A Research Report
for UNC Nuclear Industries

Fish Distribution Studies Near N Reactor, Summer 1983

D. D. Dauble
T. L. Page

June 1984

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Prepared for
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EXECUTIVE SUMMARY

Pacific Northwest Laboratory conducted studies of fish distribution in the Columbia River near N Reactor during late summer 1983 using fyke nets on anchored barges, electroshocking gear, and gill nets. The objectives of those studies were to provide estimates of the vertical and horizontal distribution of juvenile chinook salmon during their late-summer outmigration, and also to collect information on relative distribution of juvenile resident fish species. The studies indicated that:

- The bottom midchannel zone of the river was the major migration route for late-summer juvenile chinook salmon populations near N Reactor in 1983. These observations of midstream preference are consistent with studies of larger-sized salmonid smolts in other rivers.
- Principal movement of chinook salmon smolts and juvenile resident fish occurred during hours of complete darkness.
- Distribution of juvenile resident fish was restricted mainly to shoreline areas and to depths of less than 5 meters.
- Largescale sucker were the dominant resident species in the drift, and catch coincided with spawning and emergence timing.
- The small numbers of chinook salmon captured resulted in a large variance in estimates of proportional distribution, and greater numbers of fish would provide more precise estimates.
- Estimates of population size of the late-summer migrant juvenile chinook salmon in 1983 were much lower than historical levels and may have influenced catch totals.

These studies represent the first known information on the cross-sectional distribution of juvenile fall chinook salmon migrating through the Hanford Reach in late summer. Data on distribution of early life stages of resident fish supplement previously known information on occurrence of ichthyoplankton in the mid-river drift. Information gained

from these studies will be used in conjunction with N Reactor thermal plume measurements and laboratory studies of thermal tolerance to assess potential effects of the N Reactor 009 Outfall on Columbia River fish populations.

ACKNOWLEDGMENTS

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The field work and report preparation were done under the guidance of Eric M. Greager of UNC. Duane A. Neitzel was project manager for these studies and Dennis D. Dauble was the task leader. E. W. (Bill) Lusty had primary responsibility for mobilization of barges, field gear, and fyke net systems, and also functioned as a field crew leader. D. W. Carlile conducted statistical design and data analysis and was assisted by L. A. Prohammer. J. E. Campbell provided engineering support for design of the fyke net and barge anchoring systems. R. W. Hanf, Jr., D. C. Klopfer and A. J. Scott were crew leaders; C. S. Abernethy, T. M. Poston, and J. Hernandez assisted in field sampling. Technical assistance in the field was also provided by J. B. Brown, III, D. Dahlstrom, W. B. Duke, J. C. Isom, D. S. Morrow, D. E. Olson, W. R. Wassard, and R. C. Zangar. C. M. Novich edited this report. We also thank our secretaries, D. E. Davis and V. D. Woodcock, who monitored the radio while we were on the river and typed the manuscript.

Other individuals outside of PNL also contributed to this study. Thanks to M. Dell for his time spent providing data on gatewell dipping and to M. Halstead for assistance with net design. Special thanks to Pete McDonald and his staff for use of their facilities.

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INTRODUCTION

The U.S. Department of Energy and UNC Nuclear Industries, Inc., requested that Pacific Northwest Laboratory (PNL) perform a series of integrated field and laboratory studies to characterize the N Reactor plume and to assess potential impacts to juvenile chinook salmon that may pass through the heated water discharge. Pacific Northwest Laboratory staff performed field modeling studies from March 1982 through June 1983 to characterize the thermal plume from the N Reactor heated-water outfall while the reactor was in the single-purpose mode of operation (Ecker et al. 1983). Additionally, PNL staff conducted 1) field studies to determine the cross-sectional distribution of juvenile chinook salmon in the Columbia River near river mile (RM) 381, and 2) laboratory studies to determine the potential for direct and indirect mortalities to juvenile chinook salmon during passage through the N Reactor thermal discharge.

This report summarizes field studies that were initiated in July 1983 to provide estimates of the relative distribution of late-summer outmigrant juvenile salmonids and juvenile resident fish upstream of the N Reactor 009 Outfall. Chinook salmon are among the fish species most sensitive to thermal effects, and impacts to the juvenile outmigrant populations are of particular concern to state and federal regulatory and fisheries management agencies. Therefore, the distribution studies were conducted from late July through September, a period when high ambient river temperatures and low river flows make these salmonid populations most susceptible to thermal effects. In addition, data were not available on the spatial distribution of outmigrant juvenile chinook salmon in late summer. Information on the relative distribution of resident fish populations was also gathered. Previous studies of midstream distribution of juvenile resident fish were limited to a description of ichthyoplankton populations (Beak Consultants, Inc. 1980; Page et al. 1982), and no data were available on vertical or horizontal distribution of juvenile resident fish species near N Reactor.

Relative densities and spatial distribution estimates of juvenile salmonid and resident fish species will be used in conjunction with laboratory thermal effects studies (Neitzel et al. 1984) and with plume characterization studies (Ecker et al. 1983) to assess potential impacts of thermal discharge on fish populations near N Reactor.

DESCRIPTION OF STUDY AREA

The spatial distribution of juvenile chinook salmon and resident fish was studied at Columbia River mile[a] 380.3 (Figure 1), in an area immediately upstream of the Hanford Generating Project (HGP). This location was chosen because it is close to N Reactor yet is upstream of any influence of the HGP discharges (Figure 2). In addition, the study site was outside the zone of construction activity scheduled near the HGP discharge ports in August and September 1983.

The Columbia River at the site is approximately 1100 feet wide at flows of 50,000 cfs (Figure 3). The relative cross-sectional shape of the river channel at the study site was similar to that found near the N Reactor 009 Outfall. The bottom slopes gradually from the reactor side of the river (Benton County) to a distinct channel located towards the other shoreline. The bottom then slopes steeply to the opposite shoreline (Figure 4). Bottom substrate near the site was primarily packed cobble (>10 cm in diameter) and boulders.

River flow past N reactor is controlled in part by releases at Priest Rapids Dam, and annual flows range from about 36,000 to 250,000 cfs. Flows generally declined over the course of the study, and flows at Priest Rapids Dam ranged from 186,100 cfs on July 28, 1983 to 43,200 cfs on September 11, 1983. There was a vertical range in river depths of approximately 3 meters as a result of this change in flows.

Current velocities across the river were dependent on depth and river stage (Figure 5). Greatest velocities at any location occurred at the

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(a) U.S. customary units of measure are used throughout this report to describe the Columbia River. The usage is consistent with regulatory descriptions of Columbia River flows and water temperatures. Fish weight and length are reported in metric units, the customary unit of measure. Conversion factors for frequently used units are: meters = 3.281 feet, and cubic meters = 35.31 cubic feet.

surface and decreased with depth. Velocities at midchannel ranged from 1.83 to 5.74 ft/sec. Surface velocities near the shoreline ranged from 0.68 to 3.21 ft/sec. Maximum velocities were probably slightly higher than reported because measurements were not obtained when midchannel depths of 44 feet were observed on July 28.

METHODS

Several methods were employed to characterize the relative spatial distribution of juvenile salmonids near N Reactor. Fyke nets were the principal method used because they could be simultaneiously fished at a range of depths and locations. However, because of the daily and seasonal changes in river depth, permanent fyke net stations could not be placed in shoreline areas. Therefore, boat electroshocking and gill nets were also used to measure the relative abundance of nearshore populations of outmigrant salmonids.

FYKE NET SYSTEM

Four steel barges, obtained on loan from the U.S. Army Corp of Engineers, were used as fishing platforms for the fyke net systems. Two of the barges measured 4.3 by 8.2 meters (14 by 27 feet) and two were 4.9 by 9.1 meters (16 by 30 feet). Each barge was attached by a 13-mm ($\frac{1}{2}$-inch) steel cable and anchored to a 4,500 kg steel anchor (Figure 6). A drum-winch mechanism, with 6-mm ($\frac{1}{4}$-inch) windlass cables, was used for raising and lowering the net from the back of the barge. Battery-powered windlass winches (Superwinch, model EW 600) and hydraulic-powered gypsy hoists (Kolstrand model 5-24) were used to operate the drum-winch on the two shoreline and two midstream stations, respectively. Hand-hoists (come-alongs) were used to maintain tension on the windlass cables during the daily water-level fluctuations.

The fyke net had a 1.5- by 1.5-meter square opening and tapered uniformly over the 7.0 meter length to a 20-cm-diameter opening at the cod end (Figure 7). All netting was 6-mm ($\frac{1}{4}$-inch) mesh, heavy duty knotless nylon. The net frame was built from streamlined aircraft tubing measuring 86 by 36 by 1 mm. A General Oceanics Model 2030 flowmeter was attached to the mouth of the net.

Initially, a venturi apparatus with a detachable sample bag was attached to a sleeve on the cod end (Figure 8). The apparatus could be separated into two pieces so that a heavy vinyl sleeve could be attached to the cod end of the fyke net. A 1-meter-long, 6-mm-mesh detachable live catch net was tied to the downstream end. The entire setup weighed approximately 16 kilograms (35 lb). Since flows varied widely from top to bottom at each station, the venturi apparatus did not function consistently and was not used after August 3.

FYKE NET SAMPLING DESIGN AND PROCEDURE

Nets were fished for five 24-hour periods each week from July 26 through September 24, 1983. This period corresponded to a time when average ambient river temperatures historically exceeded 62.6°F (WPPSS 1978) and to the period of greatest catches of 0-age chinook salmon at Priest Rapids Dam (Raymond 1967; Hovland et al. 1982). Sampling periods within each week were selected by a stratified random sample to give equal weight to weekday and weekend intervals. To differentiate between diel variations in migration patterns, each 24-hour day was divided into four equal time blocks starting at 0400 hours daily (i.e., 0400 to 1000 hours, 1000 to 1600 hours, 1600 to 2200 hours, and 2200 to 2400 hours). The scheme provided one all-dark, one all-light and two transition (dawn and dusk) light periods. All stations were fished simultaneously and one set of approximate 2-hour duration was taken at each of the surface (Figure 9), mid-depth, and bottom depths according to a random schedule during each 6-hour period. When river depths were less than 3.7 meters (12 feet), only surface and bottom samples were taken.

Three people worked on each 6-hour shift. Generally, a net could be raised, checked for catches, cleaned of debris (Figure 10), and lowered to the next sample depth within 5 minutes. Nets at all four stations could usually be tended and placed in their designated positions within 15 to 30 minutes. The remainder of the time was used to process samples, maintain equipment, or to sample with other gear. Water temperature, sample and station depths, duration of set, and flowmeter readings were recorded for each sample taken. Secchi disc depth was recorded daily at 1200 hours. River stage was obtained from records maintained at the HGP control room.

Because of gear replacement, not all station/depth combinations were sampled equally. The pulleys for the windlass cable at the drift anchor often were a source of trouble because the slope of the river bottom varied and the water depths were constantly changing. If the lines became slack the cable would work out of the pulley and would then bind up on the pulley housing. As a result of this, the spreader anchor had to be pulled up onto the barge and the cable and/or pulley replaced.

NET EFFICIENCY TESTS

Two types of tests were conducted to give some measure of relative collection efficiency of the fyke nets under a range of river flows. We used chinook salmon smolts reared in our laboratory that ranged from 86 to 137 mm FL. Fish were transported to the field in plastic 50-gallon garbage cans and held with aeration until used. We conducted 15 retention and 15 catchability tests during daytime hours and 10 of each type of test at night. All tests were conducted without the Venturi apparatus.

Tests designed to measure retention efficiency involved releasing juvenile salmon into submerged fyke nets and counting the number remaining in the nets after the standard sample interval. Groups of 25 fish were loaded one at a time from the aft of the barge directly into the net mouth via a 3-meter-long, 10-cm-diameter PVC pipe. Nets were then positioned 1 meter below the surface for approximately 2 hours. After retrieval, the number and size of fish remaining in the net were noted. Tests designed to estimate catchability of the nets were also conducted with the net in the surface position. For these tests, groups of 25 fish were released one at a time via the PVC pipe from the bow of the barge. The pipe was angled slightly downstream and held at the midpoint of the net frame or 1 meter below the water's surface. The net was retrieved after 1 to 2 minutes and number and size of captured fish recorded. We noted that fish released on the surface oriented upstream after they had drifted 10 to 20 feet downstream.

SUPPLEMENTAL SAMPLING GEAR

The barges could not be permanently anchored and fished effectively in the immediate shoreline because of the wide daily and seasonal fluctuation in river flows. Therefore, barge sampling was restricted to depths greater than about 2.5 meters. To provide information on occurrence of salmonid smolts in the immediate nearshore area, electroshocking and gill nets were used.

Boat Shocker

A boat-mounted electroshocker unit (Smith-Root Type VI Electrofisher), powered by a 240-volt generator, was used to sample nearshore fish populations in the vicinity of the barges for nine consecutive weeks from July 29 to September 27 (see Figure 1). Each of two stations were sampled once weekly during all four of the 6-hour time blocks sampled by fyke nets. A single pass was conducted through each 400-meter transect, and sample depths were restricted to 1 to 2 meters. Stunned fish were dipnetted and identified. To improve sampling efficiency (Reynolds 1982), only salmonids were enumerated. All juvenile salmonids were identified, measured and released, and scale samples were removed from the dorso-lateral surface for age verification. Catch per unit effort was recorded as shocking time (timer units) to complete a transect.

