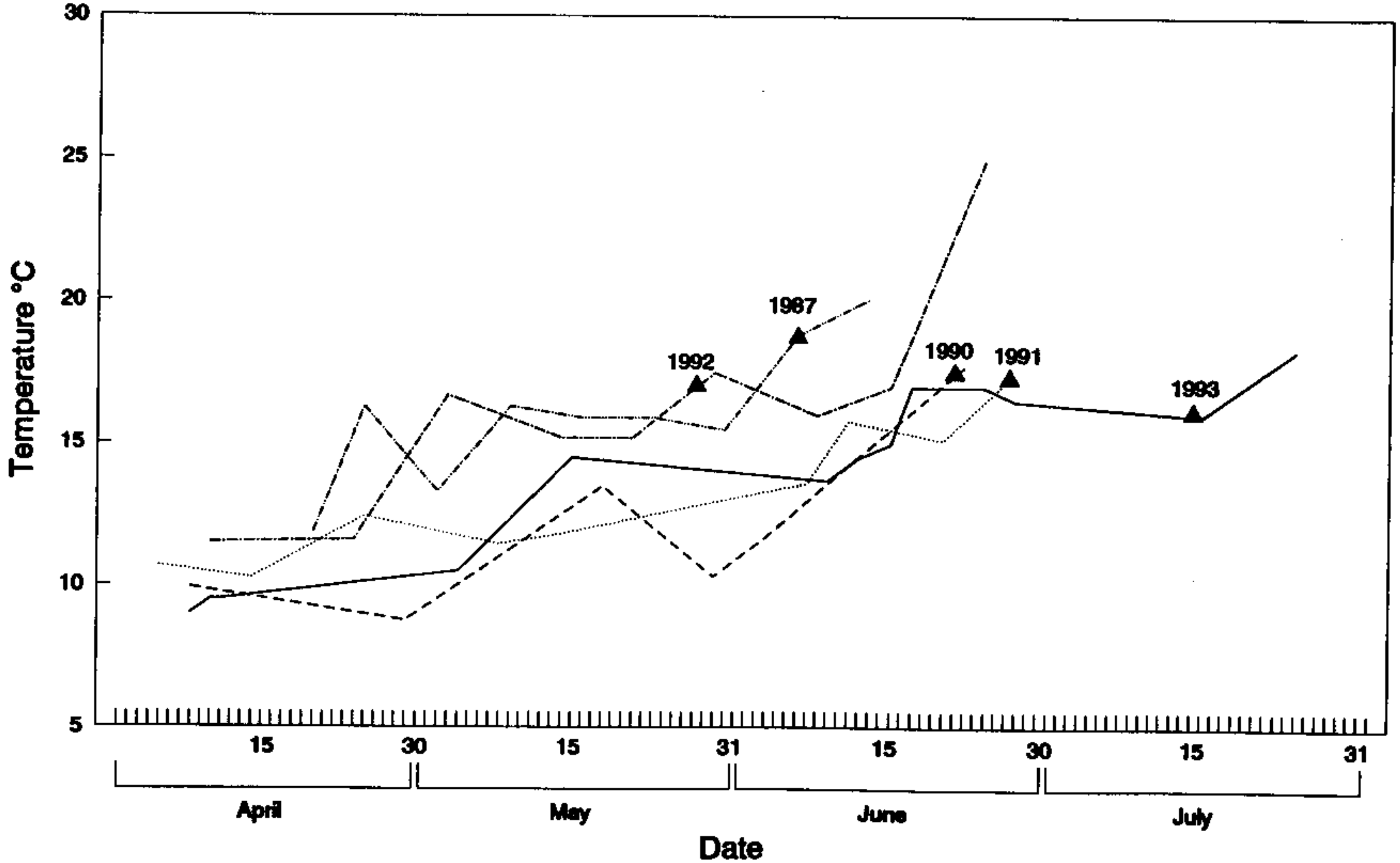

Figure 9. Mean shoreline water temperatures during 1987, 1990, 1991, 1992, and 1993 in Lower Granite Reservoir. Triangles indicate the disappearence of subyearling chinook salmon from shoreline areas.

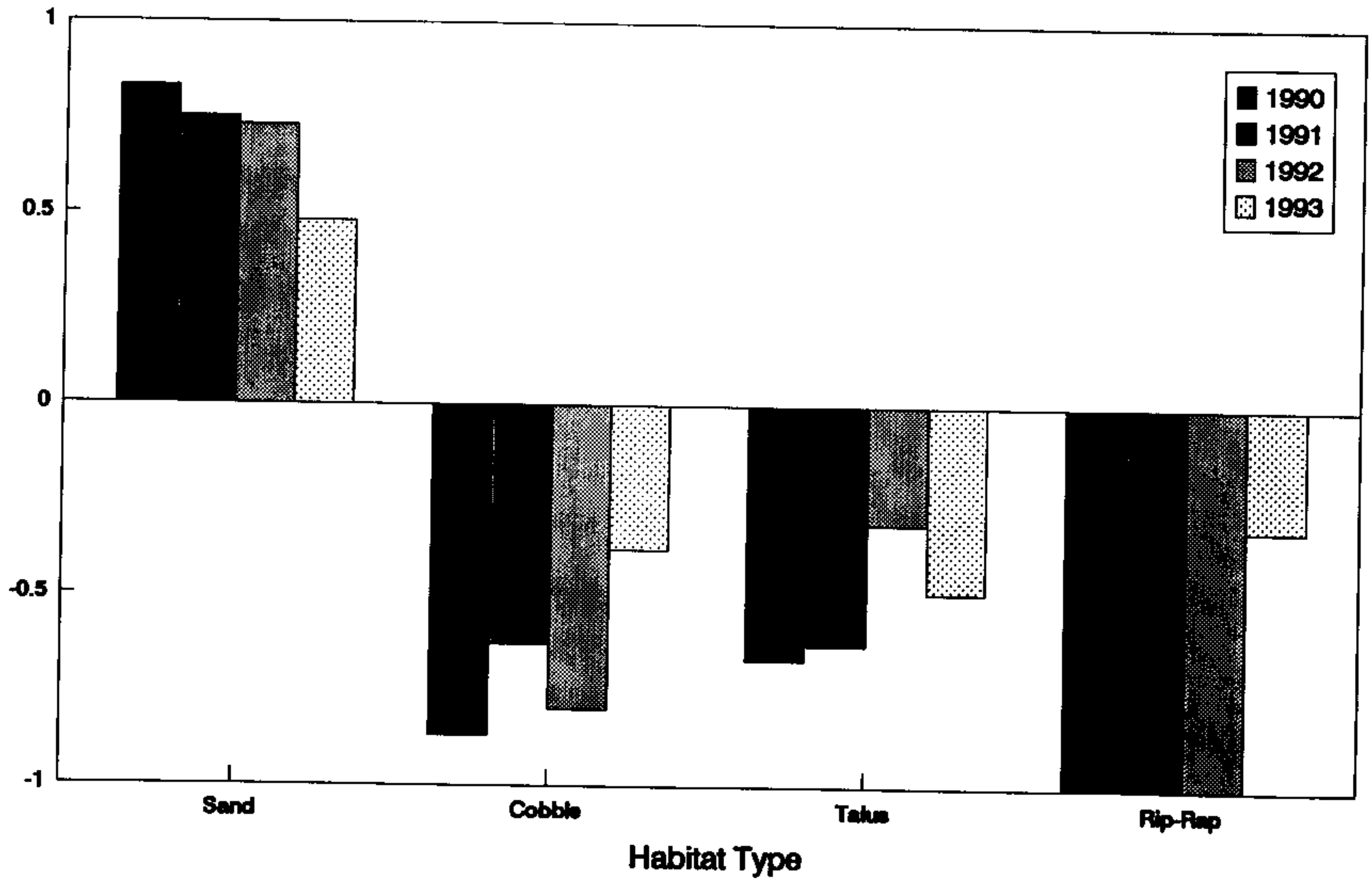

Figure 10. Substrata selected by subyearling chinook salmon during 1990, 1991, 1992, and 1993 in Lower Granite Reservoir as determined by Jacobs Utilization Index (Jacobs 1974).

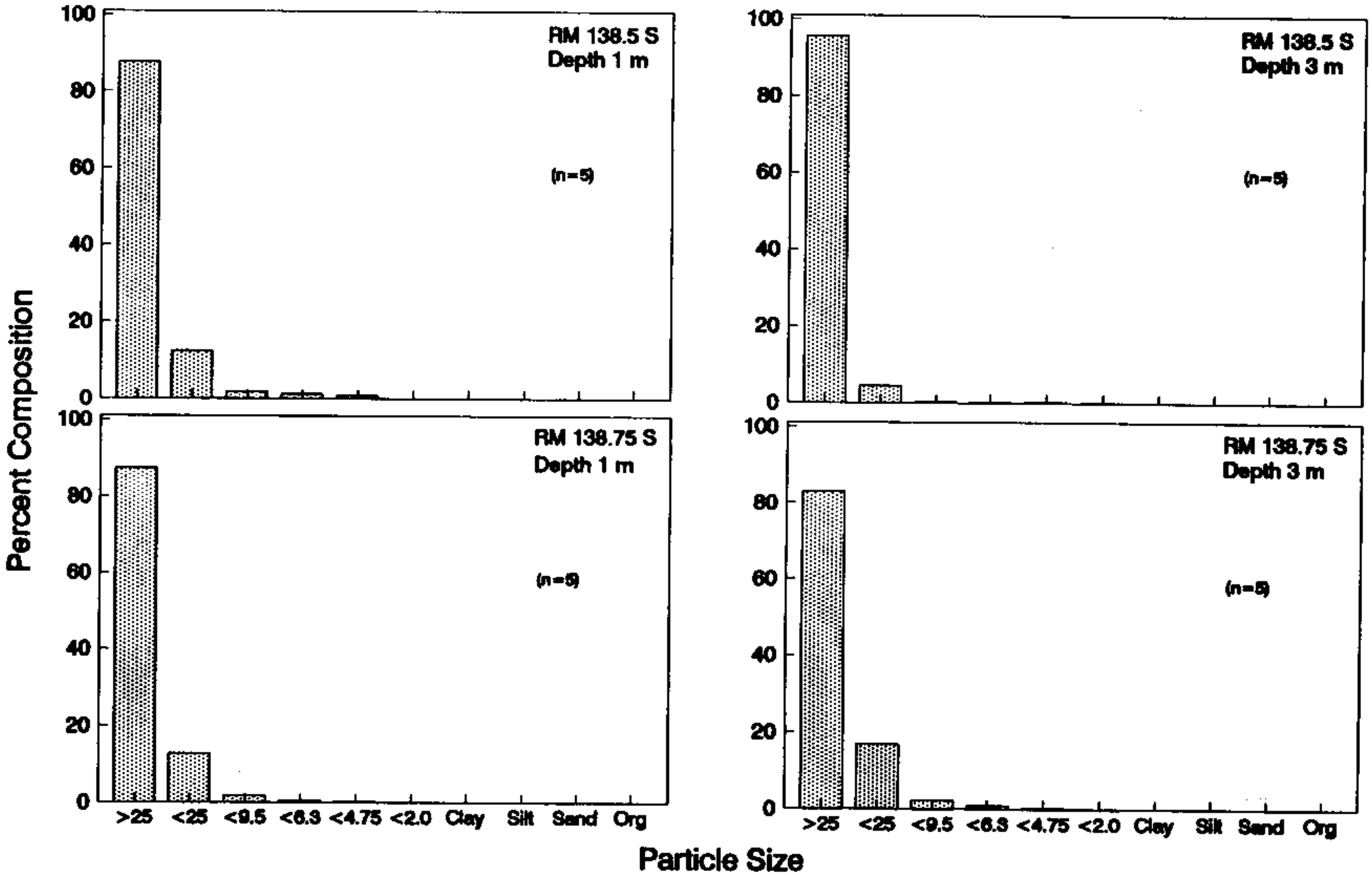

Figure 11. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir.

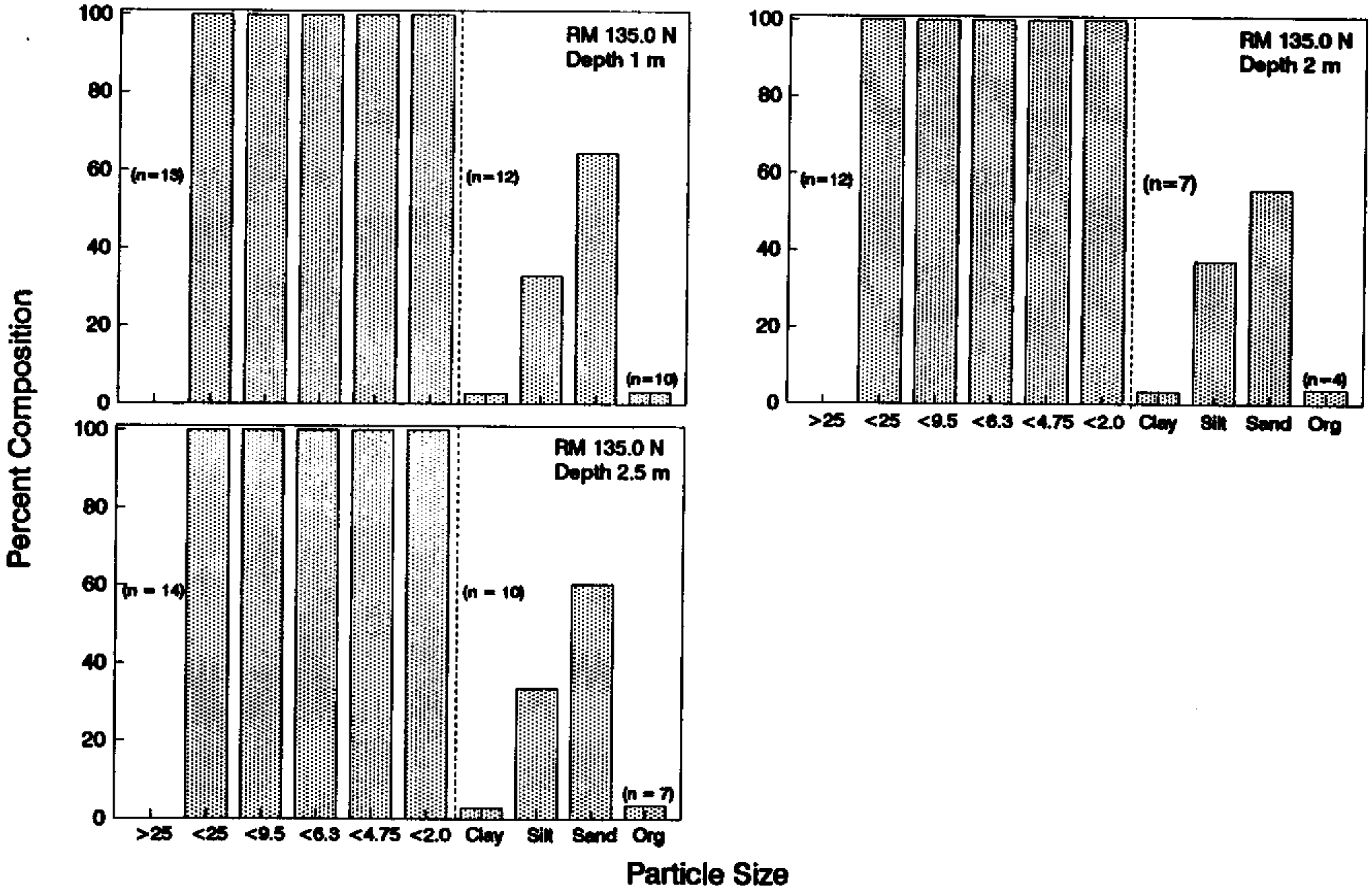

Figure 12. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

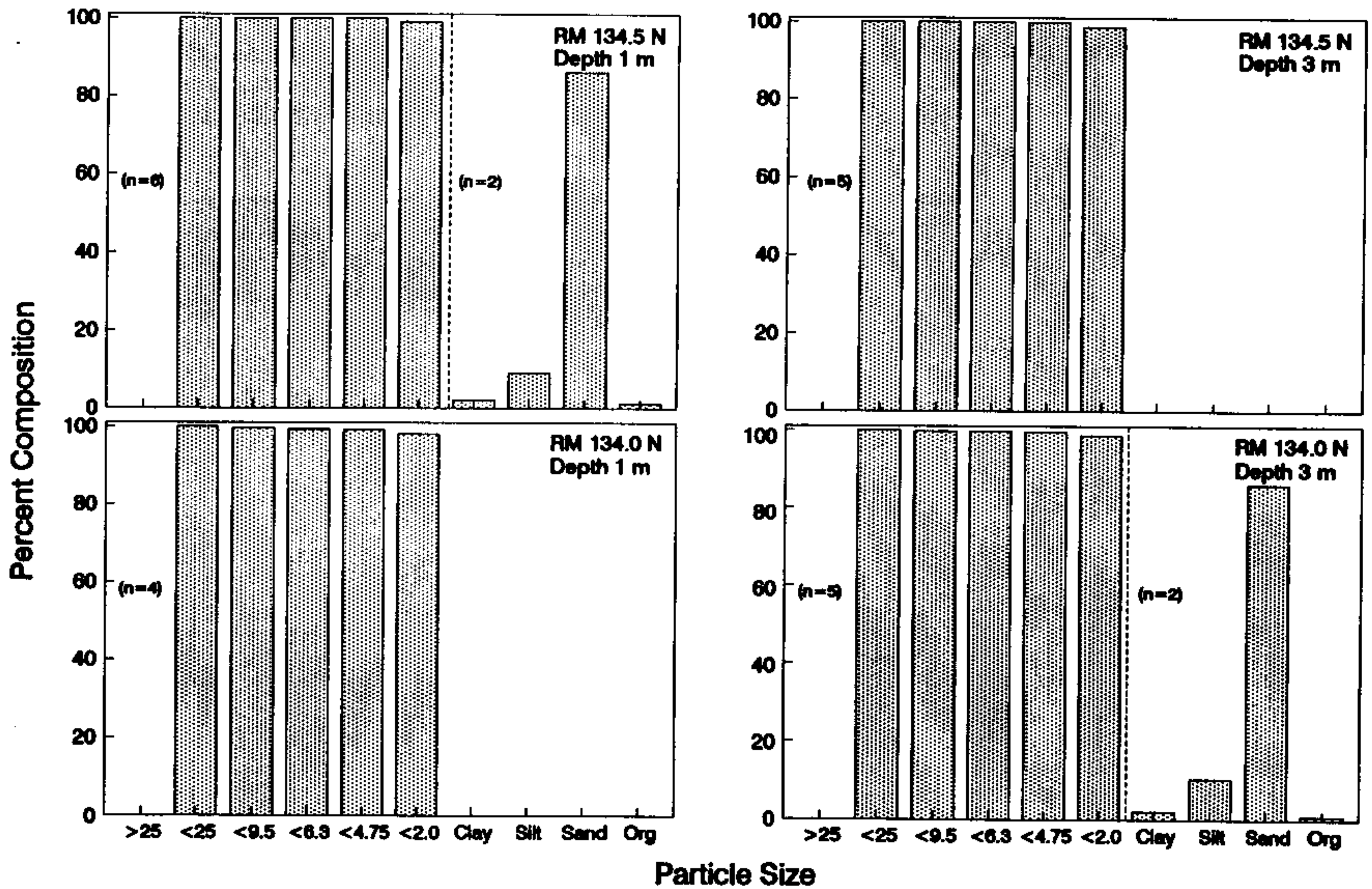

Figure 13. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 (RM 134.0 N, 3 m) and 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

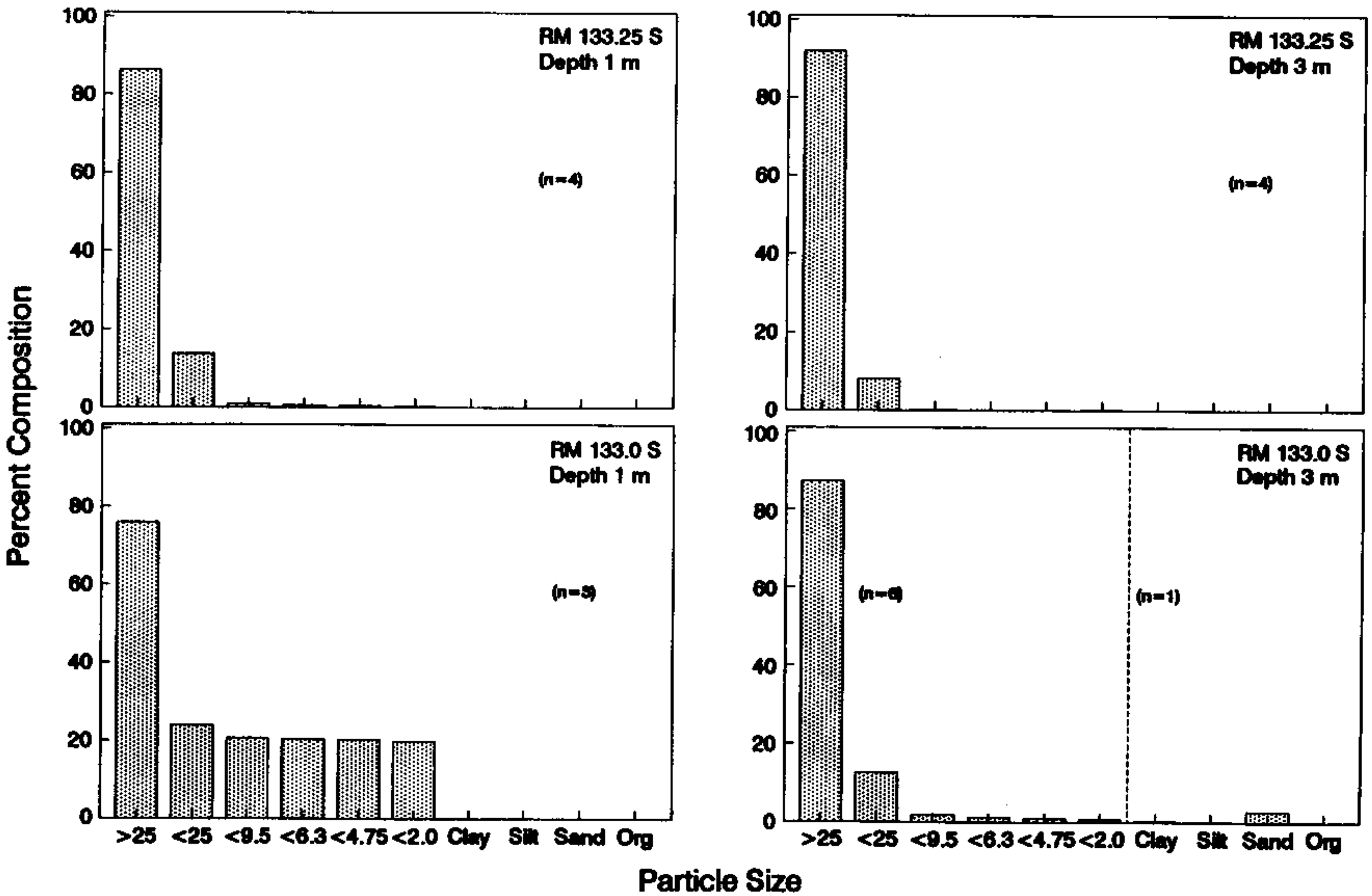

Figure 14. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted line were conducted by the Bouyoucos method (Bouyoucos 1962).

132.75 and 132.5 S (south) particles were < 2.0 mm with fine sand comprising > 75% of the substrata at both 1 and 3 m depths (Figure 15). At RMs 132.0 and 131.75 S fine sand was present at both 1 and 3 m depths (Figure 16). At RM 129.75 S, substrata remained similar to those immediately upstream (Figure 17); those at RM 128.0 S differed between 1 (> 25 mm) and 3 m depths (fine sand and silt). Larger sized materials predominated at both 1 and 3 m depths at RM 127.75 S, while the proportion of smaller particles increased from 1 to 3 m at RM 127.5 S (Figure 18). Fine sand and silt were the principal sized substrata downstream to RM 126.75 S where the proportion of particles > 25 mm ranged from about 42 to 80% (Figures 19 - 21). On the north shore at RMs 125.75 through 125.25, particles > 25 mm predominated at both 1 and 3 m depths (Figures 21 - 22). Larger particles were dominant from RM 123.25 S at both 1 and 3 m depths (Figure 23). At RM 120.48 S, particles < 2.0 mm and particularly fine sand extended from 1.5 to 4 m depths (Figure 24). On the north side of the reservoir at RM 120.19, the substrate composition was > 50% particles > 25 mm at both 1 and 3 m (Figure 25). At RM 120.19 S, adjacent to Centennial Island and downstream to RM 119.25 S, substrata were largely < 2.0 mm with fine sand predominating at various depths from 1 to 4 m (Figures 26 - 28). On the north side, substrata varied from > 25 mm at RM 119.25 to predominantly fine sand and silt at RM 111.0 (Figures 28 - 30). On the south side, sand and silt sized particles generally were more abundant from RMs 115.75 to 110.0 than larger particles (Figures 31 and 32). Substrata varied by depth, but variation among sites was larger than variation in depth.

