January 1993

IDENTIFICATION OF THE SPAWNING, REARING, AND MIGRATORY REQUIREMENTS OF FALL CHINOOK SALMON IN THE COLUMBIA RIVER BASIN ANNUAL REPORT 1993

Annual Report 1993

DOE/BP-21708-3

DOE/BP-21708-3

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do r necessarily represent the views of BPA.

This document should be cited as follows:

Rondorf,Dennis W.; Kenneth F. Tiffan, National Biological Service, Columbia River Research Laboratory, U. S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project Number199l-029, Contract NumberDE-AI79-91BP21708, 165 electronic pages (BPA Report DOE/BP-21708-3)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

IDENTIFICATION OF THE SPAWNING, REARING, AND MIGRATORY REQUIREMENTS OF FALL CHINOOK SALMON IN THE COLUMBIA RIVER BASIN

ANNUAL REPORT 1993

Prepared by:

Dennis W. Rondorf
Kenneth F. Tiffan

National Biological Service
Columbia River Research Laboratory
Cook, WA 98605

Prepared for:

U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-362 1

Project Number 9 l-029
Contract Number DE-AI79-9 1 BP2 1708

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This document is the 1993 annual progress report for selected studies of fall chinook salmon *Oncorhynchus tshawytscha* conducted by the National Biological Survey (NBS) and the U.S. Fusg and Wildlife Service. Activities were funded by the Bonneville Tower Administration (BPA) through funding of Project 93-029.

The decline in abundance of fall chinook salmon in the Snake River basin has become a growing concern. In 1992, Snake River fall chinook salmon were listed as "threatened" and in 1994 the stock was listed as "endangered" under the Endangered Species Act. Effective recovery efforts for fall chinook salmon cannot be developed until we increase our knowledge of the factors that are limiting the various life history stages. This study attempts to identify those physical and biological factors which influence spawning of fall chinook salmon in the free-flowing Snake River and their rearing and seaward migration through Columbia River basin reservoirs.

Snake River fall chinook spawning was generally a November event in 1993 as it was in 1991 and 1992 with some activity occurring in late October and early December. A total of 59 redds were counted during aerial surveys which is close to the 1987 high of 66. Underwater surveys located an additional 67 redds in deep water which represents 53% of the total number of redds found in 1993. Searches made in the Lower Granite Dam tailrace found 10-14 redds using camera and SCUBA techniques. All of the redds counted were located near the juvenile fish bypass outfall. There was no evidence of deepwater spawning below Lower Monumental Dam.

Spawning habitat availability was assessed by applying hydraulic and habitat models to known fall chinook salmon spawning sites. Using a total effective area model, suitable spawning habitat was that which successfully met slope, depth, velocity, substrate, and scour criteria. Of the spawning sites modelled, the total effective area model predicted that 9% of shallow-water-transitional, 0% of shallow-water-lateral, and 6% of deep-water-transitional habitats were suitable for spawning at the highest scour criterion used. Validation of this model found that most redds found since 1991 were wholly or partly in cells predicted as suitable by the TEA methodology. Modelling habitat availability under simulated flows revealed that TEA does not appear to be particularly sensitive to the range of flows tested. If modelling results hold river wide, then known spawning sites are probably underseeded.

Juvenile fall chinook salmon were seined and PIT tagged in the free-flowing Snake River to describe rearing patterns, emigration behavior, and emigration timing. We seined 2,396 fall chinook salmon in systematic and supplemental samples in 1993. Estimated fall chinook salmon fry emergence ranged from 16 March to 5 June with a 23 May peak. We PIT tagged and released 1,236 chinook salmon juveniles of which only 42% were considered fall chinook salmon based on electrophoretic analysis of fish recaptured at Lower Granite Dam. We tagged fall chinook salmon in the Snake River from 28 April through 21 July with a 9 May peak. About 16.4% of all tagged fall chinook salmon were recaptured by seine; most at the original site of tagging. Mean emigration rate from release sites in Hells Canyon to Lower Granite Dam was 2.1 km/d with peak and median dates of passage occurring on 20 and 17 July, respectively. Using multilinear regression we estimated that emigration rate was most influenced by release temperature and release size.

Juvenile fall chinook salmon were seined in the Columbia River in the Hanford Reach and in McNary Reservoir to identify and describe rearing habitats. Peak numbers of subyearling chinook salmon were captured in April in the Hanford Reach, in May in McNary Reservoir, and in June in the Snake River. As water temperatures increased above 15.9°C, mean catch decreased. Snake River subyearling chinook salmon attained a larger size more quickly than Columbia River subyearlings. Subyearlings were caught in significantly greater numbers during the day than during the night. Most subyearlings were caught in shallow water between 0.5 m and 2.0 m deep. Substrate did not appear to have an influence on catch of subyearling chinook salmon in the main stem Columbia River.

Subyearling fall chinook salmon were marked at McNary Dam to relate river flow and migration patterns of juvenile salmon to adult returns. A total of 107,077 fish emigrating during the early, middle, and late segments of the migration were successfully coded wire tagged and released at McNary Dam. Delayed mortality and tag loss ranged from 0.4 to 0.7% and was considered acceptable. Adequate numbers of branded fish were recaptured at John Day and Bonneville dams to determine that the three groups of fish maintained their integrity and emigrated separately in relation to when they were released. Travel time of subyearling chinook salmon through John Day Reservoir was not significantly correlated with any of the variables tested. Subyearling chinook salmon marked at McNary Dam appeared to be fully smolted and were physiologically adapted to seawater as measured in 24 h seawater challenges. The salinity preference of subyearling chinook salmon was tested but results were inconclusive.

Hydroacoustic surveys were conducted on McNary and John Day reservoirs and in net pens to obtain acoustic target strength information on migrating and captive juvenile fall chinook salmon and American shad. Kid-water trawling verified that the majority of the fish tracked in McNary Reservoir were subyearling fall chinook salmon and that juvenile American shad dominated John Day Reservoir samples. Target strengths of juvenile fall chinook salmon surveyed in McNary Reservoir were similar to those of both subyearling and yearling fall chinook salmon used in net pen tests. The target strengths of the yearling net pen chinook were lower than expected given that they were almost twice as large as all other chinook salmon surveyed or tested. A comparison of target strengths of net pen American shad and shad surveyed in John Day Reservoir showed that larger net pen shad had lower target strengths than smaller shad from field surveys. This counterintuitive finding may have been due to suboptimal equipment performance.

ACKNOWLEDGEMENTS

We thank individuals in the Idaho Department of Fish and Game, Idaho Power Company, U.S. Fish and Wildlife Service, Washington Department of Fisheries and Wildlife, U.S. Army Corps of Engineers, National Marine Fisheries Service, and the Fish Passage Center that assisted with the project activities. We extend special thanks to our colleagues at the Columbia River Research Laboratory of the National Biological Survey and the Idaho Fishery Resource Office of the U.S. Fish and Wildlife Service for their assistance. We gratefully acknowledge reviewers for the valuable comments and suggestions which we have incorporated into this report. We appreciate the assistance of Debbie Watkins, Project Manager, Bonneville Power Administration.

CHAPTER ONE

Fall Chinook Salmon Spawning Ground Surveys in the Snake River

by

A.P. Garcia and W.P. Connor
U.S. Fish and Wildlife Service
Idaho Fishery Resource Office
Ahsahka, Idaho 83520, USA

and

R.H. Taylor
U.S. Forest Service
Clearwater National Forest
Orofino, Idaho 83544, USA

Introduction

Spawning ground surveys were conducted in 1993 as part of a five year study of Snake River fall chinook salmon *Oncorhynchus ishawytscha* begun in 19 91 . Observations of fall chinook salmon spawning in the Snake River were limited to infrequent aerial redd counts in the years prior to 1987 (Haas 1965, Irving and Bjornn 1981, Witty 1988). From 1987-1990, redd counts were made on a limited basis by an interagency team and reported by the Washington Department of Fisheries (Seidel and Bugert 1986, Seidel et al. 1988, Bugert et al. 1989-1991, and Mendel et al. 1992). Starting in 1991, the U. S. Fish and Wildlife Service (USFWS), and other cooperating agencies and organizations, expanded the scope of spawning ground surveys to include: (1) additional aerial surveys to improve redd counts and provide data on spawn timing; (2) the validation (ground truthing) of redd counts from aerial surveys to improve count accuracy; (3) underwater searches to locate redds in water too deep to allow detection from the air; and (4) bathymetric mapping of spawning sites for characterizing spawning habitat.

The objectives for spawning ground surveys conducted in 1993 were to: (1) describe spawning time, redd distribution, and extent of fall chinook salmon spawning in the Snake River using redd counts from helicopter surveys, underwater searches, and ground observations; and (2) search for fall chinook salmon redds in the tailraces of Lower Granite and Lower Monumental dams. This report includes results from data we collected in the first three years of our study (1991-1993), and data collected from 1987-1990.

Study Area

The study area included the Snake River from Hells Canyon Dam to the mouth (Figure 1). We describe specific locations within the area in terms of river kilometers (RK) based on U.S. Army Corps of Engineers (COE) navigation charts of the Snake River (COE 1990) and U.S. Geological Survey topographical maps. Much of our work in 1993 was conducted in the free-flowing reach of the Snake River between Hells Canyon Dam (RK 398) and the head of Lower Granite Reservoir near Asotin, Washington (RK 235). Additional work was conducted within the 1 km downstream of Lower Monumental Dam (RK 67) and Lower Granite Dam (RK 173).

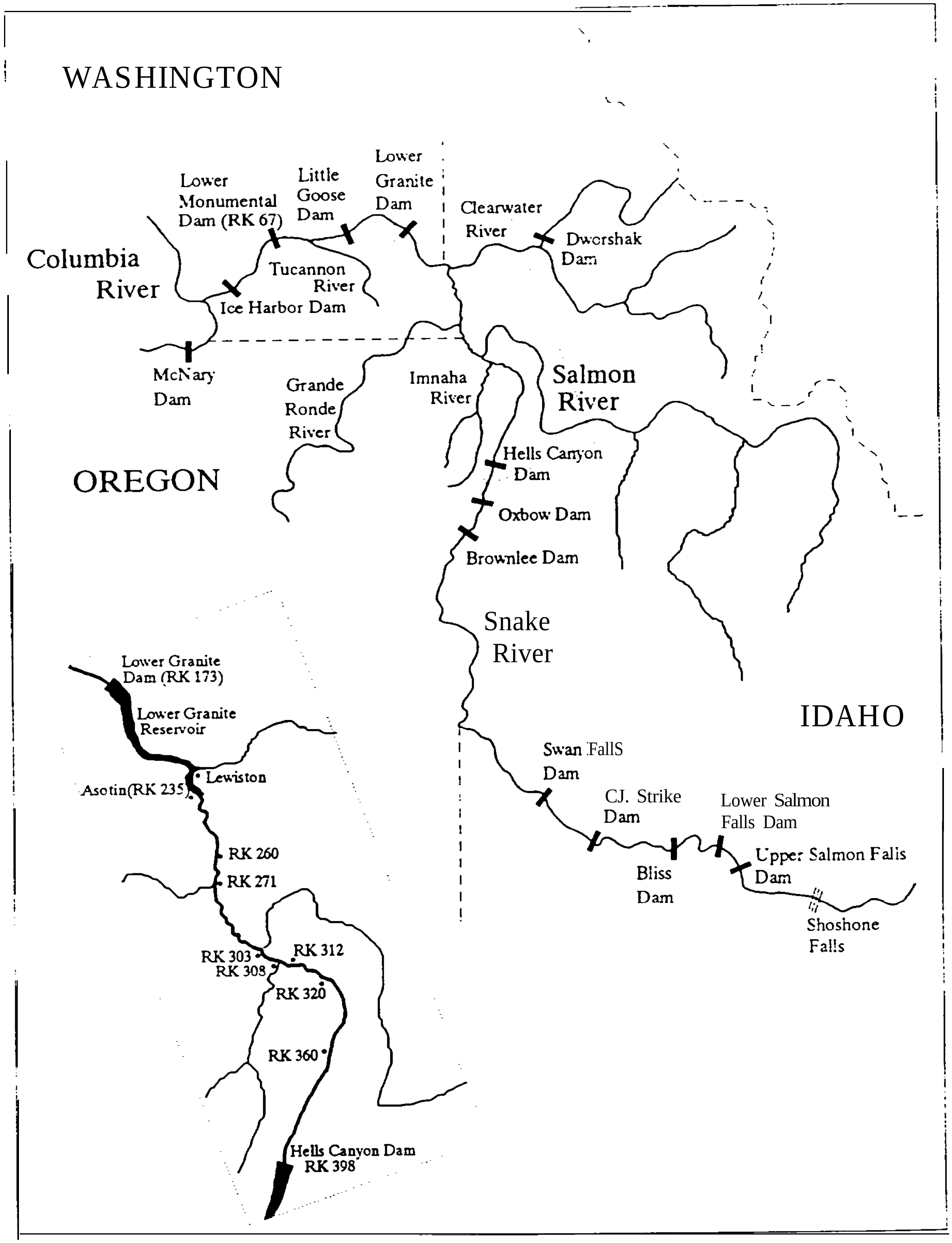

Figure 1. Map of the Snake River drainage showing Lower Monumental Dam at RK 67 and inset showing fall chinook salmon spawning study sites near RK 260, RK 266, Lower Granite Dam at RK 173, and the head of Lower Granite Reservoir near Asotin, Washington at RK 235.

Methods

Data Collection

Aerial surveys and ground truthing. - Methods used to count fall chinook salmon redds from a helicopter in 1993 were similar to those used from 1987-1992, although the number and timing of counts has varied between years (Connor et al. 1993, Garcia and Connor 1994). In 1993, eight redd counts were made at 7 d intervals from 25 October to 13 December. Eight redd counts were made at 6-11 d intervals from 16 October to 12 December 1992, and nine counts were made at 6-8 d intervals from 14 October to 9 December 1991. Only two aerial redd counts were made each year from 1987-1989, and three in 1990. Redd counts from 1987-1990 were referred to as index counts in previous reports.

Redd counts were made by two observers in a helicopter as it traveled from Asotin, Washington to Hells Canyon Dam at an altitude of 100 to 200 m. When a potential redd was observed, the helicopter was positioned for optimal viewing and one observer marked the location on COE navigation charts. Beginning in 1993, a sketch was made of each spawning site when redds were first observed, then updated on subsequent air and ground surveys. Once a redd was counted, it was not counted again on subsequent surveys.

Potential fall chinook salmon redds observed from the air were ground truthed and the corresponding aerial redd count adjusted based on ground observations. In 1991-1992, all redds observed from the air were examined by wading or from a boat. In 1993, redds were examined from a boat when their authenticity appeared questionable from the air. The locations of most validated redds observed from the air in 1993 were recorded using survey instrumentation (Groves 1994).

Redd counts in deep water. - In 1993, an underwater camera was used to systematically search for redds in water too deep to allow detection from the air. We searched near RK 261.3, RK 266.5-266.9, RK 267.4-267.7, and near RK 311.8. Search areas were selected based on: (1) the locations of redds discovered during random searches conducted by Groves (1994), (2) the presence of suitable spawning substrate (dominant size range, 2.5-15 cm; Connor et al. 1993, Raleigh and Miller 1986) extending into areas greater than 3 m deep at known spawning sites, and (3) the distribution of redds observed by underwater camera and SCUBA divers in previous years (Connor et al. 1993, Groves 1993). Data from random and systematic redd searches were combined to produce final redd counts in 1993.

Systematic searches were performed by observing the river bottom along a series of cross sections passing through each search area. Navigation markers were placed at 4.6 m intervals along one shore of each search area. These markers were extended along the shoreline to bound the area containing suitable spawning substrate and water greater than 3 m. A Sony' HVM 352 remote camera, fitted with a 110° lens and mounted between two 13 kg sounding weights (Figure 2), was suspended from a boat and passed over the river bottom along each 4.6 m cross section. The camera image was observed in the boat and recorded on 8 mm video tape for subsequent verification. Redd locations were recorded using survey instrumentation (Topcon ITS-l, total station) positioned on shore and a reflective prism mounted on the boat. Camera and substrate depth were recorded at the beginning and end of each pass and at random points between.

In 1991-1992, underwater redd searches were conducted using SCUBA divers in the Hells Canyon reach of the Snake River. Information on the methods used in these diving surveys are presented in the 1991 and 1992 progress reports (Connor et al. 1993, Garcia and Connor 1994) and are not covered in detail in this report.

Redd searches in dam tailraces. - Redd searches were conducted in areas of Lower Granite and Lower Monumental dam tailraces in 1993 using an underwater camera and SCUBA divers. Search areas were selected based on criteria for water depth, flow, lateral channel slope, and substrate composition. In the Lower Granite Dam tailrace, searches were conducted in areas within about 650 m of the dam that had water depths ranging from of O-7.6 m. Searches in the Lower Monumental Dam tailrace were conducted within 850 m of the dam in water ranging from O-9.1 m deep. All areas searched had an average water velocity ranging from 0.61-1.8 m/s, a cross sectional slope of O-20%, and a dominant substrate of cobble and gravel (Dauble et al. 1994). Areas where these criteria overlapped were considered suitable habitat. Areas of suitable habitat were displayed on a map, divided into three search blocks (Figure 3), then rated as having either a high (Area A) or low (Area B) potential for spawning based on habitat density within each block. Navigation markers were placed along one shore to create cross sections and were extended to cover each search block. Markers were placed at 7.6 m intervals in Area A search blocks, and 15.2 m intervals in Area B search blocks. Redd searches were made with the same camera equipment and procedures as were used in the Snake River upstream of Asotin, Washington in 1993.