Gill Nets

Gill net sampling was initiated on September 9, 1983 as an additional measure of nearshore salmonid abundance in nearshore areas near the site. The monofilament nets were 15 meters long and consisted of two 7.5-meter panels of 12-mm and 18-mm square mesh, respectively. Two nets were set perpendicular to the shoreline in the vicinity of the barges (see Figure 1). Nets were set twice a week (separate day and night sets) for three consecutive weeks. Nets were examined and cleaned after an approximate 12-hour set, and all fish were identified and measured.

DATA ANALYSIS

Estimates of the proportional distribution of juvenile chinook salmon caught at various stations and depths by fyke net are based on a multinomial distribution of the fish caught among the various combinations of station and depth (Cochran 1977). As with the binomial distribution, the variances, and therefore confidence intervals, about estimates of proportions are greater for smaller sample sizes. Estimates were also made of the number of fish that would have been caught if each station had been sampled for the maximum time (353 hours). The estimates are based on the assumption that the ratio of total number of fish captured to total sampling time at each station/depth combination is an approximate estimate of the catch per unit effort. These standardized estimates were only obtained for those station/depth combinations which yielded one or more fish. Finally, the estimates of catchability and retention for each station were applied to the fish catches at each depth to estimate the proportional distribution of fish. This assumed a constant catchability or retention at all depths for a particular station.

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RESULTS

Eighteen species of fish representing eight families were collected in the study area with the three sample methods employed (Table 1). Several species were collected with all three gear types, including largescale sucker and four species of cyprinids. Juvenile salmonids were collected only by fyke net or by electroshocker. The greatest number of species were collected by fyke nets, followed by boat electroshocker and by gill nets. Fyke nets collected mainly juvenile salmonids that were either actively migrating downstream or young-of-the-year resident fish that occurred in the drift. Most fish collected by boat electroshocker were adult resident fish, and gill net samples consisted primarily of juvenile resident fish.

FYKE NET STUDIES

In the period from July 26 to September 23, 1983 we completed 1921 sets with the fyke nets at the four permanent stations (see Figure 1, barge locations B1 through B4). A summary of the relative sampling effort by station and depth is given in Table 2 and shows that individual sets per station/depth combination ranged from 145 to 175. Fewer samples were taken at Stations 2 and 3 because of initial problems with gear at high current velocities. However, the total estimated sample volumes at Stations 2 and 3 were greater than at the two nearshore stations. Differences in relative sampling effort were accounted for in analysis of chinook salmon catch data.

Spatial Distribution of Juvenile Chinook Salmon

Chinook salmon smolts were concentrated in the midchannel station, where both depths and current velocities were greatest. We collected 95% of the smolts in the midchannel station, and 68% of the total collections were restricted to the lower portion of the water column (Figure 11). Further evidence for midchannel preference is indicated by the absence of fish at the other midstream station where similar current velocities occurred. Estimates of the proportional distribution of juvenile chinook salmon caught at various stations and depths, including confidence intervals about those estimates, are given in Table 3. The relatively large confidence intervals associated with these estimates are attributable to the small total number (N = 19) of fish caught over the entire sampling period.

We collected 2.17 fish per 100 hours sampled at Station 3 (all depths combined). This corresponded to 1.63 smolts per $m^3 \times 10^6$ water filtered through the nets. Catch-per-unit-efforts at Station 3 for the sampling interval in which 95% of juvenile salmon were collected were 7.11 fish per 100 hours and 4.74 fish per $m^3 \times 10^6$ water. A summary of the catch-per-unit effort for each of the three depths sampled at the midchannel station shows that maximum catches were obtained at the bottom (Table 4).

Other factors, in addition to sample size, may have influenced our estimates of vertical and horizontal distribution. Since sampling time varied among each station and depth, standardized estimates of catch (Table 5) were determined based on the maximum sample time of 353 hours. These standardized estimated can only be obtained for those station/depth combinations which yielded one or more fish. The estimates of proportional distribution based on the standardized estimates are very similar to the estimates based on actual numbers of fish caught. The similarity can be attributed largely to the low catch per unit effort. This similarity further suggests that the estimates of proportional distribution and confidence intervals derived from the actual data provide a reasonable estimate of the proportional distribution of fish when effects on sampling effort are considered.

Diel Patterns in Migration of Juvenile Chinook Salmon

All collections of chinook salmon smolts were made between 2000 hours and 0800 hours. Principal movement occurred between 2400 and 0400 hours, when 79% of the fish were collected (Figure 12).

Age/Size Composition of Juvenile Chinook Salmon

Mean size of the chinook salmon smolts collected by fyke net was 11.4 ± 1.5 cm, and fish ranged from 7.1 to 13.1 cm FL. No detectable annuli were noted on scales from 18 fish, indicating that all were age zero. Circuli counts ranged from 7 to 17 and were correlated (r^2 = 0.76) with fish length (see Appendix, Figure A.2).

Net Efficiency Tests

A measure of relative fyke net sampling efficiency among stations and depths was obtained with an additional series of studies. Because of the small mesh size of the nets, all smolts were retained by the net mesh. However, avoidance of the nets or escape from the nets was possible, as indicated by our results.

During the 15 daylight tests designed to define net retention, estimated current velocities (based on measured depths, see Figure 5) ranged from 0.92 to 4.08 ft/sec. Current velocities for the 10 nighttime retention tests ranged from 1.33 to 5.67 ft/sec. Mean test duration for the 25 tests was 119 ± 28 min. Although the percentage of fish retained in the net varied greatly for flows between 1 and 2 ft/sec, data indicated that the escape threshold for fish passing by the net opening was about 2 ft/sec. No fish ever escaped the net at velocities >3 ft/sec and results of daytime and nighttime tests were similar (Figure 13).

Estimated current velocities during the 15 daytime tests designed to provide a relative measure of net avoidance ranged from 0.79 ft/sec to 5.02 ft/sec. Current velocities for the nine nighttime avoidance tests were slightly higher and ranged from 1.27 to 5.74 ft/sec. Maximum catches were 48 percent of the total released and occurred at current velocities of >4 ft/sec. Capture efficiency or net avoidance was correlated (r^2 = 0.64) with current velocity, indicating a fairly strong relationship between the two variables. No apparent difference was noted between daytime and nighttime values (Figure 14).

Estimates of capture efficiency based on fish released from the bow of each barge ranged from 8 to 37 percent, depending on light conditons and station location. Estimates of retention range from 30 to 100 percent (Table 6). The data were expanded to provide estimates of the number of fish and proportional distribution of fish at each station/depth combination given 100 percent catch efficiency and retention (Table 7). For example, given the greater sampling efficiencies expected at Station 3, the relative proportion of fish expected in this station would be lower than that obtained by analysis of catch data alone. Estimates of percent distribution of juvenile salmon at Station 3/bottom ranged from 56 percent (Table 7) to 68 percent (Table 5). These estimates, however, only apply to those station/depth combinations which yielded fish. Consequently, the proportional distribution of fish, which has been corrected for complete retention and no avoidance, is probably underestimated for those station/depths which yielded no fish.

Differences in capture efficiencies at each station are probably a reflection of differences in water velocity. Coefficients of determination (r^2) for regressions of retention and catchability versus mean water velocity were 0.49 and 0.64, respectively. Given these moderately strong relationships, capture efficiency and retention may also vary with depth.

Spatial Distribution of Resident Fish

In contrast to catches of juvenile salmon, numbers of resident fish were greatest at the nearshore stations. Nearly 70 percent of the fish were captured at nearshore stations (Figure 15). Although overall totals according to net location (surface, mid-depth, bottom) were almost identical, depth appeared to be a factor in fish distribution. When capture locations were broken down into 1.5-meter intervals starting at the surface, the majority of fish were captured at depths of less than 5 meters. Further analysis of these trends is not possible since sampling design did not account for equal sampling at all possible depths.

Overall catch per unit effort (C/UE) can be expressed both in terms of volume sampled and duration of sampling. Greatest catches were obtained at

Station 4 on the surface and mid-depth locations (Table 8). Catch-per-unit effort at the two midstream stations was lower and showed no pattern with respect to depth. Number of fish collected per 100 hours sampled ranged from 1.03 at Station 3, bottom, to 6.90 at Station 4, mid-depth. Relative catch-per-unit-effort according to volume sampled showed similar trends (Table 8). The maximum C/UE of 2.03 fish/hr was obtained on August 26 and maximum densities of 6.28 fish/$m^3 \times 10^4$ were noted on September 10.

Largescale sucker fry were the dominant resident fish species in the drift and comprised 47 percent of the fish captured. Sucker first began to appear in the collections in early August at a size of about 3 to 4 cm FL. Peak numbers were noted from late August through early September when fish ranged from 4 to 6 cm FL. Cyprinids made up most of the remaining collections. Juvenile and adult longnose dace occurred in low numbers throughout the sample period and comprised 14 percent of the total resident fish. Numbers of 0-age peamouth, carp, and squawfish peaked in late August, and these species represented 13, 5, and 4 percent of the total, respectively.

Diel Distribution of Resident Fish

A pronounced diel pattern was evident in collections of juvenile resident fish captured by fyke net (Figure 16). Nearly 90 percent of the fish were captured from 2000 to 0400 hours; thus, peak catches were observed during the hours of complete darkness. Only about 3 percent of the total fish were collected in the daylight interval from 1000 to 2000 hours.

NEARSHORE SAMPLING

The two supplemental collection methods, although not directly comparable to each other or to the fyke nets (Hubert 1983), provided further evidence that nearshore abundance of chinook salmon smolts was low during the study period. Large numbers of adult resident fish and some adult salmonids were observed in the nearshore areas when we sampled by boat electroshocker, yet only seven chinook salmon smolts were collected in

84 separate shoreline drifts averaging 347 shocker units each. Nearshore fish populations consisted primarily of adult largescale sucker and sculpin, and greatest numbers were observed at night. All smolts were collected in the 1600 to 0400 hours sampling intervals, and the majority were collected from 2200 to 0400 hours. Chinook smolts captured by electroshocker were somewhat larger than those collected by fyke net and ranged from 9.5 to 17.2 cm FL (mean 13.6 cm FL). Smolts were collected by electroshocker only from July 28 to August 9 and again from September 8 to 13. Scale analysis indicated all electroshocked fish were age-zero. Scales from two large specimens captured in September had irregular circuli spacing, a characteristic sometimes indicative of accelerated growth in a hatchery environment.

No chinook salmon smolts were collected in the six overnight and six daytime gill nets set in the study area from September 9 to 21. Species composition of the gill net catch differed from that noted in electroshocking samples. Gill nets caught mainly juvenile cyprinids ranging from 9 to 21 cm FL. Northern squawfish, chiselmouth, and redside shiner comprised 32, 27, and 27 percent of the total, respectively.

DISCUSSION

The fish distribution studies provided evidence that late summer populations of juvenile fall chinook salmon migrated mainly in the bottom midchannel zone of the Columbia River near N Reactor. These observations were substantiated by the low catches of juvenile salmonids obtained by supplementary sampling gear in shoreline areas. In contrast to salmonids, densities of juvenile resident fish were greatest in the nearshore zone and constituted a significant component of the drift following major spawning intervals only.

DISTRIBUTION OF JUVENILE CHINOOK SALMON

The majority of the juvenile chinook salmon were collected from August 5 to 15. This corresponds to peak migration times for 0-age fall and summer chinook salmon passing Priest Rapids Dam in previous years. Sims and Miller (1977) and Hovland et al. (1982) reported that median downstream movement of chinook smolts occurred from August 8 to 12 in 1965 to 1967, 1976, and 1981. Relative timing of smolt passage at Priest Rapids Dam as determined by gatewell dipping has generally indicated a gradual increase in numbers through July, with maximum densities occurring in early August, and the run tapering off slowly through mid-September. Park (1969) noted that the August migration accounted for 60 percent of the total in 1965 and 40 percent in 1966. In 1981, 61 percent of the gatewell catch of 0-age chinook at Priest Rapids Dam occurred in August (Hovland et al. 1982). Seasonal patterns of gatewell catches of 0-age chinook salmon in 1982 and 1983 were also similar (Mike Dell, Grant Co. PUD, personal communication).

Water temperatures ranged from 63°F (17.2°C) to 67°F (19.4°C), and daily average flows ranged from 80,500 to 186,000 cfs when collections of chinook smolts were made. Water temperatures and flows at upstream rearing areas, rather than those at Hanford, probably influenced migration. The primary source of late-summer migrating chinook smolts were probably from the Wenatchee River. Lesser contributions would be expected from the Entiat, Methow, and Okanagon Rivers (letter from Thor Tollefson, Washington

Department of Fisheries, to Mark Schneider, November 1973). Only limited spawning of fall chinook occurs in the mainstem Columbia River above Priest Rapids Dam.