Growth

Total lengths of subyearling chinook salmon sampled during 5 years (1987, 1990-1993) of collections along the shorelines in Lower Granite Reservoir were similar (Figure 33). The smallest (43 mm) initial average total length sampled occurred in 1992 compared

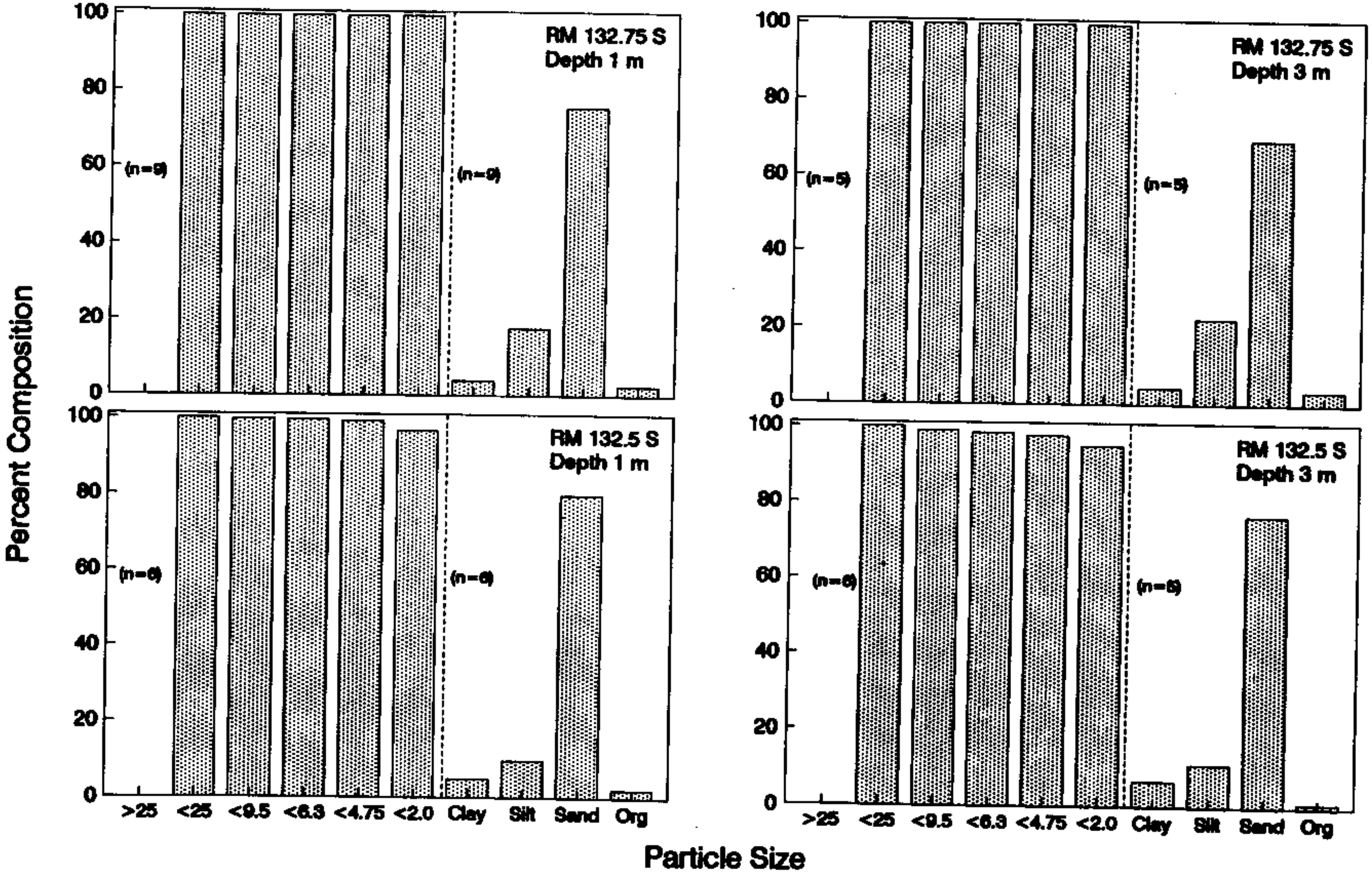

Figure 15. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

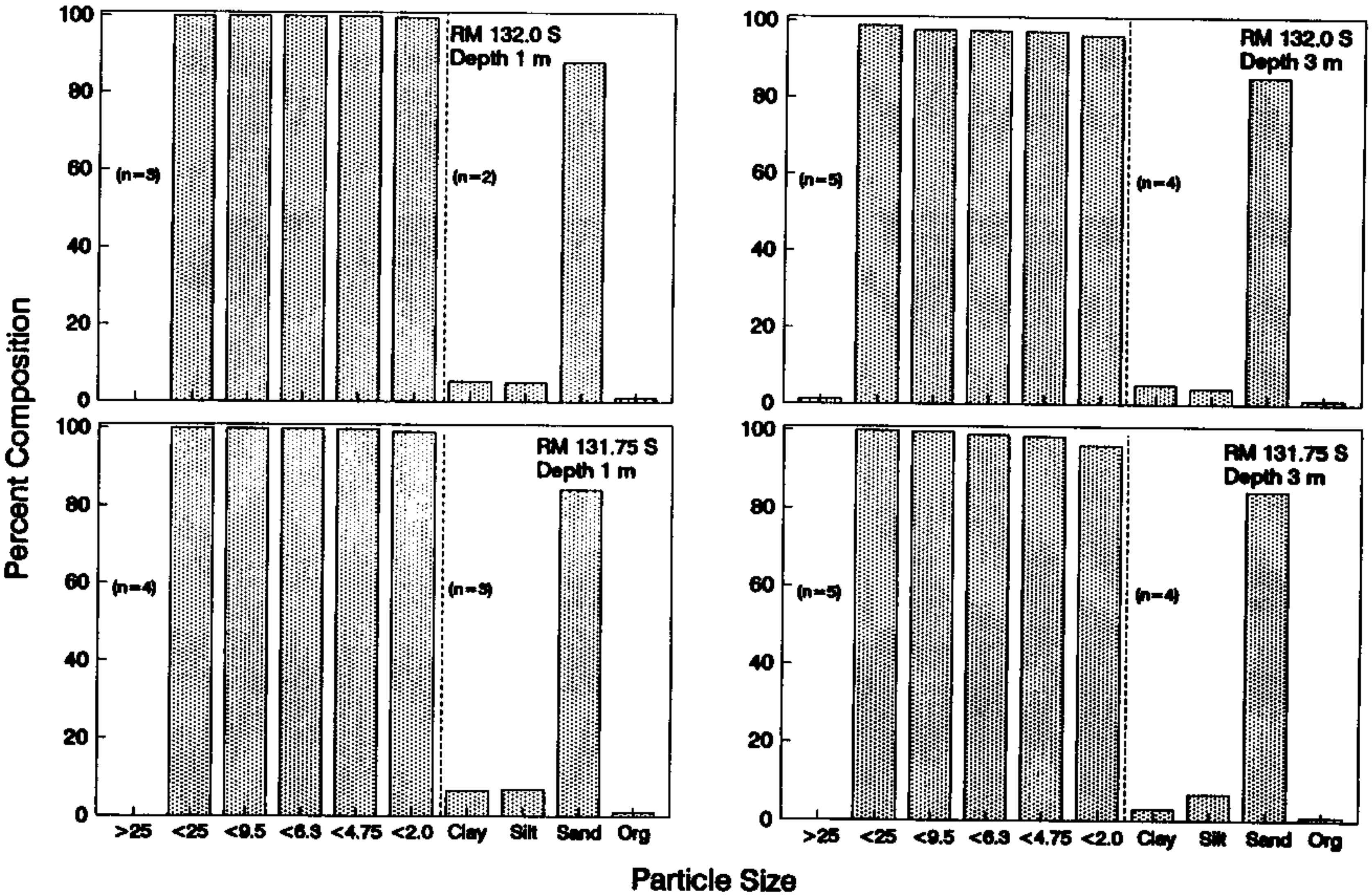

Figure 16. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

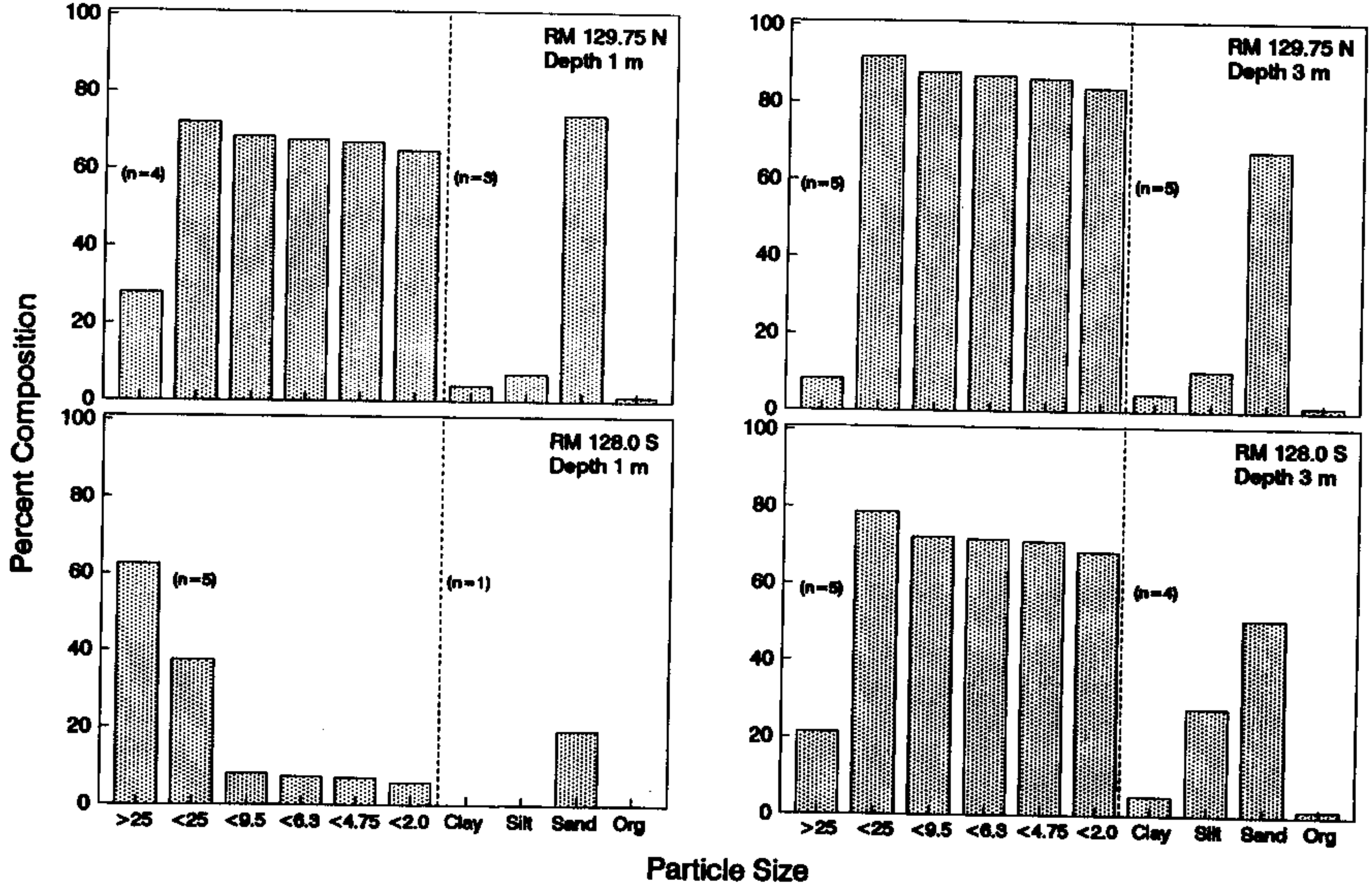

Figure 17. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

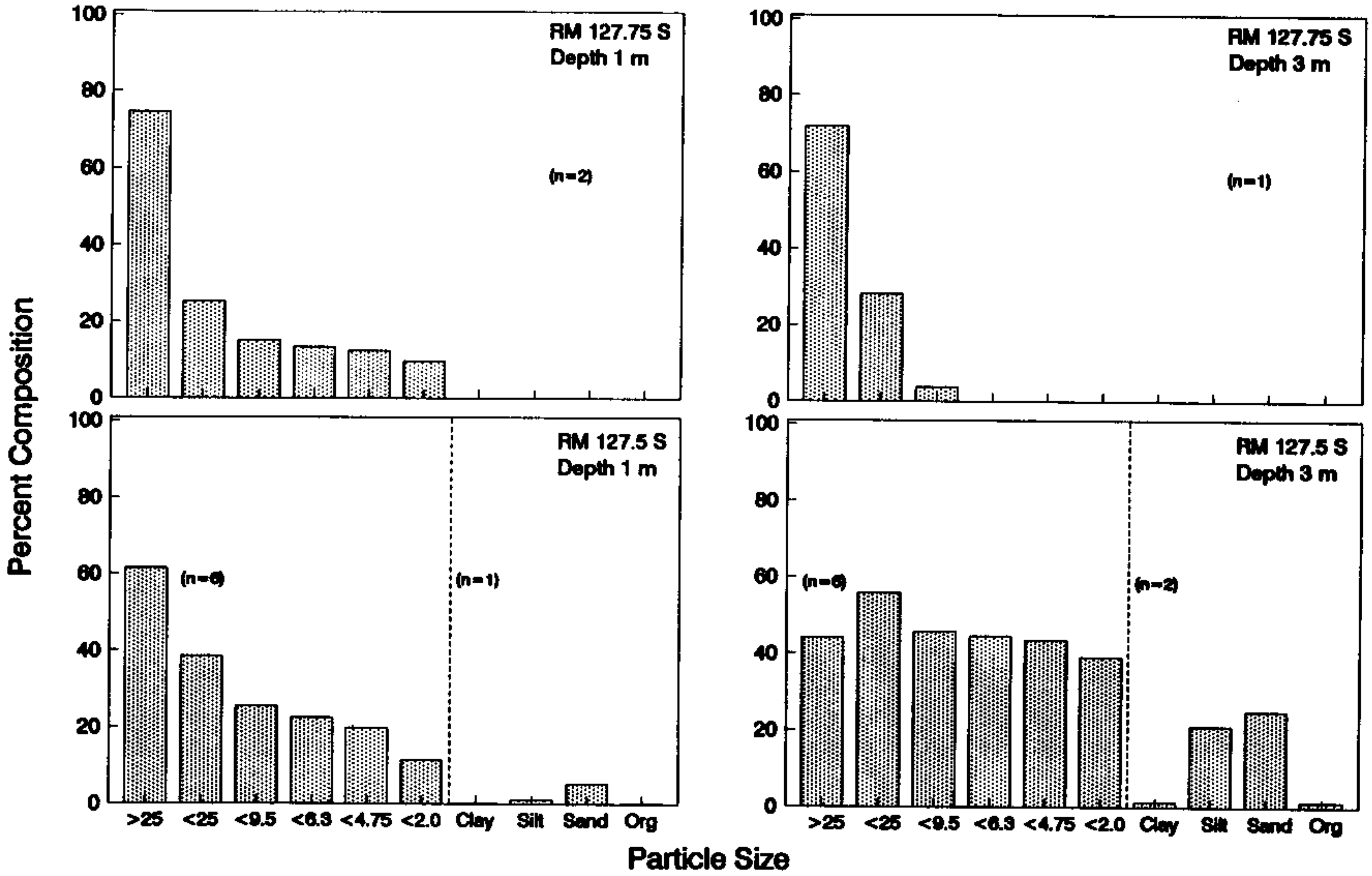

Figure 18. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

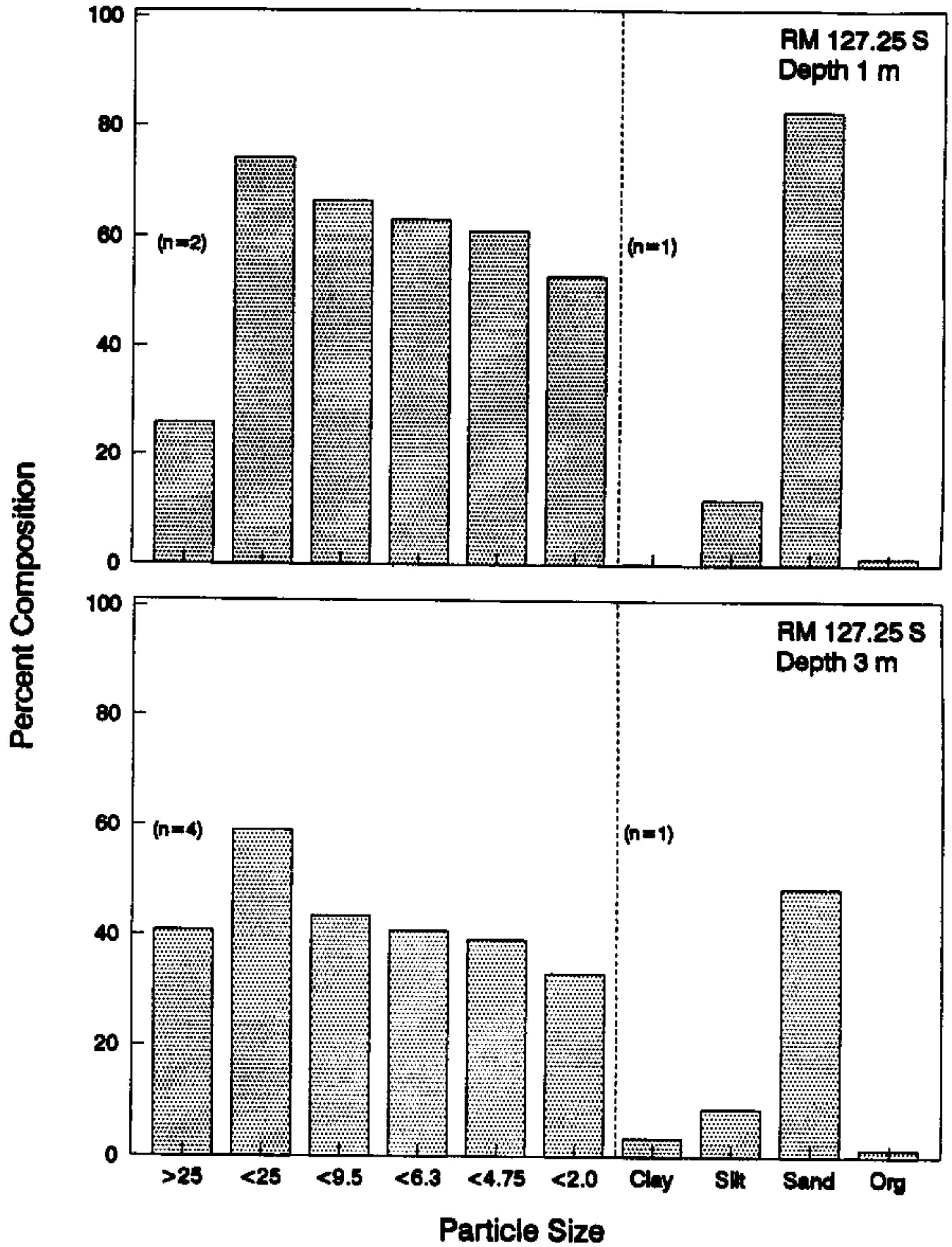

Figure 19. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

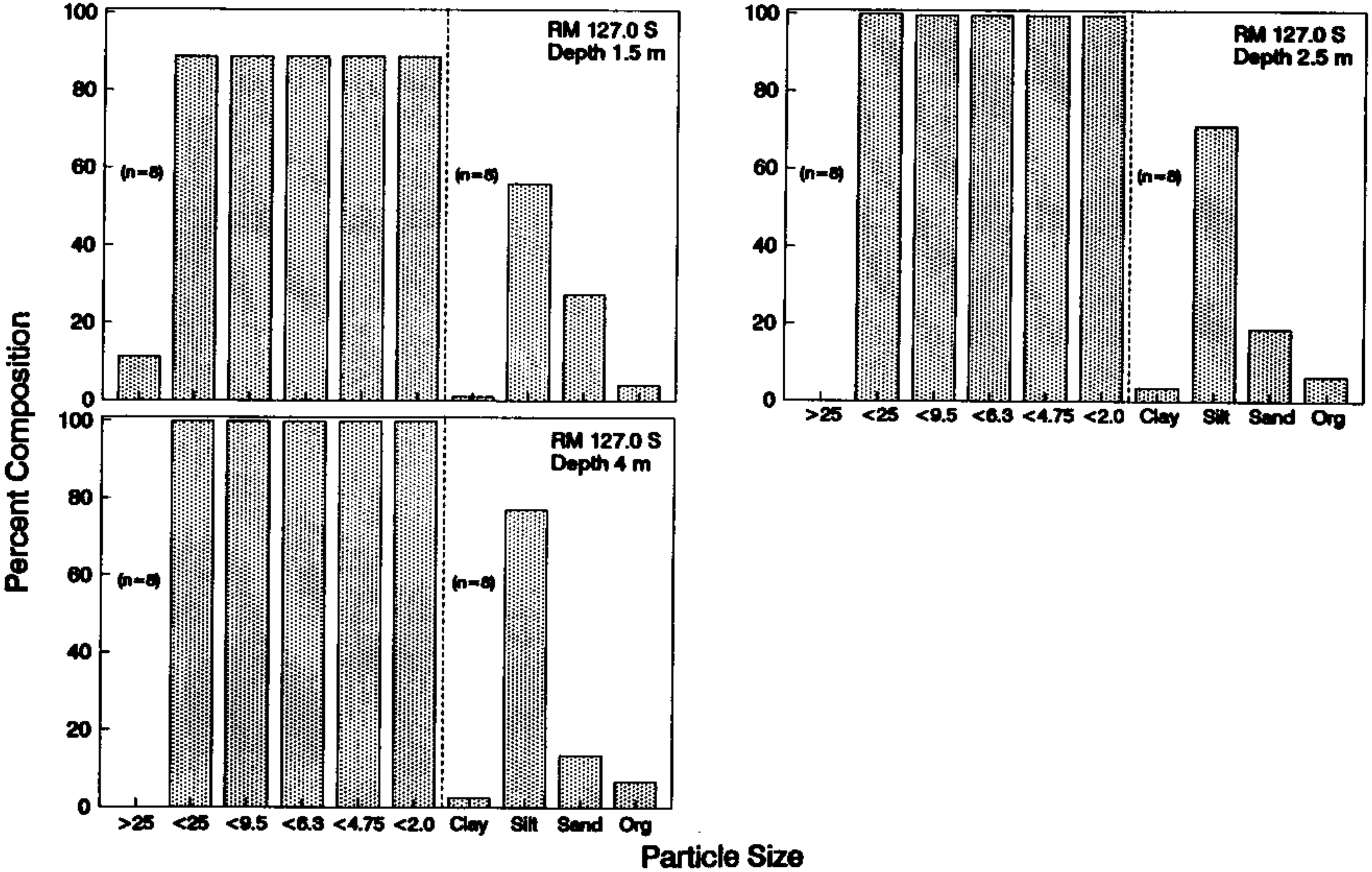

Figure 20. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

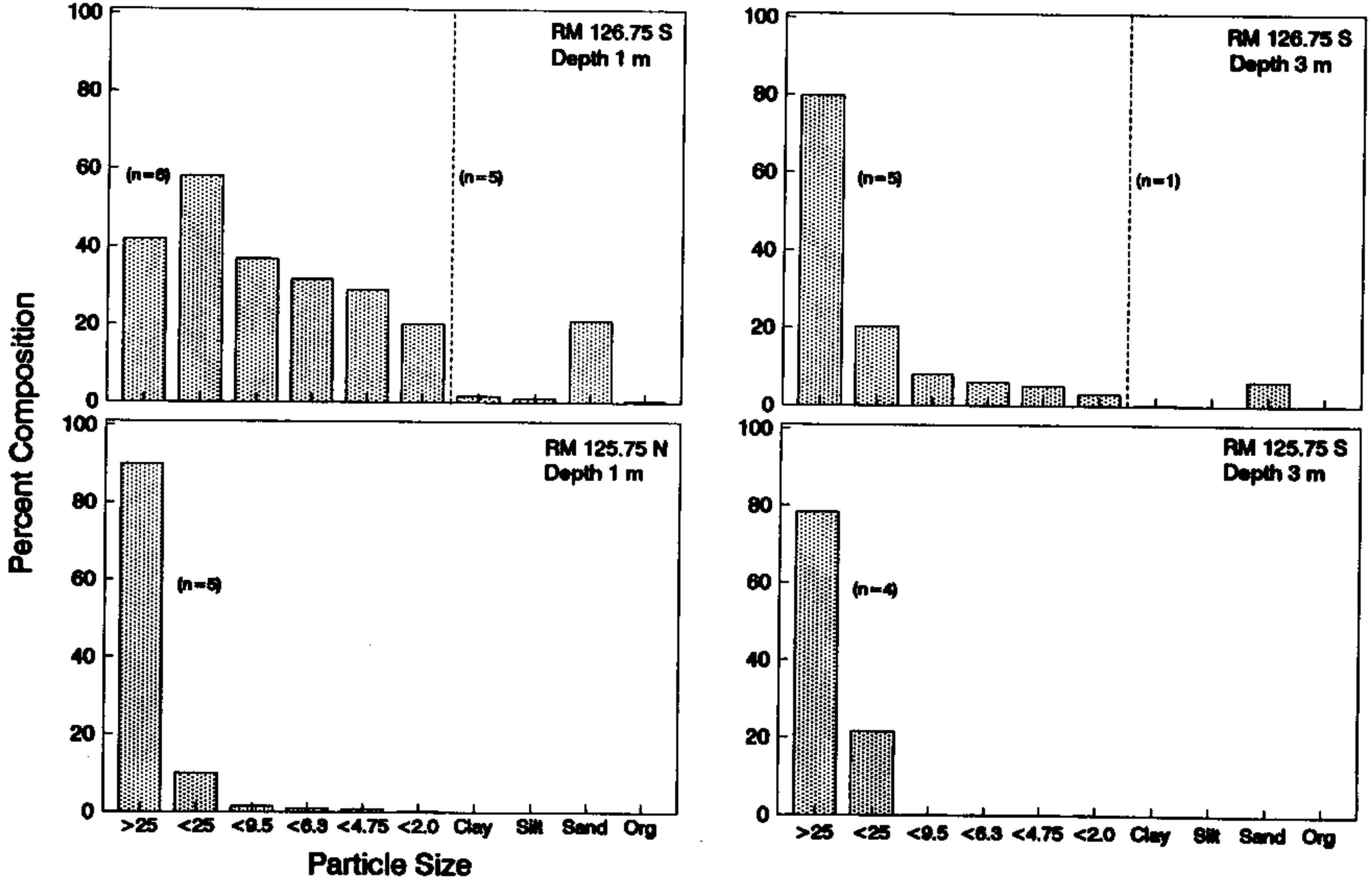

Figure 21. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

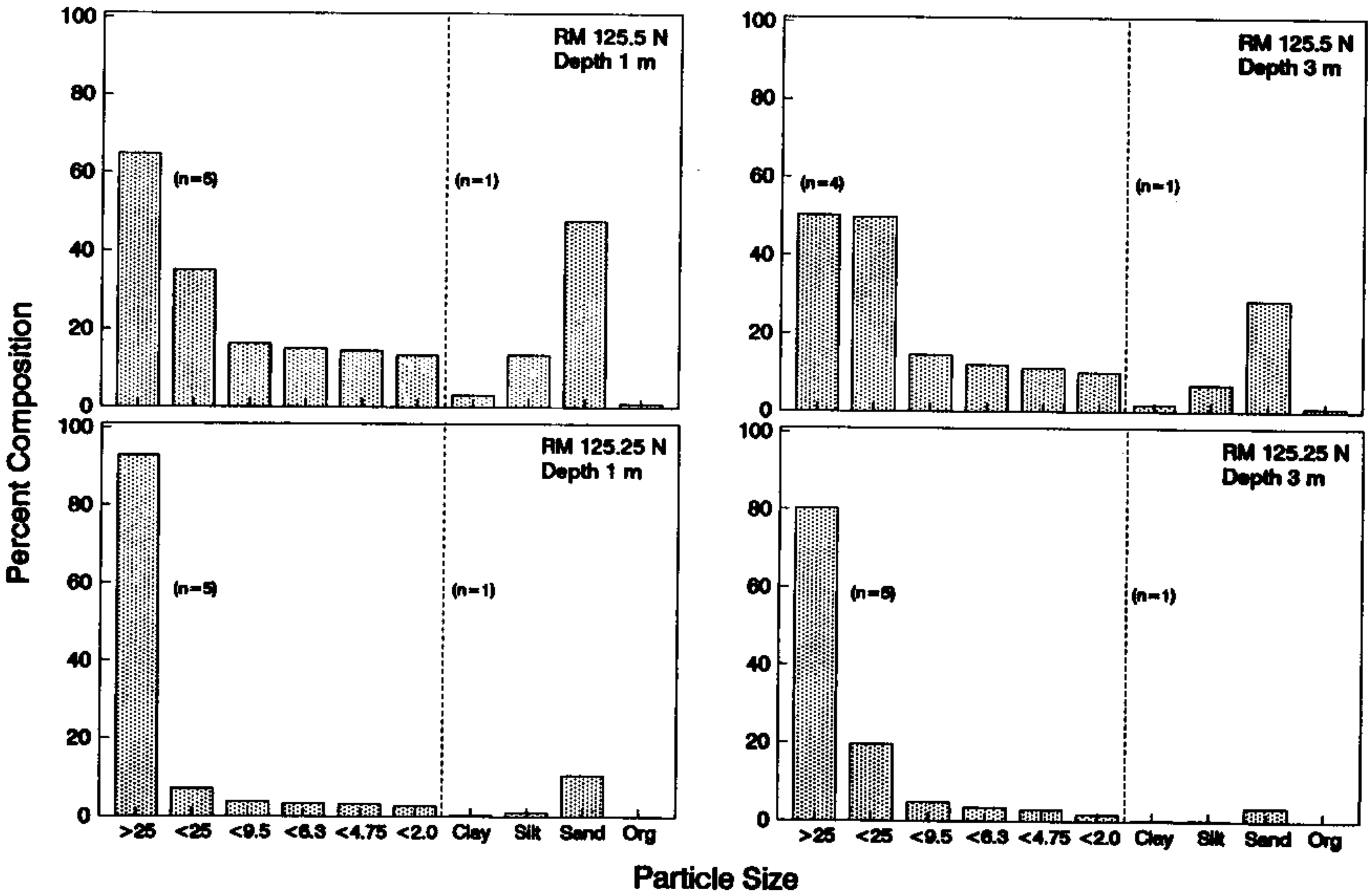