- Use of trade names does not imply endorsement by the U. S. Fish and Wildlife Service.

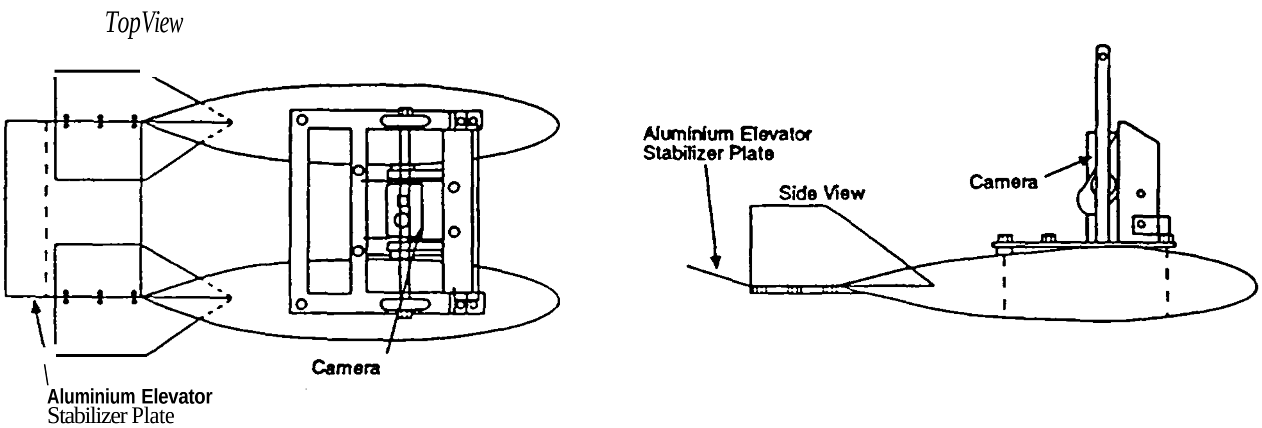

Figure 2. Underwater camera mount with two 13 kg sounding weights and aluminum frame.

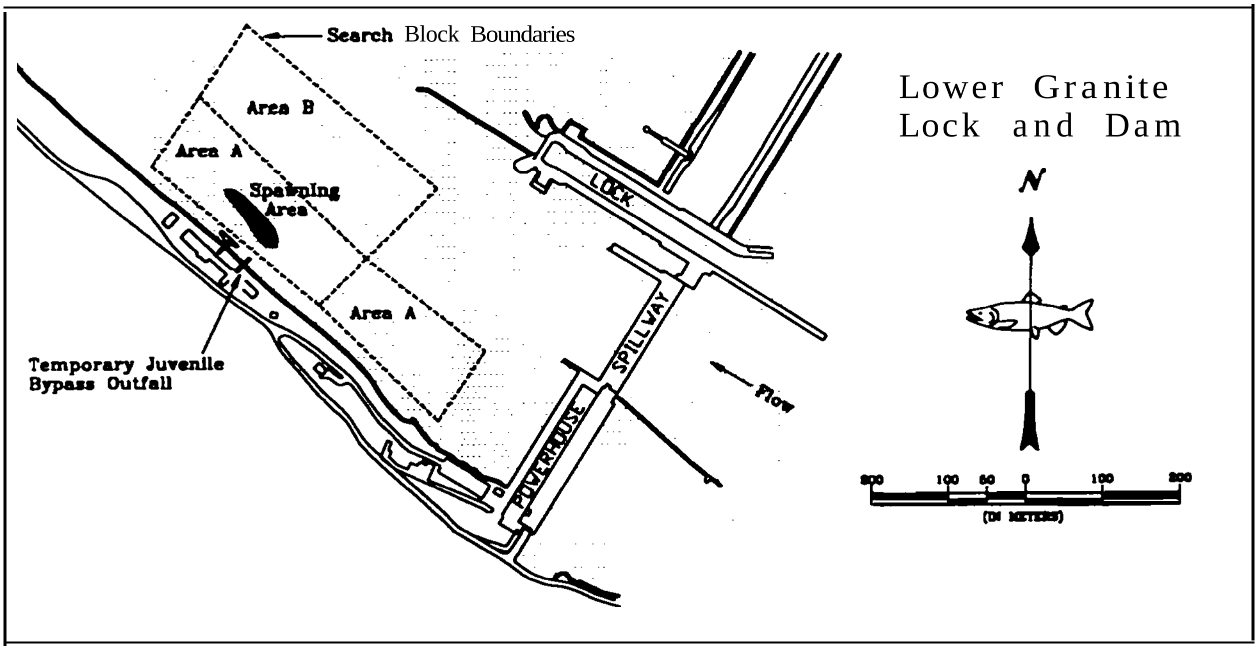

Figure 3. Areas designated as having high (Area A), and low (Area B) potentials for fall chinook salmon spawning, and the area where redds were observed in the Lower Granite Dam tailrace in 1993.

The methods used by SCUBA divers to search for redds in tailrace areas in 1993 were similar to those used by divers in the Lower Monumental Dam tailrace under zero flow conditions in 1992 (Garcia and Connor 1994). In 1993, divers conducted redd searches within a 900 m^2 area in Lower Monumental Dam tailrace that was also searched by divers in 1992. In the Lower Granite Dam tailrace, divers searched a 1,841 m^2 area that encompassed the largest group of redds observed by USFWS and Dauble et al. (1994) using underwater cameras. The boundary of each area was marked with four surface floats to form a rectangle with two sides roughly parallel with the shoreline. Ropes were attached between the upstream and downstream float anchors on two sides of the rectangle to form two submerged lines parallel with the shoreline. Two divers searched for redds along transects 2 m apart as they swam side-by-side above the river bed until they reached the submerged rope on the opposite side of the rectangle. Progress was marked and recorded by surveying a prism positioned over the submerged ropes by boat each time the divers moved to a new starting location. In addition, the general path of the divers was tracked while swimming between the submerged ropes by surveying a prism positioned over the diver's exhaled bubbles. Divers maintained contact with the surface crew using voice activated radios.

Data Analysis

Trendcomparison 11987-1993). · We attempted to simplify the comparison of redd count data from 1987-1990 when only two to three counts were made, to data from 1991-1993 when eight or nine counts were made. This was accomplished by estimating redd counts for 1987-1990 using a linear regression equation (SYSTAT 1990). The equation was calculated using the redd counts (41, 45, and 59) and adult counts at Lower Granite Dam (590, 668, and 952) from 1991-1993. The relation (redd count = 11.8 + 0.496 * dam count) produced a high coefficient of determination which was significant ($r^2 = 0.99$; $p = 0.004$).

Search area in dam tailraces · The area examined in Lower Granite and Lower Monumental dam tailraces was calculated using the distance of each camera path, and the relationship between average camera height above the substrate (0.3 m at Lower Monumental Dam, and 0.9 m at Lower Granite Dam) and view area. The general area where fall chinook salmon redds were observed in the Lower Granite Dam tailrace was mapped using the surveyed locations of redds observed by SCUBA divers and underwater camera.

Results

Redd Counts in the Free$owing Snake River

Fall chinook salmon spawning in 1993 began earlier than in 1992 and 1991 based on weekly redd counts. Redds were first observed on 25 October in 1993 compared to 5 November in 1992 and 28 October in 1991 (Figure 4). The peak count occurred on 1 November in 1993, 23 November in 1992, and 18 November in 1991. In 1993, fall chinook salmon redds were distributed between RK 239.9 and RK 381.3 (Table 1). Redds have been observed between RK 239.9 and RK 396.6 since 1987 (Table 2; Figure 5). A total of 438 redds were counted by all counting methods from 1987-1993.

More redds were counted on aerial surveys in 1993 than were counted in 1991-1992 or estimated for 1988-1990 (Figure 6). Fifty-nine redds were counted from the air in 1993, 45 redds were counted in 1992, and 41 in 1991. Redd count estimates totalled 29 in 1990, 47 in 1989, and 43 redds in 1988. Fifty-nine redds were estimated for 1987.

We observed 28 redds in deepwater areas from RK 266.5-266.9 in 1993 (Figure 7). Nineteen of these redds were located during systematic searches, and nine during random searches. Groves (1994) also observed 28 redds between RK 266.5-266.9 during random searches he made using similar camera equipment. In addition, we located 11 redds near RK 267.4, 21 redds near RK 267.7, and one redd near RK 311.8, during systematic searches; Groves observed two redds in deepwater areas near RK 289.1, one redd near RK 320.8, and three redds near RK 358.5, using the same systematic search methods (Table 3), Water depth measured over all redds ranged from 3.0-6.4 m.

Redd Searches in the Dam Tailraces

We examined 11,547 m^2 of a 84,478 m^2 search area in the Lower Granite Dam tailrace using an underwater camera between 23 November and 1 December 1993. We observed 10 to 14 fall chinook salmon redds based on the combined counts using underwater cameras and SCUBA divers. At least two additional redds were observed by Dauble et al. (1994) using similar equipment and methods. The shallowest redd **was** measured on 24 November at 5.5 m; the deepest redd was measured on 29 November at 9.2 m. Redds observed in the Lower Granite Dam tailrace were close to the temporary juveniie fish bypass outfall (Figure 3). This was also the case in the tailrace of Little Goose Dam, where four fall chinook salmon redds were located near the juvenile fish bypass outfall (Dauble et al. 1994). We examined a total of 2,555 m^2 of a 65,992 m^2 search area in the Lower Monumental Dam tailrace using an underwater camera between 16 November and 2 December 1993. In addition, Dauble et al. (1994) covered the same search

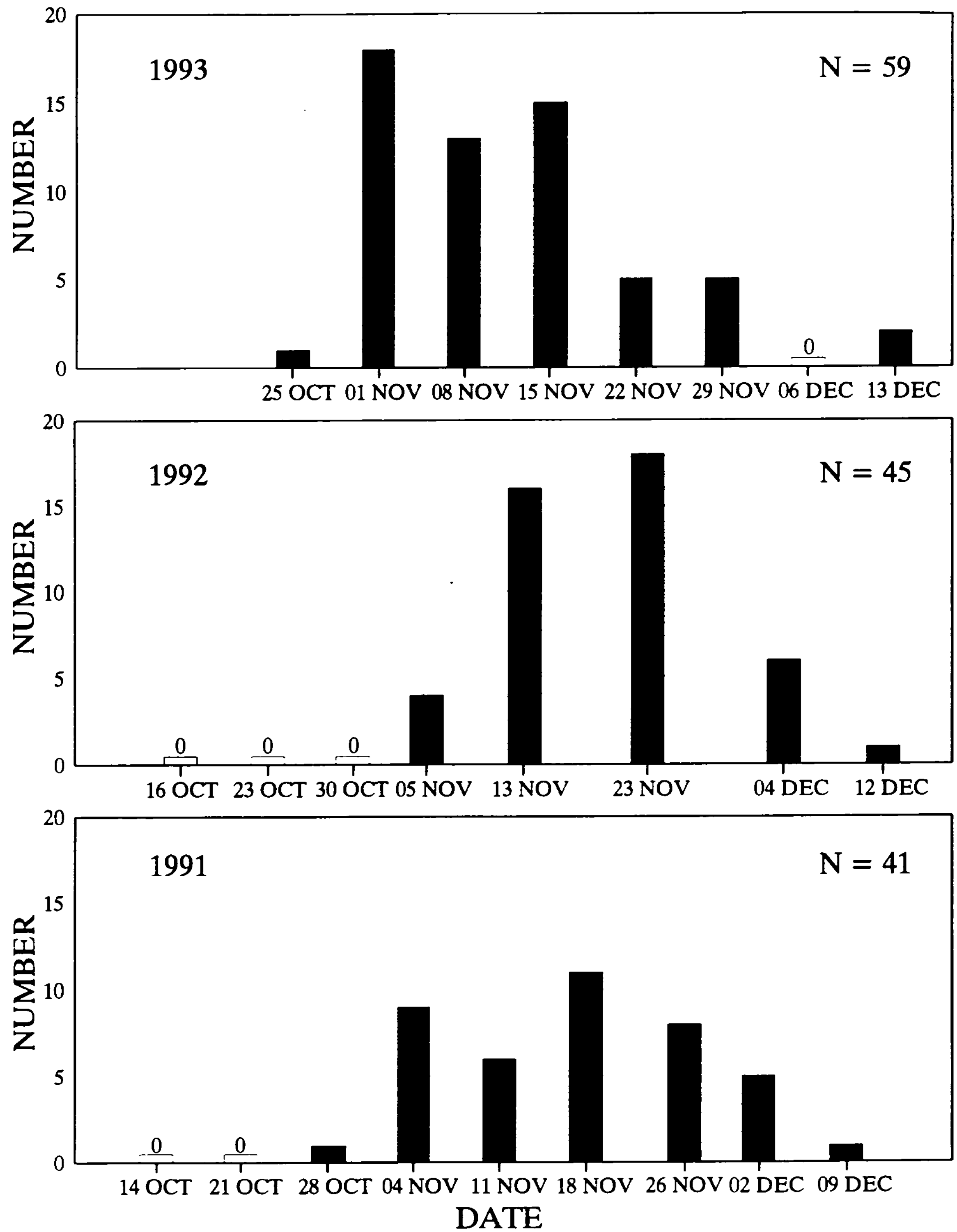

Figure 4. Number of new fall chinook salmon redds counted on helicopter surveys of the Snake River in 1991, 1992, and 1993 (Garcia 1994).

Table 1.-River kilometer (RK), landmark, and counts of new fall chinook salmon redds from helicopter surveys of the Snake River made at 7 d intervals in 1993.

RK	Landmark	New redds counted by flight date								Site Totals
		25-Oct	01-Nov	08-Nov	15-Nov	22-Nov	29-Nov	06-Dec	13-Dec	
239.9	Three Mile Island	-	-	-	1	-	-	-	-	1
243.8	Above Tenmile Creek	-	1	-	-	1	-	-	-	2
245.1	Big Bench Point	-	-	-	1	-	-	-	2	3
259.0	Upper Buffalo Rapids	1	7	2	-	-	-	-	-	10[a]
261.3	Captain Johns Creek	-	-	-	1	-	-	-	-	1
265.8	Above Perkins Gulch	-	-	-	-	-	2	-	-	2
266.0	Below Billy Ck Range	-	1	1	-	-	-	-	-	2
266.9	Below Match Line	-	4	4	-	-	1	-	-	9
267.4	Above Fisher Range	-	-	-	5	-	1	-	-	6
271.4	Mouth of Grande Ronde	-	-	-	3	1	1	-	-	5
289.1	Cougar Bar	-	-	1	-	3	-	-	-	4
311.7	Divide to Zig Zag	-	1	-	-	-	-	-	-	1[b]
312.1	Big Canyon Range	-	-	-	1	-	-	-	-	1
332.3	Below High Range 1	-	-	1	-	-	-	-	-	1
340.9	McCarty Creek	-	2	-	-	-	-	-	-	2[c]
345.1	Below Pittsburg Range	-	1	-	-	-	-	-	-	1
349.6	Coral Creek		1	1	1	-	-	-	-	3
381.3	Lower Dry Gulch	-	-	3	2	-	-	-	-	5
	Totals	1	18	13	15	5	5	0	2	59

[a] One additional redd was observed from a boat at Upper Buffalo Rapids RK 259.0 by IPC on 8 December.

[b] One large gravel disturbance observed at the site between Divide and Zig Zag creeks (RK 311.7) was judged to be 2 redds from the air on 1 November, but was considered only 1 redd by ground observation on 2 November.

[c] One redd was observed from the air on 1 November at McCarty Creek (RK 340.9), but 2 redds were observed from the ground on 2 November; the second redd was observed on subsequent helicopter surveys.

Table 2.-River kilometer (RK), landmark, and counts of fall chinook salmon redds in the Snake River from all helicopter surveys, ground observations, and underwater observations using camera and SCUBA divers from 1987-1993 (Connor et al. 1993, Garcia and Connor 1994, Garcia 1994).