No other distribution studies have been conducted in the Columbia River during the late summer, therefore comparisons are only possible between studies conducted in the spring or elsewhere. Mains and Smith (1964) conducted studies of fish distribution near Columbia River mile 347 in 1955; however, subsequent construction of several upstream dams created a totally new environment for migrating fish. In addition, hatchery production and dam-induced mortalities have altered the composition of salmonid populations in the basin. Juvenile chinook salmon collected by Mains and Smith (1964) from March through July averaged less than 8.3 cm FL and probably were from Hanford Reach stocks. Although a preference was shown for the nearshore stations and the surface zone, fish were collected throughout the river cross-section. Patterns of distribution may be expected to differ since the smaller, springtime populations could have been utilizing the river primarily as a feeding and rearing area. In contrast, actively migrating smolts could be expected to move in the swifter, deeper portions of the river if maximum energy efficiency is to be achieved.

Distribution of chinook salmon during the late-summer outmigration at Hanford can be compared to that of juvenile sockeye salmon (Oncorhynchus nerka) in other river systems. Dames and Moore (1982) found that sockeye salmon smolt were highly concentrated in the midriver channel in an area of greatest depth and velocity. Using acoustics, they detected the majority of smolts in the lower third of the water column. In contrast to spring outmigrant fry, larger-sized, summer-fall sockeye fry were spread more horizontally in the river channel (Dames and Moore 1982). Lateral distribution (catch per unit effort) of sockeye salmon and pink salmon (O. gorbuscha) fry was positively correlated with average water velocities (range 1.39 - 2.56 ft/sec), but coho salmon (O. kisutch) catches were distributed uniformly across the river width (McDonald 1960). Thus, cross-sectional distribution of juvenile salmonids varies by species and life-stage.

Diel movement patterns of fish in our study were consistent with those observed in previous studies of chinook salmon smolts. Principal movement of outmigrating juvenile chinook salmon occurred during the night at Priest Rapids Dam (Sims and Miller 1977) and in the Columbia River at Beyers Landing (Mains and Smith 1964). Smith (1974) collected 91 percent of the mainly 1-age juvenile chinook salmon at night in impounded waters on the Snake River. McDonald (1960) also observed that downstream movement of pink salmon fry was primarily nocturnal. Sockeye salmon fry showed a noticeable preference for nocturnal movement (Dames and Moore 1982), which may indicate a negative response to light. Nighttime movement into the current may also result from a loss of visual contact with surroundings (McDonald 1960). Observed diel behavior patterns may also affect cross-sectional distribution. Edmundson et al. (1968) observed that juvenile chinook salmon in aquaria settled to the bottom after dark. Coho salmon smolts showed a preference for deeper water and increased activity at night (Hoar 1953).

EFFECTS OF WATER VELOCITY ON CAPTURE EFFICIENCY

Our studies demonstrated that efficiency of capture and retention was related to water velocity. The net efficiency tests were designed to account for differences among stations; however, fish were only collected at four of the 12 station/depth combinations and estimates of proportional distribution cannot be made for all stations. Even when effects of water velocity were factored into our estimates of distribution, the overall study results remained unchanged. Gear avoidance or size selectivity at low water velocities has been reported in other studies. Dames and Moore (1982) reported that shore-based fyke nets in low velocity periods efficiently captured sockeye salmon fry, but were less efficient in capturing larger smolts. In addition, avoidance by smolts of a inclined plane trap near the surface was substantial and was attributed to its visibility. Craddock (1961) found that a winged fyke net was selective for smaller smolts (80 mm versus 85 mm), which may indicate avoidance by the larger fish. Stober and Hamalanen (1979) assumed 100 percent catch efficiency (retention) of sockeye salmon fry at velocities above 30 cm/sec (~1 ft/sec), but did not address avoidance.

All but one of the chinook salmon smolts were captured at current velocities 4.0 ft/sec. Therefore, velocities may have limited capture and retention of smolts at the two nearshore stations during the latter stages of sampling. However, the higher velocities (>2 ft/sec) encountered during the peak migration period should have been sufficient to retain captured smolts in any of the four stations in general proportion to their presence within sampled portions of the river. Other factors such as bottom topography, visibility, and temperature can influence the behavior of the migrating chinook salmon smolts; therefore, the results of the net efficiency tests cannot be extrapolated for all possible conditions. Nonetheless, these tests are the first known information on susceptibility of capture of salmonid smolts to wingless fyke nets.

Low catches of chinook salmon smolts during this study may be reflective of relatively low population size of the 1983 fall chinook outmigration. Summer and fall chinook salmon spawning above Priest Rapids Dam in 1982 was significantly reduced from the 1972 to 1981, 10-year average (Ron Woodin, Washington State Department of Fisheries, personal communication). Based on escapement of adult summer and fall chinook salmon over Priest Rapids Dam in 1982 and historical production factors (Letter from Thor Tollefson, Washington State Department of Fisheries to Mark Schneider, PNL, November 1973), the total outmigration of 0-age chinook salmon in 1983 is estimated to be about 970,000 fish. This is only about 40 percent of the numbers estimated in 1976 (Sims and Miller 1977). Daily numbers of chinook salmon smolts collected at Priest Rapids Dam by gatewell dipping in 1983 were only half of those collected in 1982 (Mike Dell, Grant County PUD, personal communication).

RESIDENT FISH DISTRIBUTION

Patterns of resident fish abundance are consistent with known spawning times and/or habitat selection of the dominant species. Largescale sucker spawn from April through July at Hanford (Dauble 1978), and newly hatched fry <20 mm FL are abundant in shallow nearshore areas in late summer. Seasonal occurrence of 0-age cyprinids were also consistent with known spawning times (Gray and Dauble 1979). The presence of longnose dace in the collections may be related to their preference for areas of higher water velocity (Page et al. 1982). Most other species were collected infrequently and are probably insignificant components of the midriver drift.

The spatial distribution of juvenile resident fish may have been related to displacement of the fish from nearshore habitats during increased flows. Daily flows during the study usually were lowest around mid-day and increased to a maximum around 2400 hours. Since most of the resident fish were <6 cm FL, an increase in current velocity in shoreline areas could have been sufficient to result in passive downstream movement.

Relative densities of resident fish in the drift were low in comparison to those observed in impounded areas of the Columbia River (Hjort et al. 1981). This difference, however, is mainly attributable to the relatively larger mesh size used in our nets that would allow most larval fish to pass through. Maximum mid-channel densities of ichthyoplankton (~0.20 fish per m^3) in the Hanford Reach occurred in May-June (Beak Consultants, Inc. 1980; Page et al. 1982). These collections were for daytime hours only, and if nighttime samples were taken, catch composition and densities would have been expected to be greater.

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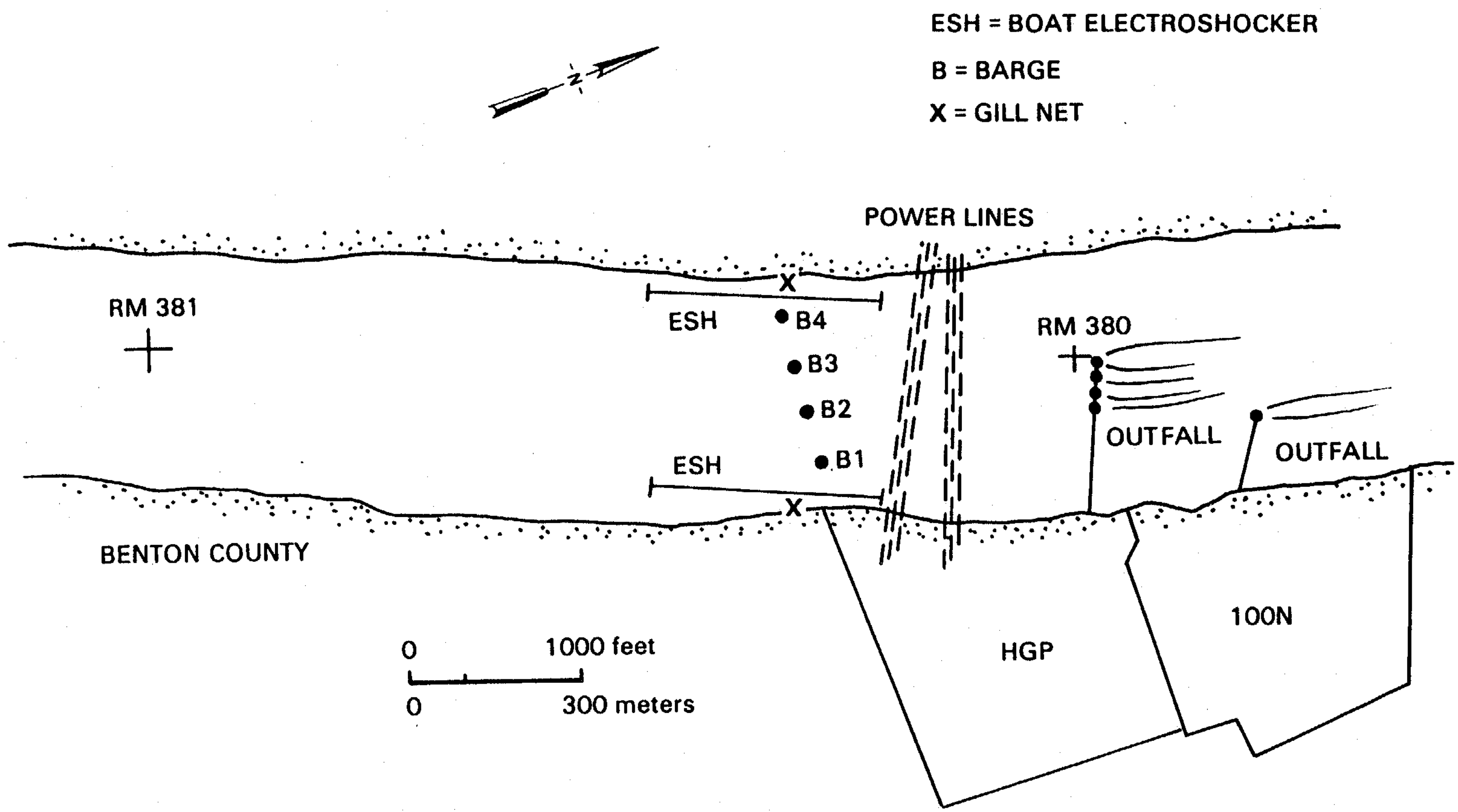

FIGURE 1. Location of the Sampling Stations in Relation to Hanford Generating Project (HGP) and N Reactor

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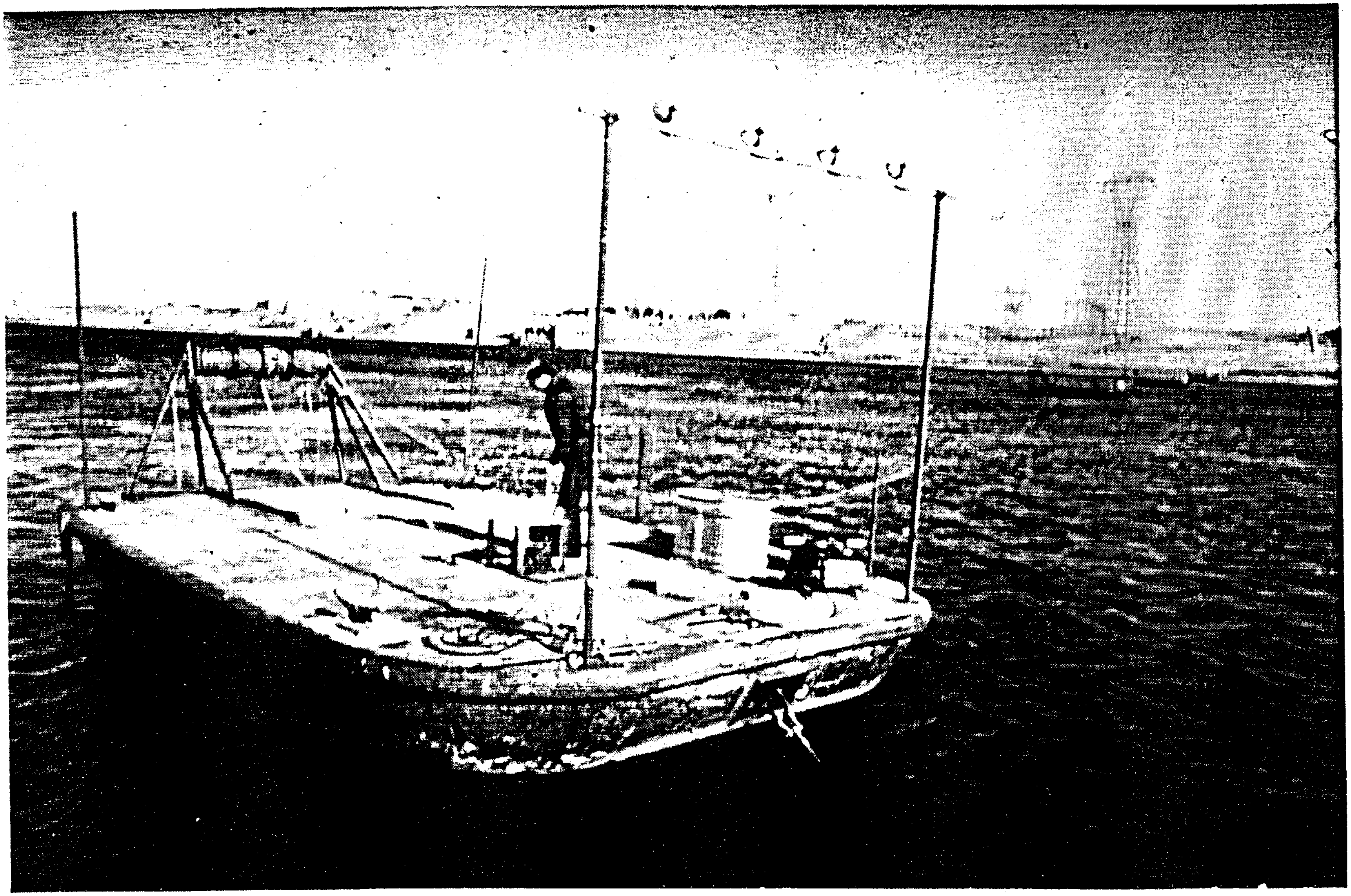