Figure 22. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

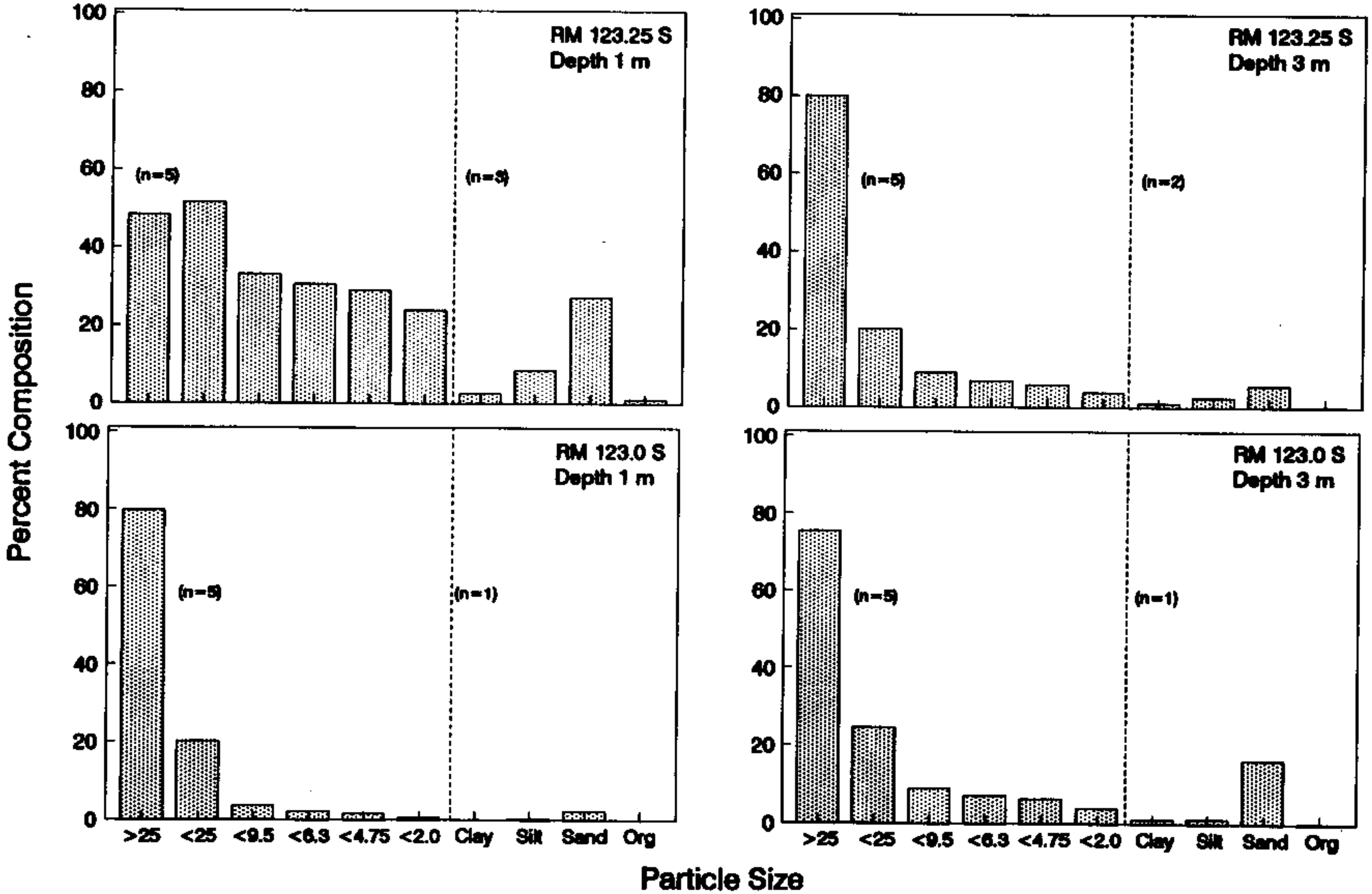

Figure 23. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

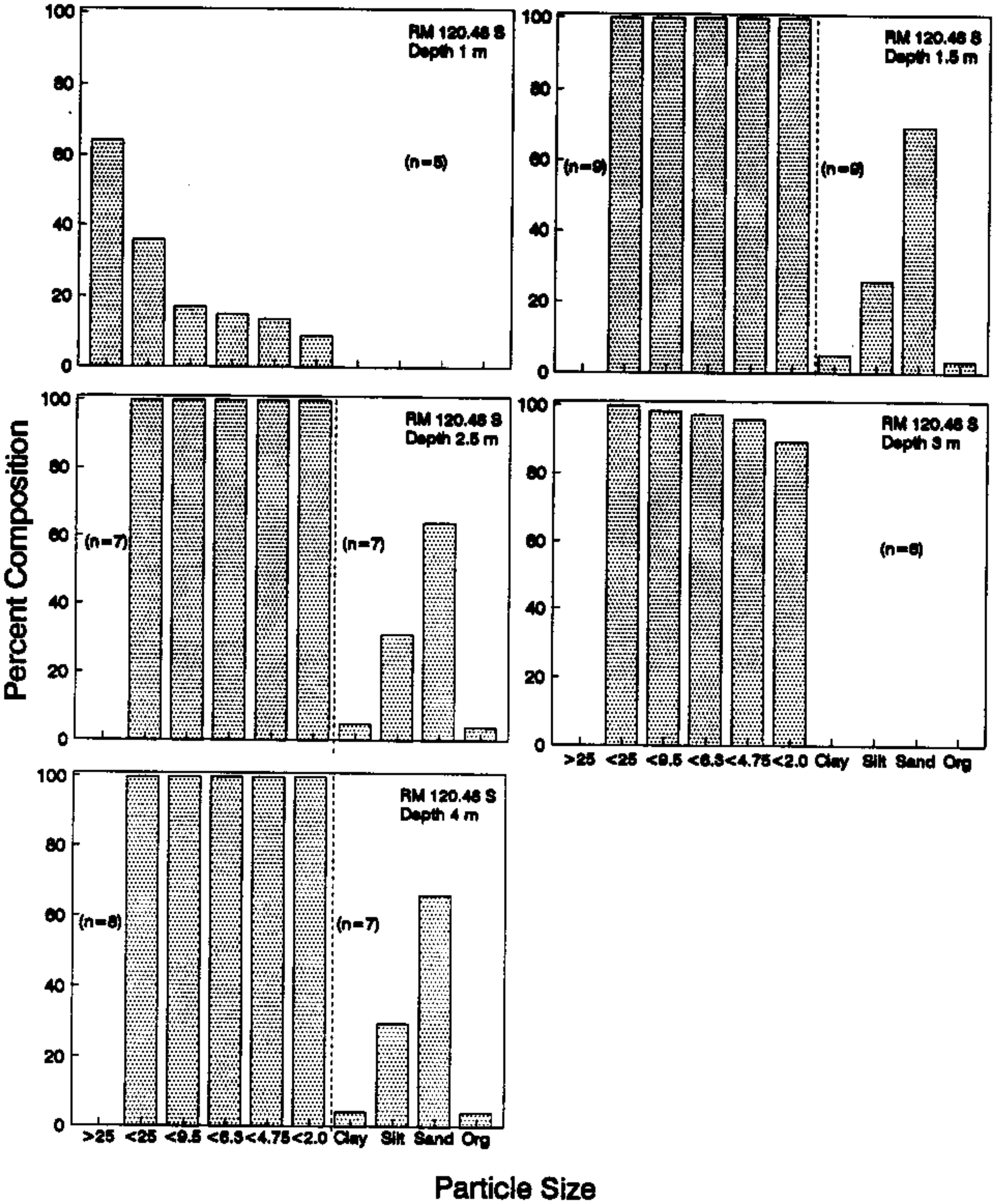

Figure 24. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 and 1994 (1 m and 3 m) in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

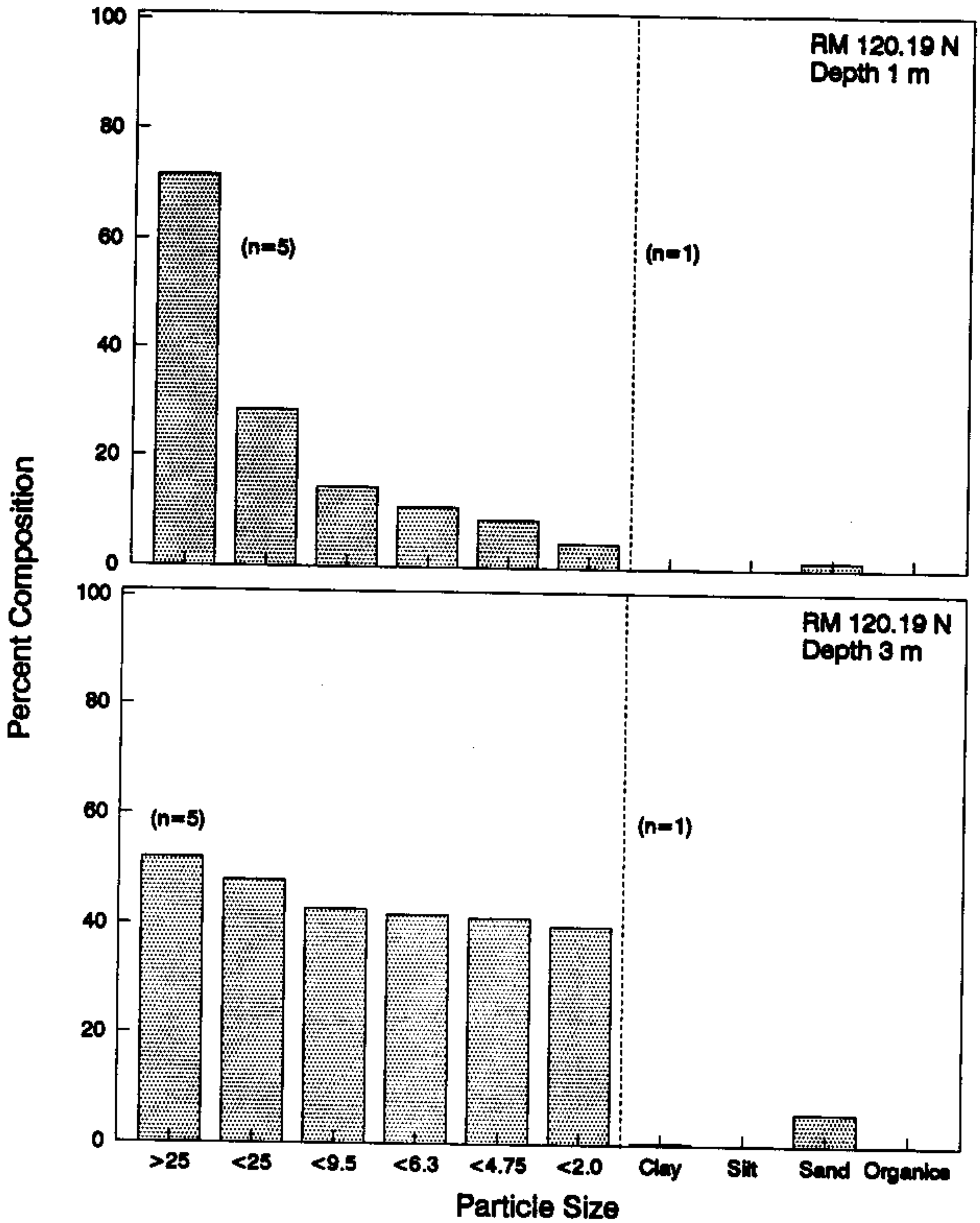

Figure 25. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

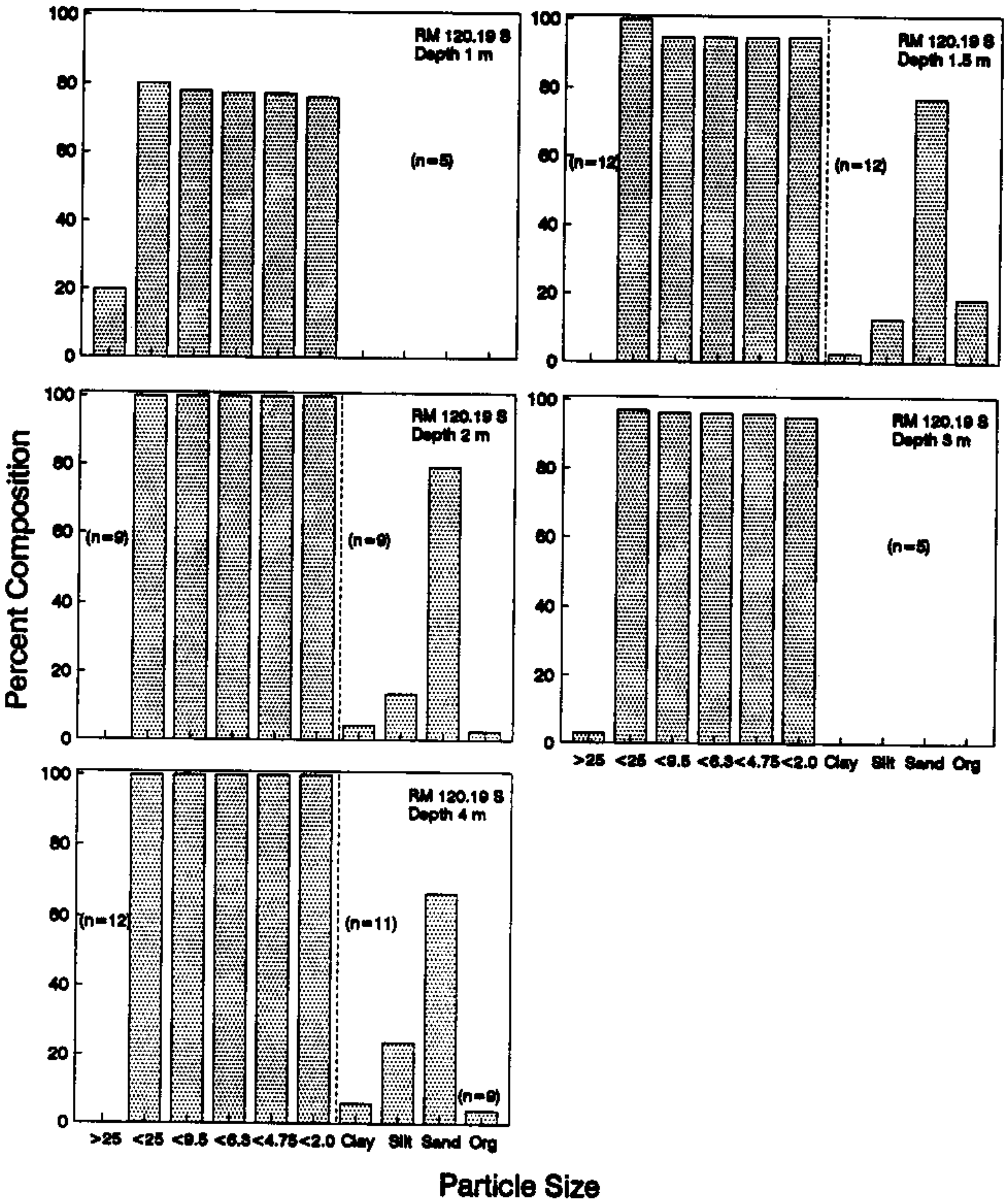

Figure 26. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 and 1994 (1 m and 3 m) in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

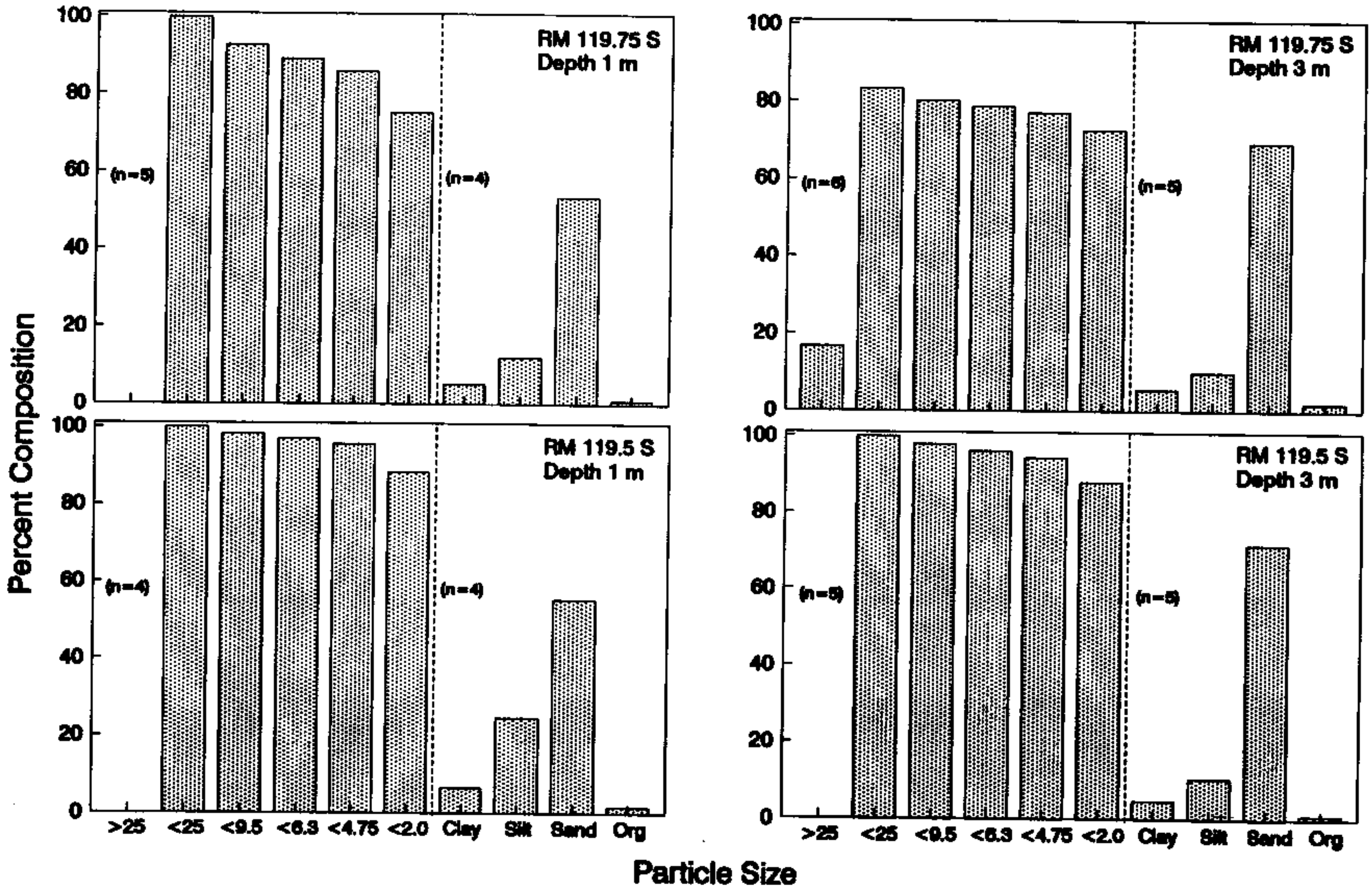

Figure 27. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

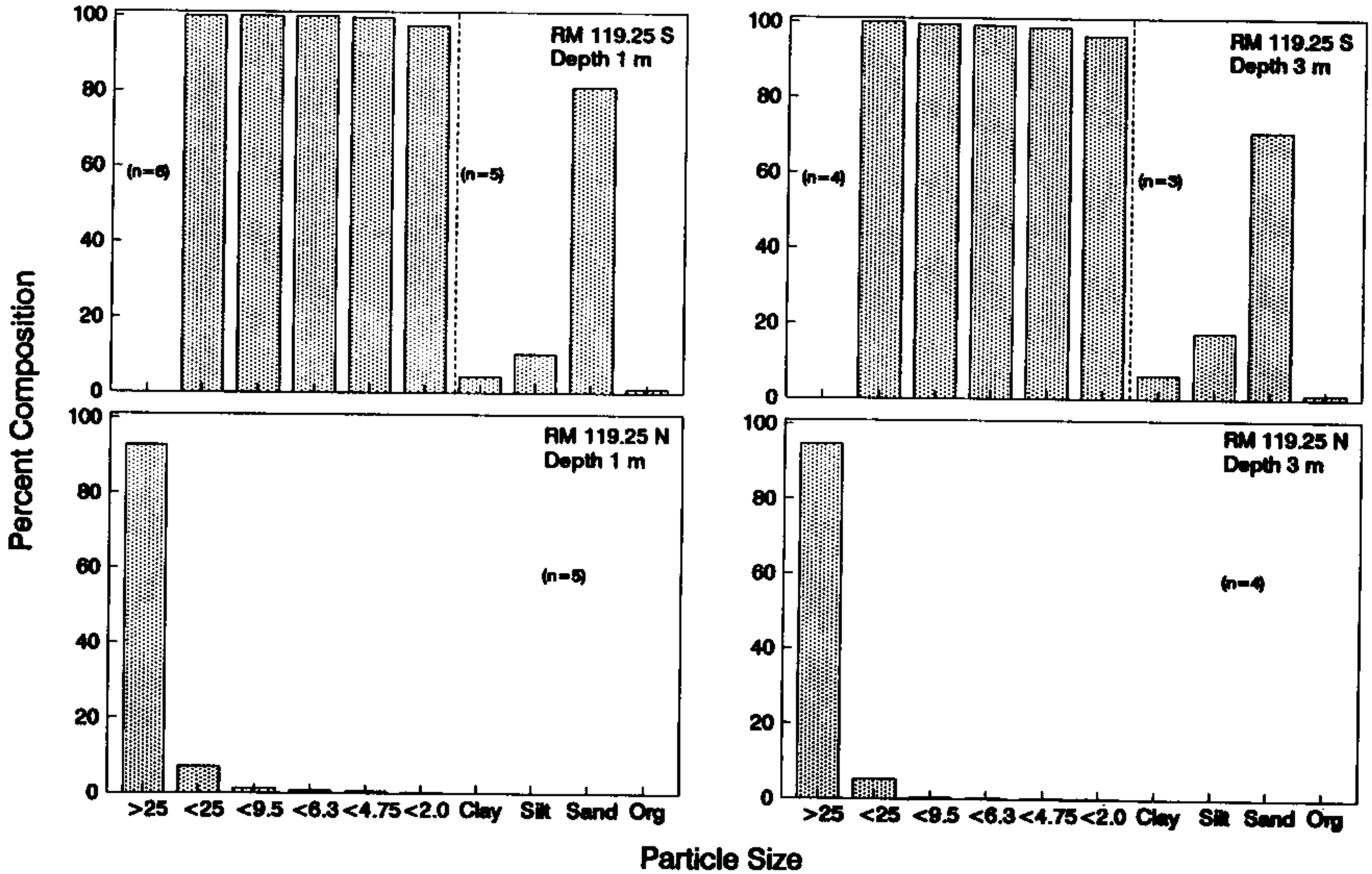

Figure 28. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

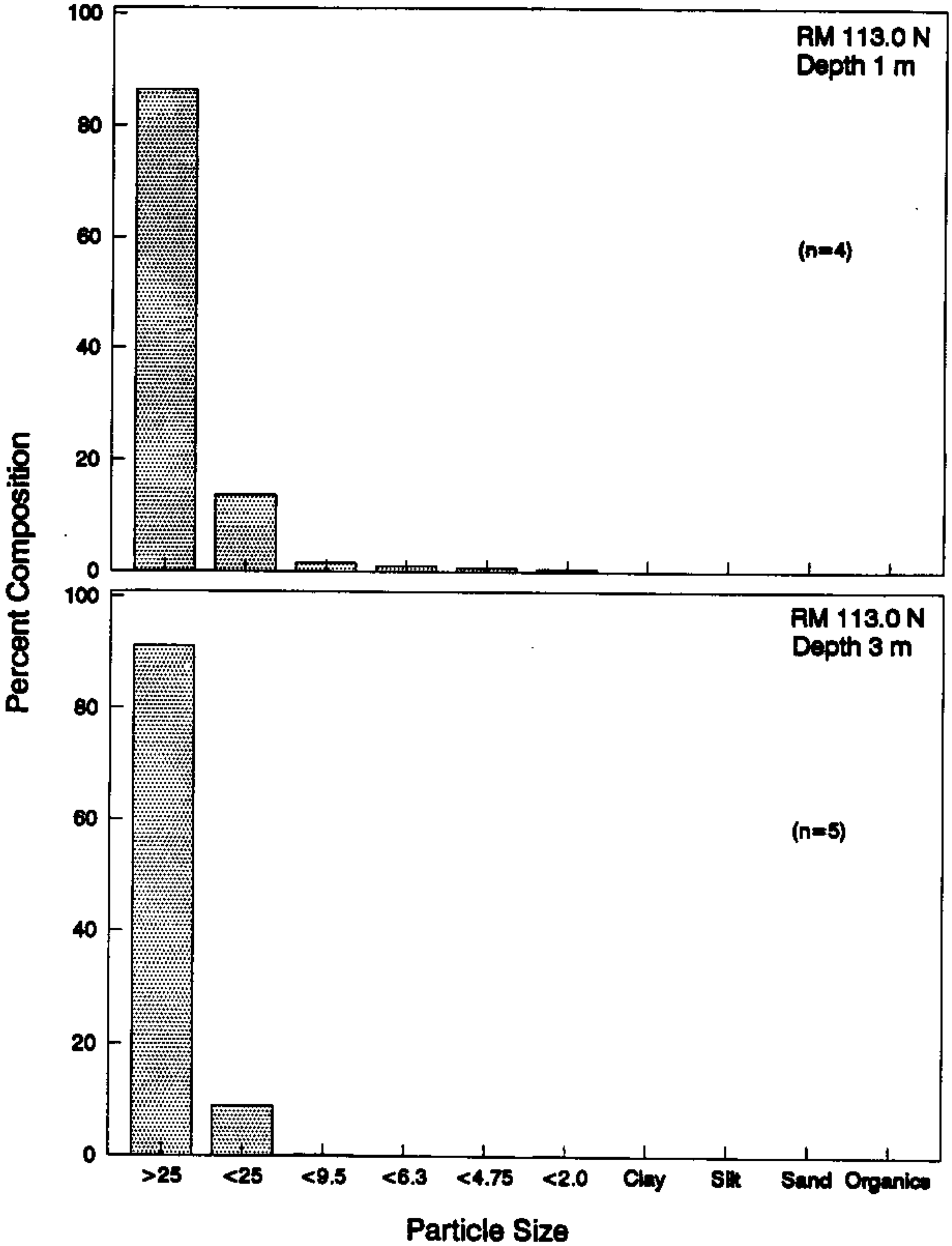

Figure 29. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics sampled during 1994 in Lower Granite Reservoir.