RK	Landmark	1987	1988	1989	1990	1991	1992	1993	Totals
238.6	Ten Mile Range	-	-	-	1	-	-	-	1
239.9	Three Mile Island	-	-	1	-	2	-	1	4
243.8	Above Tenmile Creek	-	-	-	-	-	-	2	2
244.4	Ten Mile Canyon	-	1	1	-	-	-	-	2
245.1	Big Bench Point	13	8	23	16	-	7	3	70
252.6	Warehouse at Couse Creek	-	-	1	1	-	-	-	2
257.1	Lower Buffalo Range	-	-	-	-	-	3	-	3
259.0	Upper Buffalo Rapids	-	-	-	-	-	7	11	18
261.3	Captain Johns Creek	-	-	1	2	20	11	1	35
262.6	Captain John Rapids	3	2	-	2	-	-	-	7
265.0	Billy Creek Rapids	2	5	2	1	1	-	-	11
265.8	Above Perkins Gulch	-	-	-	-	-	-	2	2
266.0	Fisher Gulch	4	-	-	-	-	-	2	6
266.5	Above Billy Creek Range	-	-	-	-	-	-	28	28
266.9	Below Match Line	2	14	-	-	-	3	9	28
267.4	Above Fisher Range	-	-	-	-	-	-	17	17
267.7	Lower Lewis Rapids	-	-	-	-	6	-	21	27
271.4	Mouth of Grande Ronde	-	-	-	-	-	-	5	5
272.7	Near Lewis Point	-	-	1	-	-	-	-	1
277.6	Deer Head Rapids	1	-	-	-	-	-	-	1
279.8	Below Shovel Creek	1	-	-	-	-	-	-	1
287.9	Cochran Island Head	-	-	1	-	-	-	-	1
289.1	Cougar Bar	-	-	-	-	-	-	6	6
307.3	Eureka Bar	1	5	-	2	4	1	-	13
308.4	Near Imnaha River	2	4	-	-	-	-	-	6
311.0	Above Divide Creek	4	-	5	2	-	-	-	11
311.7	Divide to Zig Zag	-	-	-	3	-	6	1	10
311.8	Below Big Canyon Creek	-	-	-	-	-	-	1	1
312.1	Big Canyon Range	-	-	-	-	-	-	1	1
312.3	Above Zig Zag Creek	2	2	-	2	-	-	-	6
315.7	Below Dug Bar, OR	1	3	-	-	-	-	-	4
319.9	Above Robinson Gulch	1	-	-	2	5	3	-	11
320.0	Below Deep Creek	4	-	3	-	-	-	-	7
320.8	Trail Gulch	-	-	-	-	-	-	1	1
328.4	Near Blankenship Ranch	1	-	-	-	-	-	-	1
330.2	Above Copper Creek	-	-	-	-	3	-	-	3
330.8	Below Getta Creek	1	-	-	-	-	-	-	1
332.1	Below High Range No.1	1	4	-	-	1	2	1	9
334.4	Lookout Creek Range	-	1	-	-	-	-	-	1
334.5	Below Lookout Creek	-	2	1	-	-	-	-	3
337.4	Below Camp Creek	1	-	-	-	-	-	-	1
340.9	McCarty Creek	-	-	-	-	-	-	2	2
343.7	Pleasant Valley Creek	-	-	2	1	-	-	-	3
344.0	Lower Pleasant Rapid	-	-	-	-	-	2	-	2
345.1	Below Pittsburg Range	-	-	-	-	-	-	1	1
345.5	Near Pittsburg Range	2	-	-	-	-	-	-	2
349.6	Coral Creek Reef	-	-	-	-	-	1	3	4
350.4	Durham Rapids	-	-	1	-	-	-	-	1
351.1	Below Cat Gulch	1	-	-	-	-	-	-	1
352.9	Kirby Range	-	2	-	-	-	1	-	3
358.5	Near Suicide Rock	3	-	4	-	-	-	3	10
359.9	Below Temperance Creek	-	1	-	-	-	-	-	1
379.6	Near Hat Creek Mouth	4	2	3	-	-	-	-	9
379.9	Below Saddle Creek	1	-	1	-	-	-	-	2
380.9	Below Dry Gulch	1	-	-	-	-	-	-	1
381.3	Lower Dry Gulch	-	-	-	-	-	-	5	5
383.6	Above Three Creek Rapids	2	-	2	-	-	-	-	4
387.1	Near Rocky Bar Camp	6	-	3	-	4	-	-	13
391.5	Above Warm Springs Camp	1	-	1	-	-	-	-	2
393.6	Below Brush Creek	-	-	1	2	-	-	-	3
396.6	Near Rocky Point	-	1	-	-	-	-	-	1
		66	57	58	37	46	47	127	438

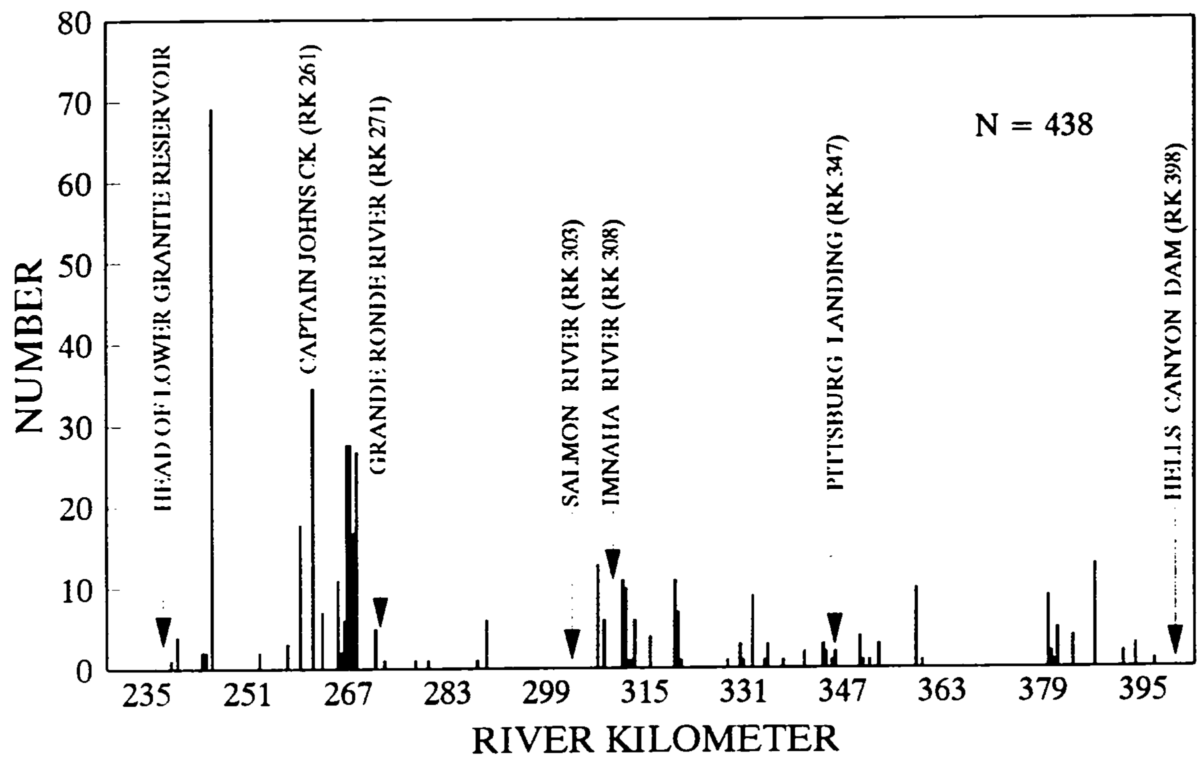

Figure 5. River kilometer, and number of fall chinook salmon redds counted in the Snake River by helicopter, diving, camera, and ground observations from 1987-1993 (data from Garcia and Connor 1994, and Garcia 1994).

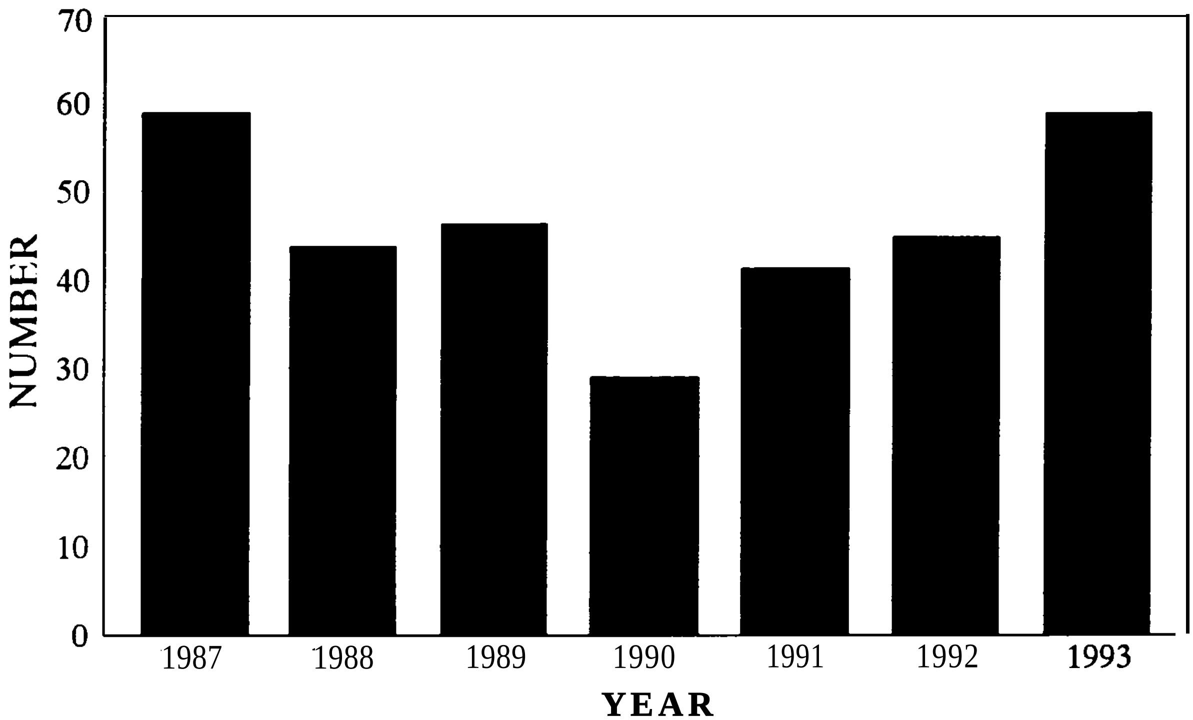

Figure 6. Fall chinook salmon aerial redd count estimates for 1987-1990, and counts from aerial surveys made from Asotin, Washington, to Hells Canyon Dam, 1991-1993. The 1987-1990 estimates are lower than the actual counts in previous reports (Garcia and Connor 1994).

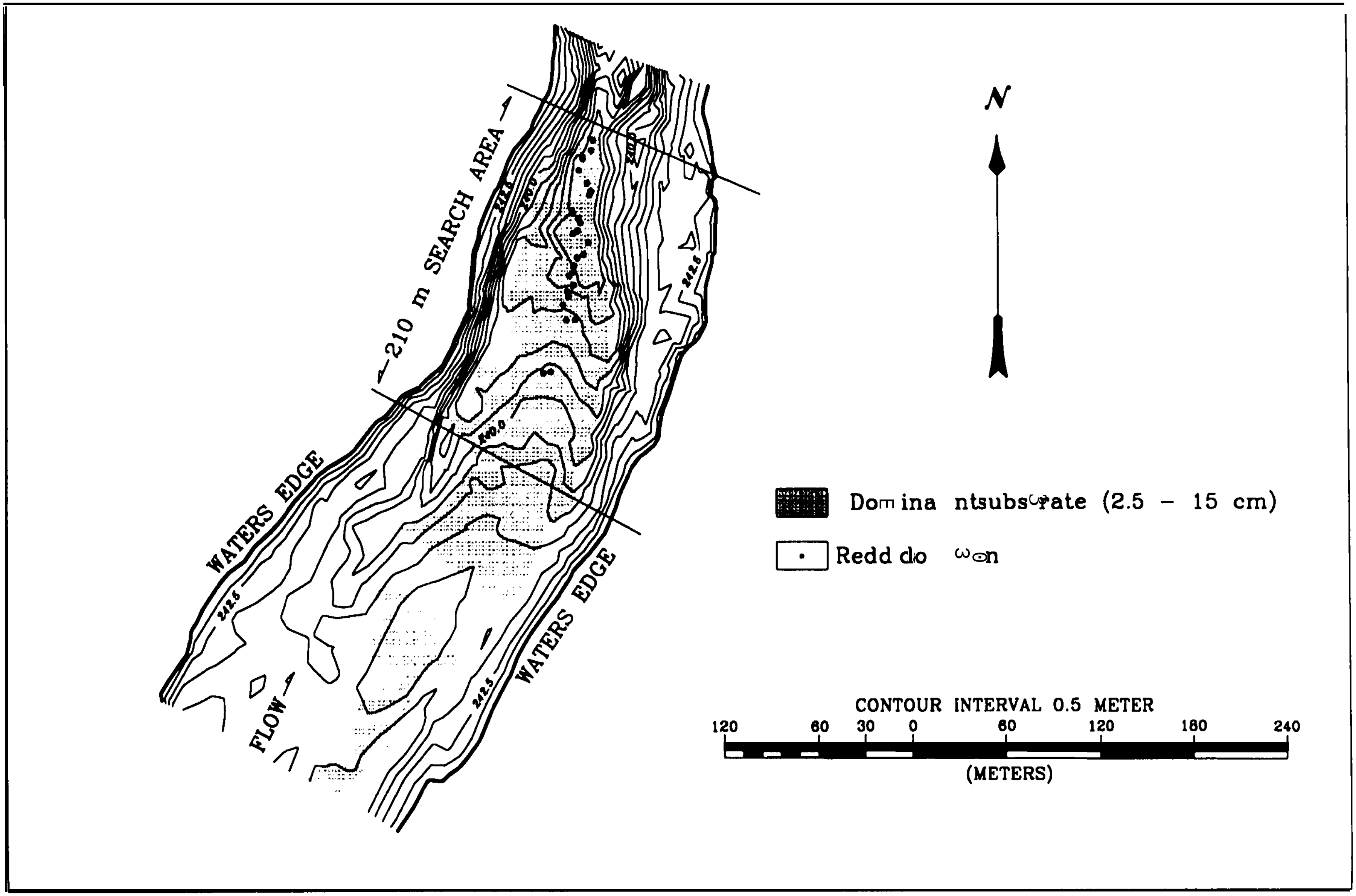

Figure 7. Locations of fall chinook salmon redds observed at RK 266.5–266.9 using underwater cameras in 1993, and the distribution of 2.5–15 cm dominant substrate. Waters edge represents a discharge of approximately 15,220 cfs.

Table 3.-River kilometer (RK), landmark, observation dates, number, and depth range of fall chinook salmon redds located in the Snake River above Lower Granite Reservoir using underwater cameras in 1993 (Garcia 1994, Groves 1994).

RK	Landmark	Dates	Number	Depth range (m)
266.5	Above Billy Creek Range	06 Dec-15 Dec	28	3.6 - 6.4
267.4	Above Fisher Range	10 Nov-10 Dec	11	3.3 - 6.0
267.7	Lower Lewis Rapids	10 Nov-10 Dec	21	3.0 - 4.7
289.1	Cougar Bar	19 Nov	2	4.7 - 4.8
311.8	Below Big Canyon Creek	16 Dec	1	5.5
320.8	Trail Gulch	17 Dec	1	5.9
358.5	Near Suicide Rock	02 Dec	3	4.1 - 4.6
		Total	67	

area from 22 November to 24 November. No redds were observed in the tailrace of Lower Monumental Dam in 1993.

Discussion

Snake River fall chinook salmon spawning is generally a November event with some activity occurring in late October and early December. The weekly helicopter surveys, conducted since 1991, show some variability in timing, such as the early commencement in 1993. The date of initial observation of redds has varied by as much as 11 d from 1991-1993, while the date of peak spawning has ranged up to 22 d for the same period.

The 1993 redd count was the highest since 1987 continuing an upward trend beginning in 1991. The relatively large number of redds counted in 1993 are likely attributed to two sources. First, counts of fall chinook salmon passing Lower Granite Dam in 1993 were the highest for the period from 1987-1993 which totalled 939, 605, 706, 343, 590, 668, and 952, respectively. Unfortunately, 17.5% of the salmon that passed above Lower Granite Dam in 1993 appear to have been of Umatilla hatchery origin (LaVoy 1994). Secondly, observation conditions in 1993 were favorable during all helicopter surveys, whereas, in past years, weather and turbidity were less favorable.

Since 1987, a disproportionate amount of fall chinook salmon spawning has occurred below the mouth of the Grande Ronde River (RK 271.4). Of the 438 redds counted in the Snake River from 1987-1993, 61.2% were observed below the Grande Ronde River, within the lower 36 km (22%) of the 163 km free-flowing reach. Annual redd distribution below the Grande Ronde River has been dominated by a few heavily used spawning sites. Fifty-one percent of the redds counted from 1987-1993 were located at only seven of 61 spawning sites and all seven sites were found within a 1.2 km river reach (Table 2; Figure 5). Other examples include 52% of the total number of redds counted in 1993 were located at three sites, and 44% were counted at one site in 1991.

The consistency of concentrated spawning behavior in lower river reaches, noted in Snake River fall chinook salmon, is not evident in the stock's spawning site fidelity. The same concentrated spawning sites were not used consistently from 1987 to 1993. For example, no redds were observed at RK 259.0 from 1987-1991, however, from 1992-1993 a total of 18 redds were counted during air and ground surveys at this location. In addition, deepwater areas at RK 261.3 were searched each year from 1991-1993, yet redds were only observed in 1991 (Connor et al. 1993). Notably, deepwater searches have become more advanced and systematic each year since 1991.