FIGURE 2. Fishing Platforms on Columbia River Upstream of N Reactor During 1983 Fish Distribution Study

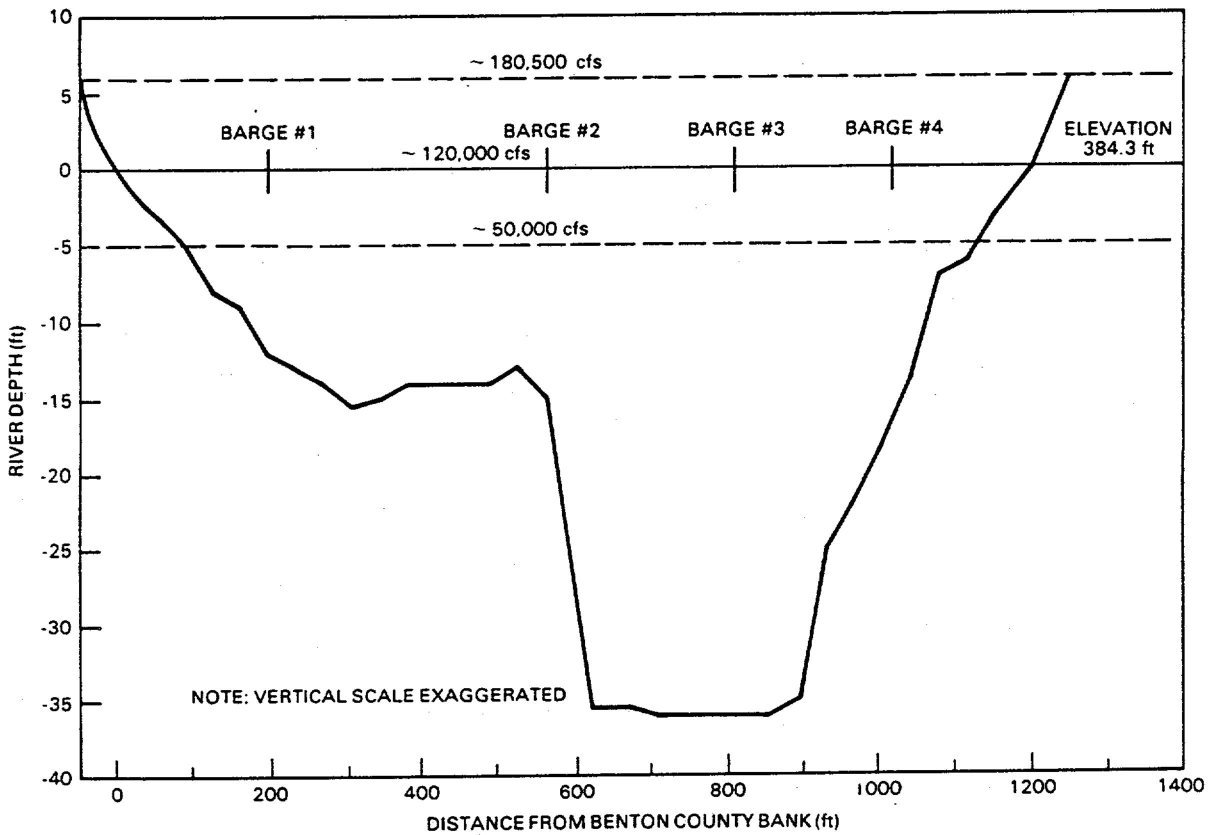

FIGURE 3. Cross-sectional View of Bottom Topography at the Study Site, Indicating Relative Position of Sampling Stations and Range in River Depths During the Study Period.

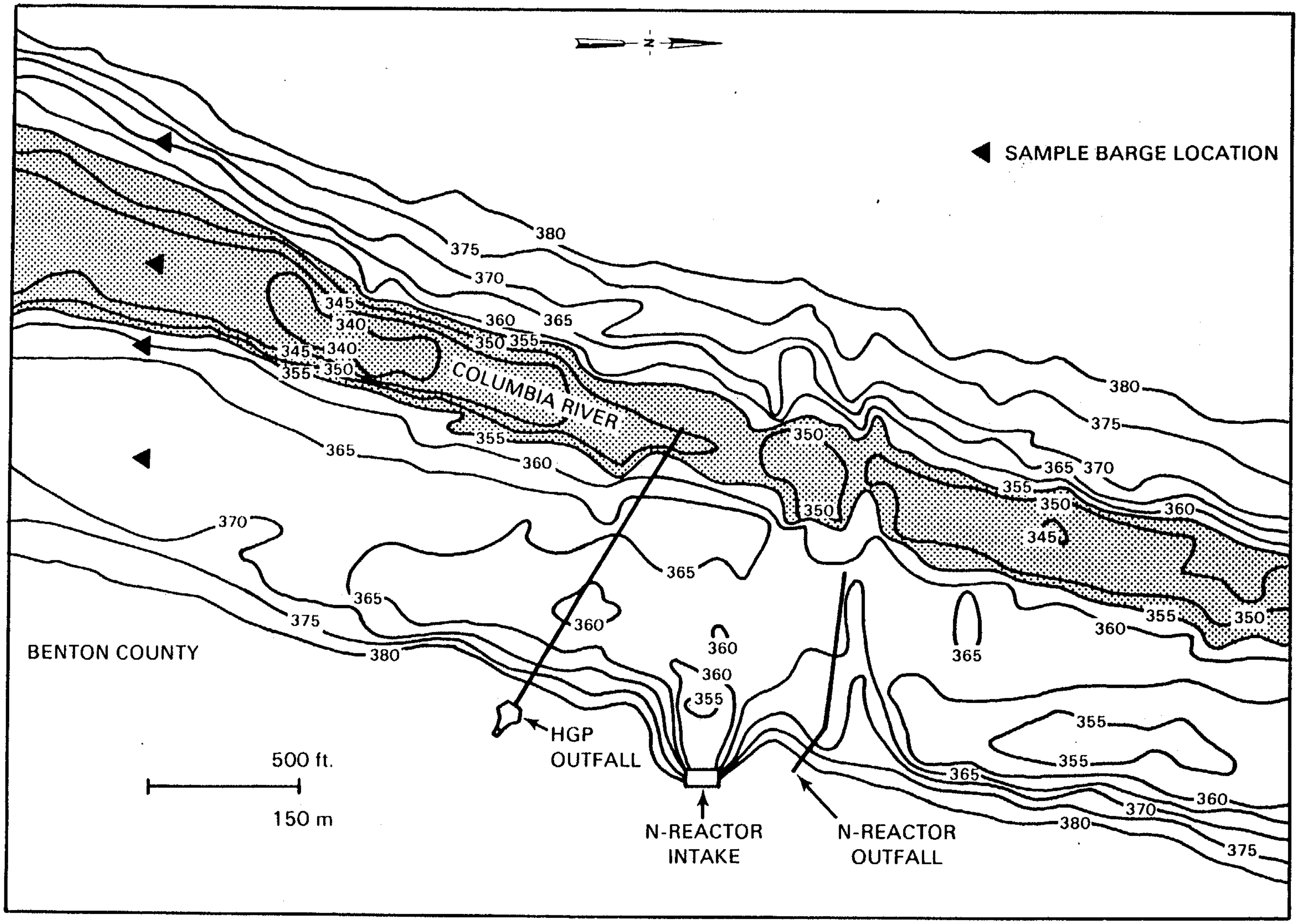

FIGURE 4. Columbia River Bathymetry near the Study Site. Countour intervals are river level elevations in feet and the stippled portion provides an indication of the mid-channel region.

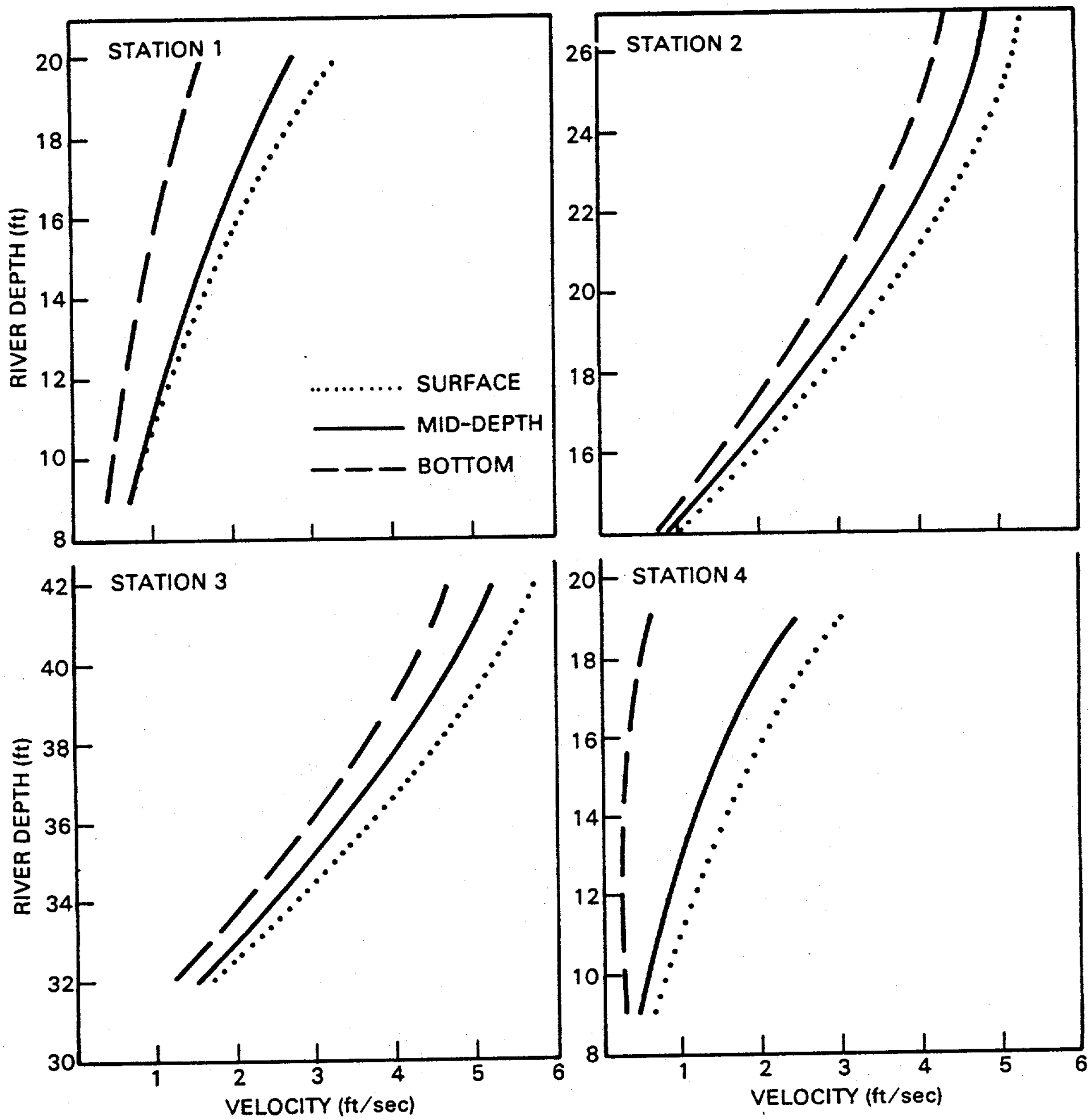

FIGURE 5. Measured Current Velocity of the Four Sample Stations and Relationship of Velocity to Depth.