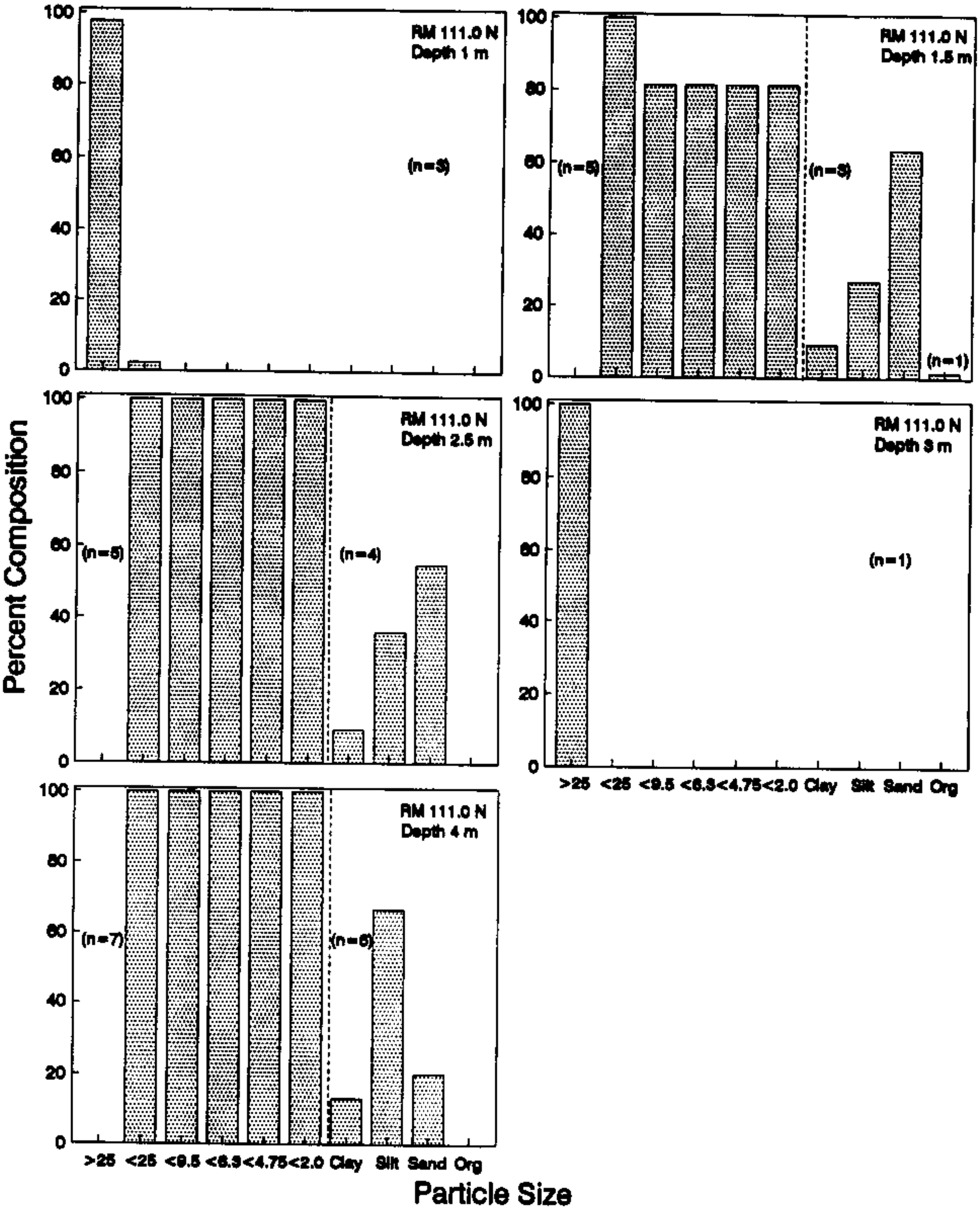

Figure 30. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 and 1994 (1 m and 3 m) in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

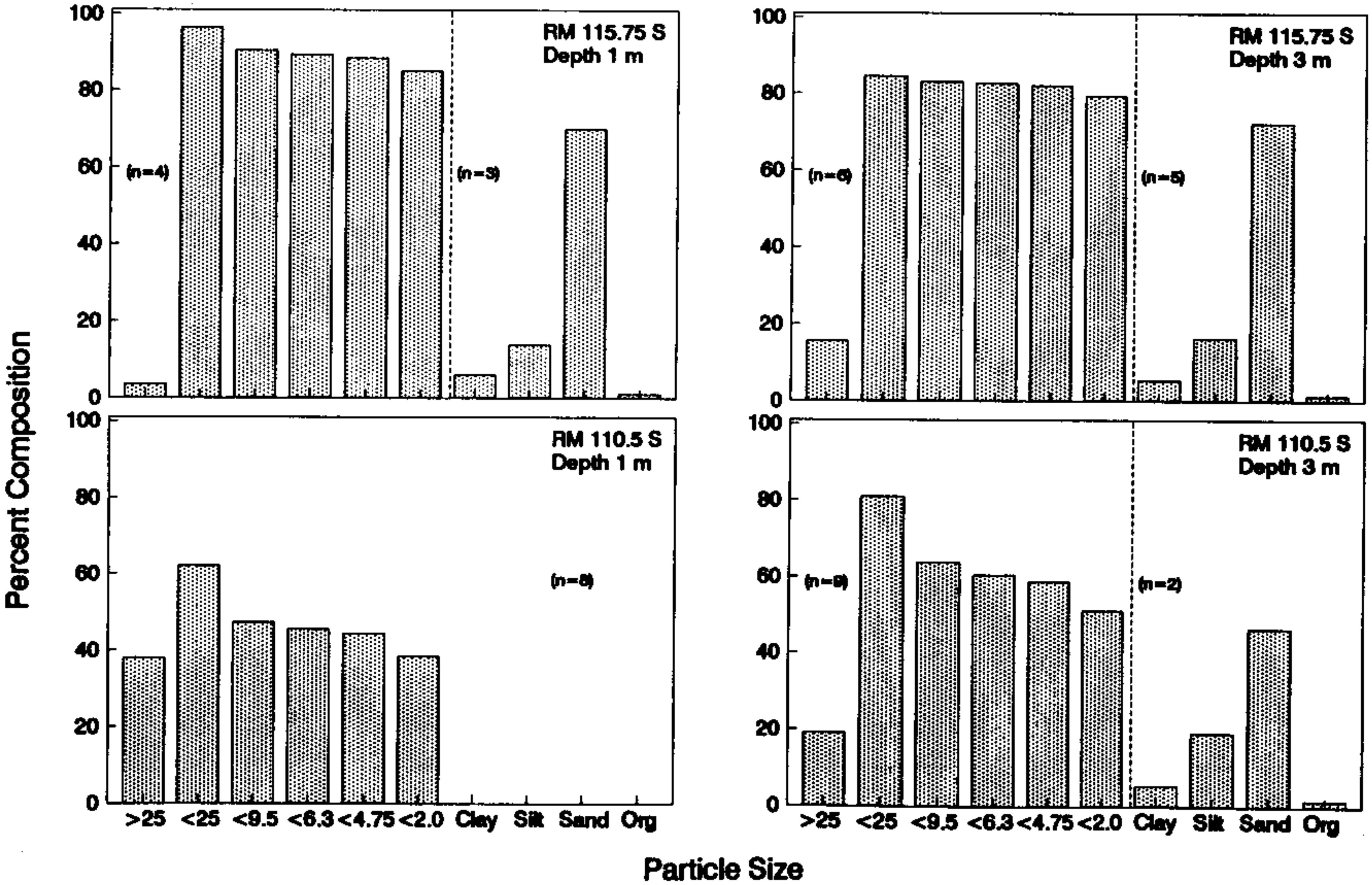

Figure 31. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 (RM 110.5 S) and 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

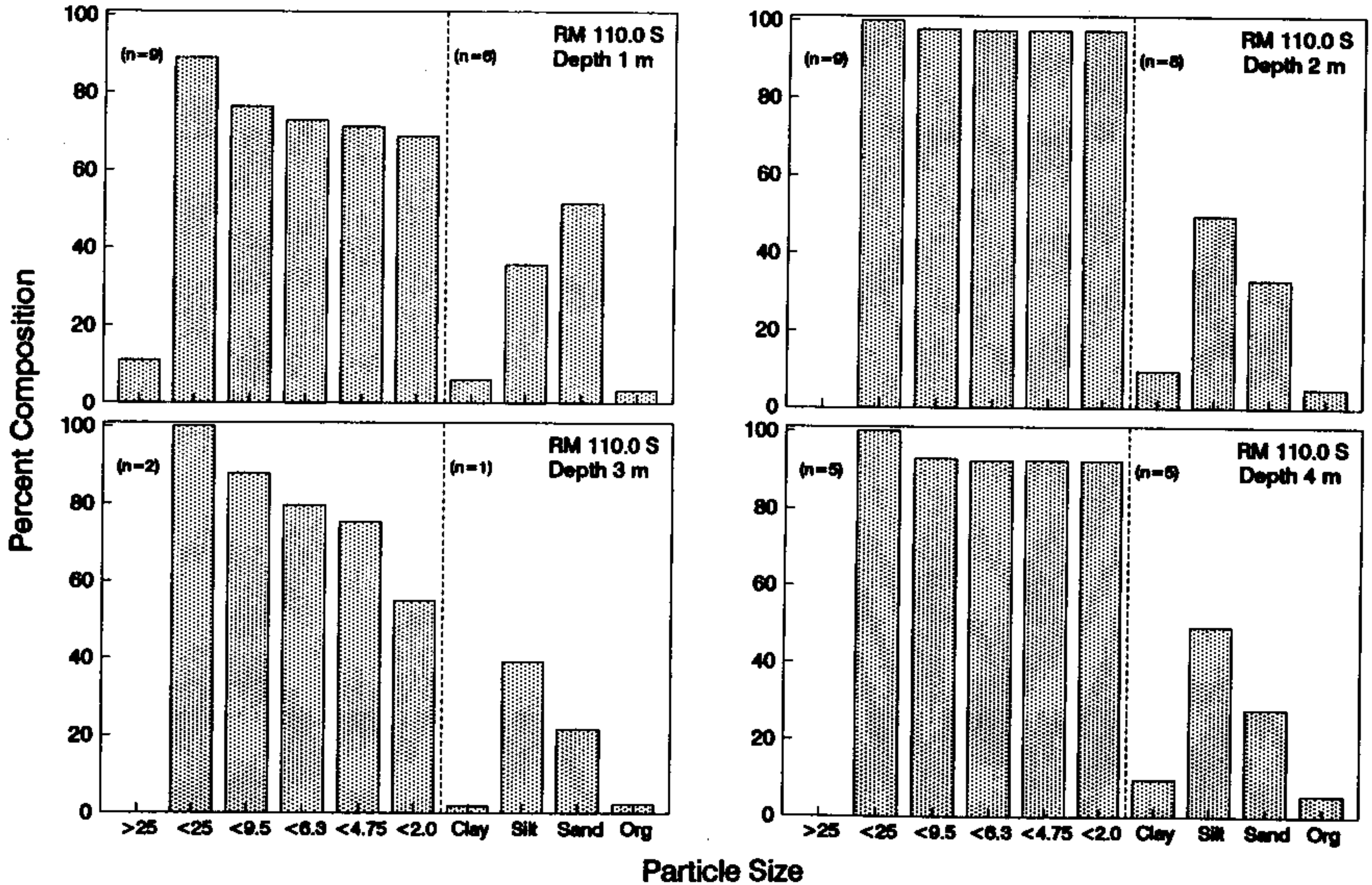

Figure 32. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1993 and 1994 in Lower Granite Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

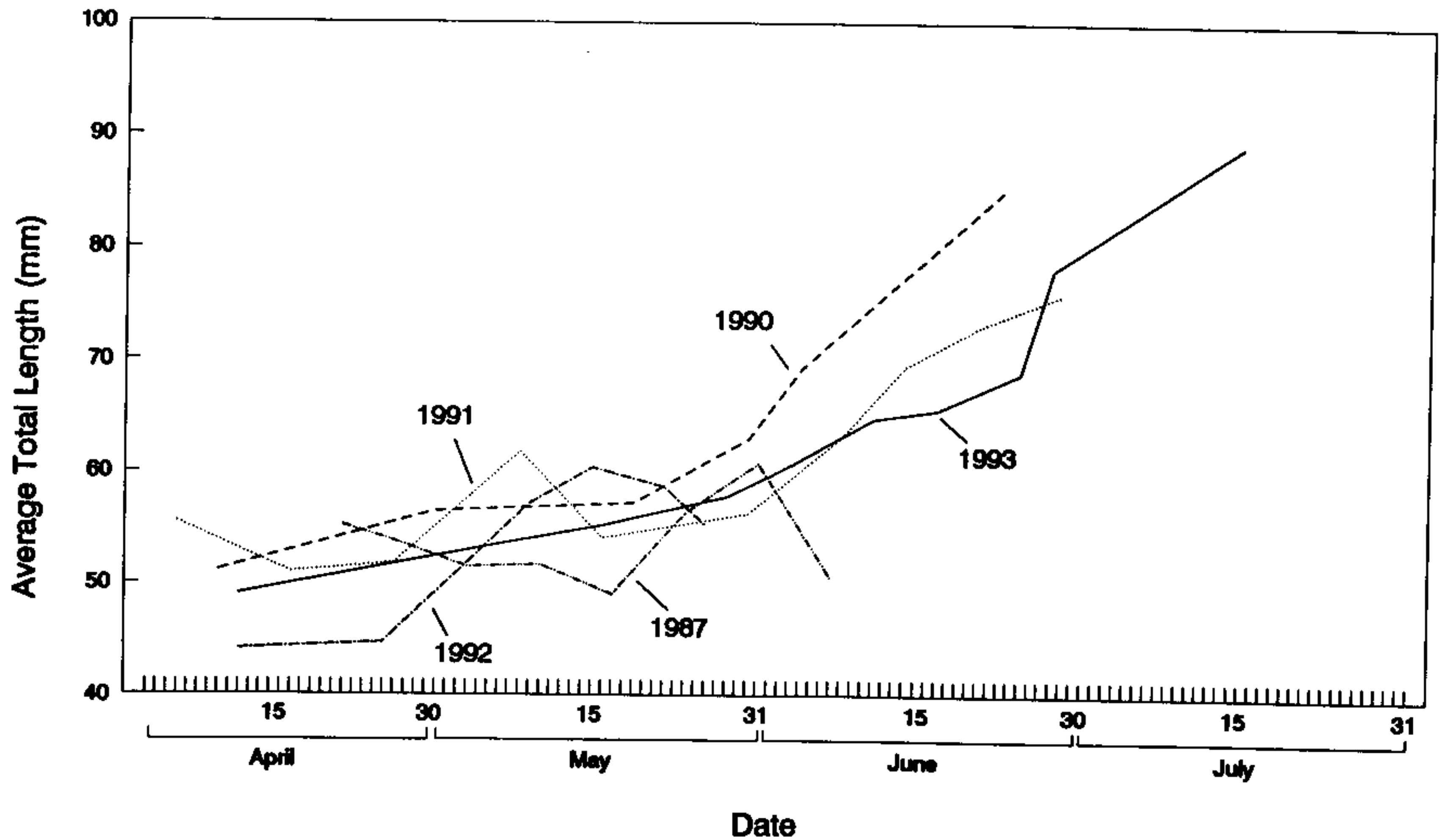

Figure 33. Average total length of subyearling chinook salmon sampled during 1987, 1990, 1991, 1992, and 1993 in Lower Granite Reservoir.

to nearly 50 mm for other years. Changes in mean total length from mid-April to mid-July suggested nearly linear growth of subyearling chinook salmon in Lower Granite Reservoir (Figure 33). In mid-April 1993, fish averaged approximately 50 mm and by mid-July mean size increased to approximately 90 mm, an average growth rate of slightly < 1 mm/day.

Factors Affecting Abundance

Abundance of Predators.—Relative abundances of northern squawfish, channel catfish, and smallmouth bass sampled by all gears were generally similar within years (1990, 1991, 1992, and 1993) and among seasons (Figure 34). Overall relative abundance was highest for smallmouth bass and lowest for channel catfish. Approximately 25% of the fishes collected from 1990 to 1993 during summer were smallmouth bass. Highest relative abundance for northern squawfish was in summer 1993, although abundance was similar among other seasons and years.

Absolute abundances of most predators in Lower Granite Reservoir have not been determined. Potential predator absolute abundances were estimated based on comparisons of catch/effort data for the same gear type between Lower Granite and John Day reservoirs. Based on this approach, Chandler (1993) estimated the abundance of northern squawfish > 250 mm at 15,850 (3602 ha x 4.4 squawfish/ha; Beamesderfer and Rieman 1991). The proportion of all squawfish > 349 mm sampled was 44%.

Curet's (1994) estimate of absolute abundance of age 1 and older smallmouth bass in Lower Granite Reservoir was 46,962 based on comparative estimates of catch/efforts of John Day Reservoir. Recently, Anglea (Steve Anglea, Department of Fish and Wildlife, University of Idaho, Moscow, personal communication) estimated absolute abundance of smallmouth bass and his preliminary estimates were similar to those of

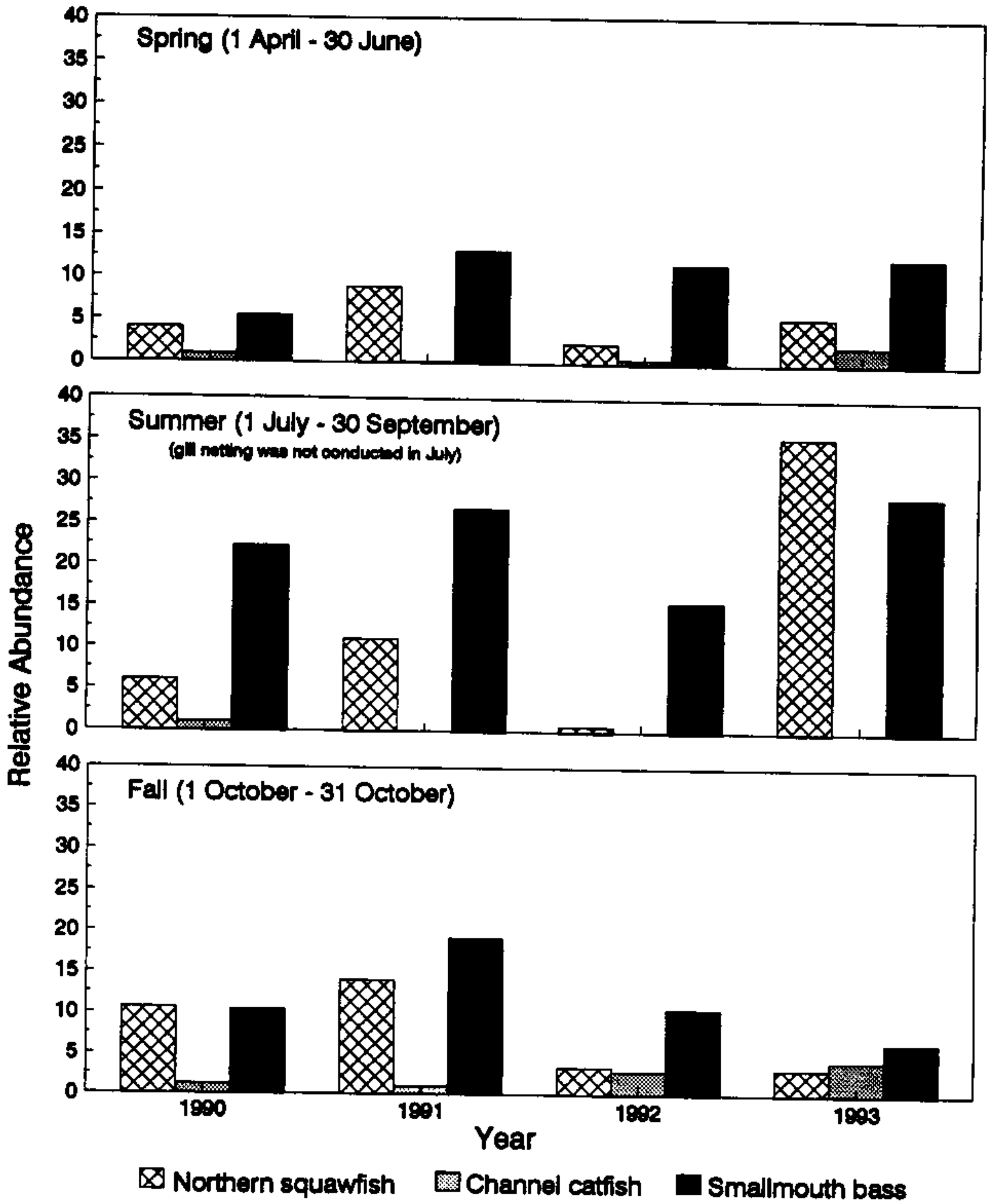

Figure 34. Relative abundance of northern squawfish, channel catfish, and smallmouth bass sampled by beach seining, electrofishing, and gill netting during spring, summer, and fall 1990, 1991, 1992, and 1993 in Lower Granite Reservoir. Gill nets were not used from 27 June to 1 October, 1993.

Curet (1994). The proportions of smallmouth bass within the three size groups examined were 83% at < 250 mm, 16% at 250 to 389 mm, and 1% > 390 mm.

Predatory Losses.—Curet (1994) estimated the loss of subyearling chinook salmon to predation in Lower Granite Reservoir during May 1992. He reported smallmouth bass and northern squawfish consumed an estimated 31,512 and 17,092 subyearlings, respectively, in May 1992. His estimate of predation was 6% of the estimated 786,470 naturally produced subyearling fall chinook that migrated through Lower Granite Reservoir in 1992. Using the appropriate coefficients, a more accurate estimate of salmonid smolt consumption by smallmouth bass for the upper reach (RM 127 to 139) of lower Granite Reservoir was 35,576, or about 4.5%. However, this predation loss was for about the upper third the reservoir.

Numbers of Adult Fall Chinook.—The number of adult fall chinook salmon that crossed Lower Granite Dam in the year preceding the collection of subyearling chinook in Lower Granite Reservoir showed no relationship between the index of adult numbers and our peak catches of subyearling chinook (Figure 35). The correlation was not significant ($r=0.08$; $P=0.896$) and adult numbers accounted for < 1% of the variation in the peak catches of subyearling chinook in the reservoir.