One of our objectives in systematically sampling deepwater spawning areas in the Snake River was to test whether we could expand redd counts tc accurately estimate the total number of redds at each site. Swan (1989) expanded counts of fall chinook salmon redds made by SCUBA divers in deepwater areas of the Hanford Reach of the Columbia River, Washington. Swan's sample design was similar to ours, observing the river bottom along evenly spaced cross sections. Redd counts were expanded using the average number of redds observed per cross section, the site length, and cross section width. Using Swan's technique, we estimated a total of 98 deepwater redds at RK 266.5-266.9 based on 19 redds counted along 46 cross sections placed along a 210 m deepwater reach. The expanded estimate (98 redds) at RK 266.5-266.9 overestimated what we considered to be the actual number (28 redds: by about 3.5 times. Estimating redds using this expansicr approach assumes there was an equal probability of observing redds throughout the 210 m reach. We defined the limits of the deepwater reach by the longitudinal distribution of suitable spawning gravel. However, substrate suitability is only one of many variables (flow, slope, fish behavior) that can be a factor in the use of habitat by spawners. Therefore, part of the error in this expansion approach may result from limits in habitat suitability that are not represented by the distribution of suitable spawning substrate alone. The ability to estimate the number of fall chinook salmon redds in deepwater habitat of the Snake River will be refined with the collection of additional empirical data.

The extent of deepwater spawning in the Hells Canyon Reach is unknown but remains critical to understanding the Snake River's production potential (Connor et al. in this report).

Redds observed in deepwater areas of the Snake River made up 52.8% of the total number of redds counted in 1993, none in 1992, and 10.9% in 1991. As previously mentioned, comparisons of deepwater redd counts between years is confounded by variability in search effort. In 1993, eight areas were systematically searched, and numerous areas randomly searched (Groves 1994), using underwater cameras. This compares to four areas searched by SCUBA divers and underwater camera in 1992, and one area searched by divers in 1991. Since the areas where most deepwater spawning cccurred in 1993 were not searched in previous years, it is not known whether deepwater spawning occurred there. Although the extent of deepwater spawning cannot be quantified at this time, it is clear that redds constructed in water greater than 3 m make u-p a considerable portion of fall chinook salmon redds in the Snake River.

Fall chinook salmon spawning in the tailraces of the lower Snake River dams occurred in 1993. Most of the redds were counted below Lower Granite Dam near the juvenile fish bypass outfall. Likewise, the few redds that were located in the Little Goose Dam tailrace were also located near the juvenile fish bypass outfall. Based on the work of Daubie et al. (1994), suitable habitat was located in other areas below each dam yet spawners chose to concentrate below the juvenile fish bypass outfalls. In 1992 and 1993, no redds were found below Lower Monumental Dam (Garcia and Connor 1994). To date, the only evidence cf fall chinook salmon spawning In the Lower Monumental Dam tailrace was eggs and fry found in dredge spoils in February 1992 near the juvenile fish bypass cutfall (Kenney 1992).

In summary, our findings during 1993 Indicate: (1) Snake River fail chinook salmon spawning cccurred earlier in 1993 than in 1991 or 1992; (2) redd counts have been increasing slowly since 1990, but hatchery strays from the Columbia River may be influencing this trend; (3) redd count accuracy has been improved by standardized cccnting methods; (4) substantial deepwater spawning In the Snake River was documented in 1993; and (5) limited deepwater spawning was documented in the tailraces of Lower Granite Dam and Little Goose Dam.

References

Bugert, R., P. Seidel, P. LaRiviere, D. Marbach, S. Martin, and L. Ross. 1989. Lower Snake Compensation Plan, Lyons Ferry Hatchery Evaluation Program, 1988 Annual Report. Cooperative Agreement 14-16-001-88519, U.S. Fish and Wildlife Service, Boise, Idaho.

Bugert, R., P. LaRiviere, D. Marbach, S. Martin, L. Ross, and D. Geist. 1990. Lower Snake Compensation Plan, Lyons Ferry Hatchery Evaluation Program, 1989 Annual Report. Cooperative Agreement 14-16-0001-89525, U.S. Fish and Wildlife Service, Boise, Idaho.

Bugert, R., C. Busack, G. Mendel, K. Petersen, D. Marbach, L. Ross, and J. Dedloff. 1991. Lower Snake Compensation Plan, Lyons Ferry Hatchery Evaluation Program, 1990 Annual Report. Cooperative Agreement 14-16-001-90525, U.S. Fish and Wildlife Service, Boise, Idaho.

COE (U.S. Army Corp of Engineers). 1990. Navigation charts of the Snake River, Oregon, Washington, and Idaho. Lewiston, Idaho to Johnson Bar. U.S. Army Corp of Engineers, Walla Walla District, Walla Walla, Washington.

Connor, W.P., A.P. Garcia, H.L. Burge, and R.H. Taylor. 1993. Fall chinook salmon spawning in free-flowing reaches of the Snake River. Pages l-29 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Dauble, D. D., R. L. Johnson, R. P. Mueller, C. S. Abernathy, B. J. Evans, and D. R. Geist. 1994. Identification of fall chinook salmon spawning sites near Lower Snake River hydroelectric projects. Draft Annual Progress Report 1993. Pacific Northwest Laboratory report to the U. S. Army Corps of Engineers, Walla Walla District, Walla Walla Washington.

Garcia, A.P. and W.P. Connor. 1994. Fall chinook spawning ground surveys in the Snake River. Pages l-19 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Groves, P.A. 1993. Habitat available for, and used by, fall chinook salmon within the Hells Canyon Reach of the Snake River. Annual Progress Report 1992. Environmental Affairs Department, Idaho Power Company, Boise, Idaho.

Groves, P.A. 1994. Habitat available for, and used by, fall chinook salmon within the Hells Canyon reach of the Snake River. Draft Annual Progress Report 1993. Environmental Affairs Department, Idaho Power Company, Boise, Idaho.

Haas, J.B. 1965. Fishery problems associated with Brownlee, Oxbow, and Hells Canyon Dams on the middle Snake River. Investigational Report Number 4. Fish Commission, Portland Oregon.

Irving, J.S. and T.C. Bjornn. 1981. Status of Snake River fall chinook salmon in relation to the Endangered Species Act. Prepared for the U.S. Fish and Wildlife Service, Portland, Oregon.

Kenney, 3. 1992. Memorandum of fish eggs and fry recovered in dredged material below Lower Monumental Project. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Lavoy, L. 1994. Stock Composition of fall chinook at Lower Granite Dam in 1993. Columbia River Laboratory Progress Report 94-10. Washington Department of Fish and Wildlife, Columbia River Laboratory, Battleground, Washington.

Mendel, G., K. Petersen, R. Bugert, D. Milks, L. Ross, J. Dedloff, and L. LaVoy. 1992. Lcwer Snake River Ccmpensation Plan Lyons Ferry fall chinook salmon hatchery prcgram. 1991 Evaluation Report. Cooperative Agreement 14-16-0001-91534, Washington Department of Fisheries report to the U.S. Fish and Wildlife Service, Lower Snake River Compensation Plan Office, Boise, Idaho.

Raleigh, R. F. and W. J. Miller. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish and Wildlife Service, Biological Report 82110.122).

Seidel, P., R. Bugert. 1987. Lower Snake River Compensation Plan, Lyons Ferry Salmon Evaluation Program, 1986 Annual Report. Cooperative Agreement 14-16-0001-86521. U.S. Fish and Wildlife Service, Boise, Idaho.

Seidel, P., R. Bugert, P. LaRiviere, D. Marbach, S. Martin, and L. Ross. 1988. Lower Snake River Compensation Plan, Lyons Ferry Evaluation Program, 1987 Annual Report. Cooperative Agreement 14-16-0001-87512. U.S. Fish and Wildlife Service, Boise, Idaho.

Swan, G.A. 1989. Chinook salmon spawning surveys in deep waters of a large, regulated river. Regulated Rivers: Research and Management 4:355-370.

SYSTAT. 1990. SYSTAT for DOS, version 5.02. SYSTAT Inc., Evanston, Ilinois.

Witty, K.L. 1988. Annual Fish Report. Wallowa Fish District. Oregon Department of Fish and Wildlife, Enterprise, Oregon.

CHAPTER TWO

Fall Chinook Salmon Spawning Habitat Availability in the Free-flowing Reach of the Snake River

by

W.P. Connor and A.P. Garcia
U.S. Fish and Wildlife Service
Idaho Fishery Resource Office
Ahsahka, Idaho 83520, USA

A.H. Connor and R.H. Taylor
U.S. Forest Service
Clearwater National Forest
Orofino, Idaho 83544, USA

and

C. Eaton, D. Steele, R. Bowen, and R.D. Nelle
U.S. Fish and Wildlife Service
Idaho Fishery Resource Office
Ahsahka, Idaho 83520, USA

Introduction

Knowledge of the effects of Snake River flows on fall chinook salmon *Oncorhynchus tshawytscha* spawning habitat in the free-flowing reach of the Snake River is currently needed. When the National Marine Fisheries Service was petitioned to list Snake River fall chinook salmon under the Endangered Species Act (ESA; National Marine Fisheries Service 19923, our understanding of how the operation of Brownlee, Oxbow, and Hells Canyon dams (Hells Canyon Complex) affect the spawning success of Snake River fall chinook consisted of an 18 year-old flow versus habitat study (Bayha 1974). With the ESA petition came renewed interest in obtaining information on Snake River fall chinook salmon spawning since the present understanding was not sufficient for recovery planning.

Our 1993 work was a continuation of research that began in 1991 to establish the relation between Hells Canyon Complex discharge and the availability of Snake River fall chinook salmon habitat at selected index sites (Connor et al. 1993, 1994a). The objective of work reported here is to model fall chinook salmon spawning habitat availability as related to Snake River discharge.

Study Area

The study area included the Snake River from Hells Canyon Dam to the mouth (Figure 1). We describe specific locations within the area in terms of river kilometers (RK) based on the navigation charts of the Snake River produced by the U.S. Army Corps of Engineers (COE). Our main focus in 1993 was on the free-flowing reach of the Snake River between Hells Canyon Dam (RK 398) and the head of Lower Granite Reservoir near Asotin, Washington (RK 235).

Methods

Data Collection

Discharge.-Snake River provisional discharge data collected near Anatone, Washington (Anatone gage; RK 270), were furnished by the U.S. Geological Survey (USGS) for the 1967-1994 time period. The USGS also provided Snake River provisional discharge data for Hells Canyon Dam, and the Imnaha, Salmon, and Grande Ronde rivers for 1993-1994. Water discharge data are reported in this chapter in thousands of cubic feet per second (KCFS) based on USGS standards.

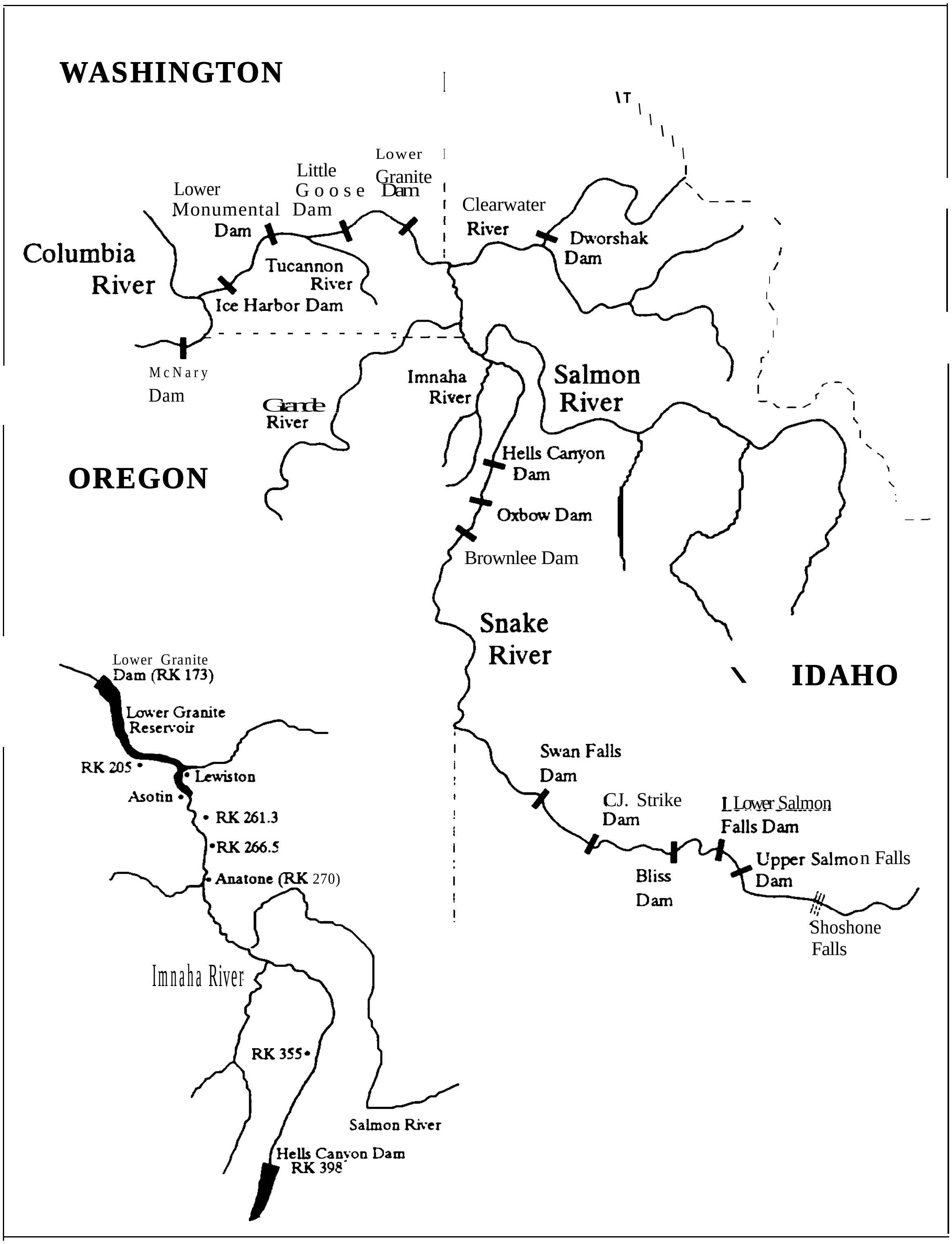

Figure 1.- Map of the Snake River drainage with an insert to show the RK 261.3 and RK 266.5 spawning habitat study sites.

Site maps-Maps of spawning sites were constructed using surveyed river channel elevations and substrate data collected using video cameras. Cross sections were created by placing navigation markers at 15.2 m intervals along both shores of each spawning site. Markers extended far enough upstream and downstream to bound the area containing suitable spawning substrate (dominant substrate size 2.5-15 cm). Video recordings of substrate were collected along cross sections at: (1) the high water mark (vegetation line) on both sides of the river; (2) points where the dominant substrate changed; (3) points of considerable slope change; and (4) intervals to achieve at least 20 recordings per cross section. In addition to data collected along the evenly placed cross sections, elevation measurements and substrate recordings were collected along cross sections established for hydraulic modelling. Additional elevation measurements and substrate recordings were collected in areas with erratic elevation changes, and complex substrate distribution patterns. Video recordings on land were made using a Sony TR-812 8 mm video camera positioned 1.2 m above the substrate. Submerged substrate was filmed using a Sony HVM 352-110° remote camera, mounted between two 13 kg sounding weights, and positioned 61 cm above the substrate. Elevations were measured at each substrate recording location. Elevations on dry land were measured by surveying a hand-held reflective prism using a Topcon ITS-l electronic total station. Underwater elevations were measured by surveying a prism positioned above the camera, as the camera contacted the substrate, and correcting for the prism-to-camera distance. Video recordings of substrate were later displayed on a monitor that was overlaid with a grid pattern so that the substrate images could be partitioned into defined units. Substrate particle sizes were estimated from the video images and converted into a modified Brusven code (Brusven 1977; Garcia and Connor 1994).

Hydraulic modelling.-We used the Instream Flow Incremental Methodology (IFIM; Bovee 1982) to collect hydraulic and channel morphology data at 10 fall chinook salmon spawning sites from 1991-1993. The details of data collection can be found in Connor et al. 1993 and 1994.'

Data Analysis

Discharge-Discharge data from Anatone Gage, Washington were used to provide various flows for spawning habitat modelling: a calibration flow for IFIM IFG4 hydraulic simulation model (Connor et al. 1993, 1994), a pre-emergence flow for scour modelling, and

---

[2]Use of trade names does not imply endorsement by the U.S. Fish and Wildlife Service.

a flow to validate habitat simulation. In addition, we modelled a range of historical flows for simulating fall chinook salmon spawning habitat for comparison to the flows being provided by the Idaho Power Company (IPCo) via their interim Snake River fall chinook salmon recovery plan. All flows were rounded to the nearest 1 KCFS. The calibration flow was the flow at which depth and velocity data was collected in the field. The median daily discharge from 1967-1993 for the 30-d period prior to fall chinook salmon emergence !15 March-15 April) was selected to represent a scour flow (41 KCFS). The median daily discharge from 1991-1993 for the spawning period (24 October-7 December) was selected as a representative spawning flow for model validation (15 KCFS!. Flow exceedance values were calculated from 1967-1993 using daily discharge tc identify the 5th, 25th, and 50th percentiles (95% exceedance, 75% exceedance, and 50% exceedance; 14 KCFS, 18 KCFS, 23 KCFS). "lows of 11 KCFS and 25 KCFS were modelled to bracket the variaticn in available habitat. Flow ccntribution from Hells Canyon Complex required to achieve 14 KCFS, 18 KCFS, and 23 KCFS at Anatone gage was calculated by subtracting 4 KCFS <the median Salmon River flow during fall chinook salmon spawning from 1991-1993) from each exceedance flow.