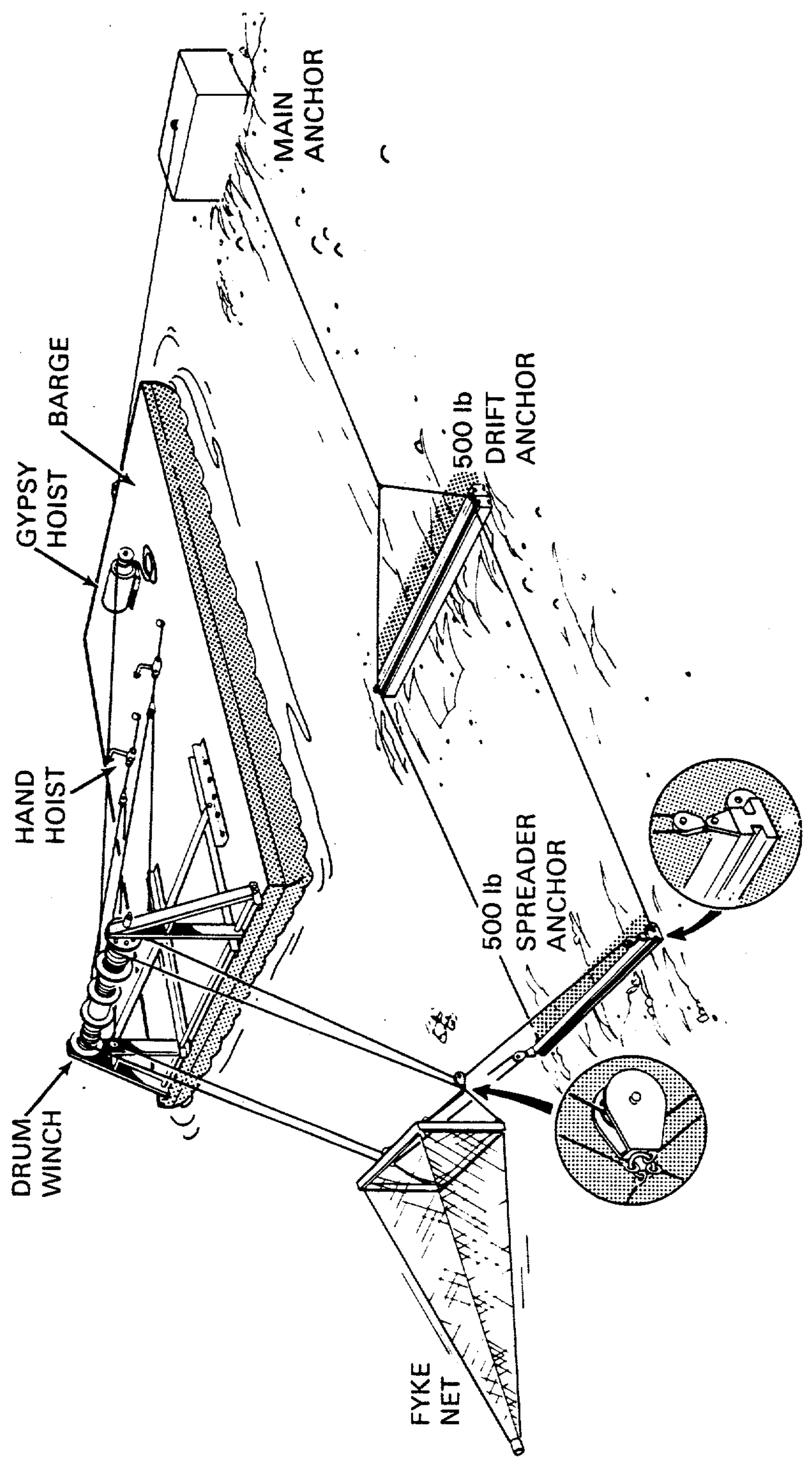

FIGURE 6. Design of the Fyke Net Rigging and Anchoring System

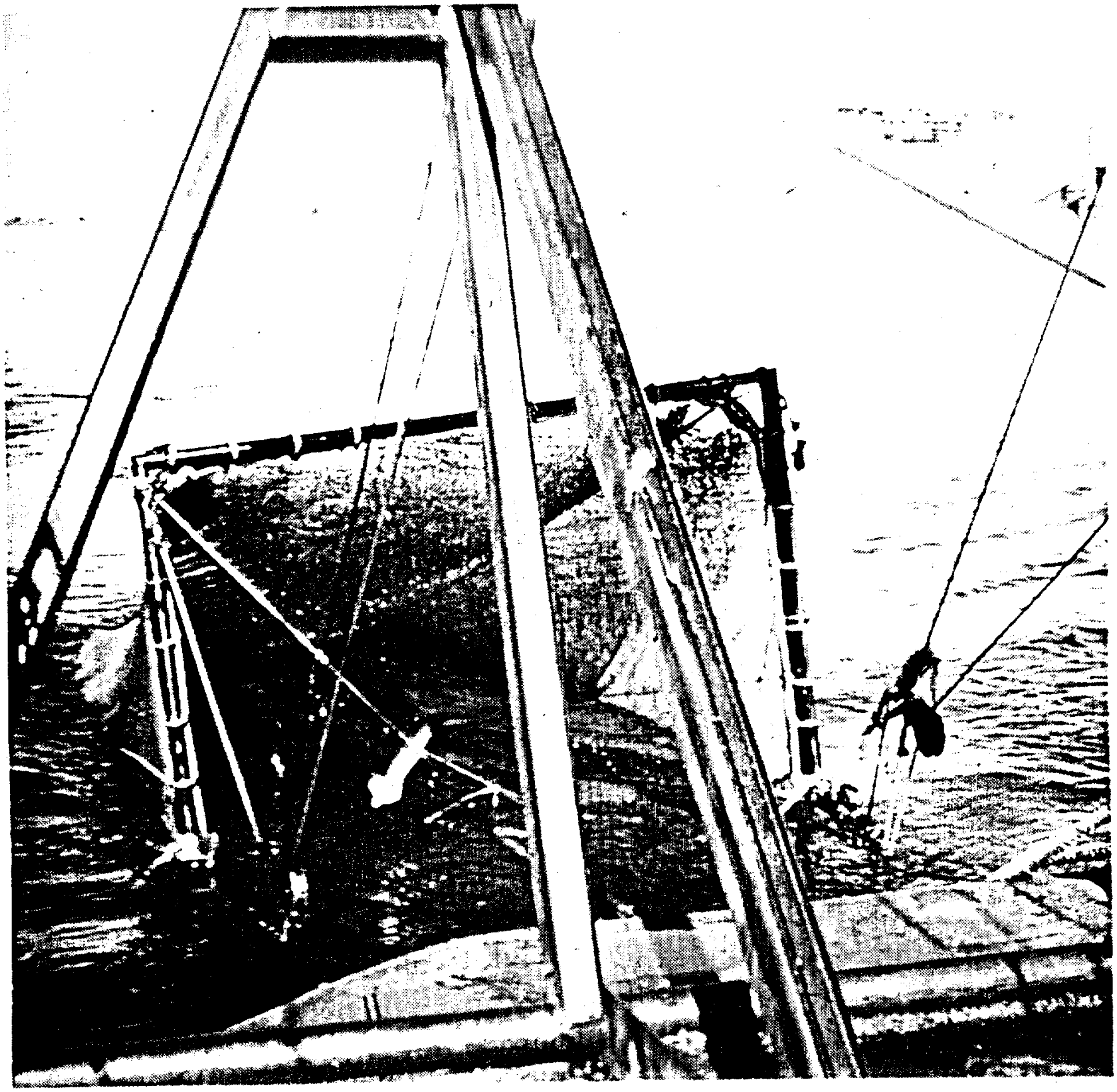

FIGURE 7. Fyke Nets Used During Fish Distribution Study at N Reactor in 1983

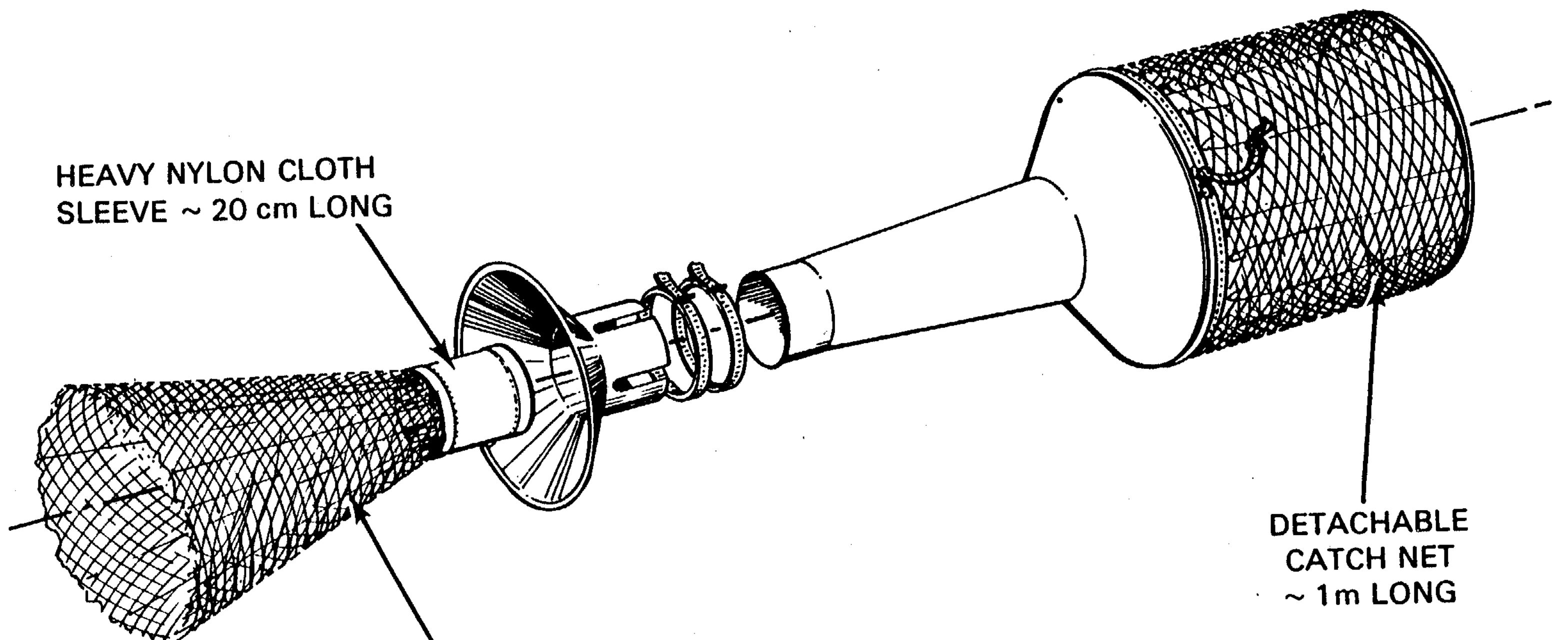

FIGURE 8. Venturi Apparatus and Detachable `atch Net Used During Initial Stage of Sampling

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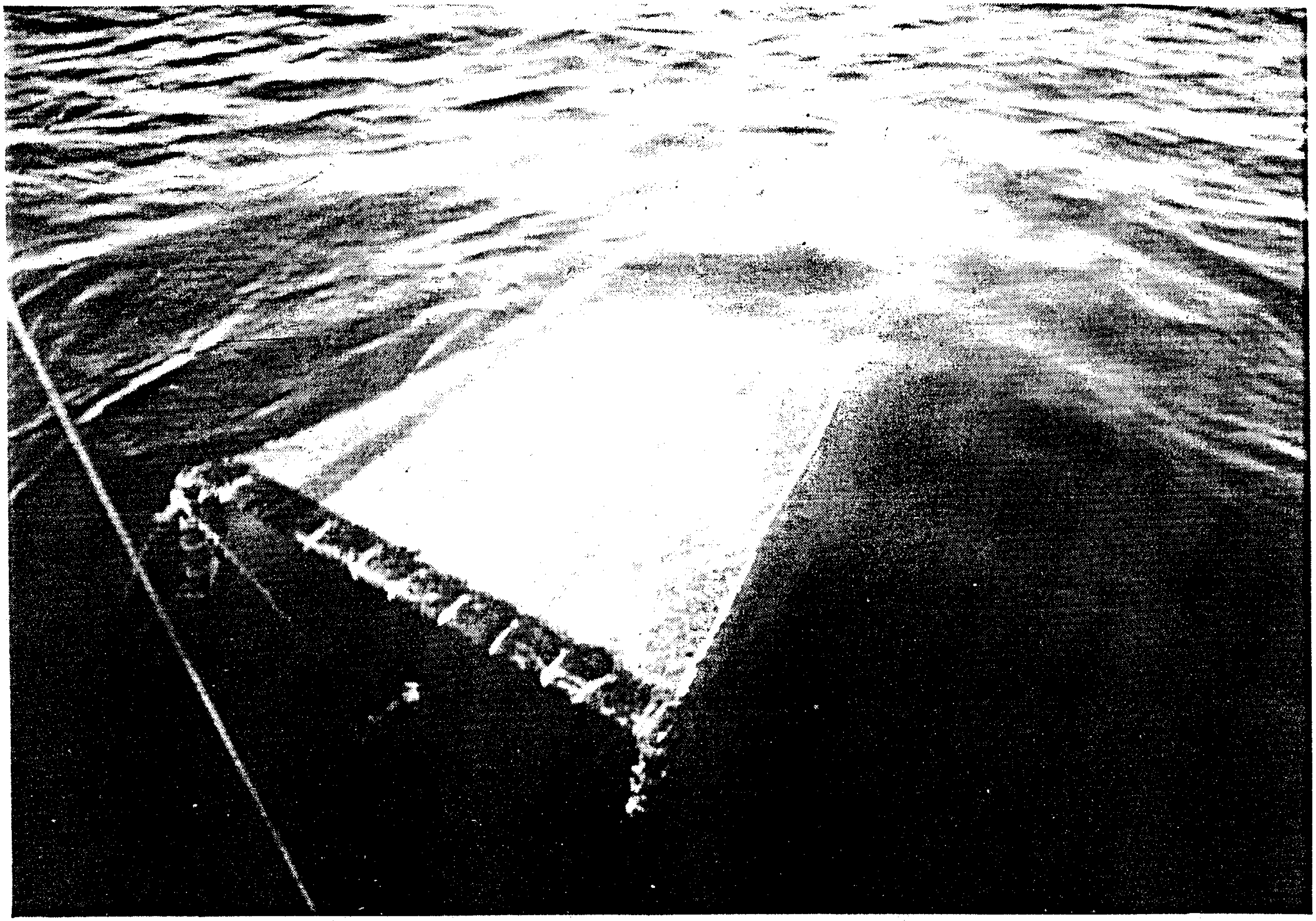