Water Temperatures. —Water temperatures in Lower Granite Reservoir increased from about 8 to 11°C in early April and attained 16 to 18°C earlier in 1987 and 1992 than in 1990, 1991, and 1993 (Figures 36 and 37). We found no significant correlation ($r=-0.915$; $P=0.26$) with the number of shoreline rearing days with the peak catches in Lower Granite Reservoir probably because we only had data for 3 years. However, we believe the relationship does show some association that suggests higher juvenile abundance in Lower Granite Reservoir may be inversely related to the duration of rearing (that is directly related to water temperature). These data provide some support

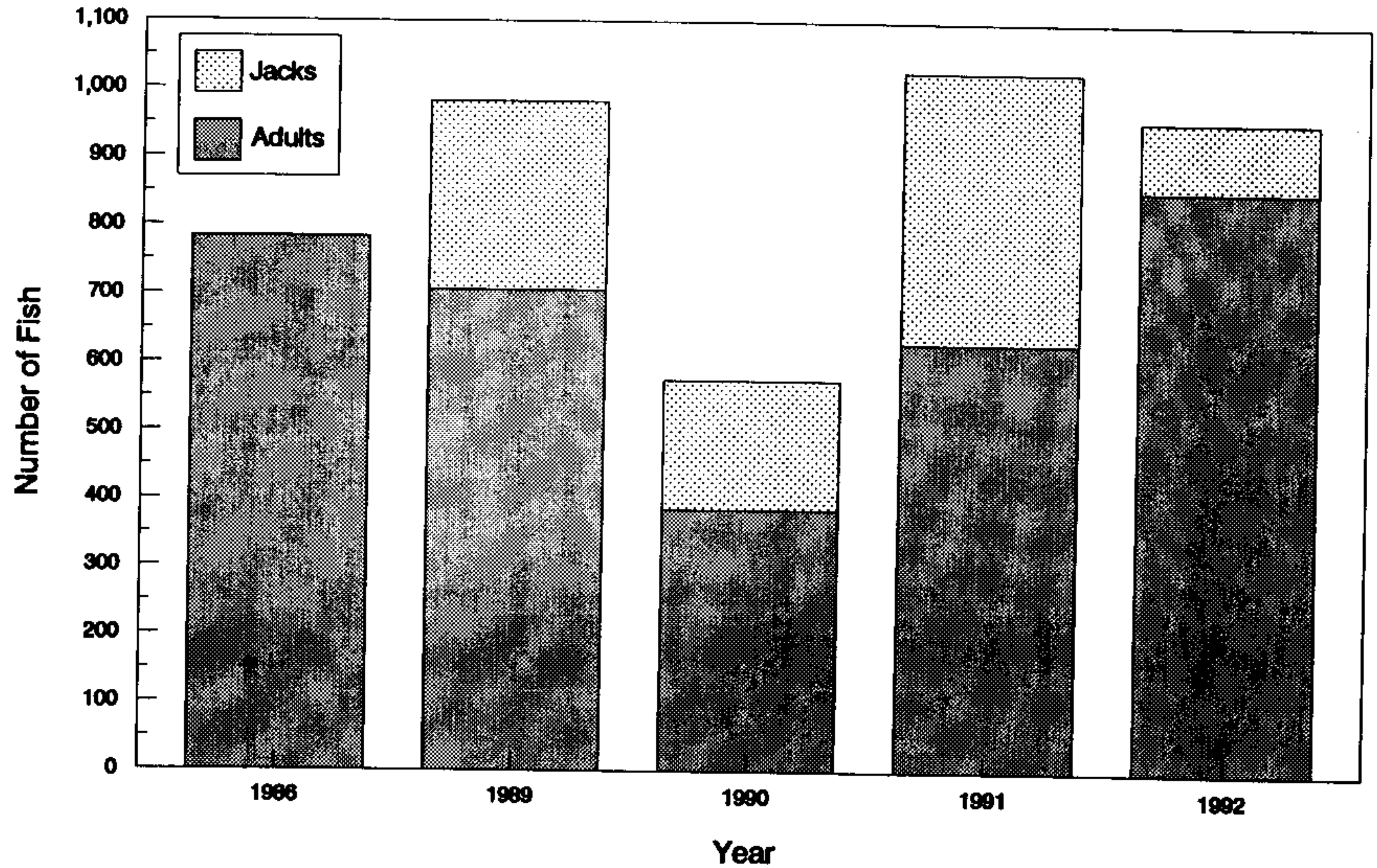

Figure 35. Numbers of fall chinook salmon, adults,and jacks counted during 1986, 1989, 1990, 1991, and 1992 at Lower Granite Dam. Number of jacks is not given for 1986.

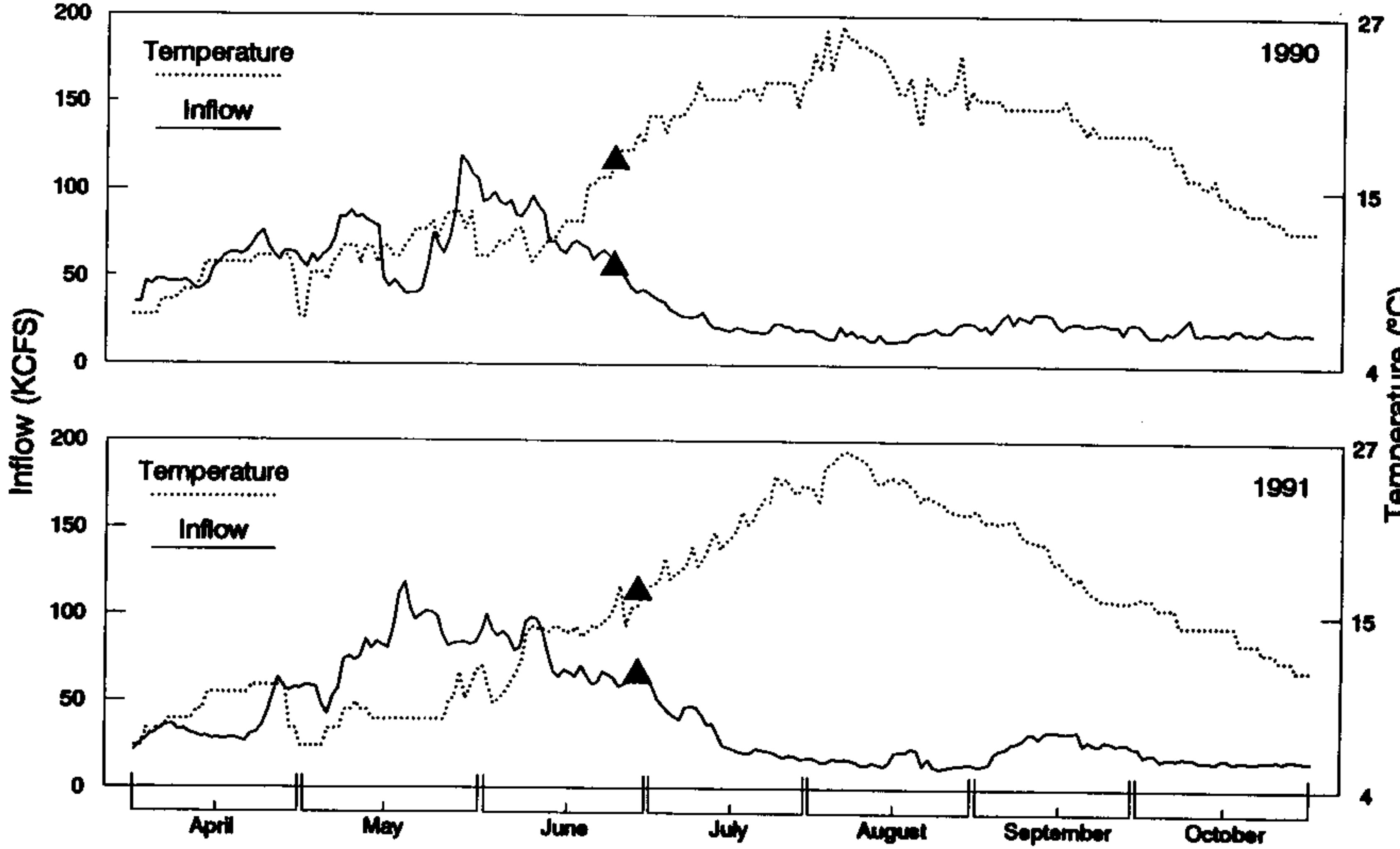

Figure 36. Daily average inflows and water temperatures from April through October during 1990 and 1991 into Lower Granite Reservoir. Triangles indicate date of last capture of subyearling chinook salmon along the shoreline.

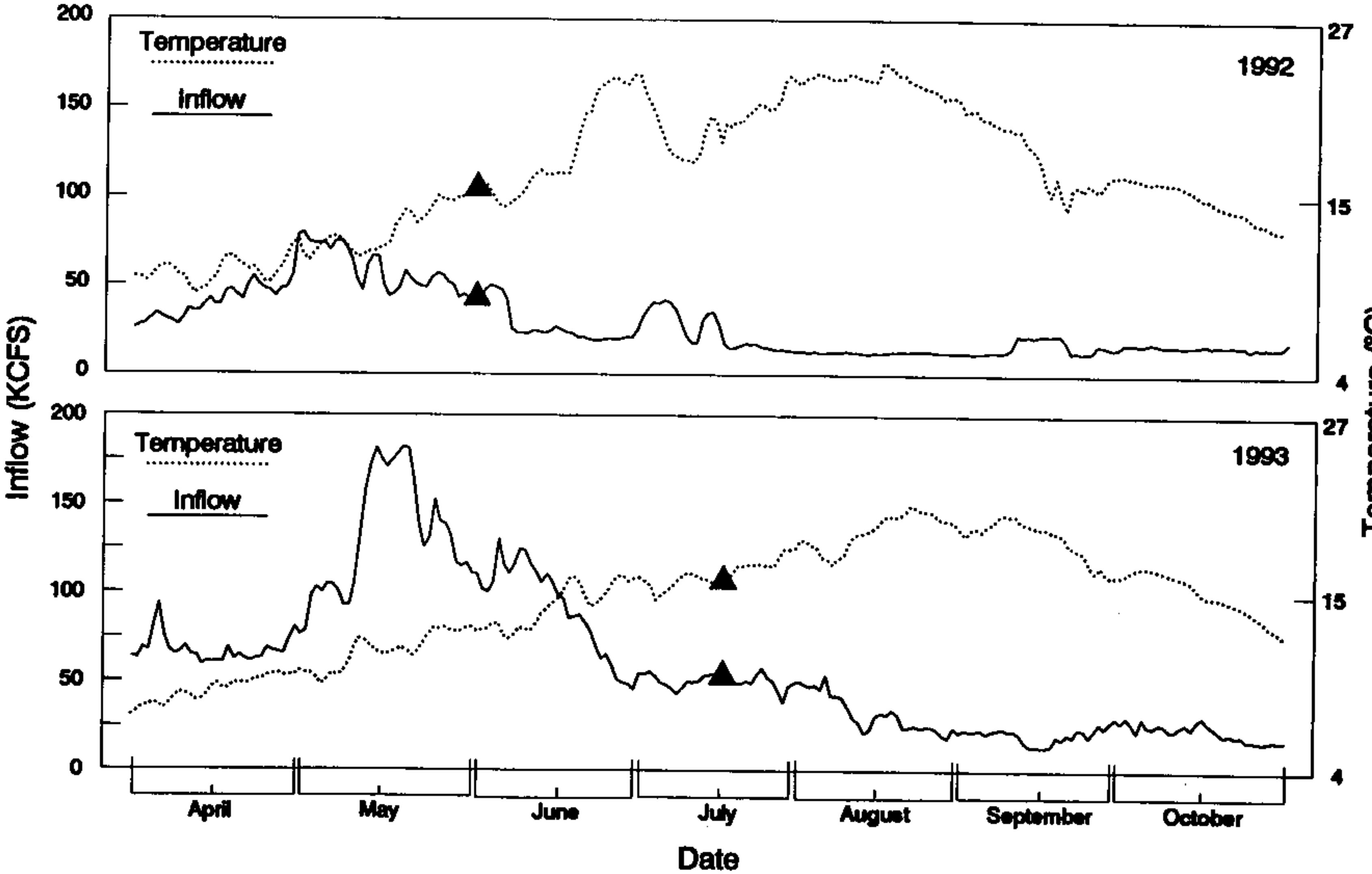

Figure 37. Daily average inflows and water temperatures from April through October during 1992 and 1993 into Lower Granite Reservoir. Trianges indicate date of last capture of subyearling chinook salmon along the shoreline.

for the hypothesis that higher in-reservoir abundance of subyearling chinook salmon may occur under higher ambient water temperatures in spawning areas.

Inflows. —Daily average inflows to Lower Granite Reservoir from 1990 to 1993 peaked from mid-May to early June (Figures 36 and 37). Peak flows in 1992 were about 40% of those in 1993. During the years of sampling, flows in 1993 were the highest throughout the spring and into mid-August.

Correlations of the peak number of juvenile subyearlings collected in Lower Granite Reservoir were not significant ($P<0.05$) with flow variables selected, although sample size was ostensibly a factor ($n=4$). Peak numbers of juvenile subyearlings collected were more closely correlated with the duration of rearing following peak flows ($r=-0.805$; $P=0.195$) and the average June flow into Lower Granite Reservoir ($r=-0.891$; $P=0.109$). In general, these correlations are colinear with water temperature. When temperature is held constant at peak flow, these correlations increase (duration of rearing following peak flows; $r=-0.9978$) and the average June flow ($r=-0.9196$) that substantially demonstrates the negative association of peak numbers with flow.

Little Goose Reservoir

Abundance

We estimated absolute population abundance of subyearling chinook from 1991 to 1993 in Little Goose Reservoir. Estimated abundance was similar between 1991 and 1992 but about three times higher in 1993. Abundance was consistently highest in Reach 2 (RM 103.5 - RM 83.5). Confidence intervals on these estimates were about 50% of the point estimates.

1991. —Little Goose Reservoir was the only reservoir sampled for subyearling chinook salmon in 1991. A total of 120 subyearling chinook was collected within the three reaches of Little Goose Reservoir between May and August, 1991 (Figure 38).

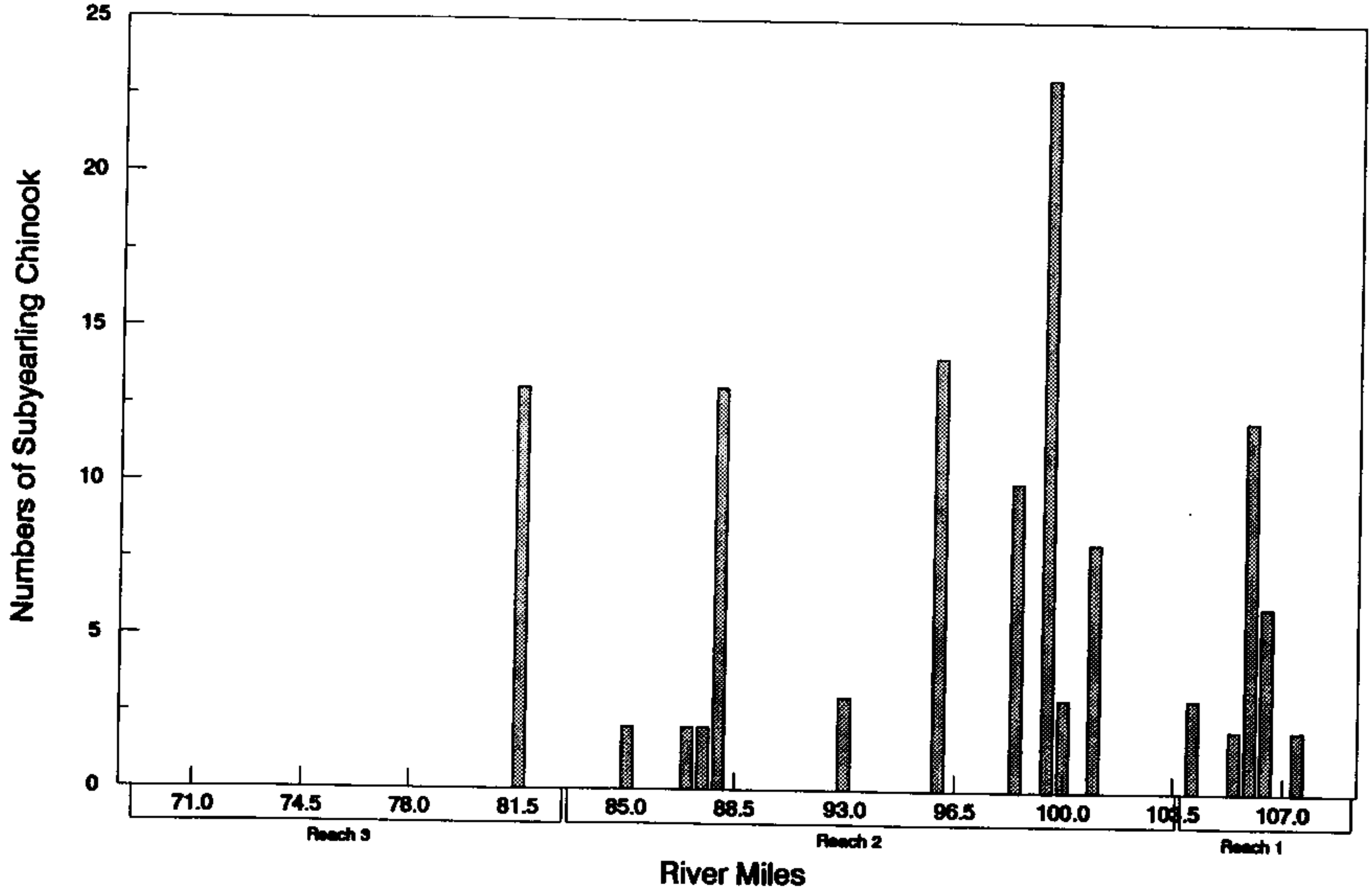

Figure 38. Number of subyearling chinook salmon collected at various locations during 1991 in Little Goose Reservoir.

Highest numbers of salmon were collected in Reach 2 (n=85), followed by Reach 1 (n=22) and Reach 3 (n=13). Highest estimated absolute abundance of subyearling chinook salmon based on our samples from Little Goose Reservoir occurred during June (Figure 39), and no subyearling chinook salmon were collected after mid-July. Population estimates by reach indicated the majority of subyearling chinook salmon was rearing within Reach 2 between RMs 83.5 and 103.5. Abundances of rearing chinook within Reach 1 were consistently lower than in Reach 2, and chinook rearing within Reach 3 were detected through June.

1992.—A total of 28 subyearling chinook was collected within the three reaches in Little Goose Reservoir between April and June 1992. Highest numbers of fish were collected in Reach 2 (n=24), followed by Reach 3 (n=3), and Reach 1 (n=1). Highest absolute abundance of subyearling chinook salmon in Little Goose Reservoir occurred during mid-May and no subyearlings were collected after mid-May. Population estimates by reach indicated highest numbers of fish reared in Reach 2 followed by Reach 3, while numbers in Reach 1 were consistently low (Figure 40).

1993.—A total of 155 subyearling chinook salmon was collected within the three reaches of Little Goose Reservoir between 27 April through 16 July 1993. Highest numbers of subyearling chinook were collected in Reach 2 (n=100), followed by Reach 1 (n=35), and Reach 3 (n=20). The estimated population abundance of subyearling chinook along the shoreline in Little Goose Reservoir peaked at 5,439 fish on 29 May 1993 (Figure 41). No subyearling chinook salmon were collected after 16 July. Population estimates of subyearling chinook by reach for Little Goose Reservoir indicated the highest numbers of chinook were found in Reach 2 for all sampling dates. Comparison of population estimates for Reaches 1 and 3 indicated subyearling abundance was higher at Reach 3 than Reach 1 for the earlier sampling dates (27 April - 29 May), while Reach 1 was higher than Reach 3 during the later sampling dates (4 June - 16 July).

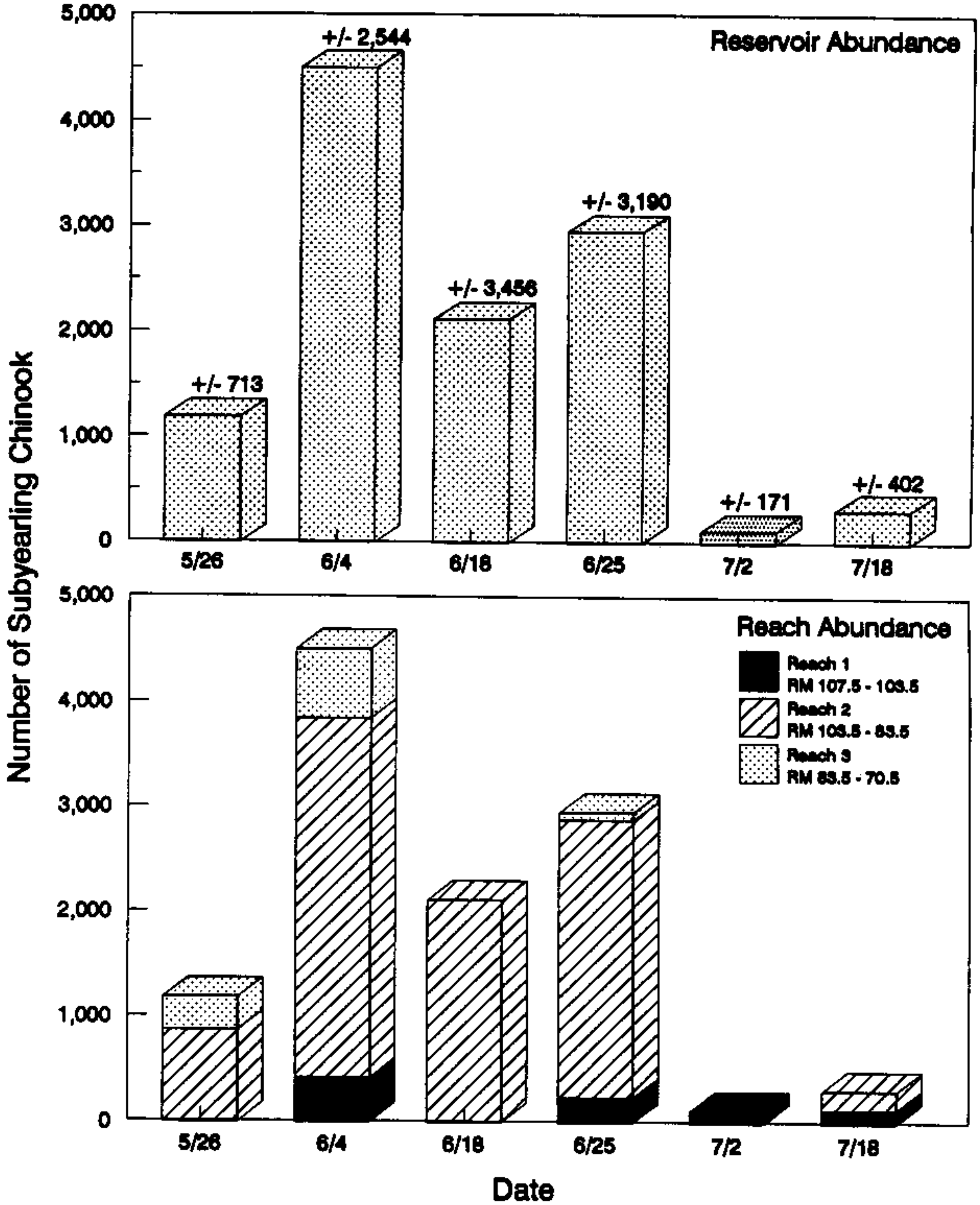

Figure 39. Population estimates of subyearling chinook salmon by date during 1991 in Little Goose Reservoir. Estimates for reservoir abundance were calculated by stratified random sampling and those for reach abundance by simple random sampling. Confidence intervals were calculated with 95% bounds.

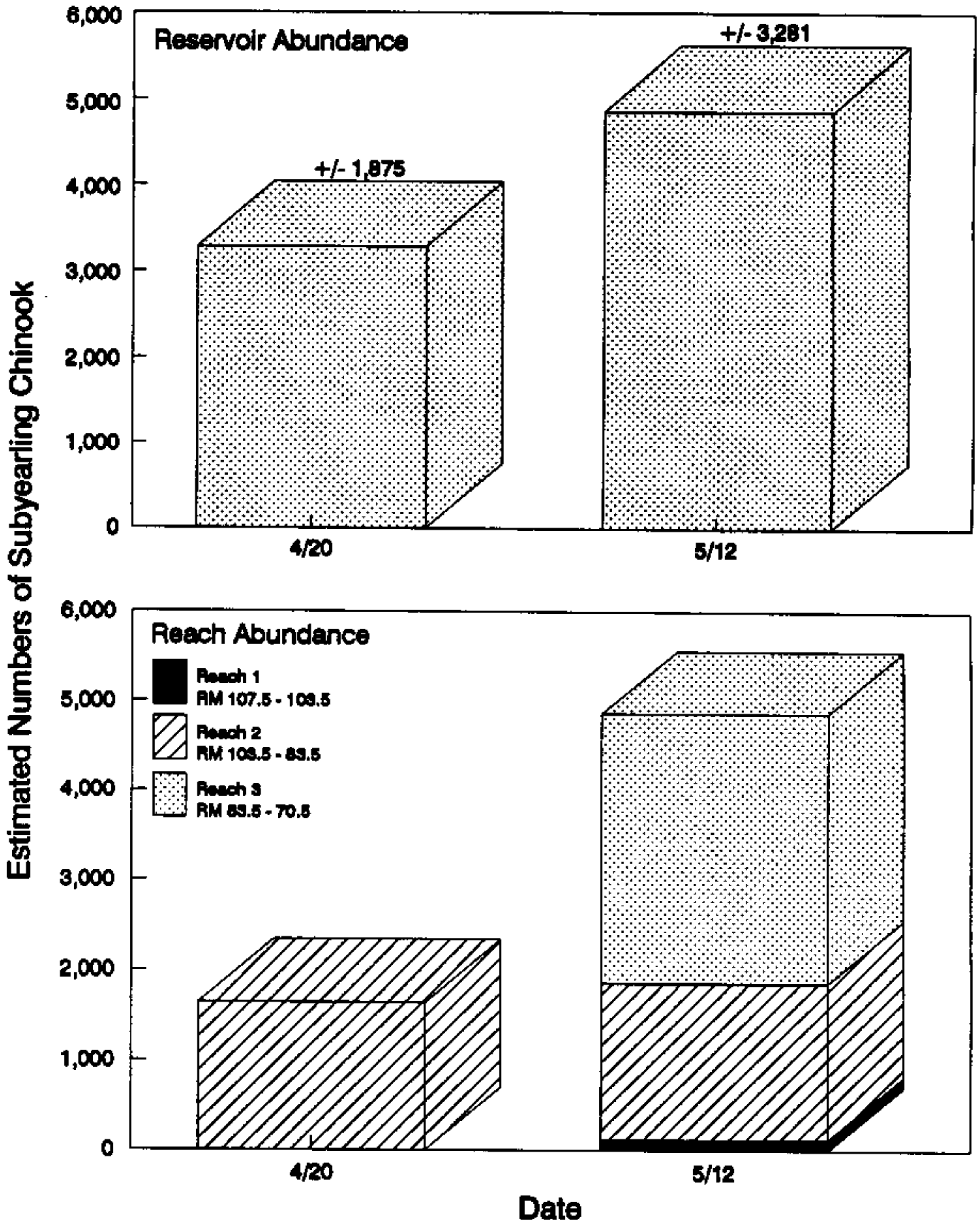

Figure 40. Population estimates of subyearling chinook salmon by date during 1992 in Little Goose Reservoir. Estimates for reservoir abundance were calculated by stratified random sampling and those for reach abundance by simple random sampling. Confidence intervals were calculated with 95% bounds.