Spawning habitat modelling -The goal of this model ling was to provide realistic and accurate predictions of fall chinook salmon spawning habitat. A method was developed to estimate the total effective area of spawning habitat. By definition, total effective area is the habitat area which will be maintained throughout incubation to produce button-up fry. To be considered total effective area, the habitat must meet the physical criteria for spawning, remain submerged throughout incubation, and not scour at high flows.

In this report, data analysis was limited to the spawning sites near RK 261 and RK 267. Cross sections were established at RK 261.1 261.4 and RK 266.5-266.9 for hydraulic modelling. Each cross section was characterized according to channel morphology and dominant habitat type. Cross sections through reaches where spawning occurred are referred to hereafter as spawning cross sections. Spawning cross sections were positioned perpendicular tc the river flow bisect ng the redds within a reach. Habitat types fell into three categories: transitional (riffles or glides), lateral (lateral gravel bars), or runs. These three categories were further divided into shallow water (≤ 3 m) and deep water i >3 m). At RK 261.1-261.4, the spawning cross section was characterized as a shallcw-water-lateral bar. At RK 266 .5-266.9, there were two spawning habitat types; one shallow-water-transitional (represented by three spawning cross sections) and one deep-water-transltlonal [represented by two spawning cross sections!.

We used the IFG4 model (Milhous et al. 1989) to simulate water velocities and depths at each spawning cross section. IFG4 generates these statistics for 3 dimensional rectangular cells distributed between measurement points (verticals) along each cross section. The width of each cell was defined by the spacing between adjacent verticals. All cells at a spawning cross section were the same length and extended upstream and downstream from the cross section to cover the dominant habitat type represented by the cross section, or half the distance to adjacent cross sections covering the same habitat. Further details regarding input files for IFG4 and other aspects of the hydraulic analysis are provided in Connor et al. (1993 and 1994).

Maps with 0.5 m contours were produced for RK 261.1-261.4 and RK 266 5-266.9 by applying the triangulated irregular network (TIN) method to elevation measurements using AutoCAD and Softdesk (Survey, COGO, and DTM modules; computer software). Site maps were overlaid with surveyed redd locations (Connor et al. 1993; Garcia and Connor 1994; Groves 1993; and Garcia et al. in this report! and the distribution of suitable spawning substrate. Substrate distribution was determined by displaying the substrate code associated with each surveyed point on site maps and fitting lines through the points at the outer edges of homogenous areas of 2.5-15 cm dominant substrate (Brusven codes 2-4).

We approximated the amount of available spawning habitat at the RK 261 and RK 267 sites by comparing various attributes (lateral slope, depth, velocity, substrate, and potential to scour! of cells along the spawning cross sections to values of these attributes found at existing redds. Cells which had an unsuitable value for any attribute were filtered from consideration as fall chinook spawning habitat.

We used lateral slope as the first filter to determine which cells could potentially contain spawning habitat. Cells with lateral slopes greater than 5% were filtered from consideration as fall chinook salmon spawning habitat. We calculated lateral channel slope (rise/run) for each cell using the distance (run) between, and elevation difference (rise) of, the two verticals defining the width of each cell.

The 0-5% lateral slope criterion was calculated based on the 75th quartile of measurements taken at 64 redds located near RK 261 and RK 267 from 1991-1993. Lateral and longitudinal slopes at each redd were determined from the site maps based on the distance (run) of a redd to the nearest 0.5 m (rise) contours surrounding it. Lateral slope run for an individual redd was the length of a line oriented parallel to the spawning cross section, passing through the redd, and extending to the first contour lines on either side of the redd. Longitudinal slope run was the length of a line oriented perpendicular to the nearest cross section, passing through the redd, and extending to the first contour lines upstream and downstream of the redd.

Next, each cell along the spawning cross-section was filtered for suitable depths, velocities, and substrate. Depths and velocities are flow dependant and were modelled for the validation flow (15 KCFS) using IFG4 and MANSQ (Milhous et al. 1989). The modified Brusven codes for substrate were recorded i the field along the IFIM cross sections and were considered constant over flow. Cells that had unsuitable depth, velocity, or substrate were eliminated from consideration as fall chinook spawning habitat at the validation flow.

Suitable depth, velocity, and substrate for fall chinook salmon spawning habitat utilization were determined using binary criteria developed cooperatively between biologists from the IPCo and Fish and Wildlife Service. These analyses are based on field data described in detail by Groves (in press). Groves reported fall chinook salmon spawning in depths from 0.4-6.5 m, velocities from 0.4-2.0 m/s, and substrates from 2.5-15.2 cm in diameter.

The final filter involved identifying the cells which would scour at a flow of 41 KCFS (the median flow prior to fall chinook salmon fry emergence from 1967-1993) and eliminating these cells from consideration as fall chinook spawning habitat. We calculated Shield's mean bed shear stress criteria for each cell to predict whether the substrate of a fall chinook redd in that cell would move. Shield's criterion (θ_c) was calculated from the following relationship (Richard 1982) :

$$\theta_c = \rho_w ds / (\rho_s - \rho_w) D_{65}$$

where:
- ρ_w = density of water
- d = depth of water at scour flow
- s = water surface slope
- ρ_s = density of bed material
- D_{65} = diameter of the redd substrate

The depth of water in each cell at 41 KCFS (d) was predicted using the stage discharge relationship developed at each cross section and the bottom elevation of the ceil. We used the measured high flow water surface slope and Manning's equation to predict the water surface slope (s) at 41 KCFS. We used a value for substrate density (ρ_s! typical for granitic gravels (2.65 g/cm^3). The 65th percentile substrate size (D_{65}) was determined by Arnsberg et al. (1992) to be 65 mm at the spawning site at RK 261 on the Snake River. This value was assumed to be representative cf the spawning sites at RK 257.

Two threshcld scour criterion values were used to determine whether redds wculd be damaged by scour at high flows. A threshold scour criterion of 0.03 indicates the initial movement of the loose substrate on the surface of a redd while a threshold scour criterion of 0.06 indicates movement of the compacted substrate of the redd (Arnsberg et al. 1992). Two model runs were made to determine model sensitivity to the scour criterion. Cells with criterion values greater than 0.03 or 0.06 were removed from calculations cf spawning habitat availability.

The summed area of all cells passing through the five filters (slope, depth, velocity, substrate, and scour) is referred to as total effective area. The validity of total effective area estimates was checked by comparing the proximity of known fall chinook salmon redds to the location of cells that were predicted as total effective area. We used the 15 KCFS discharge calculated for the 1991-1993 spawning period for validation.

Once the above process was validated, we proceeded to simulate total effective area for 11 KCFS, 14 KCFS, 18 KCFS, 23 KCFS, and 25 KCFS. We used IFG4 and HABTAE (Milhous et al. 1989) to model multiple flows and predict total effective area using all five filters. HABTAE uses IFG4 output to simulate total effective area for spawning over a specified range of flows based on suitable depths, velocities, and channel index. We used the substrate code as channel index unless that cell had a lateral slope greater than 5% or was predicted to scour. All cells with unsuitable lateral slope were given a channel index value of 99.9 in the IFG4 data decks while those that had suitable lateral slope but were predicted to scour were given channel index values of 11.1. HABTAE was then run for the validation flow (15 KCFS) and the simulated flows (11 KCFS, 14 KCFS, 18 KCFS, 23 KCFS, and 25 KCFS).

The model output for the simulated flows was then graphed to show how habitat changes with flow. The maximum value from this graph was used as the denominator when calculating the percent of maximum habitat being provided under each simulated flow. Seeding level and production potential of each habitat type modelled was estimated by dividing tctal effective area for each simulation by 35.7 m^2 (the average area required for a fall chinook salmon redd based on data from five Columbia River sites; Swan 1989).

Results

Spawning Habitat Modelling

The area available in each habitat type that was predicted to be usable for fall chinook spawning was first reduced by eliminating those cells that had lateral slope greater than 5%

(Table 1). In the shallow-water-transitional habitat, 26% of the total wetted area represented by the spawning cross sections was eliminated using only the slope criterion, while 51% of the shallow-water-lateral habitat and 44% of the deep-water-transitional habitat were eliminated. As lateral slope is independent of flow, the cells that were eliminated at the validation flow were also unsuitable at other flows.

Table 1. -Usable area statistics for fall chinook salmon spawning after cells with lateral slopes > 5% were removed. Data are presented by habitat type including shallow-water-transitional (SWT; RK 257 cross sections 2, 2.1, and 3), shallow-water-lateral (SWL; RK 261 cross section 4), and deep-water-transitional (DWT; RK 267 cross sections 1 and 1.1).

Habitat type	Wetted area (m^2)	Total usable area (m^2)	Percent of wetted area usable
SWT	43000	32000	74
SWL	14500	7100	49
DWT	217C0	12200	56

The remaining area in each habitat type was then filtered for suitable depths, velocities, and substrate at the validation flow cf 15 KCFS (Table 2). In the shallow-water-transitional habitat type, 11% of the total wetted area represented by the Spawning cross sections remained potentially usable after cells with unsuitable lateral s o depth, velocity, or substrate were eliminated. In the shallow-water-lateral habitat type, 17% of the wetted area was potentially usable after these filters were applied, while in the deep-water-transitional habitat type, 27% cf the wetted area remained potentially usable. Depth and velocity are dependent on flow, thus the usable habitat available at the simulation flows may differ from the amount available at the validation flow.

Finally, those cells predicted to scour at 41 KCFS were removed from consideration as suitable habitat. Two separate scour criteria were examined: a scour criteria of 0.03 indicating initial movement cf loose substrate and a scour criteria of 0.06 indicating scour cf compacted gravels (Table 3). Using the 0.06 criterion none 0f the cells predicted as usable at the validation flow will have scour of the compacted gravels in any of the habitat types (Tables 2 and 3). However, when cells with loose gravel scour (θ_c = 0.03) were eliminated from consideration as potential fall chinook spawning habitat, the total effective area at the validation flow was reduced to 9% of the total wetted area in the shallow-water-transitional habitat type, 0% in the shallow-water-lateral habitat type, and 6% in the deep-water-transitional habitat type.

Table 2. -Usable area statistics for fall chinook salmon spawning after cells which were predicted to have unsuitable depth, velocity, or substrate at 15 KCFS are removed. Data are presented by habitat type including shallow-water-transitional (SWT; RK 267 cross sections 2, 2.1, and 3), shallow-water-lateral (SWL; RK 261 cross section 4), and deep-water-transitional (DWT; RK 267 cross sections 1 and 1.1).

Habitat type	Wetted area (m^2)	Total usable area (m^2)	Percent of wetted area usable
SWT	43000	4900	11
SWL	14500	2500	17
DWT	21700	5800	27

Table 3.-Total effective area statistics for fall chinook salmon spawning simulated at 15 KCFS (the median flow during the 24 October - 7 December 1991-1993 time period). Data are presented by habitat type including shallow-water-transitional (SWT; RK 267 cross sections 2, 2.1, and 3), shallow-water-lateral (SWL; RK 251 cross section 4), and deep-water-transitional (DWT; RK 267 cross sections 1 and 1.1).

Habitat type	Sheilds scour criterion	Wetted area (m^2)	Total effective area (m^2)	Percent of wetted area usable
SWT	0.03	32000	4100	9
	0.06	32000	4900	11
SWL	0.03	14500	0	0
	0.06	14500	2500	17
DWT	0.03	21700	1300	6
	0.06	21700	5800	27

Validation consisted of comparing areas predicted to contain effective spawning habitat to the surveyed location of actual fall chinook salmon redds and showed that model accuracy was high in all three habitat types. All fall chinook salmon redds located since 1991 at RK 261 were wholly or partially in cells predicted as total effective area (Figure 2). The one cell which did not contain redds appeared suitable for spawning, to the trained observer, and may support spawning under higher adult escapement levels. Similar accuracy was achieved for the RK 267 site, except when the cross sections were above or below usable gravel (cross section three; Figure 3), or under logistical constraints caused when gaging at cross section one. Cross section one is located at the site's hydraulic control and was through a narrow fast-moving tongue which caused vertical spacing to be wide. This error was corrected at a later date, but is not presented in this analysis.

The simulated flows were then modelled and total effective area was predicted for the three habitat types. The total effective area in the shallow-water-transitional habitat (RK 267) type did not vary with flow over the range of flows simulated. Substrate and lateral slope were the limiting filters at this site, neither of which were affected by flow. In the shallow-water-lateral habitat type (RK 261), total effective area peaked at 14 KCFS to 23 KCFS when a scour criterion of 0.06 was used. When the scour criterion of 0.03 was used, none of the area was predicted to be usable. The total effective area of deep-water-transitional habitat peaked at 18 KCFS when a scour criterion of 0.06 was used. However, no peak was evident within the range of flows modelled when we used a scour criterion of 0.03 (Tables 4 and 5).

Discussion

The use of the HABTAT (replaced by HABTAE in 1994) model has been criticized in the past as being an inaccurate tool for modelling chinook salmon spawning habitat. Shrivell (1990) found that HABTAT often over predicted spawning habitat by 200-600%. Arnsberg et al. (1992) used HABTAT to predict that 61 km of the Clearwater River in Idaho could support 95,000 fall chinook salmon redds. The inflation in the above redd estimate was traced to three sources including: 1) predicting usable spawning habitat in large mainstem runs with armored gravel; 2) counting channel reaches with steep lateral slopes as habitat; and 3) counting areas that might scour prior to fry emergence. We cooperated with Arnsberg et al. (1992) to re-analyze the Clearwater River data to calculate total effective area. The re-analysis reduced the redd estimate from 95,000 to 3,600 and the predicted redd distribution by river kilometer mirrored the historic distribution since 1988. Shrivell (1990) also pointed out HABTAT's tendency to predict spawning habitat in areas which

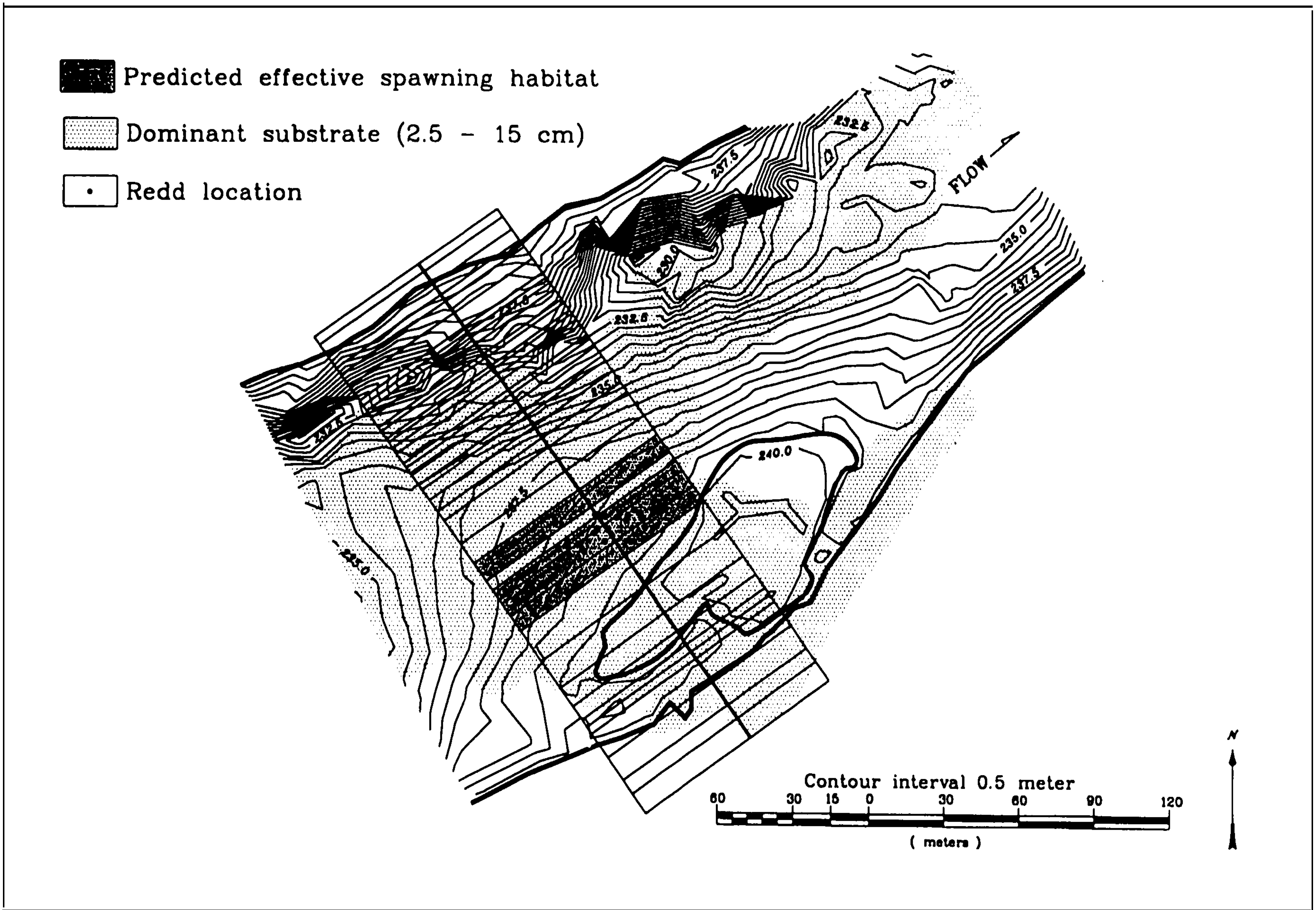

Figure 2.- Validation of modelling accuracy in lateral bar spawning habitat of Snake River fall chinook salmon. A scour criterion of 0.06 and hydraulic simulation flow of 15 KCFS were used.