FIGURE 9. Fyke Net Towed Behind Barge to Collect Surface Samples

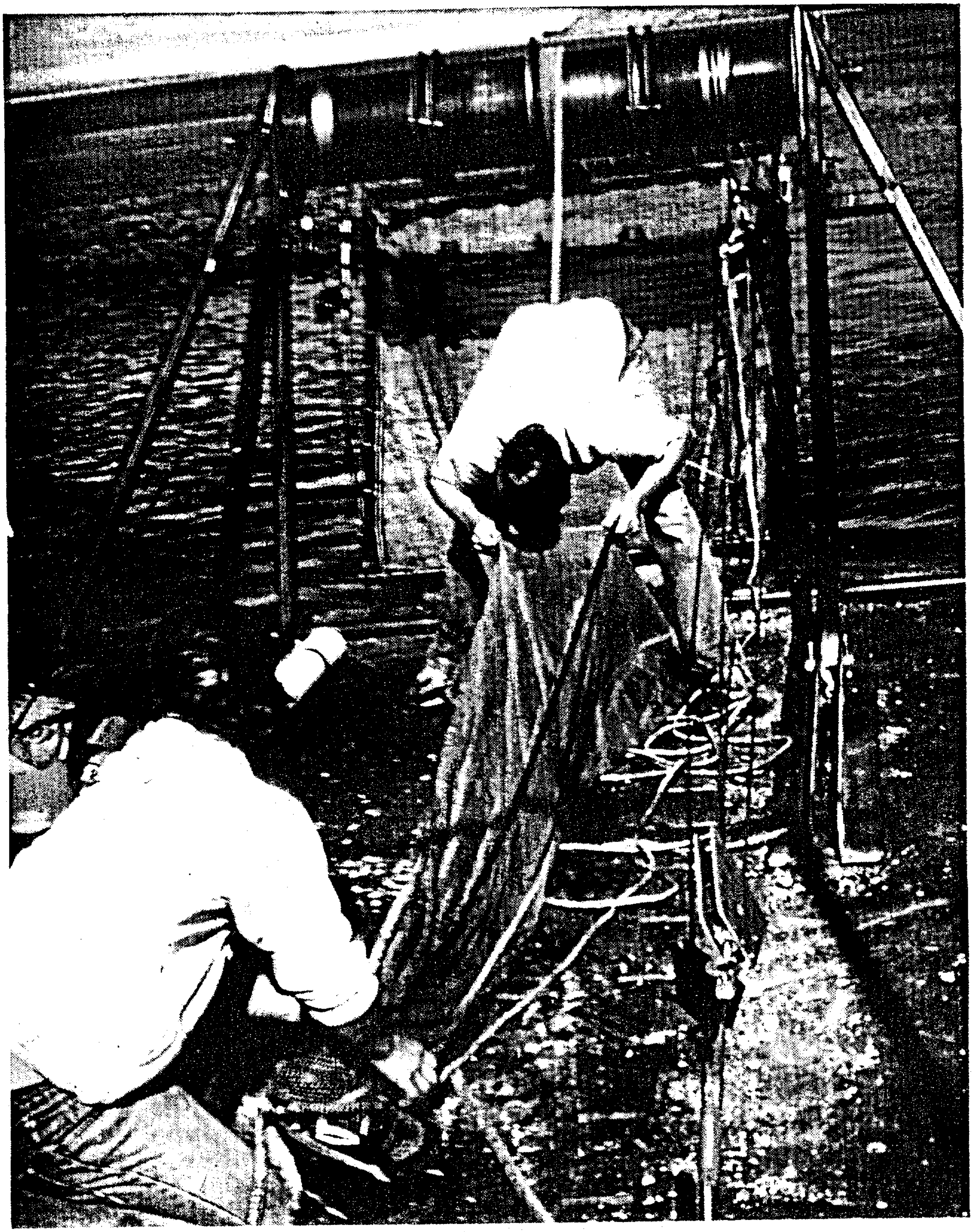

FIGURE 10. Fyke Net Checked for Fish and Cleaned of Debris

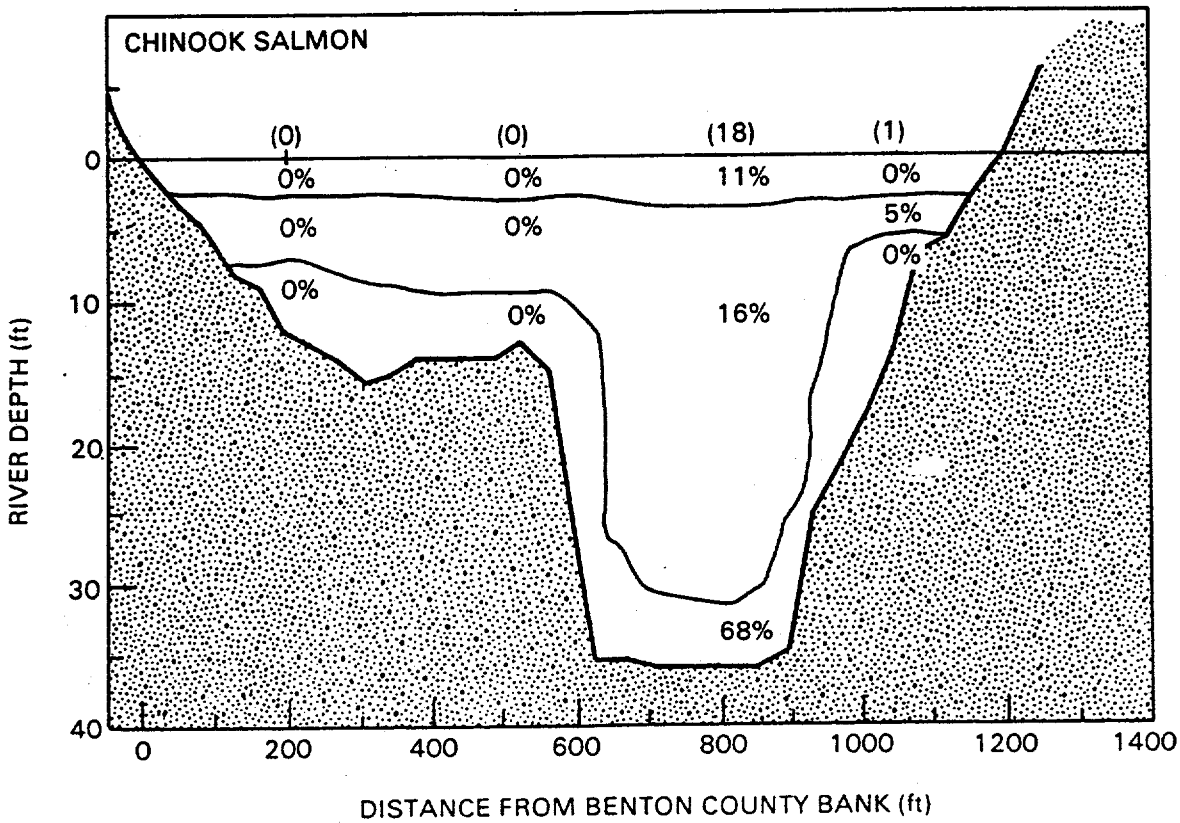

FIGURE 11. Distribution of Downstream Migrant Juvenile Chinook Salmon in the Columbia River near N Reactor. Numbers in parentheses indicate relative sample size.

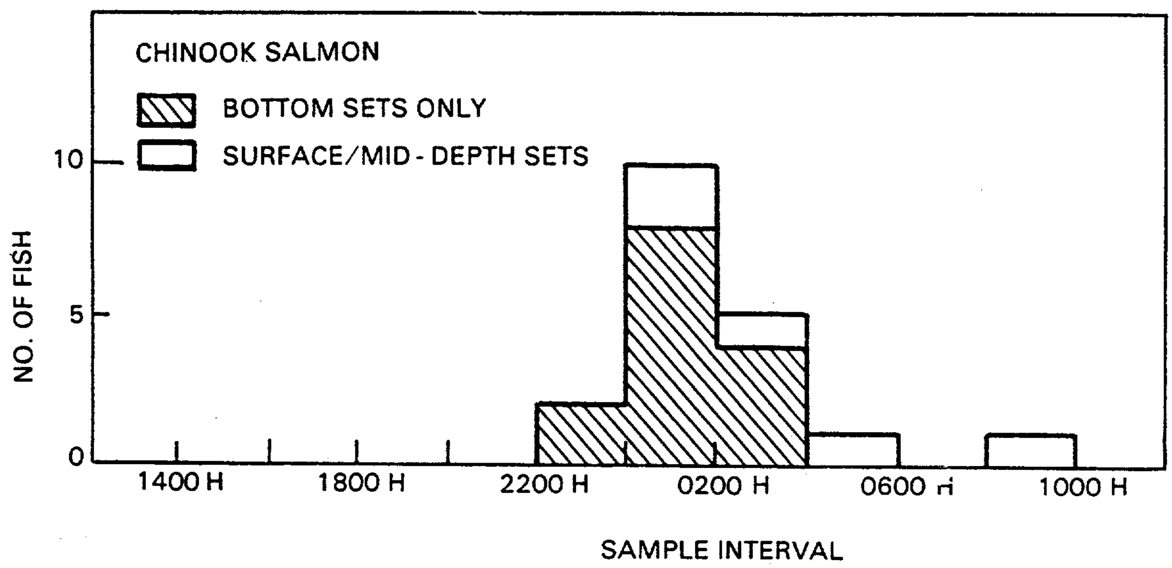

FIGURE 12. Diel Pattern in Catches of Juvenile Chinook Salmon by Fyke Net in the Columbia River near N Reactor

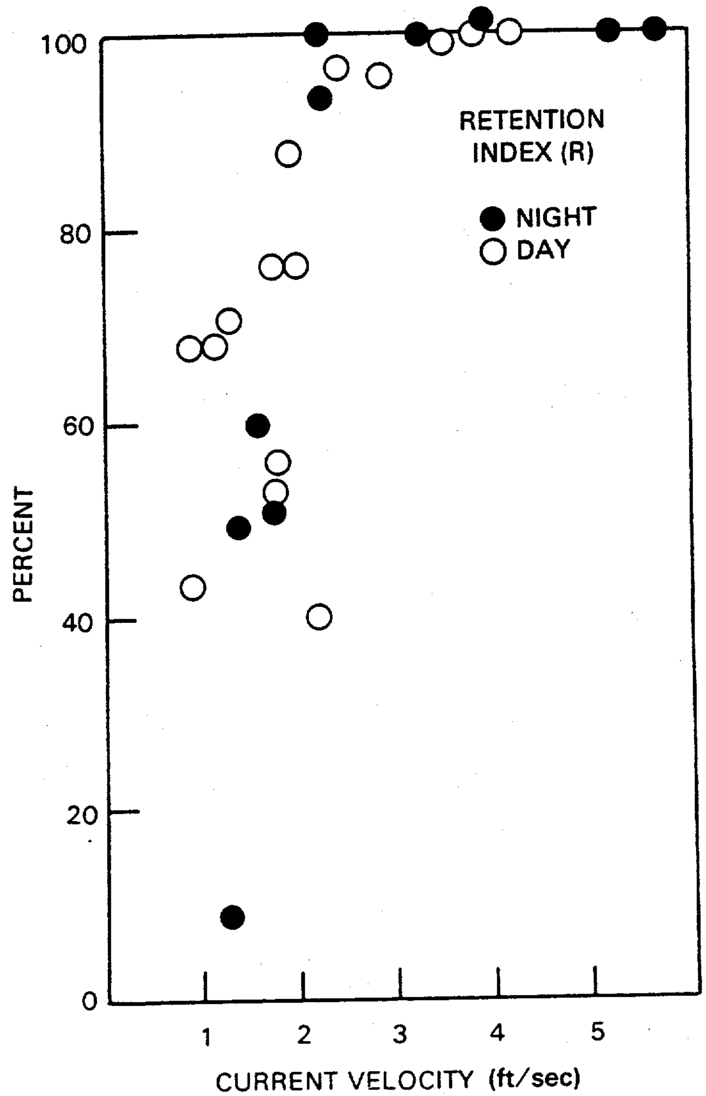

FIGURE 13. Relationship of Current Velocity to Retention of Chinook Salmon Smolts in Fyke Nets, or Retention Index (R).