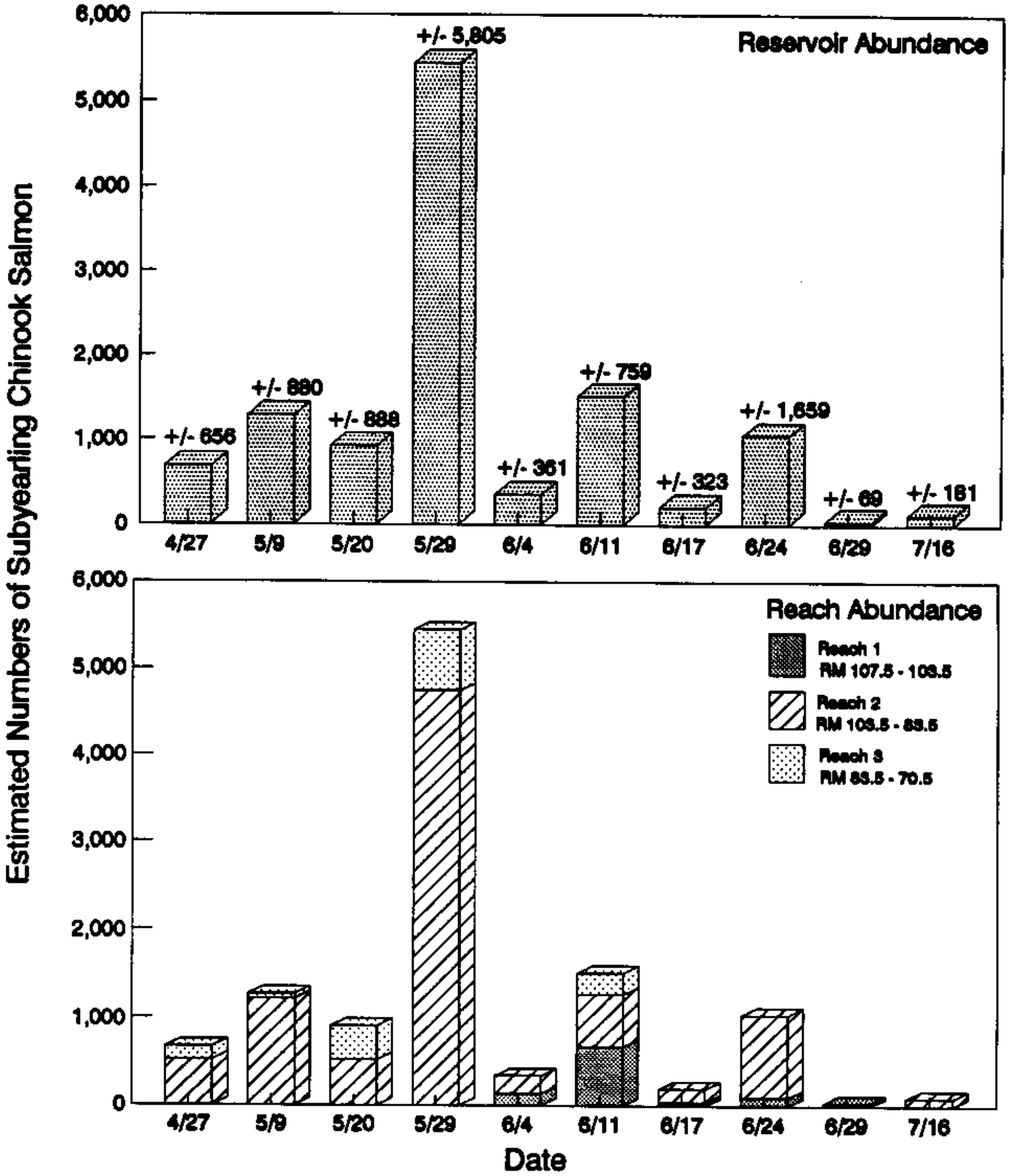

Figure 41. Population estimates of subyearling chinook salmon by date during 1993 in Little Goose Reservoir. Estimates for reservoir abundance were calculated by stratified random sampling and those for reach abundance by simple random sampling. Confidence intervals were calculated with 95% bounds.

Timing

Estimated timing of peak population abundance of subyearling chinook salmon in littoral areas differed between years 1991 through 1993 (Figure 42). In 1993, estimated peak population along the shoreline of Little Goose Reservoir occurred on 29 May, compared to 12 May in 1992 and 4 June in 1991 (Curet 1994).

Abundance of subyearling chinook along the shoreline in Little Goose Reservoir during 1993 appears related to water temperature (Figure 43). Subyearlings left the shoreline when water temperatures approached 18°C (64.4°F) on 19 July, 1993. In 1991, water temperatures exceeded 20°C at the last time of collection, although few subyearlings were collected.

Habitat Use

Subyearling chinook salmon rearing along the shoreline of Little Goose Reservoir exhibited a strong preference for sand substrata during 1991, 1992, and 1993 using Jacobs Utilization Index (Figure 44). Most subyearlings were collected over fine substrata that consisted of either mud/sand, sand/cobble, or strictly sand occasionally colonized by *Potamogeton crispus* (Figure 45). Subyearling chinook salmon were most abundant in areas where water velocities were low. Subyearling chinook showed a slight avoidance of cobble/sand substrates during 1991 and 1993 and a high avoidance of cobble during spring 1992. A moderate to high avoidance of a talus/sand and rip-rap was shown for all 3 years.

Water Temperatures

Water temperatures in Little Goose Reservoir were coolest in Reach 1 followed by Reaches 2 and 3 in 1991 (Figure 46). By mid-July, surface temperatures exceeded 20°C throughout Little Goose Reservoir and subyearling chinook were not collected along

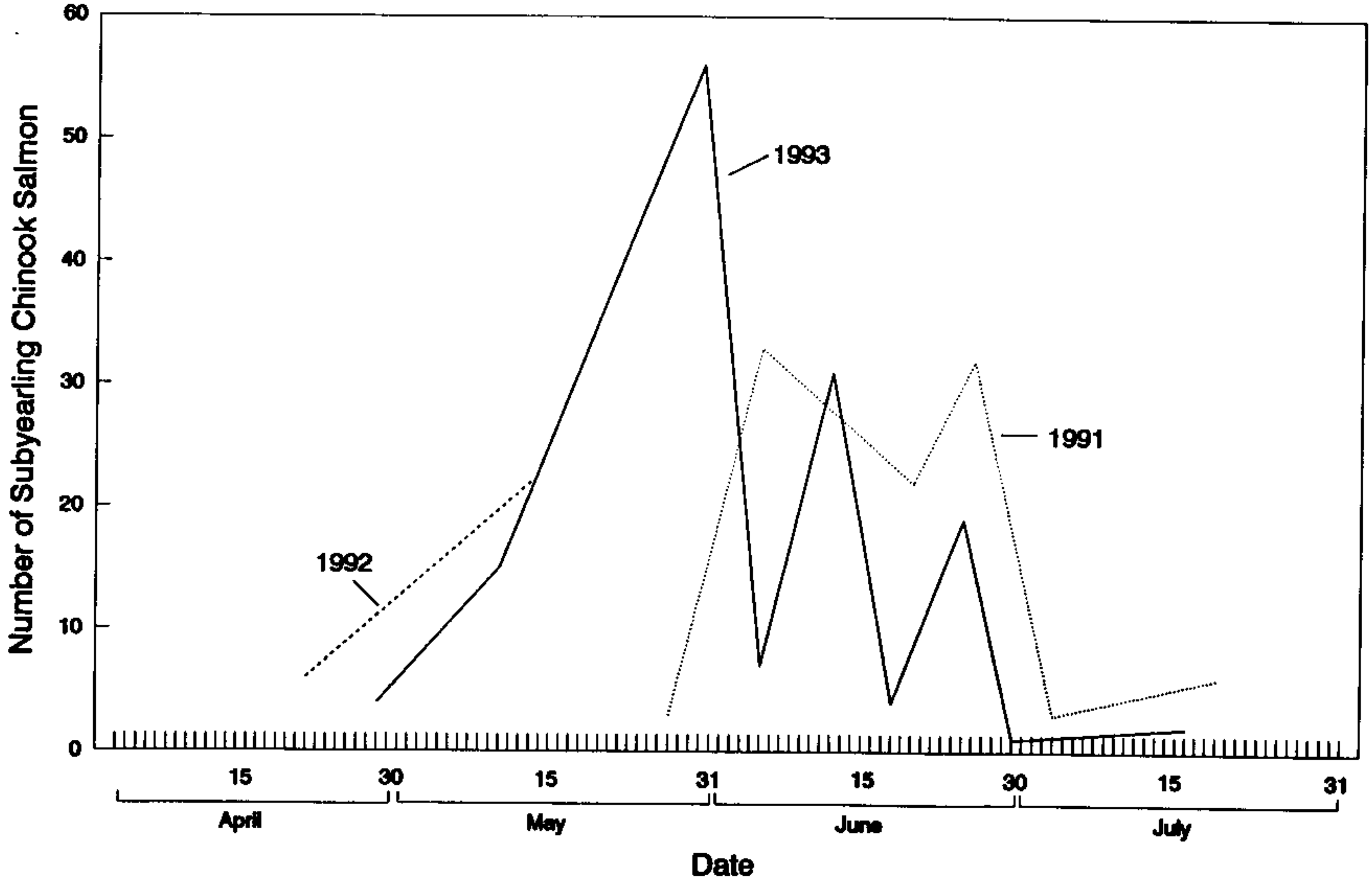

Figure 42. Annual comparisons of shoreline abundance of subyearling chinook salmon during 1991, 1992, and 1993 in Little Goose Reservoir.

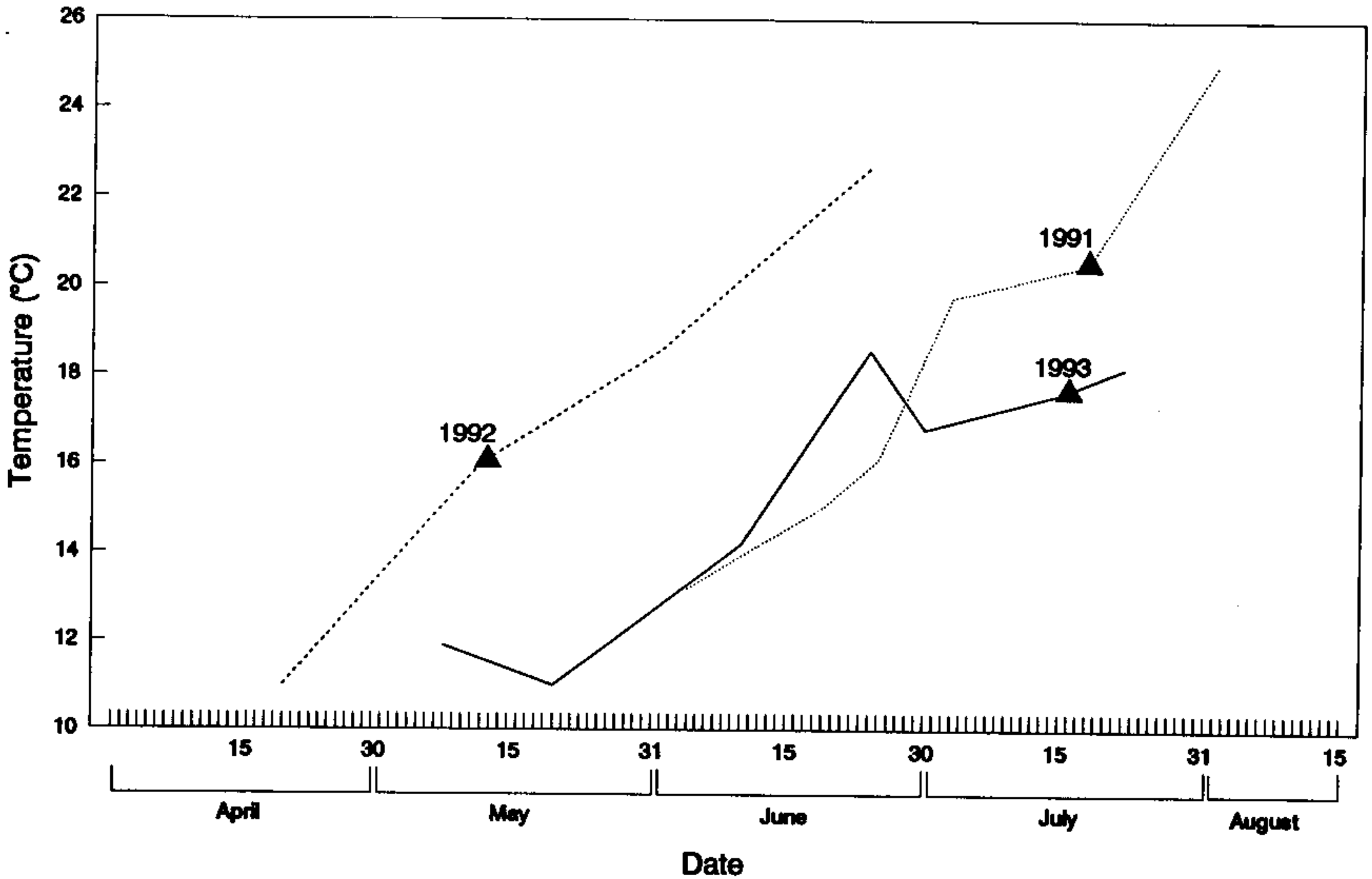

Figure 43. Mean shoreline water temperatures during 1991, 1992, and 1993 in Little Goose Reservoir. Triangles indicate disappearence of subyearling chinook salmon from shoreline areas.

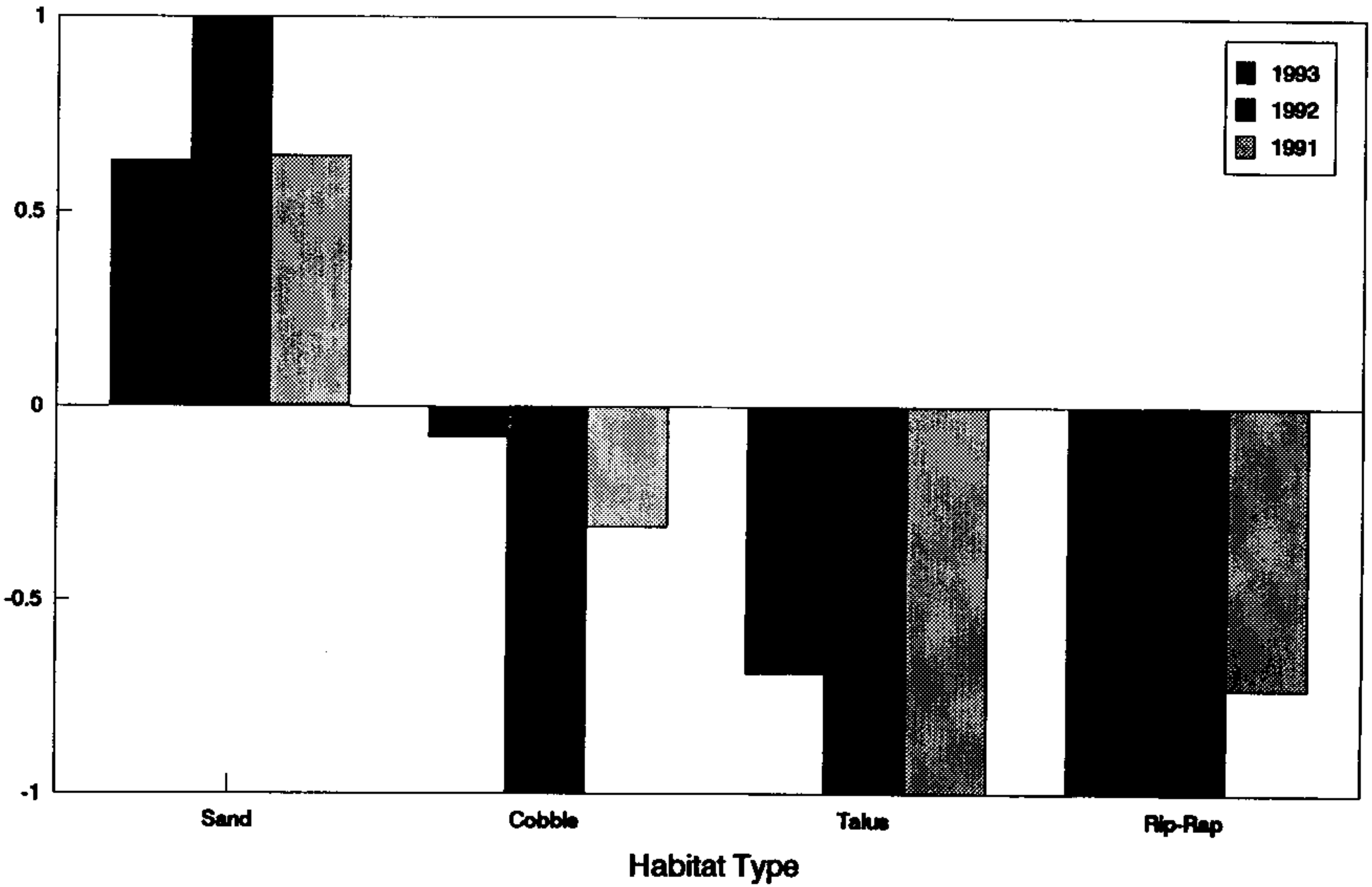

Figure 44. Substrata used by subyearling chinook salmon during 1991, 1992, and 1993 in Little Goose Reservoir as determined by Jacobs Utilization Index (Jacobs 1974).

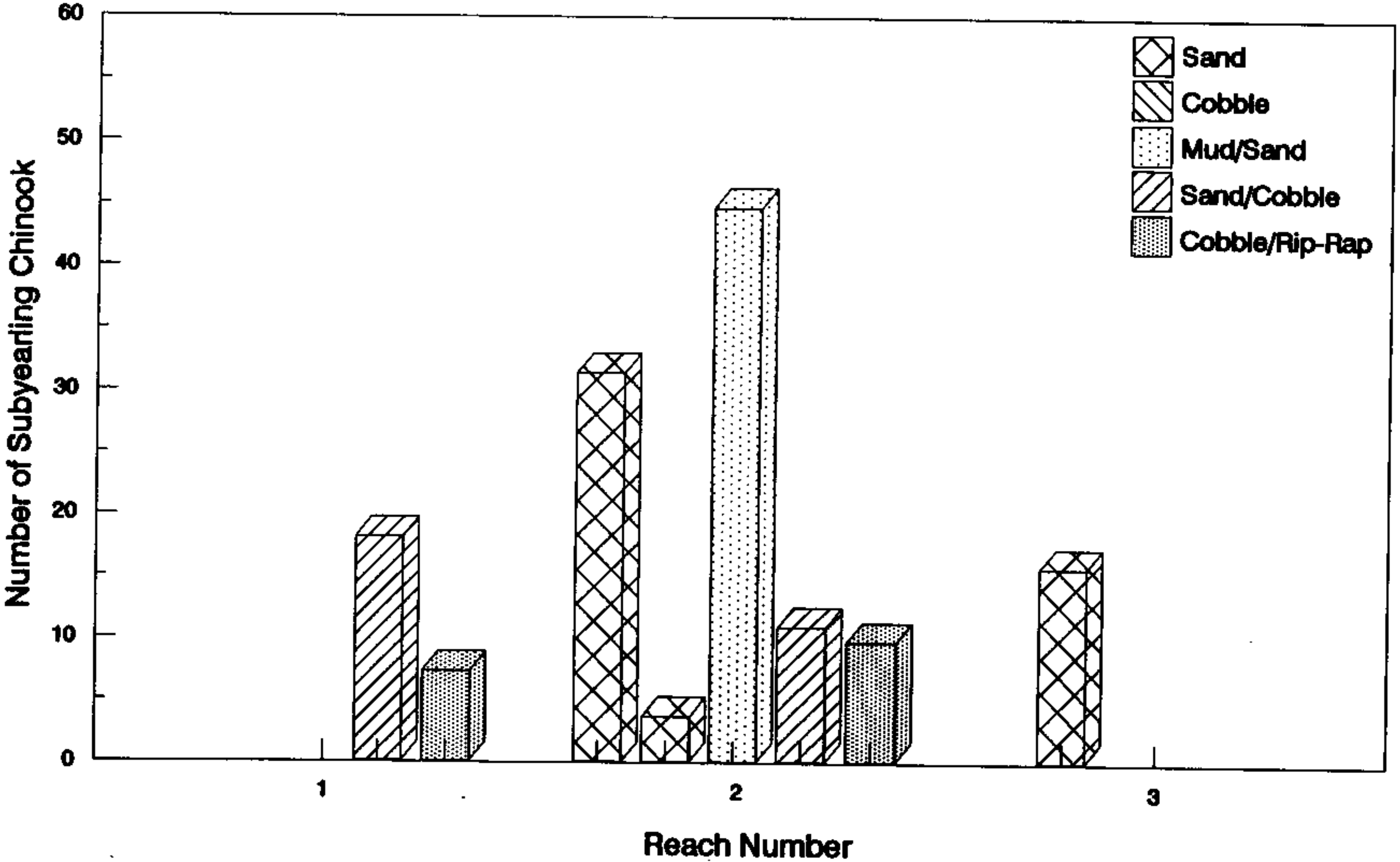

Figure 45. Number of subyearling chinook salmon sampled over various substrate types during 1991 in Little Goose Reservoir.

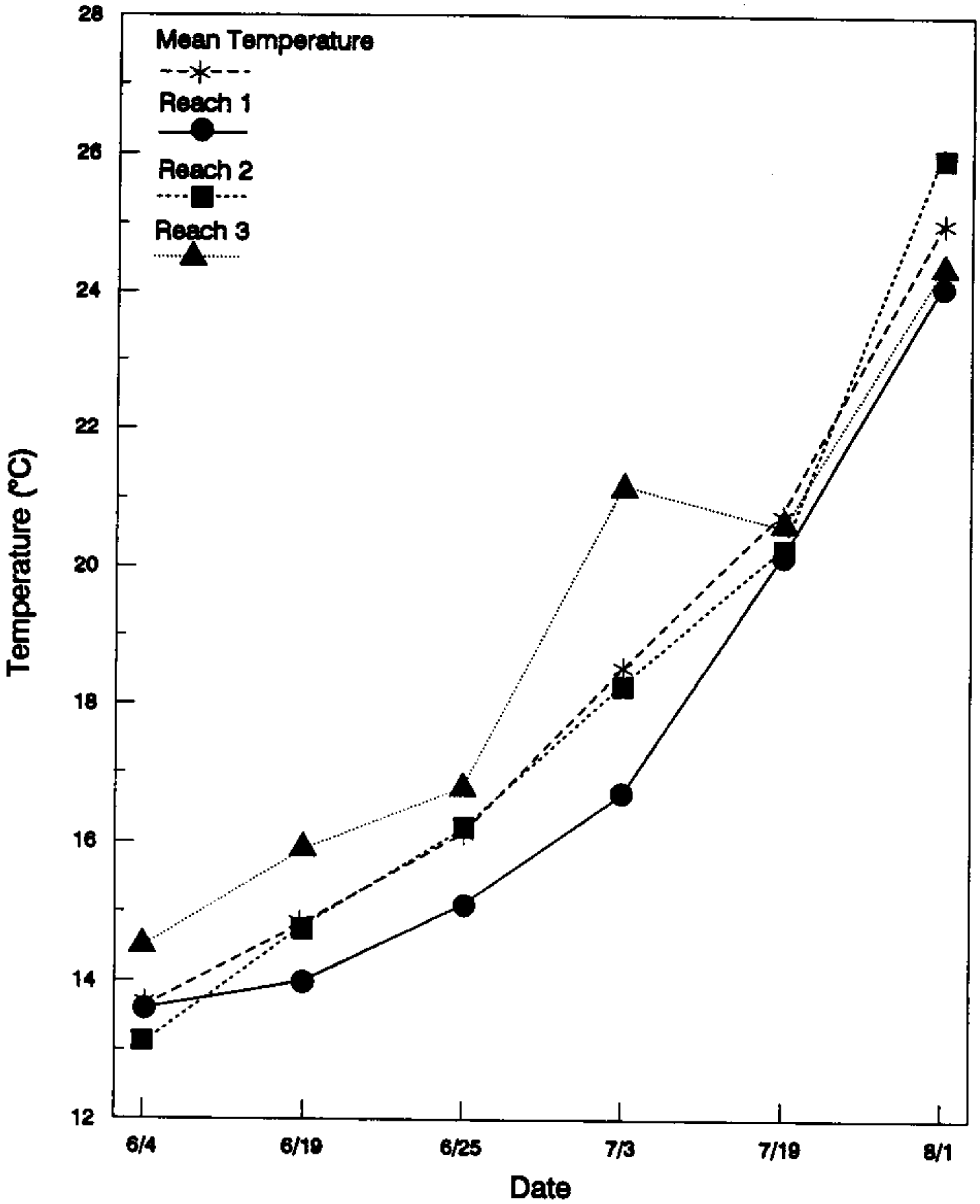

Figure 46. Surface water temperatures from June to August 1991 in Little Goose Reservoir.

the shoreline. In 1992, water temperatures were about 46°C and was higher than those in 1991 and 1993 through mid-June (Figure 46). Dates when temperatures at 20°C were attained were 10 June 1992, 2 July 1991, and after 23 July 1993.

Substrate Analyses

Shoreline substrata in Little Goose Reservoir were mainly particles > 25 mm on the north side and fine sands on the south side in the upstream end. Further downstream, differences in substrata between shorelines were not as obvious differences as upstream.

Immediately downstream of Lower Granite Dam at RM 107.5 N substrata at 3 m were almost all > 25 mm (Figure 47). At RM 106.5 N and 1.5 m depth substrata consisted of 88% particles > 25 mm. On the south shoreline, substrata at RM 106.0 S were predominantly fine sand at 1.5 m, while on the north side at 6 m > 25 mm particles were dominant (Figure 47). Downstream at RM 105.5 N, larger particles (>25 mm) comprised nearly 70% of the samples (Figure 48). At 6 m depth at RM 104.0 S particles > 25 mm were abundant, although fine sand comprised nearly 30% of the substrate. Larger particles were dominant at RM 101.0 N at 1.5 m depth and at RM 100.0 N at 2.4 m depth (Figure 48). Fine sand was the predominant substrate at RM 99.5 S at 1.5 m depth and RM 96.0 S at 3 m depth (Figure 49). Fine sand accounted for about 50% of the substrate particles across the reservoir at RM 98.5 N at 3.7 m and 52% of the substrate at RM 93.5 N (Figure 49). At RM 92.0 S and 1.8 m depth, fine sand accounted for > 83% of substrata and about 50% at RM 88.0 S and RM 87.5 S (Figure 50). Further downstream at RMs 87.0 S, 85.0 S, and 81.5 S, fine sand was the predominant substrate (Figure 51) as on the north side at RMs 90.5 N (Figure 50) and 85.0 N (Figure 51).

Organic contents of substrata in Little Goose Reservoir were consistently < 3% (Figures 47-51). Organics increased from upstream to downstream.