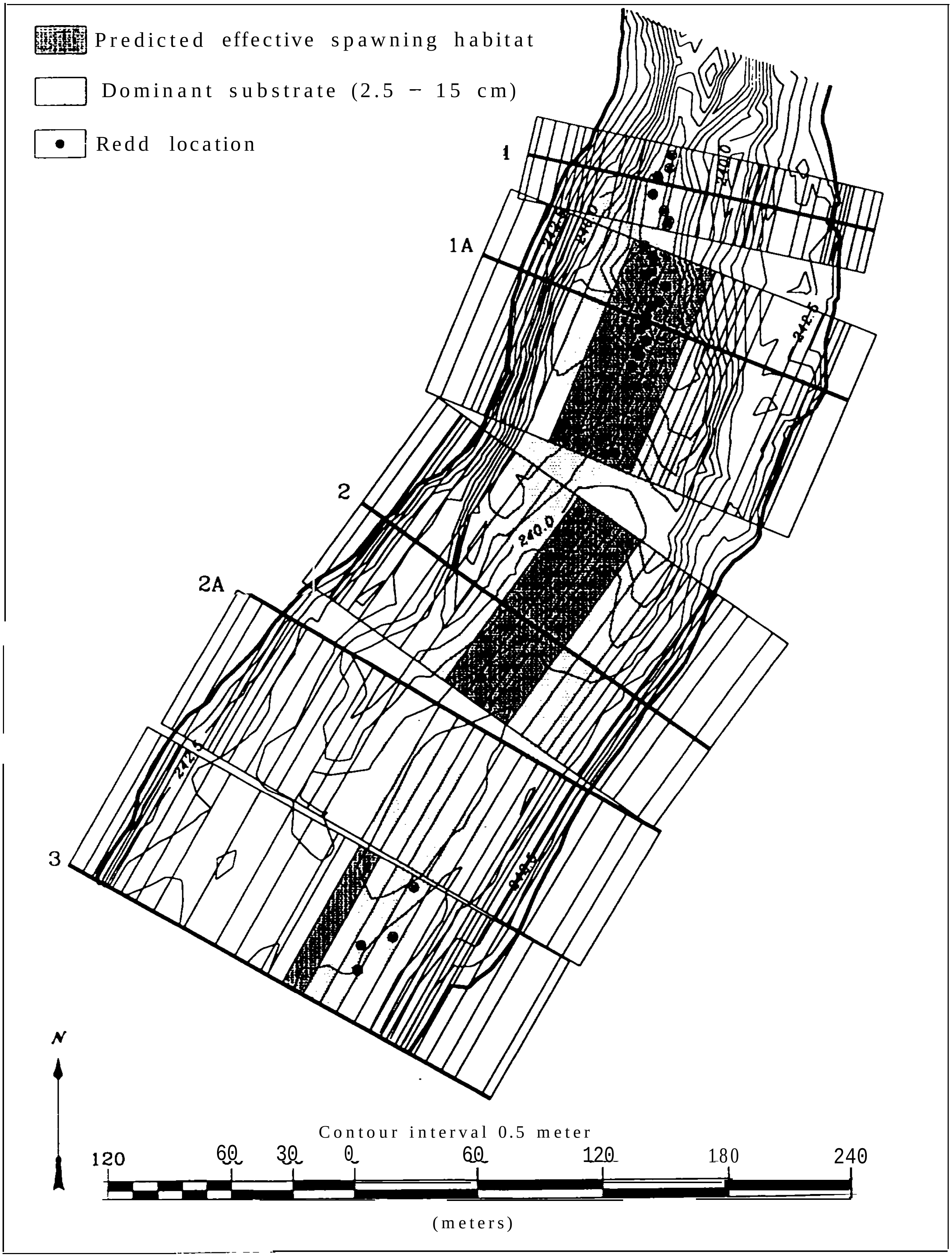

Figure 3.- Validation of modelling accuracy in shallow (cross sections 2, 2A, and 3) and deep (cross sections 1 and 1A) water transitional spawning habitat of Snake River fall chinook salmon.

Table 4.-Total effective area (TEA) statistics for fall chinook salmon spawning simulated at 14 KCFS, 18 KCFS, and 23 KCFS (95%, 75%, and 50% exceedance flows since 1967) and at 11 KCFS and 25 KCFS. A threshold Sheilds scour criterion of 0.06 (θ_c = 0.06) was assumed. Data are presented by habitat type including shallow-water-transitional (SWT; RK 267 cross sections 2, 2.1, and 3), shallow-water-lateral (SWL; RK 261 cross section 4), and deep-water-transitional (DWT; RK 267 cross sections 1 and 1.1).

Habitat type	Flow (KCFS)	Wetted area (m^2)	TEA (m^2)	Percent of maximum habitat	Estimated redd number
SWT	11	41900	4930	100%	138
	14	42800	4930	100%	138
	18	44300	4930	100%	138
	23	45600	4930	100%	138
	25	46100	4930	100%	138
SWL	11	13000	1850	75%	52
	14	14300	2480	100%	69
	18	15900	2480	100%	69
	23	18400	2480	100%	69
	25	18700	1720	69%	48
DWT	11	20900	5820	88%	163
	14	21600	5820	88%	163
	18	22400	6640	100%	186
	23	22900	5200	78%	146
	25	23000	5200	78%	146

Table 5. -Total effective area (TEA) statistics for fall chinook salmon spawning simulated at 14 KCFS, 18 KCFS, and 23 KCFS (95%, 75%, and 50% exceedance flows since 1967) and at ii KCFS and 25 KCFS. A threshoid Sheilds scour criterion of 0.03 (θ_c = 0.03) was assumed. Data are presented by habitat type including shallow-water-transitional (SWT; RK 267 cross sections 2, 2.1, and 3), shailow-water-lateral (SWL; RK 261 cross section 4), and deep-water-transitional (DWT; RK 267 cross sections 1 and 1.1).

Habitat type	Flow (KCFS)	Wetted area (m^2)	TEA (m^2)	Percent of maximum habitat	Estimated redd number
SWT	11	41900	4070	100%	114
	14	42800	4070	100%	114
	18	44300	4070	100%	114
	23	45600	4070	100%	114
	25	46100	4070	100%	114
SWL	11	13000	0	-	0
	14	14300	0	-	0
	18	15900	0		3
	23	18400	0	-	0
	25	18703	0		0
DWT	11	20900	1270	61%	36
	14	21600	127C	61%	36
	18	22400	2090	100%	59
	23	229oc	2090	ic)C%	59
	25	23000	2090	lOC%	59

never supported spawning. This was not true of the Clearwater River re-analysis, which in most cases, predicted usable habitat in the proximity of former fall chinook salmon redds.

We made estimates of fall chinook salmon spawning habitat and potential redd number for two sites composed of three habitat types in the Snake River. The estimates appeared believable and were the result of careful application of the slope, scour, and binary spawning criteria (velocity, depth, and substrate) filters. Each filter functioned to reduce spawnable area estimates incrementally. Lateral slope reduced the area for fall chinook salmon spawning from 26-51% depending upon the habitat type modelled. An additional 28-63% of the remaining available area was eliminated from consideration as total effective area based on velocity, depth, and substrate criteria. The.accuracy of the calculated total effective area appeared good based on the ability to predict the locations of actual fall chinook salmon redds. Cases of inaccuracy resulted primarily from placing spawning cross sections up or down stream of usable substrate or measurement error associated with complex morphology. In addition, the model assumes that the conditions within a cell are constant up and down river and that they match the conditions at the cross section. Obviously, this is an oversimplification of the river. Thus, suitable spawning habitat and observed redds may occur within a cell that the model predicts as unsuitable and vice versa. Additional data collection and analyses in upcoming years will further refine the calculation of total effective area.

The calculation of total effective area was very sensitive to the selected scour criterion (0.03 or 0.06). The selection of scour criteria was based upon values in the literature but needs to be refined for each particular reach of river. One example of model sensitivity to the value of scour criterion was a reduction of total effective area from 5,820 m^2 to 1,270 m^2 (163 redds to 36 redds) for deep-water-transitional habitat. Deepwater spawning has always been suspected in the free-flowing reach of the Snake River but not to the extent documented in 1993 (Garcia et al. in this report). There are over 90 potential deepwater spawning sites in the Snake River from about RK 250 to RK 395 (Phil Groves, IPCo, personal communication). Documenting scour mechanisms will be critical to understanding the production potential of the deepwater sites in the Snake River.

Total effective area does not appear to be particularly sensitive to flow throughout the range of flows simulated. This may in part be due to overly broad binary criteria for the flow related phenomena of depth and especially velocity. Spawning suitability criteria have been studied in detail for chinook salmon in shallow water areas of mainstem rivers (Hampton 1988, Arnsberg et al. 1992, Groves 1993). A paucity of information exists for deepwater spawning in the Snake River (Groves, unpublished data). The measurement of mean water column and facing velocities over the deepwater redds and the calculation of a regression equation tc calculate facing velocity in HABTAE would increase the accuracy of total effective area predictions. Specific binary criteria for habitat type may further increase modellicg accuracy. The 2.0 m/s velocity criterion used as the upper end of the suitable velocity range in this analysis was partially responsible for the lack of a marked response in total effective area as higher flows were modelled. A deepwater habitat, with mean column velocities of 2.0 m/s, may be used by spawning fall chinook salmon because the velocity experienced by the fish near or at the bottom of the river may be substantially less than the mean column velocity. Conversely, the same velocity over a lateral bar may inhibit redd construction because of a shallower boundary layer. The binary spawning criteria should be refined in future years by habitat type.

Finally, if our modelling results hold river wide, then the three habitat types (two sites) we modelled are probably underseeded. The two sites, representing at most 8 km of river, were predicted to accommodate about 370 fall chinook salmon redds at i4 KCFS. Under current escapement levels, there are generally less than 50 redds counted in this river reach in a high escapement year (Garcia et al. in this report). Concerns that spawning habitat availability is limiting natural fall chinook salmon production are probably unfounded.

In conclusion our findings during 1993 indicate: (1) estimates cf fall chinook salmon spawning habitat can be made using hydraulic and habitat models; and (2) fall chinook salmon spawning habitat in the free-flowing reach of the Snake River is underseeded. Finally, the information we have presented in this chapter will be modified upon the analysis of additional data.

References

Arnsberg, B.D., Connor, W.P., and Connor, E. 1992. Mainstem Clearwater River Study: Assessment for salmonid spawning, incubating, and rearing. Final Report to Bonneville Power Administration, Contract DE-BI79-87BP37474, Portland, Oregon.

Bayha, K. 1974. Anatomy of a River Study: An evaluation of water requirements for the Hell's Canyon reach of the Snake River. Pacific Northwest River Basins Commission, Vancouver, Washington.

Bovee, K.D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12, FWS/OBS-82/26, U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Connor, W.P., A.P. Garcia, H.L. Burge, and R.H. Taylor. 1993. Fall chinook salmon spawning in free-flowing reaches of the Snake River. Pages l-29 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Connor, W.P., A.H. Connor, and R.H. Taylor. 1994. Snake River flows and temperatures during the 1992 Snake River fall chinook salmon Brood Year. Pages 20-38 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Garcia, A.P. and W.P. Connor. 1994. Fall chinook spawning ground surveys in the Snake River. Pages l-19 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Groves, P.A. 1993. Habitat available for, and used by, fall chinook salmon within the Hells Canyon Reach of the Snake River. Annual Progress Report 1992. Environmental Affairs Department, Idaho Power Company, Boise, Idaho.

Hampton, M. 1988. Development of habitat preference criteria for anadromous salmonids of the Trinity River. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, California.

Milhous, R.T., T. Wegner, and T. Waddle. 1984. User's guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper No. 11 U.S. Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Computer reference manual for the Physical Habitat Simulation System (PHAHSIM)-Version II. U.S. Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado.

NMFS- (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Final rule, April 22, 1992. Federal Register, Volume 57, Number 78.

Richards, K. 1982. Rivers: form and process in alluvial channels. Methuen, London.

Shrivell, C.S. 1990. Ability of PHABSIM to predict chinook salmon spawning habitat. Regulated Rivers 3:277-289.

CHAPTER THREE

Rearing and Emigration of Naturally Produced Snake River Fall Chinook Salmon Juveniles

by

W.P. Connor, H.L. Burge,
D. Steele, C. Eaton, and R. Bowen
U.S. Fish and Wildlife Service,
Idaho Fishery Resource Office
Ahsahka, Idaho 83520, USA

Introduction

The understanding of Snake River fall chinook salmon *Oncorhynchus tshawytscha* rearing and emigration has steadily increased over the past three years. When Snake River fall chinook salmon were listed as a threatened species under the Endangered Species Act (ESA; NMFS 1992) in 1992, much of the contemporary information on these subyearling emigrants was based on our 1991 and 1992 research (Connor et al. 1993, 1994). The purpose of our study is to increase the information on naturally produced Snake River fall chinook salmon juveniles for ESA recovery efforts. cur objectives in 1993 were: (1) to describe the early life history and emigration timing of naturally produced fall chinook salmon from the Snake and Clearwater rivers, and (2) to estimate the influence of water flow, water temperature, and juvenile fall chinook salmon size on emigration rate.

Study Area

The study area in 1993 included the Snake and the Clearwater rivers (Figure 1). Data were collected on the Snake River from RK 176 in Lower Granite Reservoir to Two Corral Creek at RK 355. Data were collected on the Clearwater River from RK 14, near Hog Isles, to RK 34 below Cherry Lane Bridge. Mean daily Snake River discharge at the United States Geological Survey (USGS) gage at Anatone, Washington (RK 270) ranged from about 27.3 to 118 thousand cubic ft/s (KCFS) during sampling (Figure 2). Mean daily water temperature collected at Billy Creek (RK 265) ranged from about 9 to 19°C during sampling (Figure 2). Mean daily Clearwater River discharge at the USGS gage at Spalding, Idaho (RK 19) ranged from about 11.7 to 26.9 KCFS during sampling and water temperature at RK 10 ranged from about 11.7 to 14°C (Figure 23.