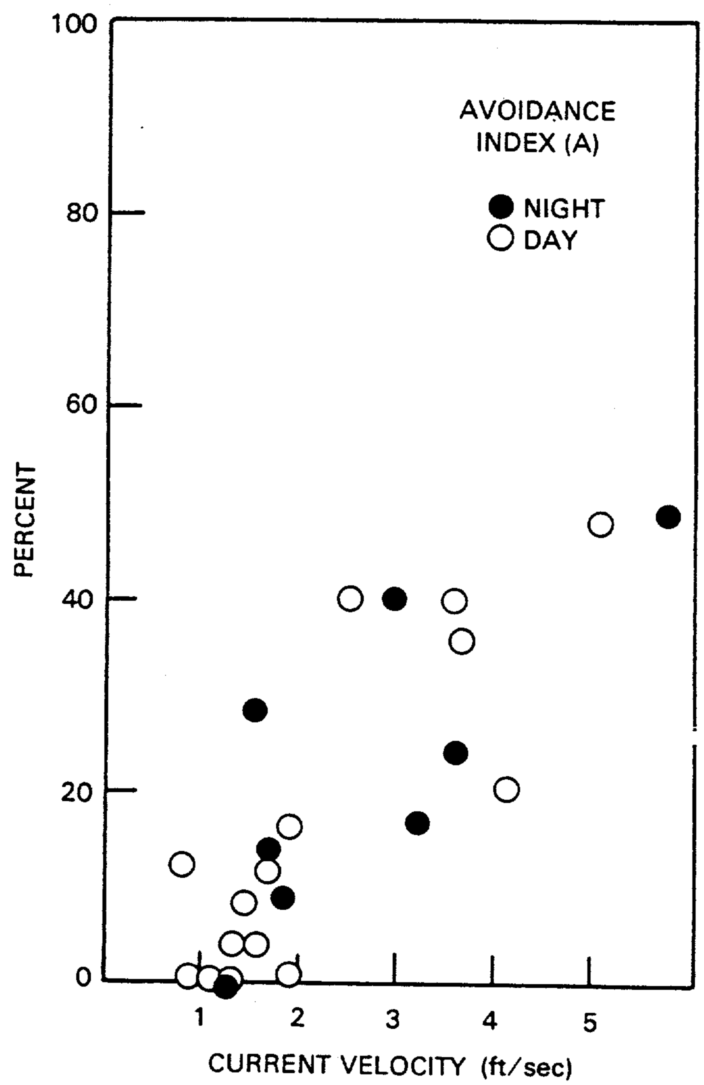

FIGURE 14. Relationship of Current Velocities to Capture Efficiency of Chinook Salmon Smolts in Fyke Nets, or "Avoidance Index" (A)

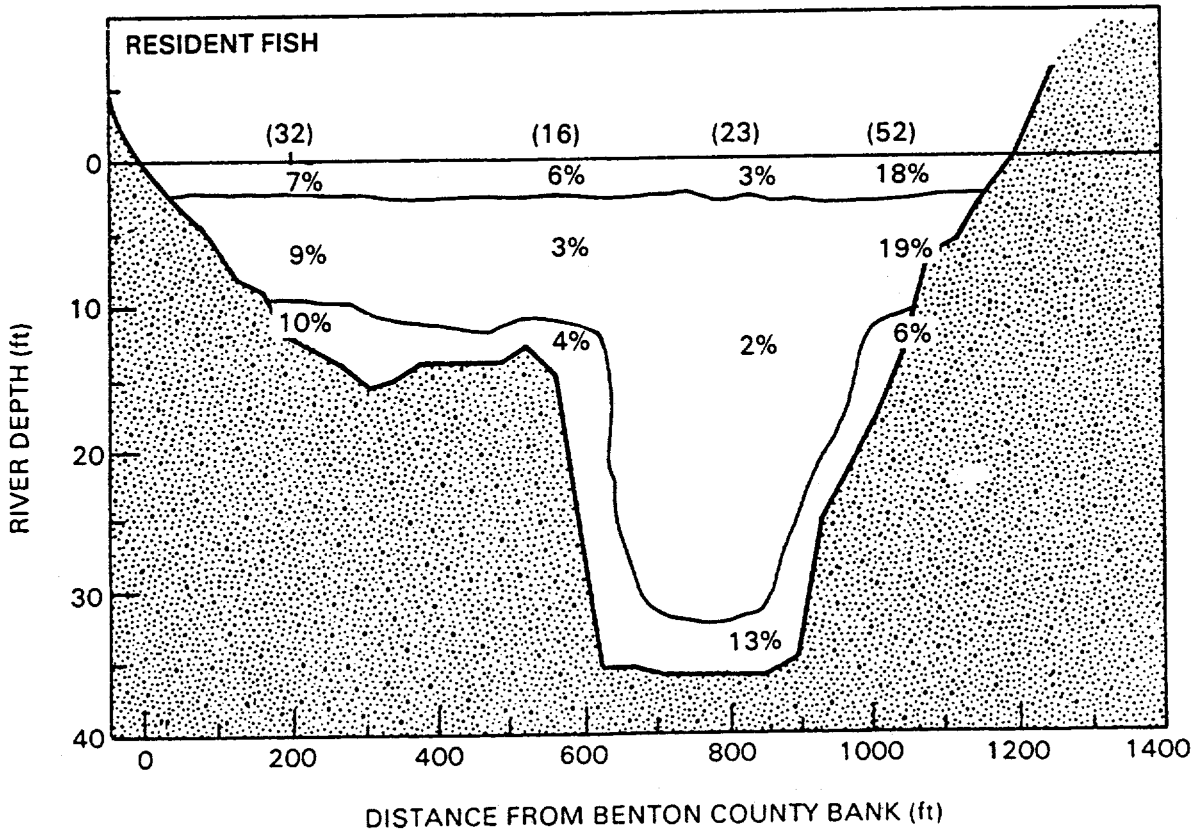

FIGURE 15. Spatial Distribution of Resident Fish by Fyke Net in the Columbia River near N Reactor. Numbers in parentheses indicate relative sample size.

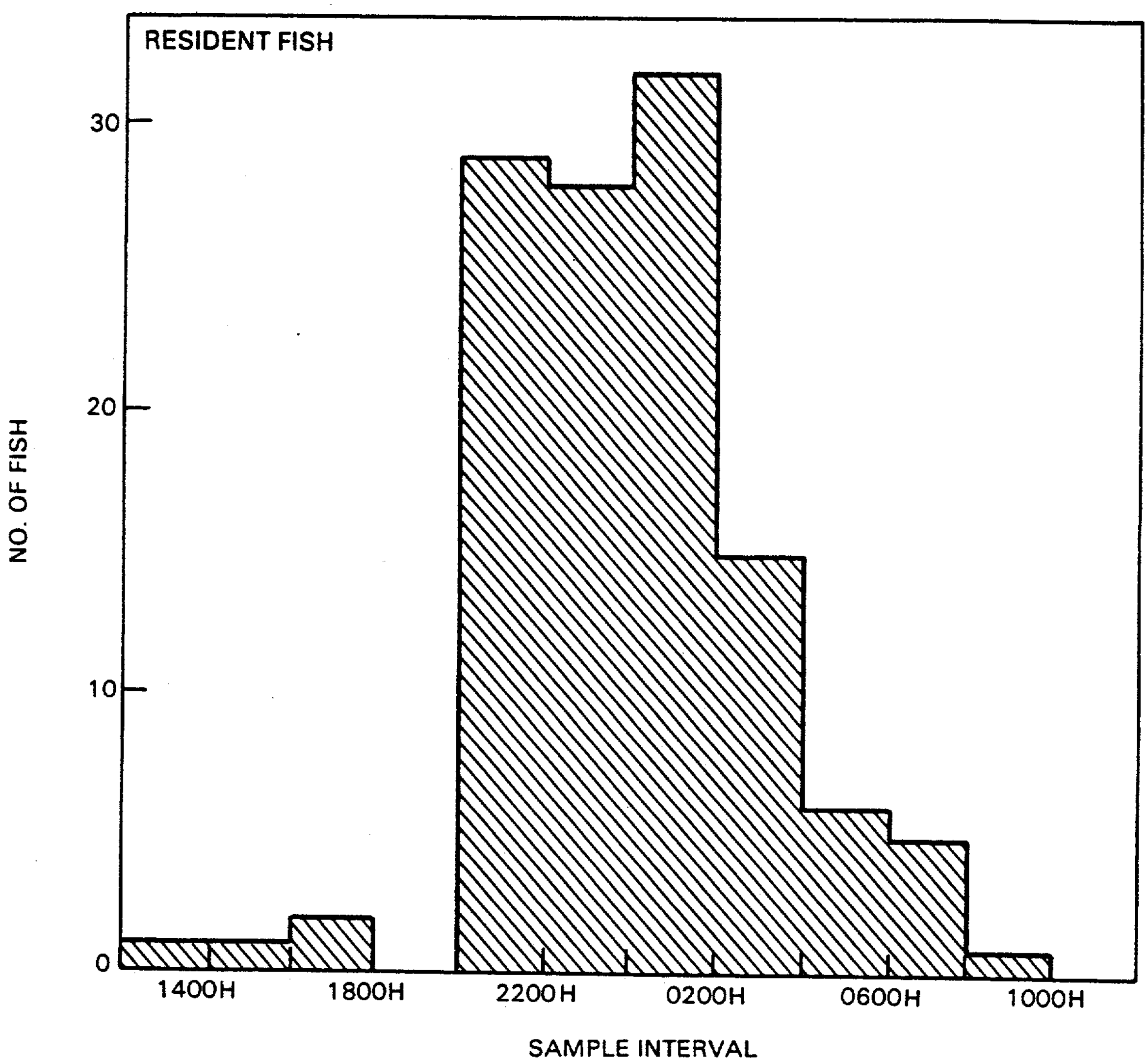

FIGURE 16. Diel Pattern in Catches of Resident Fish Species by Fyke Nets in the Columbia River near N Reactor

TABLE 1. Composite List of Fish Species Collected by Sample Method

Family	Scientific Name	Common Name	Fyke Net	Boat[a] Electroshock	Gill Net
Catostomidae - sucker	*Catostomus macrocheilus*	Largescale sucker	X	X	X
Centrarchidae - Sunfish	*Lepomis gibbosus*	Pumpkinseed	X		
Clupeidae - Herrings	*Alosa sapidissima*	American shad	X	X	
Cottidae - Sculpins	*Cottus asper*	Prickly sculpin	X	X	
Cyprinidae - Minnows	*Acrocheilus alutaceus*	Chiselmouth	X		X
	Cyprinus carpio	Carp	X	X	X
	Mylocheilus caurinus	Peamouth chub	X	X	X
	Ptychocheilus oregonensis	Northern squawfish	X	X	X
	Rhinichthys cataractae	Longnose dace	X		
	R. falcatus	Leopard dace	X		
	Richardsonius balteatus	Redside shiner	X	X	X
	Tinca tinca	Tench	X		
Gasterosteidae-Sticklebacks	*Gasterosteus aculeatus*	Three-spined stickleback	X	X	
Percidae - Perches	*Perca flavescens*	Yellow perch	X	X	
	Stizostedion vitreum	Walleye		X	
Salmonidae - Salmon, Trout Whitefish	*Oncorhynchus tshawytscha*	Chinook salmon	X	X	
	Prosopium williamsoni	Mountain whitefish		X	
	Salmo gairdneri	Rainbow (steelhead) trout		X	

(a) Includes species that were shocked but not collected.

TABLE 2. Sampling Effort at the Four Fyke Net Stations near N Reactor in 1983. Values in parentheses indicate the proportional time that each station/depth was sampled.

Station[a]	Depth	No. Sets	Total Hr Fished	Sample Volume ($m^3 \times 10^3$)
1	surface	172	353 (0.095)	2312
	mid-depth	168	332 (0.090)	2528
	bottom	175	328 (0.089)	1792
2	surface	147	297 (0.080)	2867
	mid-depth	145	298 (0.081)	2687
	bottom	146	276 (0.075)	3126
3	surface	158	283 (0.077)	4135
	mid-depth	153	290 (0.079)	4041
	bottom	157	302 (0.082)	3495
4	surface	169	308 (0.083)	1485
	mid-depth	163	319 (0.086)	2497
	bottom	168	314 (0.085)	8625

(a) Stations refer to barge locations (see Figure 1).

TABLE 3. Estimates of Proportional Distribution of Chinook Salmon Caught at Various Stations and Depths

Depth	Statistic	Station 1	Station 2	Station 3	Station 4
Surface	N[a]	0	0	2	0
	P[b]	0	0	0.105	0
	95% CI	0.00-0.176	0.00-0.176	0.013-0.331	0.00-0.176
Mid-depth	N	0	0	3	1
	P	0	0	0.158	0.053
	95% CI	0.00-0.176	0.00-0.176	0.034-0.396	0.001-0.260
Bottom	N	0	0	13	0
	P	0	0	0.684	0
	95% CI	0.00-0.176	0.00-0.176	0.435-0.874	0.00-0.176

(a) N = Number of chinook salmon caught.