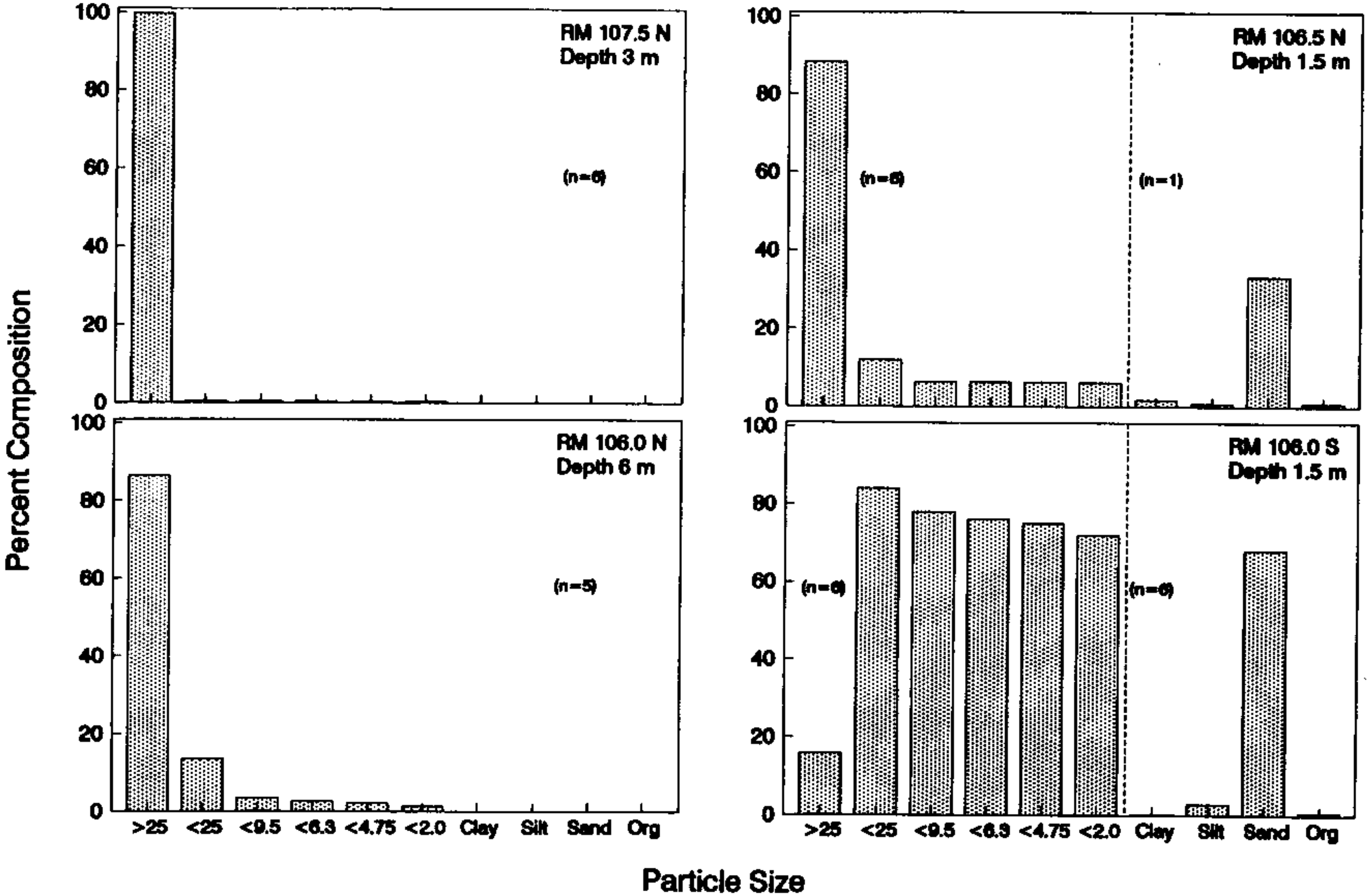

Figure 47. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Little Goose Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

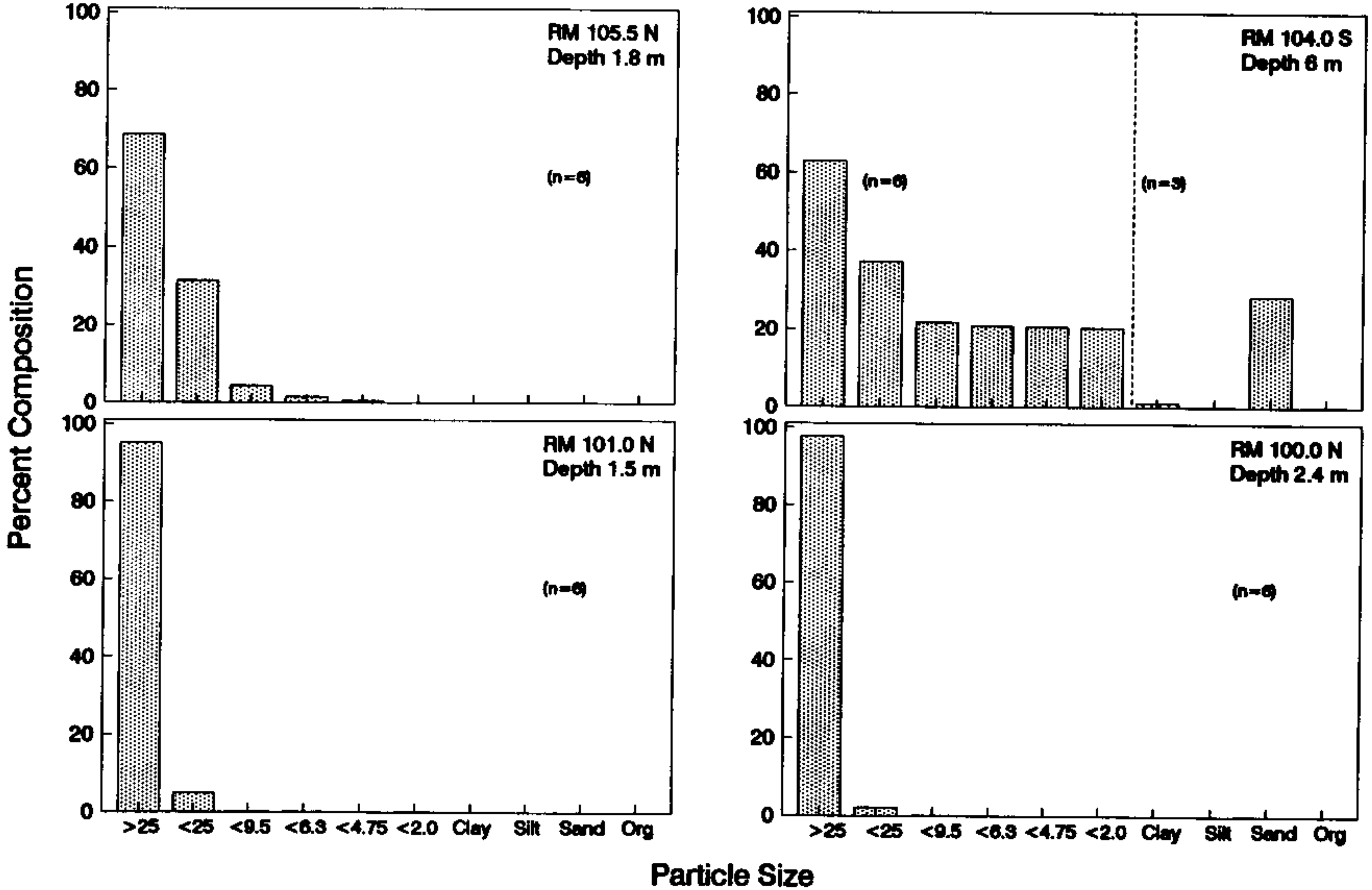

Figure 48. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Little Goose Reservoir. Analyses to the right of the dotted line were conducted by the Bouyoucos method (Bouyoucos 1962).

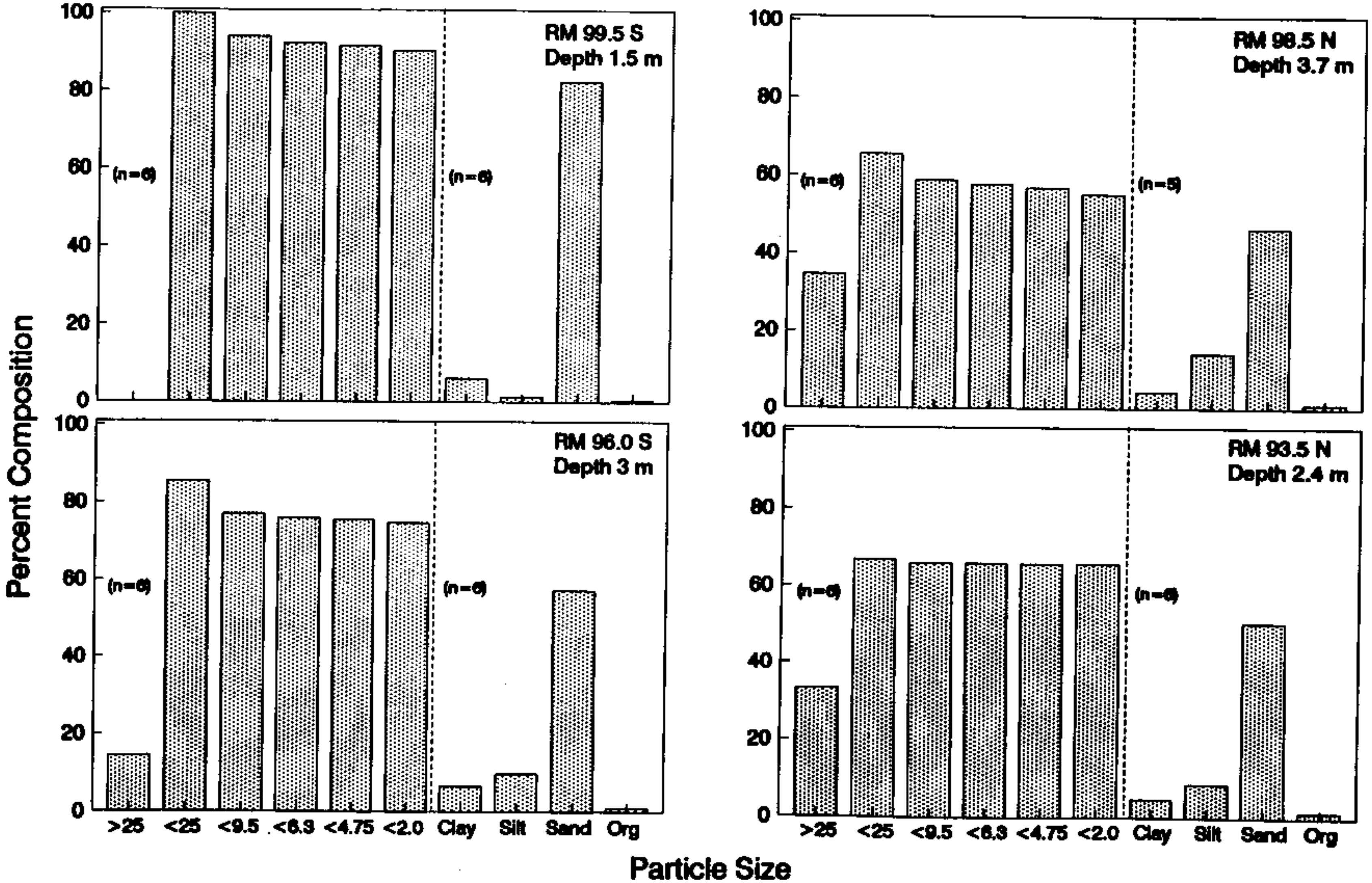

Figure 49. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Little Goose Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

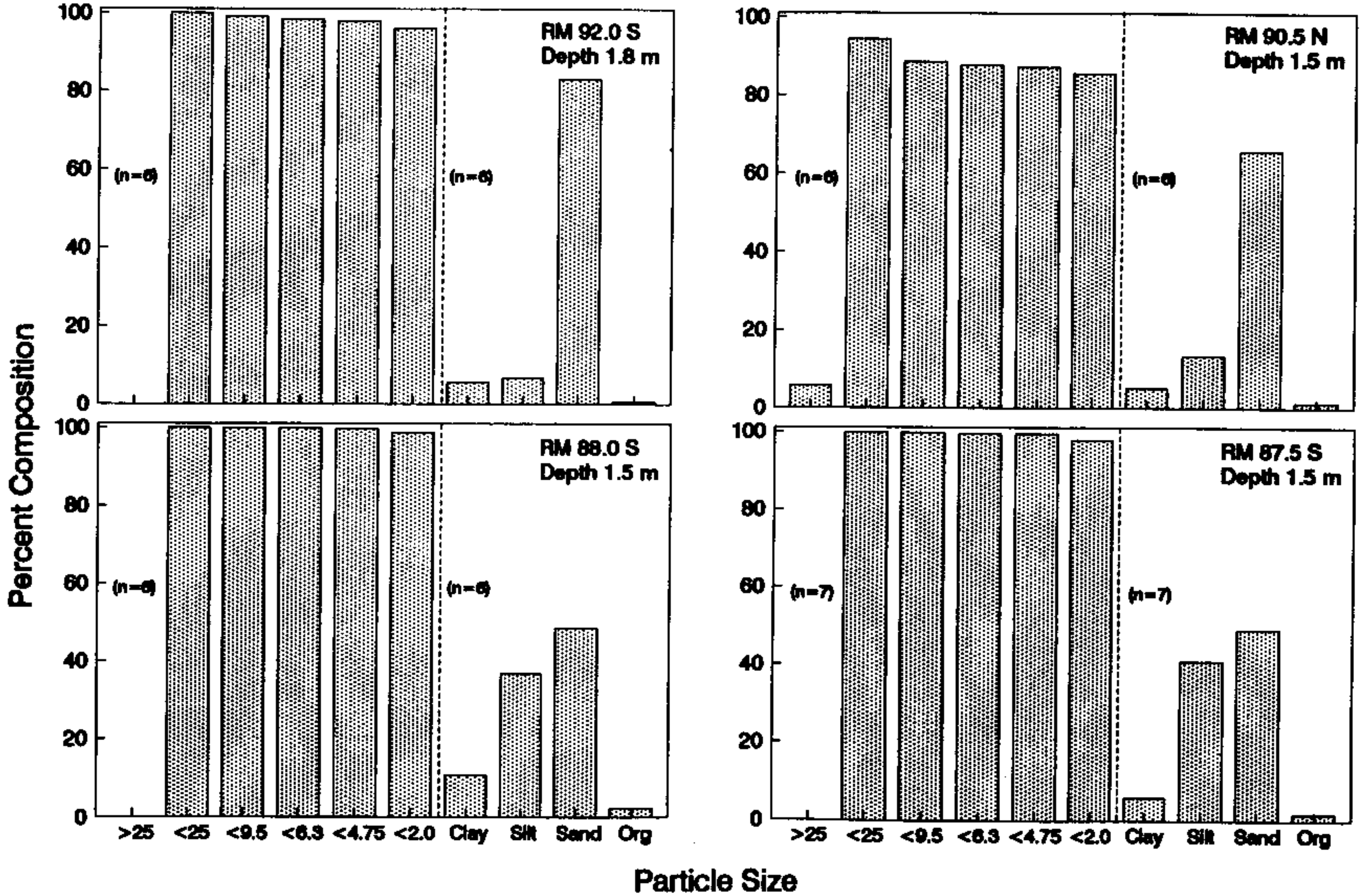

Figure 50. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Little Goose Reservoir. Analyses to right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1962).

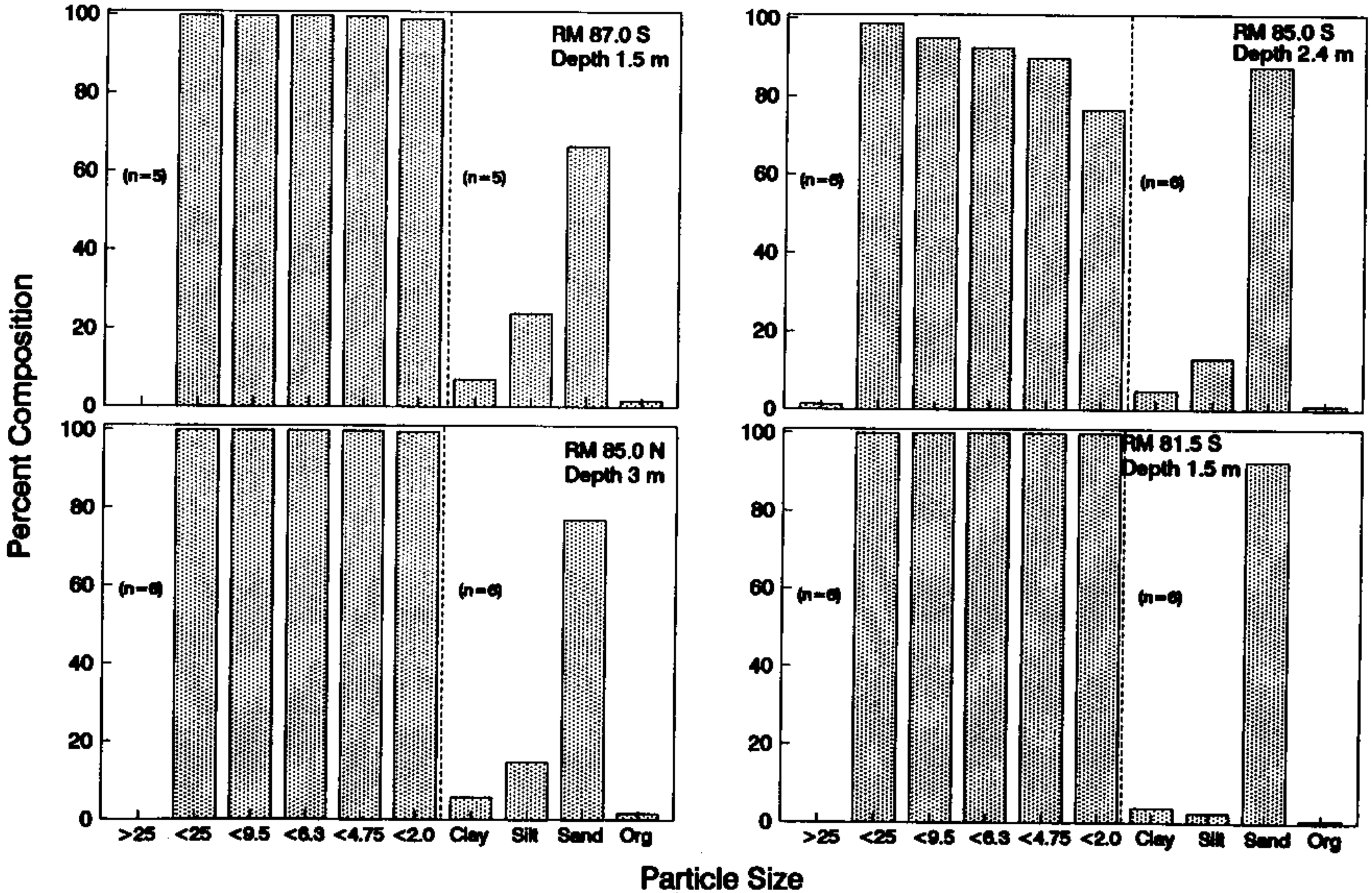

Figure 51. Substrate composition based on percent weight > 25, < 25, < 9.5, < 6.3, < 4.75, and < 2.0 mm and percent clay, silt, sand, and organics (Org) sampled during 1994 in Little Goose Reservoir. Analyses to the right of the dotted lines were conducted by the Bouyoucos method (Bouyoucos 1926).

Growth

Changes in mean length of subyearling chinook salmon during 1991 from late May to mid-July suggested nearly linear growth. Changes in mean total length of subyearling chinook salmon during 1993 from late April to mid-July suggest nearly linear growth. Comparison of average total length of subyearling chinook salmon in Little Goose Reservoir indicates linear growth for 1991 and 1993 (Figure 52). In late April, fish averaged approximately 45 mm and by mid-July mean total length increased to 93 mm. Growth rates averaged about 0.50 mm/day. Initial average total lengths for both years begin at about 42 mm and increase to about 100 mm by mid-July. Average total lengths during 1992 show a larger initial size, although the sampling duration was 2 weeks. In early June 1991, fish averaged 60 mm and by mid-July and mean size increased to < 110 mm. Growth rates in 1991 averaged about 1 mm/day. Instantaneous growth in length from early June to July followed the exponential model: $Lt=60\ e^{0.013(t)}$, where t = time in days from 4 June.

Adult Abundance

The number of potential spawners in Little Goose Reservoir was approximately 250% more in 1992 than in 1991. However, peak numbers of subyearlings estimated in Little Goose Reservoir were generally similar, although dates of sampling were highly different for 1992 and 1993 (Figures 40 and 41).

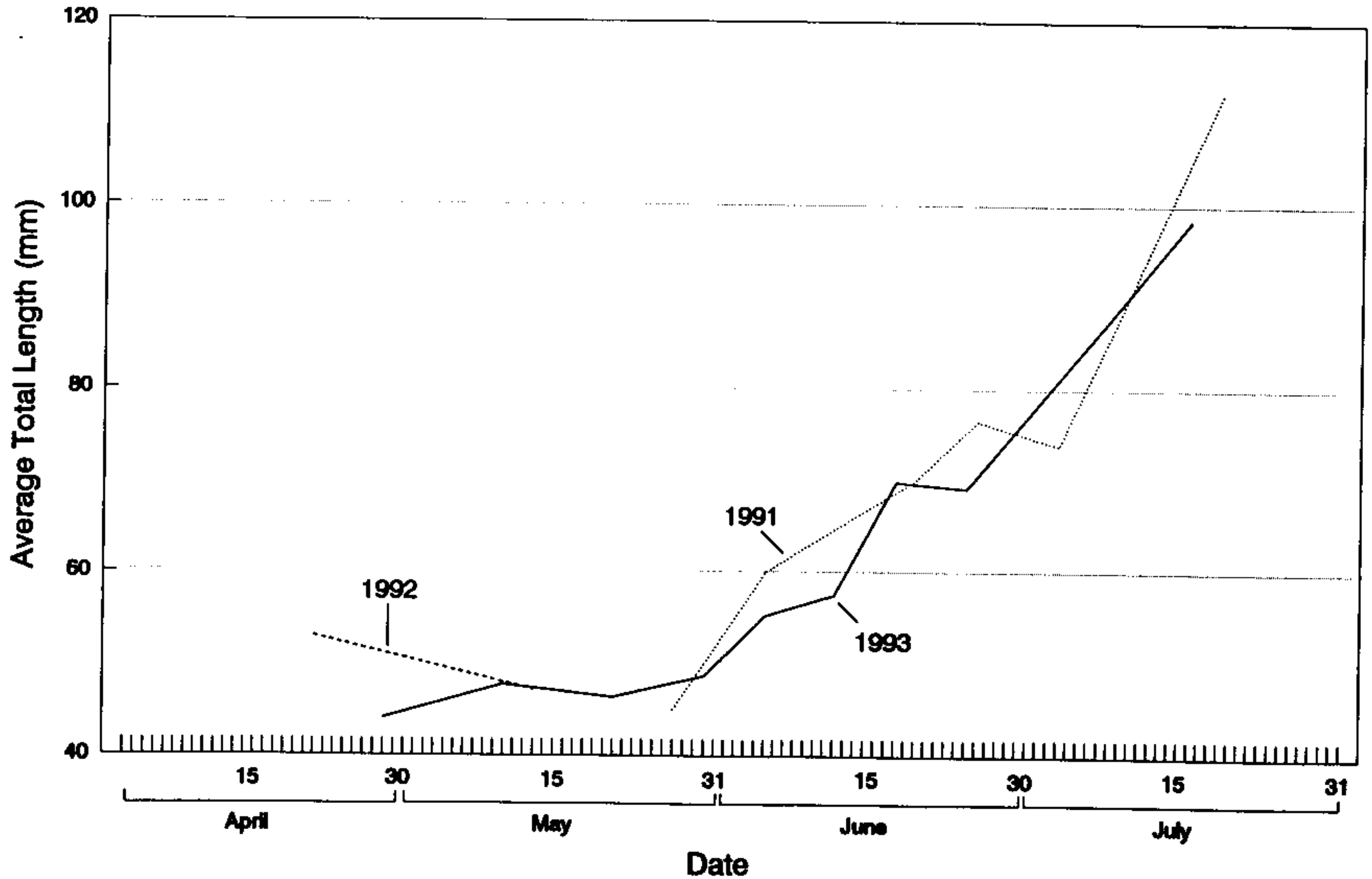

Figure 52. Average total length of subyearling chinook sampled during 1991, 1992, and 1993 in Little Goose Reservoir.

Lower Monumental Reservoir

Presence/Absence

1992.—During 1992, one subyearling chinook salmon was captured in 63 beach seine hauls in Lower Monumental Reservoir (RM 64.5). High water temperatures may have accounted for the low abundance of subyearling chinook as mean temperatures averaged 20°C (68°F) during June at the sampling locations.

1993.—Nineteen subyearling chinook salmon were captured in Lower Monumental Reservoir during the three dates of collection in June and early July 1993. Highest numbers of fish were collected in Reach 1 (n=9) followed by Reaches 2 (n=7) and 3 (n=3). Based on our sampling, the highest abundance of subyearling chinook salmon in Lower Monumental occurred on 13 June 1993. Population estimates by reservoir and reach during our sampling effort indicated numbers of fish rearing in Reaches 1 and 3 on 13 June and 7 July were generally similar (Figure 53). During 18 June fish were found rearing only in Reach 2 whereas in July subyearlings were collected in each of the three reaches.

Mean shoreline temperatures remained < 20°C (68°F) during our sampling efforts (Figure 54). Water temperatures in Reach 1 were the lowest during the period of study and those for Reach 3 increased more rapidly than other reaches. Subyearling chinook salmon were still inhabiting the shoreline at 19.2°C (66.6°F) on 7 July 1993.

Changes in total mean length from mid-June to early July suggest linear growth of subyearling chinook salmon (Figure 55). On 13 June, fish averaged 64 mm and by 7 July mean size increased to 93 mm. Growth during this period was slightly more than 1 mm/day.