Methods

Data Collection

Systematic samples. Eight sample sites below RK 251 (Table 1) were systematically beach seined from 6 April until 20 July. Each site was visited about once a week and normally seined three times in an upriver direction; each consecutive set started where the previous one ended. The beach seine had a weighted multistranded mudline, 0.48 *cm* mesh and was 30.5 m x 1.8 m with a 3.9 m^3 bag. Each end of the seine was fitted with a brail weighted at the bottom and attached to 15.2 m lead ropes. The seine was set parallel to shore from the stern platform of a 6.7 m jet boat. The net was then hauled straight into shore by both lead ropes. The net sampled approximately 465 m^2 to a depth of

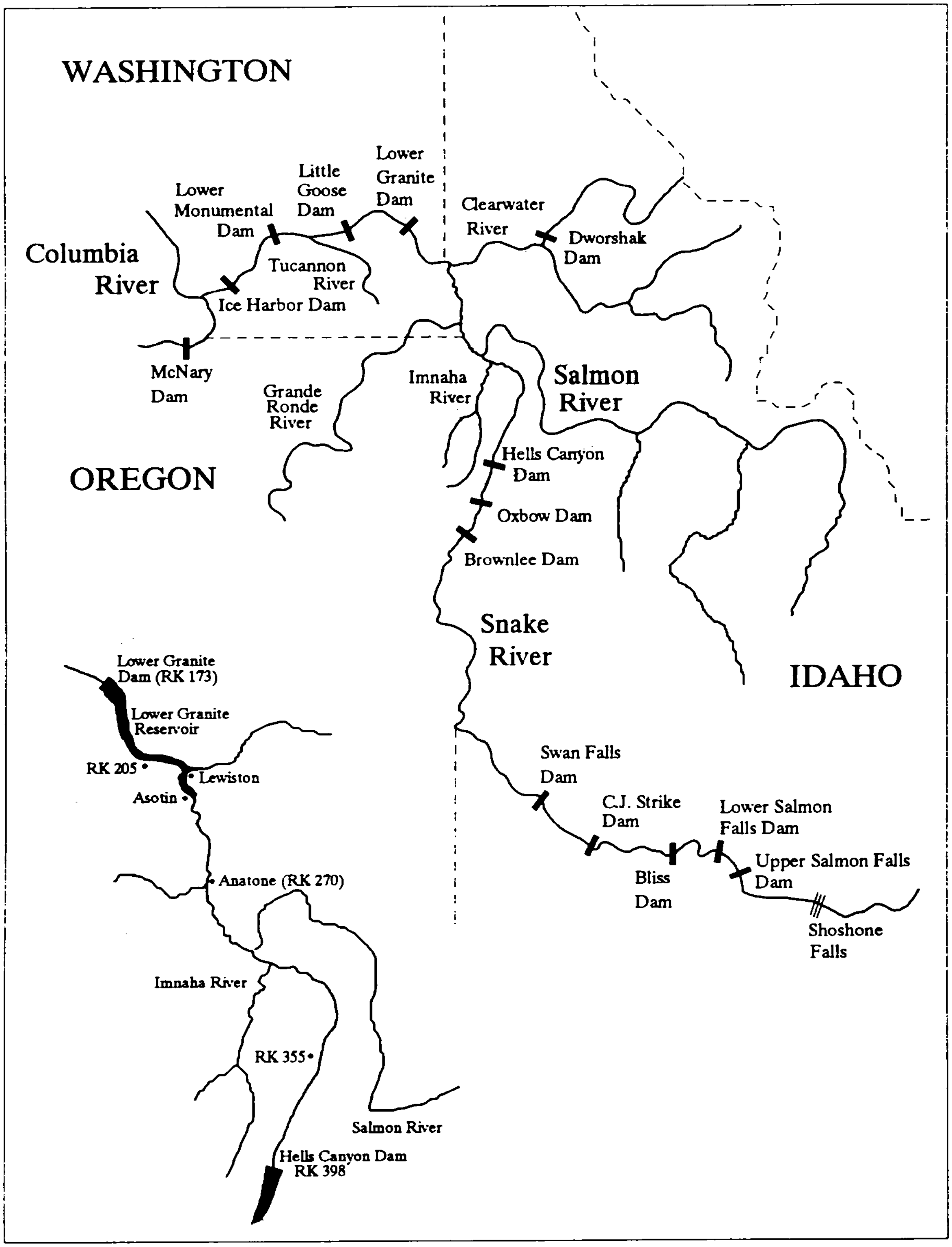

Figure 1.- Map of the Snake River drainage with an insert to show the 1993 seining area boundaries of RK 205 and RK 355.

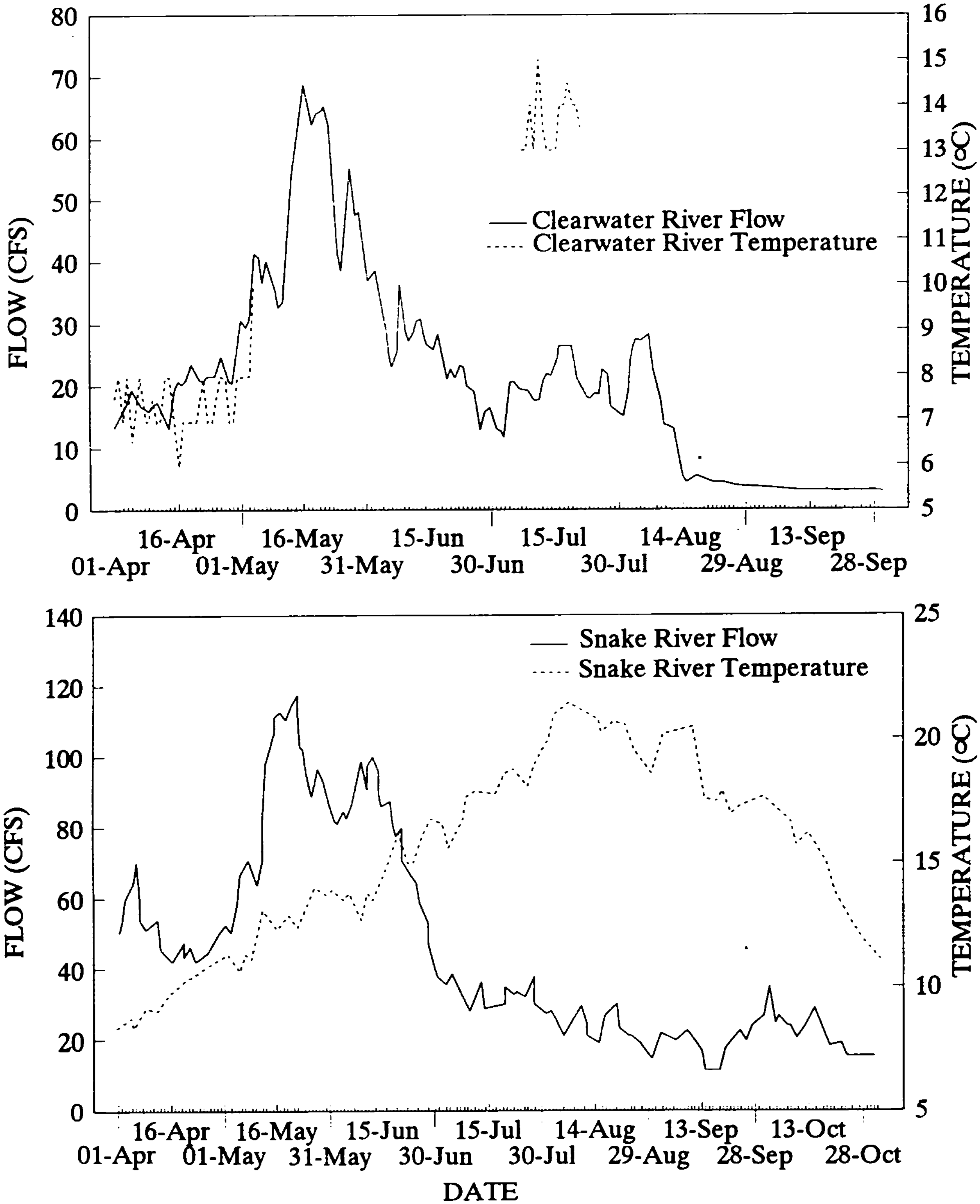

Figure 2. Mean daily Snake and Clearwater River flows and temperatures during the 1993 sampling period.

Table 1.-Sites and dates for systematic seining of fall chinook salmon juveniles in the Snake River in 1993.

River kilometer	Shore	Date range
226	West	S-April to 20-July
229	East	6-April to 20-July
232	East	6-April to 20-July
242	East	6-April to 20-July
242	West	6-April to 20-July
248	West	6-April to 20-July
251A	East	6-April to 20-July
251B	East	6-April to 20-July

1.8 m. There was no systematic sampling of the Clearwater River in 1993.

Supplemental samples.-In addition to seining at the eight systematic sampling sites in the Snake River, supplemental samples were also collected to increase the number of PIT-tagged chinook salmon for emigration analyses. There were about 65, 5, and 30 supplemental sites in the Snake River, Clearwater River, and Lower Granite Reservoir, respectively. Supplemental sites were similar to our systematic seining sites in that they were characterized by low velocity and had minimal obstructions for landing a beach seine. Supplemental sampling effort was highest around the peak of the systematic catch. Sampling in the Clearwater River and Lower Granite Reservoir was done cooperatively with the Nez Perce Tribe and University of Idaho, respectively.

Anesthetic.-Once seined, chinook salmon were transferred to a 94.6 L oxygenated live-well supplied with water at river temperature, 100 g of NaCl, and 12.5 mL of Polyaqua. All chinook salmon were anesthetized in an 18.9 L bucket containing a dilute tricane methanesulfonate (MS-222) solution (10-26 mg/L), which was buffered with 0.5 gm of $NaHCO_3$. Chinook salmon were anesthetized in groups of 6-10 fish.

In-season race identification.-We calculated a size limit to separate the smaller subyearling chinook salmon juveniles "in-season" from larger yearling chinook salmon in the Snake River. The size limit was calculated based on water temperature, projected fry emergence dates, and projected growth rate. Water temperature data for the size limit calculation were collected in the Snake

River at Chalk Creek (RK 303) and Billy Creek (RK 265). These temperature data were used to project the beginning of fry emergence at 895 Celsius temperature units (CTU) after the first redds were counted in 1992. For the size limit calculation, emergent fry were estimated to be 38 mm fork length (FL) (Arnsberg et al. 1992), and estimated to have a growth rate of 1. c mm/d. Emergence timing had to be projected separately for chinook salmon juveniles collected above and below the Salmon River confluence because of differences in water temperature. We calculated the upper fall chinook salmon size limit in Table 2 using water temperatures from RK 303. The lower fall chinook salmon size limit in Table 2 was calculated using a 60 mm minimum tagging size (McCann et al. 1993) and water temperatures from RK 265. There was no size limit calculated for the Clearwater River in the absence of water temperature data. Therefore, the emergence timing of fall chinook salmon in the Clearwater River was estimated to occur from late May to early June based on Arnsberg et al. (1992). We started sampling the Clearwater River on 1 July when most of the fall chinook salmon were estimated to be 50 mm FL based on a presumed growth rate of 1.0 mm/d.

Table 2. -Upper and lower size limits calculated for in-season race identification of chinook salmon seined in the Snake River, 1993.

Limit	Estimated fall chinook salmon size by date							
	04-May	ll-May	18-May	25-May	01-Jun	08-Jun	15-Jun	22-Jun
Upper	63	70	77	84	91	98	105	112
Lower	60	60	60	60	60	60	60	60

PIT tagging-Chinook salmon within the size limits defined in Table 2 or had the sharper body features and smaller eyes we noted in fall chinook salmon during 1991 were tagged with a Passive Integrated Transponder (PIT) tag (Prentice et al. 1990a). Tags were disinfected with 70% ethyl alcohol and blotted dry prior to insertion into the fish. Chinook salmon juveniles were immobilized by placing them in a cool, wet, notched foam pad. Tags were manually implanted with a 12 gauge needle affixed to a syringe. After tagging, we transferred the fish to an oxygenated 18.9 L recovery bucket filled with saline water (20 gm NaCl) and 12.5 mL of polyaqua. The salmon were held in the recovery bucket for 15 min prior to release after tagging.

PIT-fug data.-The data collected from the PIT-tagged chinook salmon juveniles were recorded in computer files (PIT Tag Work Group 1993) and uploaded to the PIT Tag Information System (PITAGIS!. Emigrating chinook salmon juveniles that bypass Lower Granite Dam turbines are monitored for PIT tags (Prentice et al. 1990b). Both PIT-tagging and PIT-tag detection data are available to interested parties through PITAGIS.

Electrophoresis.-A subsample of the PIT-tagged chinook salmon detected at Lower Granite Dam were diverted by a hydraulic slide gate, scanned for tag codes, and measured by Smolt Monitoring Program (SMP) personnel. When our tag codes were detected in chinook salmon, a scale sample was taken for aging (Jerald 1983) and the fish was labeled and frozen. The Washington Department of Fisheries (WDF) validated the race of the frozen chinook salmon using tissue extracts and horizontal starch-gel electrophoresis (Abbersold et al. 1987).

Dutu Analysis

Overall subyearling *collection.-Age* I chinook salmon were separated from subyearlings in the systematic and supplemental data (pooled sample) using the growth rates and size at capture of known-age salmon from the electrophoretic sample. This process involves back calculation of size over time (Connor et al. 1993 and 1994). Subyearling chinook salmon catch and the number of fish PIT tagged are summarized by date and river kilometer. Data from the Snake River, Lower Granite Reservoir, and Clearwater River samples were analyzed separately.

Post-season race separation.-Electrophoresis separated the sample of juvenile chinook salmon diverted at Lower Granite Dam into two races; fall and spring/summer chinook salmon. The majority of the subyearling chinook salmon we PIT tagged were not electrophoretically analyzed and are referred tc hereafter as being of mixed race. Average release fork iength, detection fork length, growth rate, and emigration rate were compared between and among fall, spring/summer, and mixed race chinook salmon which were detected at Lower Granite Dam. Analysis of variance (ANOVA) and f-tests were used for these comparisons (P=O.05; Zar 1984, Systat 1990). Only the Snake River sample had adequate numbers of each race for these analyses. The races of fish in the mixed race sample were identified using data from known race juvenile chinook salmon and a race separation technique (Connor et al. 1993 and 1994). This technique is based on back calculation of size by date and requires that the fork length of the known fall chinook salmon and known spring/summer chinook salmon are different over time.

Emergence and rearing.-Fall chinook salmon emergence timing was estimated using only data from known fall chinook salmon from the pooled Snake River sample. The emergence date of each fall chinook salmon was calculated by subtracting 38 mm (assumed emergence size) from fork length at capture and dividing by an average growth rate of 1.4 mm/d (observed fall chinook growth rate in 1993). This number was then subtracted from the Julian date of capture to estimate emergence date for each fish. Catch per unit effort (CPUE) of subyearling chinook salmon was calculated using data collected at the eight systematic sites in Table 1. The CPUE values were then multiplied by 0.42 (42% of the salmon in the electrophoretic sample were fall chinook salmon) to represent fall chinook salmon catch. Emergence and rearing analyses were not performed on the Clearwater River or Lower Granite Reservoir samples because there were too few fish from these locations in the electrophoretic sample.

Emigration rate.-Emigration rates were analyzed using PIT-tag data only from known fall chinook salmon (Appendix 1). Multiple General Linear Hypothesis testing (MGLH; SYSTAT 1990) was used to test for relations between emigration rate and Snake River average discharge at Lower Granite Dam between last capture date and detection at Lower Granite Dam (emigration flow), the Snake River average water temperature for the same time period (emigration temperature), Snake River water temperature when the fish was released (release temperature), and the fork length of the PIT-tagged chinook salmon when it was released.

Results

Overall subyearling collection and tugging

We captured 2,396 subyearling chinook salmon in beach seines from 6 April to 21 July, 1993 in the Snake River between RK 224 and RK 322 (Figures 3 and 4). Of these, we PIT tagged 1,236 between RK 224 and RK 290 (Figures 5 and 6). A total of 277 subyearling chinook salmon were seined and 146 tagged in Lower Granite Reservoir from 26 May to 23 June between RK 176 and RK 219 (Figures 5 and 6). In the Clearwater River, a total of 554 subyearling chinook salmon were seined from 1 to 21 July between RK 17 and RK 34. Almost all of the 396 subyearling chinook salmon tagged on the Clearwater River were seined near RK 34 (Figures 5 and 6). A concentration of redds has been observed immediately above this area since 1988.

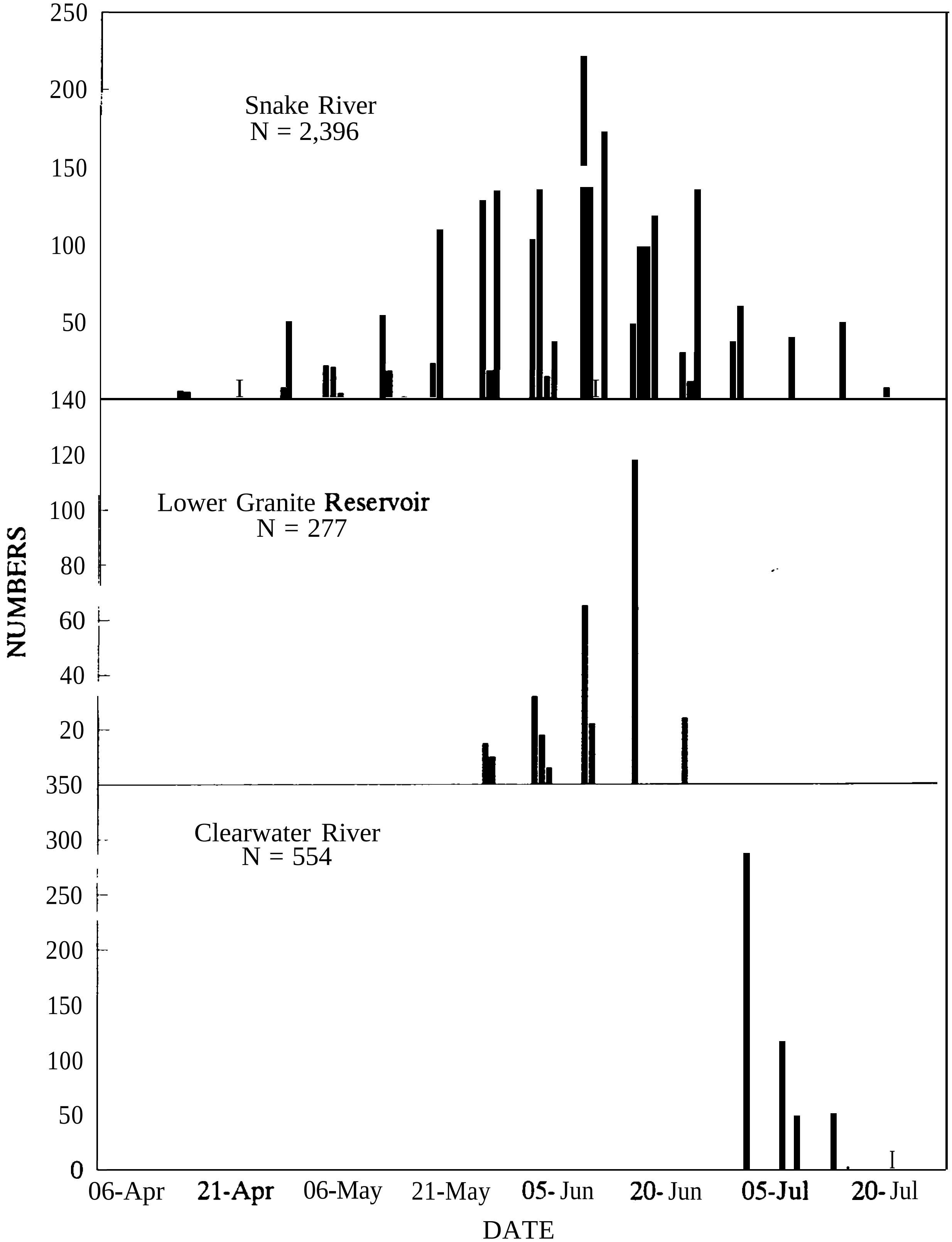

Figure 3.–Number of subyearling chinook salmon juveniles seined by date in the Snake River, Lower Granite Reservoir, and the Clearwater River, 1993.