(b) P = Proportional distribution of salmon among various station/depth combinations.

TABLE 4. Summary of Catch Per Unit Effort for Juvenile Chinook Salmon at Station 3, Expressed in Terms of Sample Duration and Sample Volume

	July 26 to September 23		July 26 to August 17	
Depth	No./hr x 10^3	No./ m^3 x 10^6	No./hr x 10^3	No./100 m^3
Surface	7.06	0.48	25.93	1.54
Mid-depth	10.33	0.74	34.50	2.19
Bottom	43.00	3.72	146.10	11.55

TABLE 5. Standardized Estimates of Proportional Distribution of Chinook Salmon Caught at Various Stations and Depths

Depth	Statistic	Station 1	Station 2	Station 3	Station 4
Surface	N[a]	0	0	2.49	0
	P[b]	0	0	0.111	0
Mid-depth	N	0	0	3.65	1.11
	P	0	0	0.163	0.050
Bottom	N	0	0	15.19	0
	P	0	0	0.677	0

(a) $N = (n_{ij} t_{ij}^{-1}) \cdot T_m$ = standardized estimate of fish caught at station i, depth j

where n_{ij} = actual number of fish caught at station i, depth j

t_{ij} = total time (hours) sampled at station i, depth j

T_m = maximum time sampled at any of the 12 station/depths = 353.18 hours at station 1, depth 1.

(b) P = proportional distribution of fish.

TABLE 6. Estimates of Percent Capture Efficiency and Retention of Chinook Salmon

Time	Parameter	Station 1	Station 2	Station 3	Station 4
Day & Night	Catch	10.0	10.7	33.7	13.6
	Retention	65.3	82.2	98.3	47.2
Day	Catch	11.0	11.0	31.0	9.3
	Retention	58.0	84.0	97.0	58.7
Night	Catch	8.0	10.0	37.3	20.0
	Retention	80.0	79.7	100.0	30.0

TABLE 7. Estimates of Proportional Distribution of Chinook Salmon Caught at Various Stations and Depths, Given 100% Capture Efficiency and Retention

Depth	Statistic	Station 1	2	3	4
Surface	N[a]	0	0	6.04	0
	P[b]	0	0	0.086	0
Mid-depth	N	0	0	9.06	15.58
	P	0	0	0.130	0.223
Bottom	N	0	0	39.24	0
	P	0	0	0.561	0

(a) N = estimate of number of fish which would have been caught given 100% net efficiency = $N_{ij}(C_i R_i)^{-1}$

where N_{ij} = number of fish caught at station i, depth j

C_i = proportion of fish caught at station i

R_i = proportion of fish retained at station i.

(b) P = proportional distribution of fish among the station/depths which yielded fish.

TABLE 8. Summary of Catch Per Unit Effort for Juvenile Resident Fish, Expressed in Terms of Sample Duration and Sample Volume. All values summarized from July 28 through September 22.

Station	Depth	No./hr x 10^2	No./m^3 x 10^6
1	surface	2.55	3.89
	mid-depth	3.31	4.35
	bottom	3.96	7.25
2	surface	2.69	2.79
	mid-depth	1.34	1.49
	bottom	1.45	1.28
3	surface	1.77	1.21
	mid-depth	1.03	0.74
	bottom	4.30	3.72
4	surface	6.81	14.14
	mid-depth	6.90	11.76
	bottom	2.87	10.44

APPENDIX

APPENDIX

The tables and figures included in the appendix provide detailed information on fyke net catch totals, river flows and temperatures, and specific data on age and growth of the juvenile chinook salmon.

TABLE A.1 Sampling Frequency and Relative Timing of the Three Capture Methods Employed. Numbers represent a 24-hour sample as described in Methods.

	DATE									
Gear Type	7/24 - 7/31	8/1 - 8/7	8/8 - 8/14	8/15 - 8/21	8/22 - 8/28	8/29 - 9/5	9/5 - 9/11	9/12 - 9/18	9/19 - 9/25	TOTALS
Fyke Net	5	5	5	5	5	5	4	6	4	44
Boat Electroshocker	1	1	1	1	1	1	1	1	1	9
Gill Net	0	0	0	0	0	0	1	1	1	3

TABLE A.2 Weekly Catch Totals of All Fish Collected by Fyke Nets

Scientific Name	DATE 7/24-7/31	8/1-8/7	8/8-8/14	8/15-8/21	8/22-8/28	8/29-9/4	9/5-9/11	9/12-9/18	9/19-9/25	TOTALS
Catostomus macrocheilus			6	9	13	14	7	1	1	51
Catostomid fry			7	3						10
Lepomis gibbosus							1			1
Alosa sapidissima	1				1					2
Cottus asper	1									1
Cottus spp.				1	1		1			3
Acrocheilus alutaceus						1				1
Cyprinus carpio			1	2	2	3				8
Mylocheilus caurinus			1	2	8	2	3			16
Ptychocheilus oregonensis						5	1			6
Rhinichthys cataractae	1	2	1	2	4	4	1	1	1	17
R. falcatus					1					1
Richardsonium balteatus						1			1	2
Tinca tinca						1				1
Cyprinid fry				1						1
Gasterosteus aculeatus				1	1					2
Perca flavescens				1		1			1	3
Oncorhynchus tshawytscha	2	6	9	1				1		19
Unidentifiable						1				1
Weekly Totals	5	8	25	23	31	33	14	3	4	146

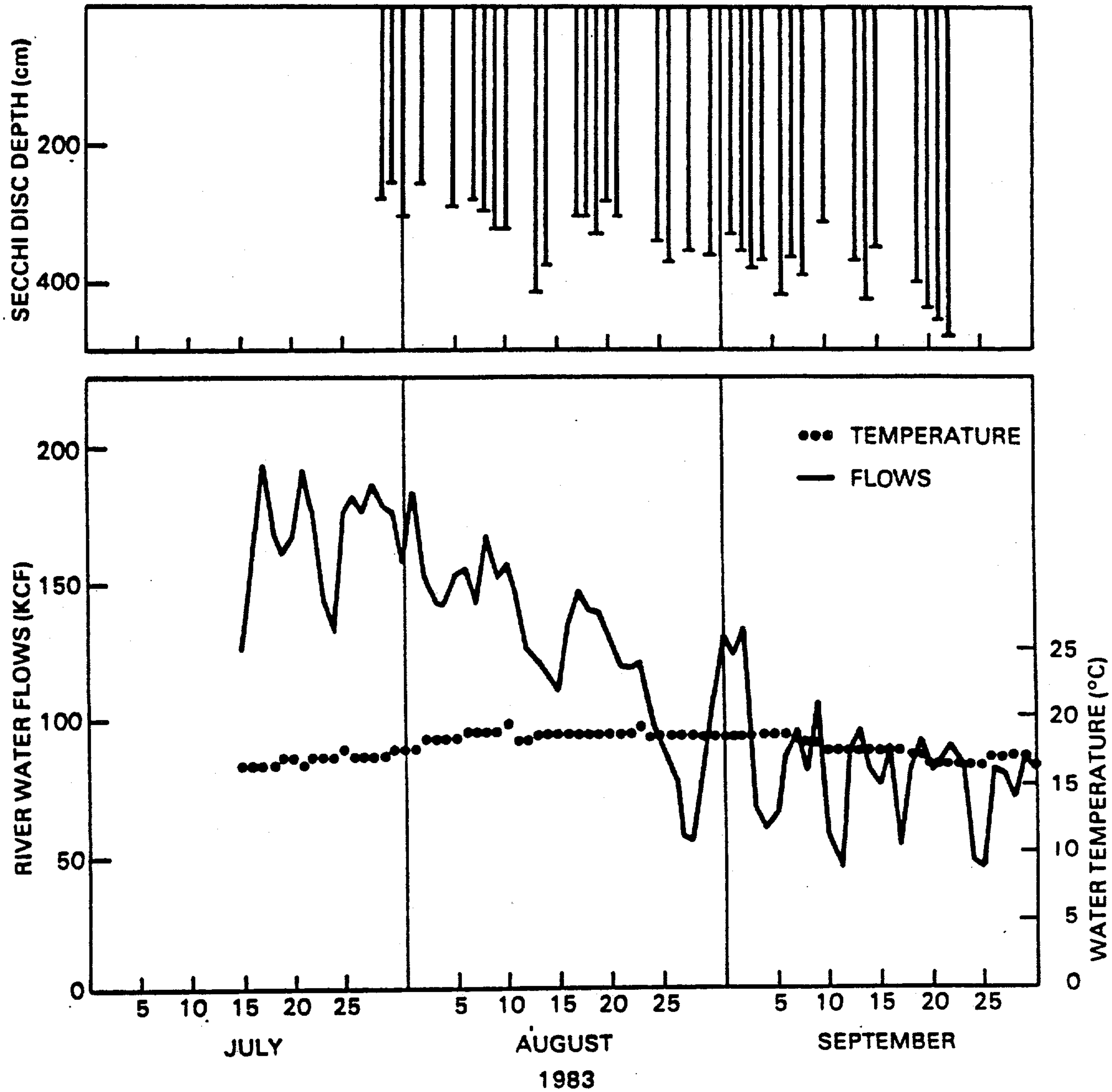

FIGURE A.1. Seasonal Changes in Water Clarity, Temperature, and Flow Near the Study Site

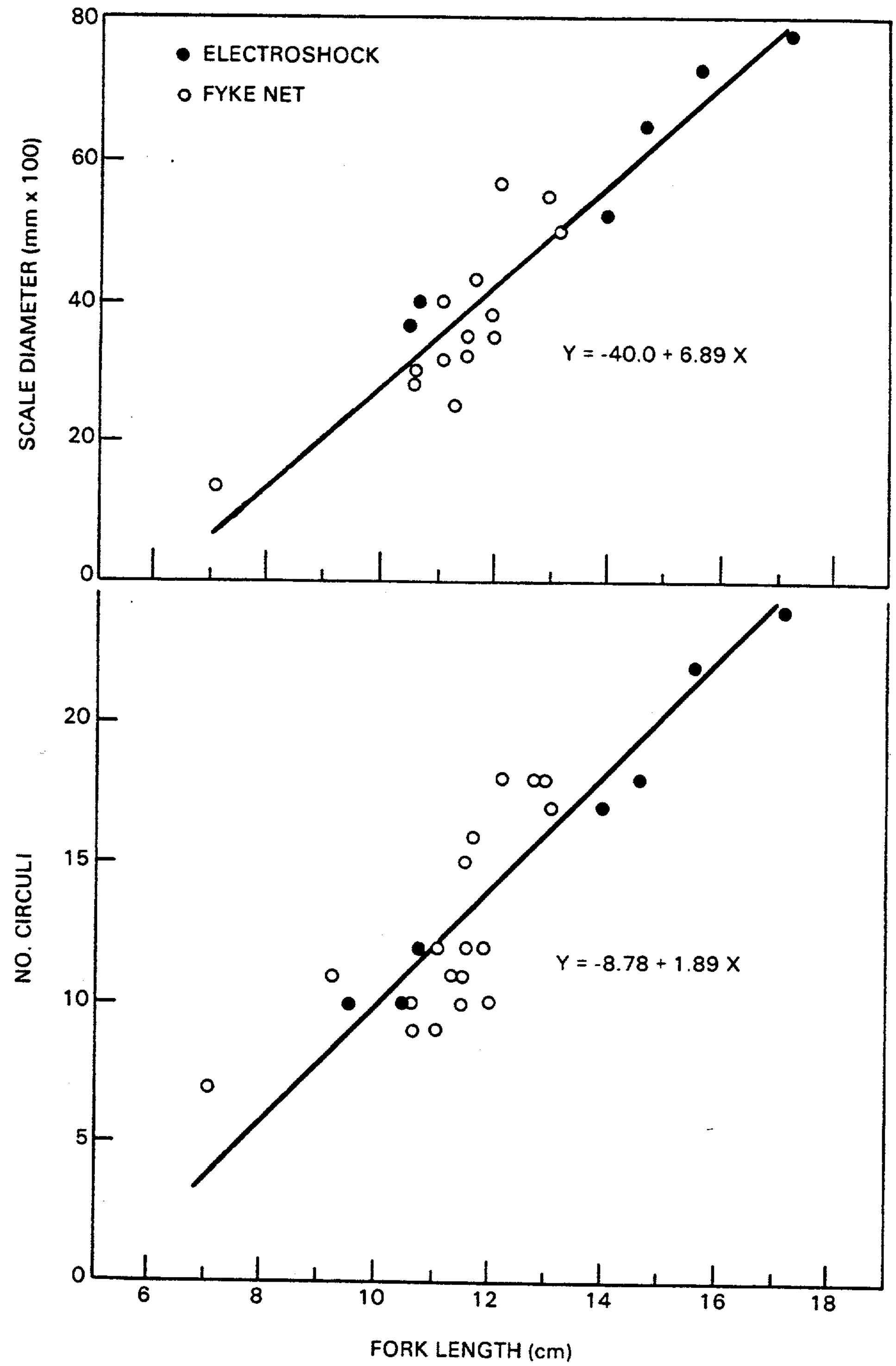

FIGURE A.2. Relationship of Fish Size and Scale Growth Parameters of Chinook Salmon