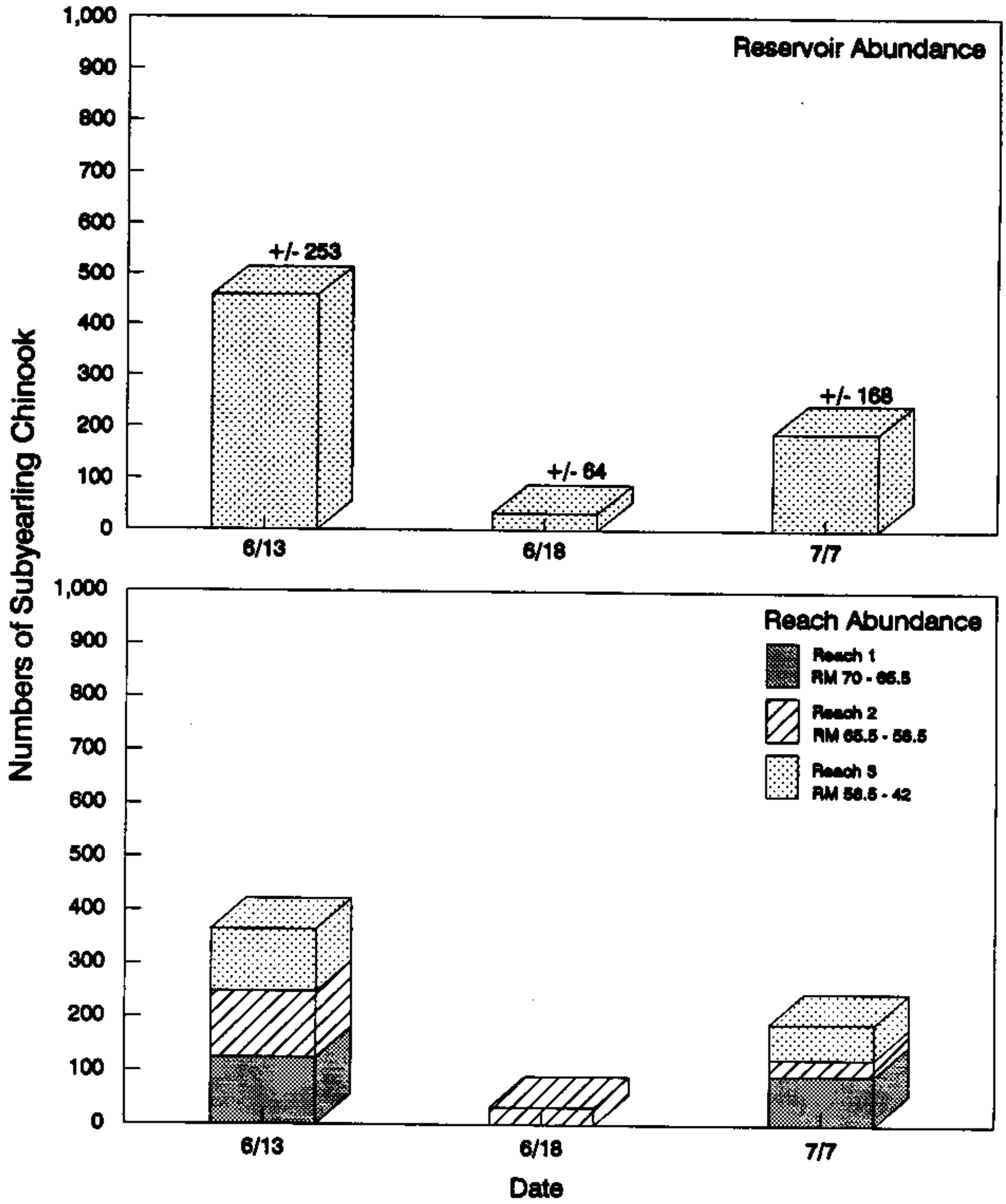

Figure 53. Population estimates of subyearling chinook salmon by reservoir and reach during 1993 in Lower Monumental Reservoir. Estimates for reservoir abundance were calculated by stratified random sampling and those for reach abundance by simple random sampling. Confidence intervals were calculated with 95% bounds.

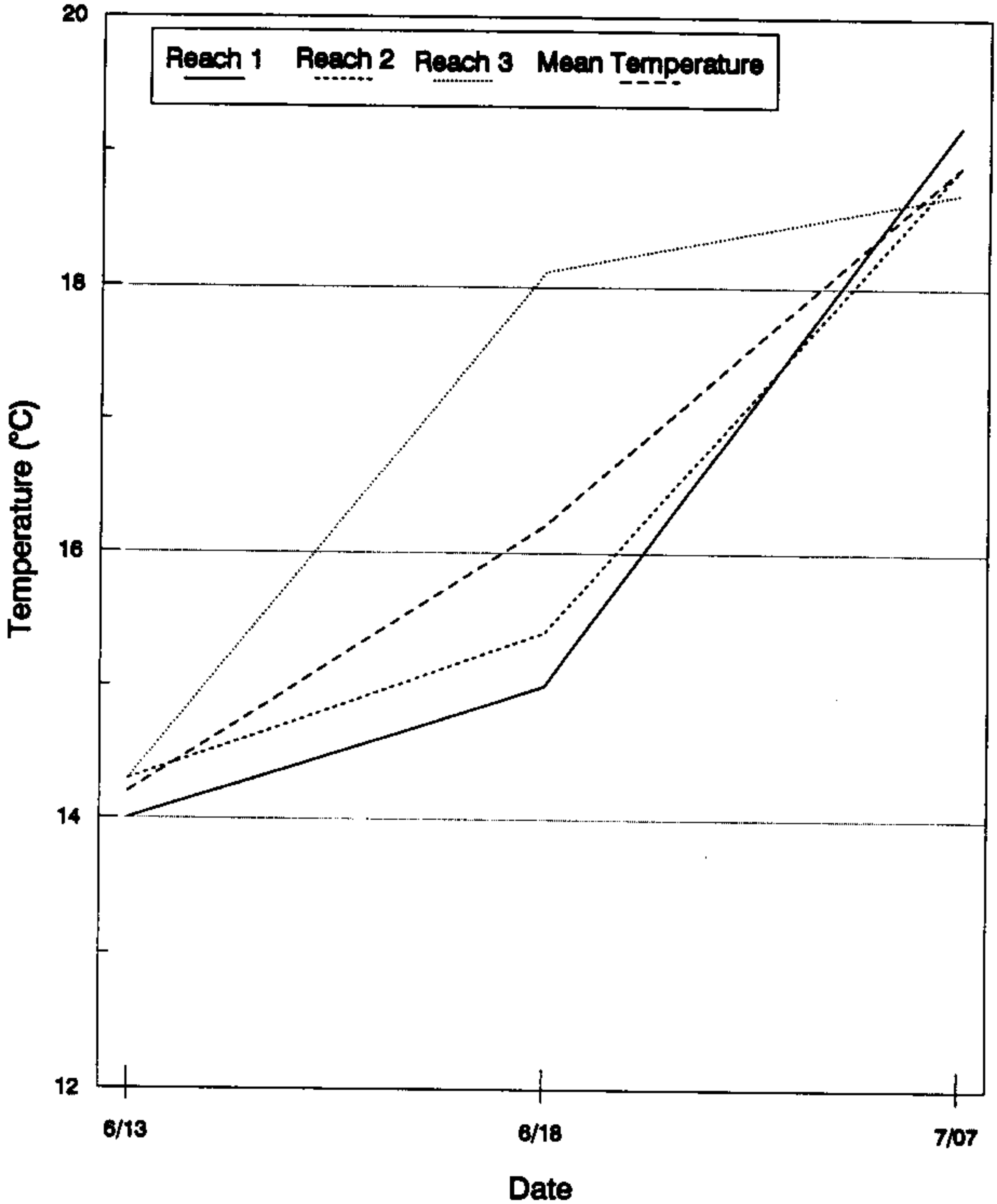

Figure 54. Mean shoreline water temperatures by reach during 1993 in Lower Monumental Reservoir.

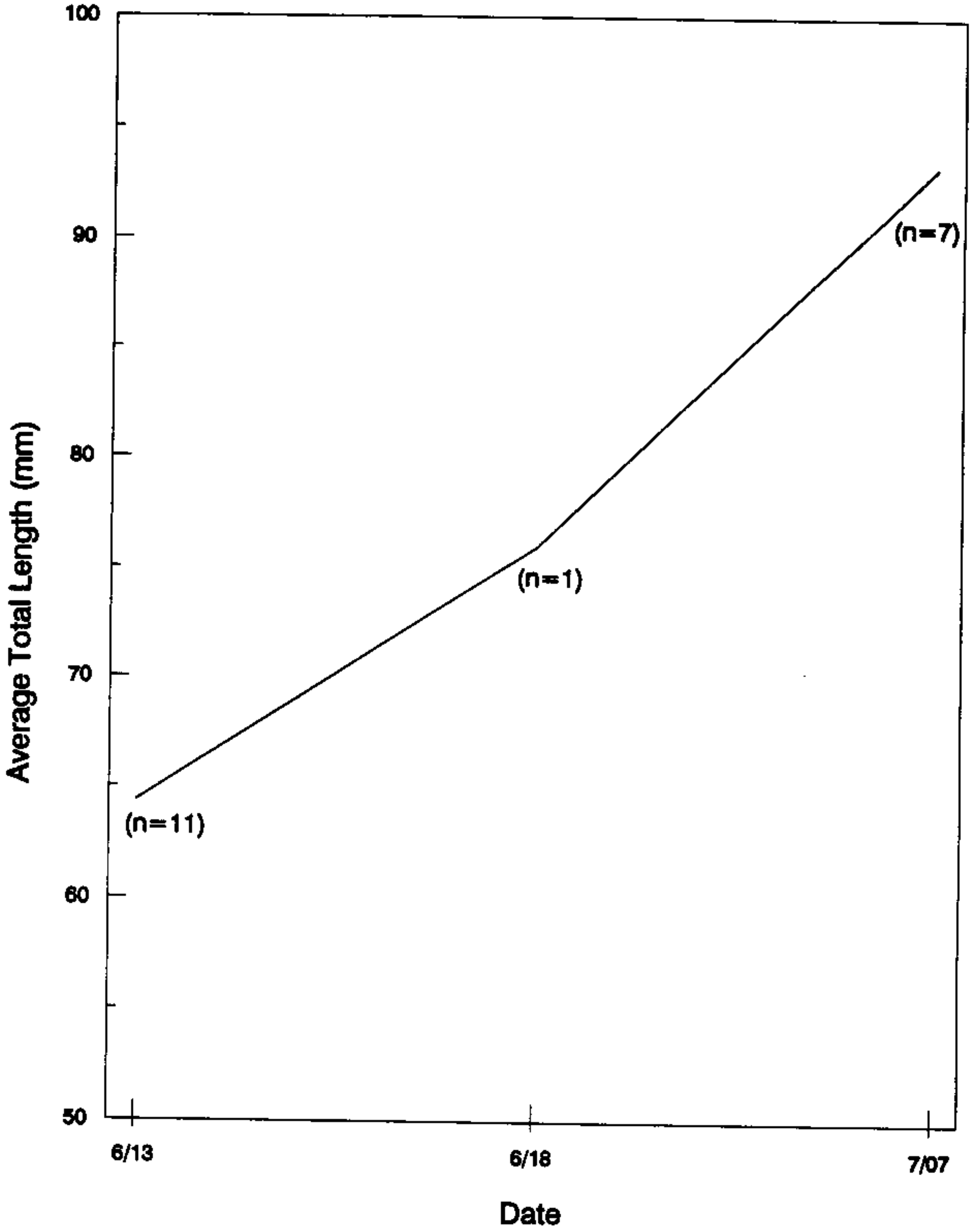

Figure 55. Average total length of subyearling chinook salmon sampled during 1993 in Lower Monumental Reservoir.

Ice Harbor Reservoir

Presence/Absence

1992.—During 1992, no subyearling chinook salmon were collected in Ice Harbor Reservoir in 63 beach seine hauls. High water temperatures in the reservoir may have accounted for the low abundance of subyearling chinook as water temperatures averaged 23°C (73°F).

1993.—A total of ten subyearling chinook salmon was collected in Ice Harbor Reservoir by beach seining during 1993. Highest numbers of fish were collected in Reach 1 (n=4) during our first sampling effort (18 June 1993). Collections in Reaches 2 (n=1) and 3 (n=2) were also low. Highest abundance of subyearling chinook salmon in Ice Harbor Reservoir occurred on 8 July 1993. Population estimates by reservoir and reach during our sampling effort indicated fish were rearing in all reaches on 18 June (Figure 56). Estimated population size was higher in July than June.

Mean shoreline temperatures in Ice Harbor Reservoir remained < 20°C (<68°F) during our sampling effort (Figure 57). Subyearling chinook salmon were inhabiting the shoreline on 8 July 1993 in Reaches 2 and 3 when the water temperature was 19.2°C (66.6°F). Subyearling chinook averaged approximately 75 mm on 18 June and by 8 July mean size had increased to 87 mm.

DISCUSSION

We collected subyearling chinook salmon in each of the four lower Snake River reservoirs. Abundance estimates in Ice Harbor and Lower Monumental reservoirs were generally similar while abundance estimates in Lower Granite and Little Goose reservoirs also were similar. Our estimates of abundance are not intended to be interpreted as absolute estimates but as relative estimates. Confidence intervals were generally about 100% of the population estimate and we believe these are realistic for the intensity of

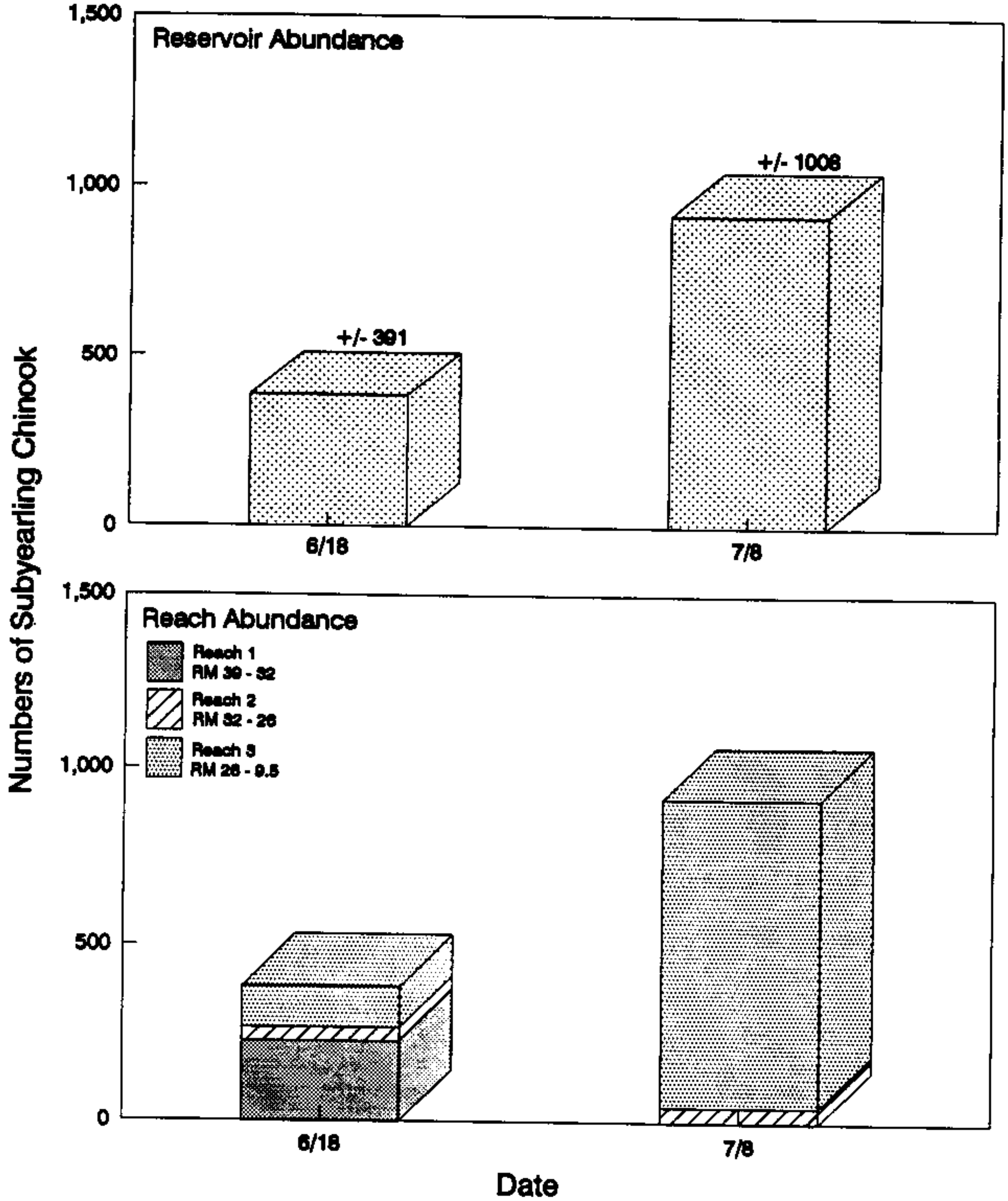

Figure 56. Population estimates of subyearling chinook salmon by date during 1993 in Ice Harbor Reservoir. Estimates for reservoir abundance were calculated by stratified random sampling and those for reach abundance by simple random sampling. Confidence intervals were calculated with 95% bounds.

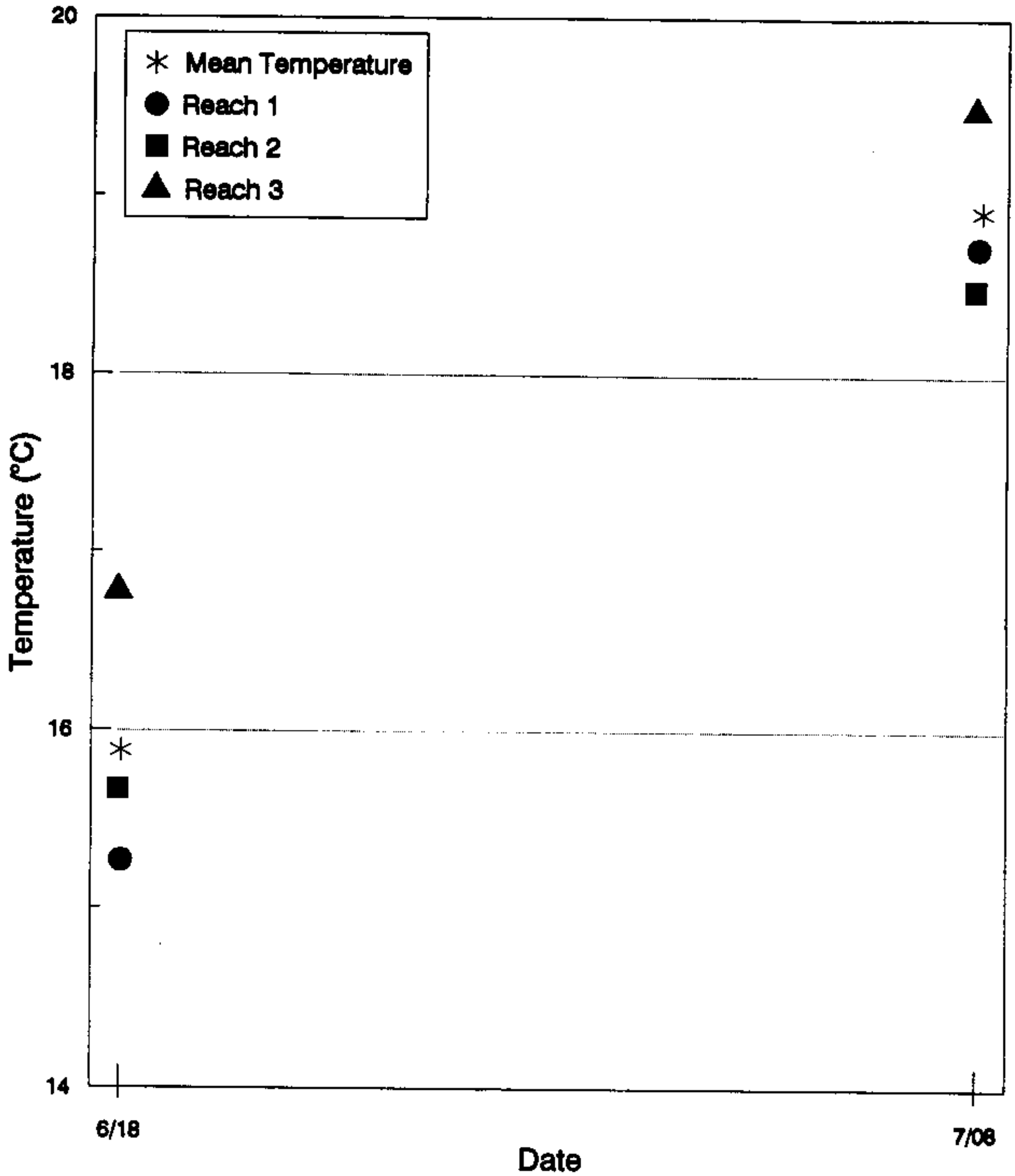

Figure 57. Mean shoreline water temperatures by reach from mid-June to early July 1993 in Ice Harbor Reservoir.

sampling. Estimates of abundance in Lower Monumental and Ice Harbor reservoirs are considered minimal because sampling was conducted later in the spring when water temperatures were at or near the upper range of temperatures for shoreline habitation of subyearling chinook.

Collections of subyearling chinook in Little Goose and Lower Monumental reservoirs prior to their downstream migration suggest successful occurrence of spawning in lower Snake River dam tailwaters. In 1980, Bennett et al. (1983) inferred that spawning was probably occurring downstream of Lower Granite Dam. Recently, fall chinook spawning in tailwaters has been confirmed by the identification of spawning redds downstream of several lower Snake River dams (Dauble et al. 1994). Our collections of subyearling chinook in these reservoirs indicate spawning is successful.

Our estimates of abundance for Lower Granite Reservoir were probably more representative of actual numbers than estimates from other reservoirs. More effort per area was expended in Lower Granite Reservoir and we generally sampled over a range of water temperatures. Highest estimates of shoreline abundance occurred in 1993, coinciding with the longest shoreline rearing period. In 1993, inflow to Lower Granite Reservoir continued above 50 kcfs into July. We believe higher estimates of abundance in the reservoir during 1993 were probably related to the duration of high discharges and corresponding lower water temperatures.

Shoreline abundances of subyearling chinook salmon in Little Goose Reservoir also were highest in 1993 of all years sampled. Peak abundance estimates were similar among years, although substantial differences in abundance were found among reaches in Little Goose Reservoir. Highest abundance was generally found in Reach 2 from RM 83.5 to RM 103.5 and was probably a result of the highest quantity of suitable shoreline habitat.

Habitats selected by subyearling chinook salmon were similar among and within reservoirs. Habitats selected were strongly sand substrata on low gradient shorelines. Jacobs Utilization Index for all years sampled indicated subyearling habitat selection was strongest for sand substrata. We believe this habitat selection is real rather than a reflection of higher gear efficiencies. We have sampled extensively using electrofishing over all types of substrata in Lower Granite Reservoir (Bennett et al. 1993a, 1993b, 1995, 1997) and habitats where subyearling chinook were collected were similar to those estimated by beach seining.

The reasons for higher abundances of subyearling chinook over sand and mud/sand substrata are not clear. A number of factors are characteristic of these areas including fine substrata and slightly warmer water temperatures in the early spring and lower water velocities. Low velocities may be as much responsible for subyearling abundance as well as prevailing substrata. Also, Curet (1994) found that zooplankton and larval fishes were food items of subyearlings early in their reservoir rearing. These food items are often more abundant in low velocity areas than along the main shoreline. Therefore, higher zooplankton and larval fish abundances may also account for the selection of the low gradient, sand shoreline areas for rearing.

Water temperatures are important in the timing and duration of shoreline rearing by subyearling chinook salmon. We found shoreline rearing generally was curtailed after water temperatures exceeded 18°C. Variation in the timing of warming of the shoreline areas to 18°C was substantial during the 5 years of sampling in Lower Granite Reservoir. For example, this temperature was attained the end of May 1992 compared to mid-July in 1993, a period of about 50 days. Timing of 18°C was similar between 1991 and 1992. However, our sampling indicated shoreline habitation occurred in Lower Monumental and Ice Harbor reservoirs at slightly higher water temperatures. The significance of 18°C is probably related to metabolic demands. Curet (1994) reported using a bioenergetics model where 18°C was approximately the temperature when food intake would at best satisfy metabolic demands; no growth occurred at higher temperatures.

We conducted several correlations to assess associations between subyearling chinook abundance and various environmental and population factors. A number of these factors accounted for high variation (r^2=0.98) in the peak numbers of subyearling chinook in Lower Granite Reservoir, although the correlations lacked significance because data were limited to 4 to 5 years. These correlations do show, however, the importance of flows and rearing days, as both correlations were negative. Although these correlations could be spurious, they suggest that reservoir rearing may be more important for subyearling chinook under low flow and temperature conditions. We do not want to falsely suggest the importance of these factors, but during the years of study, these conditions prevailed and, therefore, may enhance our understanding of the importance of the lower Snake River reservoirs in the life cycle of rearing subyearling chinook salmon.

We estimated the length of rearing in Lower Granite Reservoir based on timing differences between peak shoreline abundances and peak arrivals at Lower Granite Dam. We interpreted the difference in time as the length of pelagic rearing. We consider this relationship crude, but it is supported by two items. First, the length of pelagic rearing that we computed was similar to that determined by Connor (William Connor, U.S. Fish and Wildlife Service, Ahsahka, Idaho, personal communication) using PIT tags on subyearling chinook from the free-flowing section of the Snake River. Second, our limited pelagic sampling with surface, midwater, and bottom trawls 3 weeks after no additional subyearling chinook were collected along the shoreline of Lower Granite Reservoir was successful; however, the potential for high mortality precluded extensive sampling. These two independent assessments corroborate our hypothesis of pelagic rearing of subyearling chinook in Lower Granite Reservoir. Temperature differences from surface to bottom are sufficient to provide bioenergetic benefits to the subyearling chinook (Bennett et al. 1997a, 1997b, 1997c).

Predatory losses in Lower Granite Reservoir were not as high as anticipated. We corrected Curet's (1994) reported estimated subyearling salmonid consumption by smallmouth bass, thus our estimate was similar to the estimate for northern squawfish. These estimates of consumption were for about one third of the reservoir. Anglea (Steve Anglea, Department of Fish and Wildlife, University of Idaho, Moscow, unpublished data) has conducted two additional years of study evaluating smallmouth bass as a predator throughout Lower Granite Reservoir. Tentative analysis of his data suggests substantial year to year variation in predation. During low flow years, like 1992 when Curet (1994) conducted his study, higher levels of predation coincided with higher water temperatures and water clarity. These data combined with the rearing information strongly suggest the importance of flow augmentation during low flow years to maintain higher flows during June and July through Lower Granite Reservoir. Our findings are supported by unpublished data on PIT tag interrogations at Lower Granite Dam. Higher numbers of interrogations were found during years when flows through Lower Granite Reservoir were high. Benefits of higher flows seem to be associated with lower predation rates and possibly improved migration through the reservoir.

Substrate analyses of largely shallow shoreline areas of Lower Granite and Little Goose reservoirs indicated the substrata were comprised of mainly finer materials. Substrata were generally < 25 mm and, based on laboratory analyses, were composed largely of fine sands and silts.

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