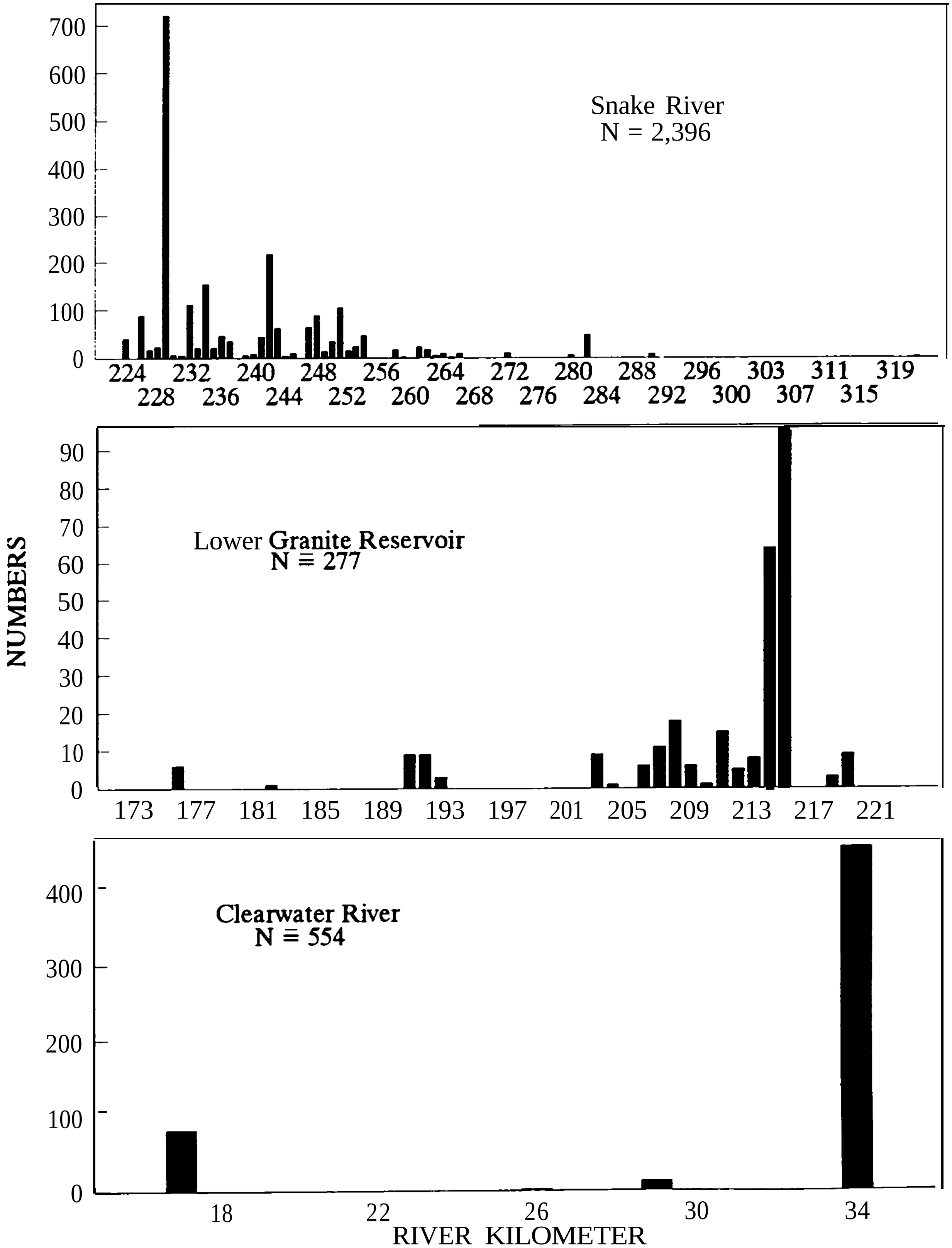

Figure 4.- Number of subyearling chinook salmon juveniles seined by river kilometer the Snake River, Lower Granite Reservoir, and Clearwater River, 1993.

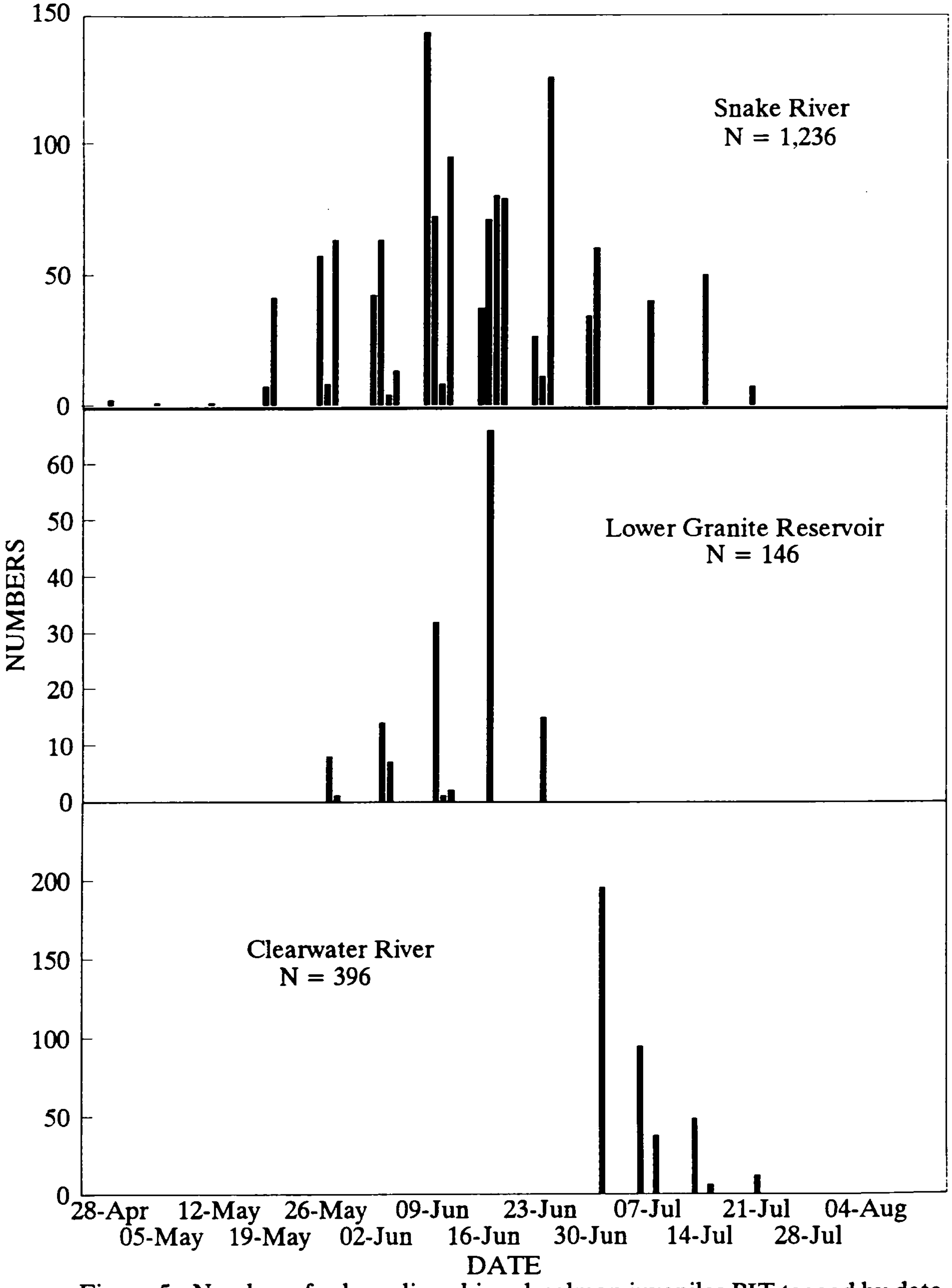

Figure 5.- Number of subyearling chinook salmon juveniles PIT tagged by date in the Snake River, Lower Granite Reservoir, and the Clearwater River, 1993.

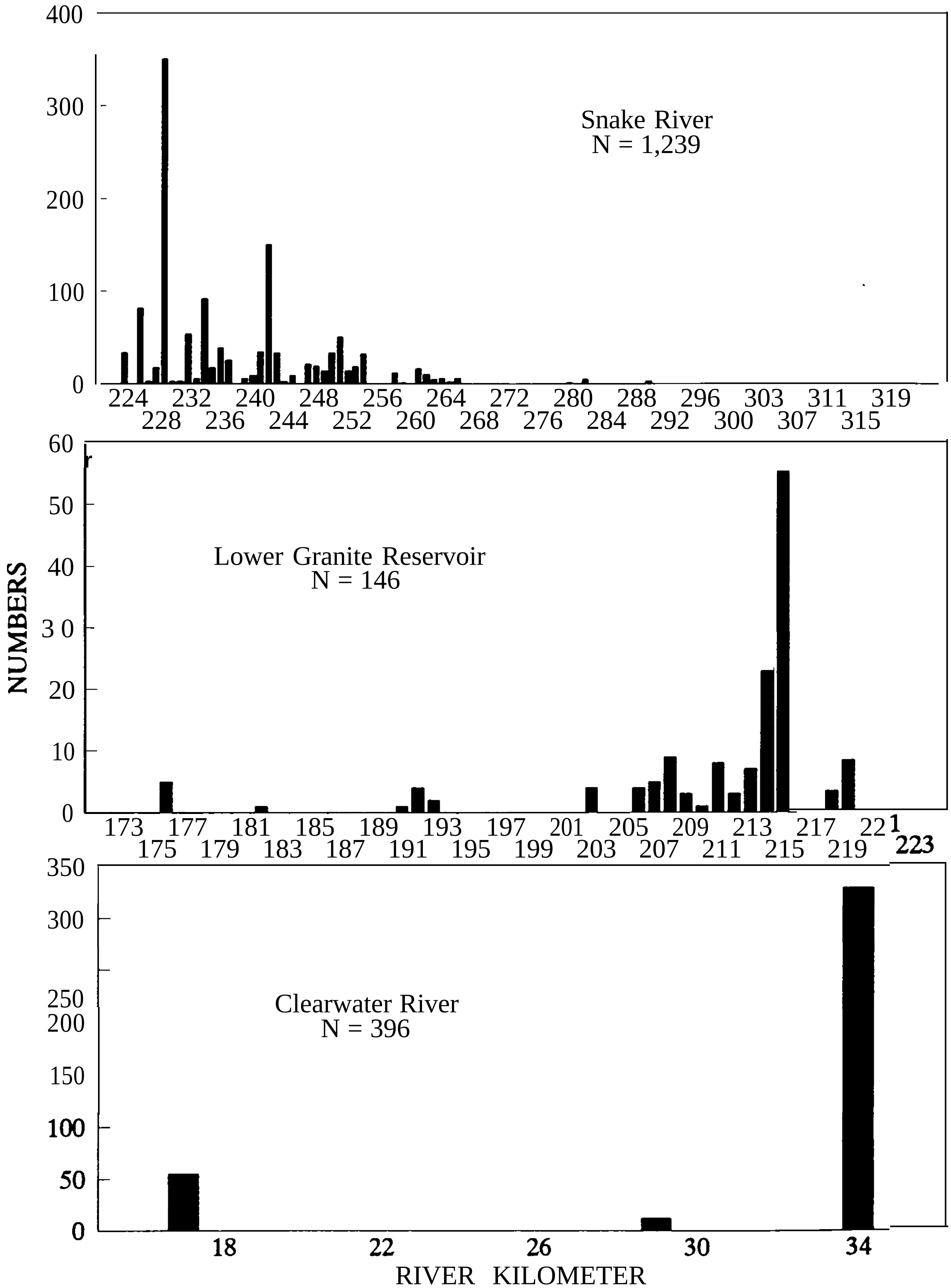

Figure 6.- Number of subyearling chinook salmon juveniles PIT tagged by river kilometer the Snake River, Lower Granite Reservoir, and Clearwater River, 1993.

A total of 268 PIT-tagged subyearling chinook salmon were detected at Lower Granite Dam, of which 124 were diverted and collected. Of the 124 fish collected, 116 were PIT tagged in the Snake River, 5 were tagged in Lower Granite Reservoir, and 3 were from the Clearwater River (Table 3). Electrophoresis validated 67 (57.8%) of the 116 fish from the Snake River sample as spring/summer chinook salmon and the remaining 49 (42.2%) as fall chinook salmon. Spring/summer chinook salmon dominated the electrophoretic samples from Lower Granite Reservoir (60%, 3 fish) and Clearwater River (67%, 2 fish).

PIT tagging of both fall and spring/summer chinook salmon on the Snake River began the third week of May (Table 3). The median dates of PIT tagging occurred during the second week of June for both fall and spring/summer chinook salmon. The last eiectrophoretically validated fall chinook salmon was tagged on 14 July, 15 d after the last validated spring/summer chinook. Average release fork length of fall, spring/summer, and chinook salmon of mixed race averaged 74, 78, and 76 mm, respectively. The fork length when detected at Lower Granite Dam averaged 126 and 122 mm for fall and spring/summer chinook salmon and their growth rates were 1.4 and 1.3 mm/d, respectively (Table 3). Fall chinook salmon emigrated at a rate of 2.1 km/d, spring/summer chinook salmon averaged 2.5 km/d, and chinook of mixed race traveled 2.0 km/d. There were no statistically significant differences between any of the variables tested when compared between race. The similarities in the parameters described above, combined with the complete overlap of fall and spring/summer chinook salmon fork length by date (Figure 7), precluded the determination of the race of any fish in the mixed race sample.

Emergence and Rearing

The emergence of fall chinook salmon in the Snake River was estimated to occur from 16 March to 5 June with a median date of 17 May and estimated peak occurring on 23 May (Figure 8). Mean weekly CPUE of fall chinook salmon ranged from 0.0 to 5.4 from 4 April to 18 July and peaked (5.4) during the week of 13 June (Figure 9) . Mean CPUE dropped quickly after the peak and remained low throughout the remainder of the sampling season. The 1993 mean CPUE of fall chinook salmon varied by RK with the low (0.3) occurring at RK 251 and the high (3.0) occurring at RK 229 [Figure 10). The overall 1993 mean CPUE was 1.2.

Table 3.-Statistics on subyearling chinook salmon juveniles that were PIT tagged in the Snake River, Lower Granite Reservoir, and the clearwater River prior to diversion at Lower Granite Dam for mcosurcmcnt, aging, and electrophoresis, 1993. Differences in fork lengths, growth rates, and emigration rates were tested for using either ANOVA (three means) or a t-test (two means) at the 95% Level of significance. Note that there were no significantly different comparisons. Data for each fish is given in Appendix 2.

Release site	Race	N	Percent of sample by site	Release date min	Release date median	Release date max	Avcragc FL at release (mm; ± SD)	Detection date min	Detection date median	Detection date max	Average FL at detection (mm; ± SD)	Average growth rate (mm/d; ± SD)	Average emigration rate (km/d; ± SD)
Snake River	Spring/sumser	67	57.8%	18-May	08-Jun	29-Jun	78 ± 13	17-Jun	06-JUL	25-Aug	122 ± 16	1.3 ± 0.5	2.5 ± 1.6
	Fall	49	42.2%	19-May	11-Jun	14-Jul	74 ± 12	25-Jun	17-Jul	02-Sep	126 ± 19	1.4 ± 0.3	2.1 ± 0.9
	Mixed	113	N/A	3-May	15-Jun	14-Jul	76 ± 12	31-May	09-Aug	25-Oct	---	---	2.0 ± 3.0
	Total	229											
Lower Granite Reservoir	Spring/summer	3	60.0%	---	---	---	-	---	---	---	---	---	---
	Fall	2	40.0%	---	---	---	-	---	---	---	---	---	---
	Mixed	15	N/A	---	---	---	---	---	---	---	---	---	---
	Total	20											
Clearwater River	Spring/summer	2	66.7%	---	---	---	---	---	---	---	---	---	---
	Fall	1	33.3%	---	---	---	---	---	---	---	---	---	---
	Mixed	16	N/A	---	---	---	---	---	---	---	---	---	---
	Total	19											

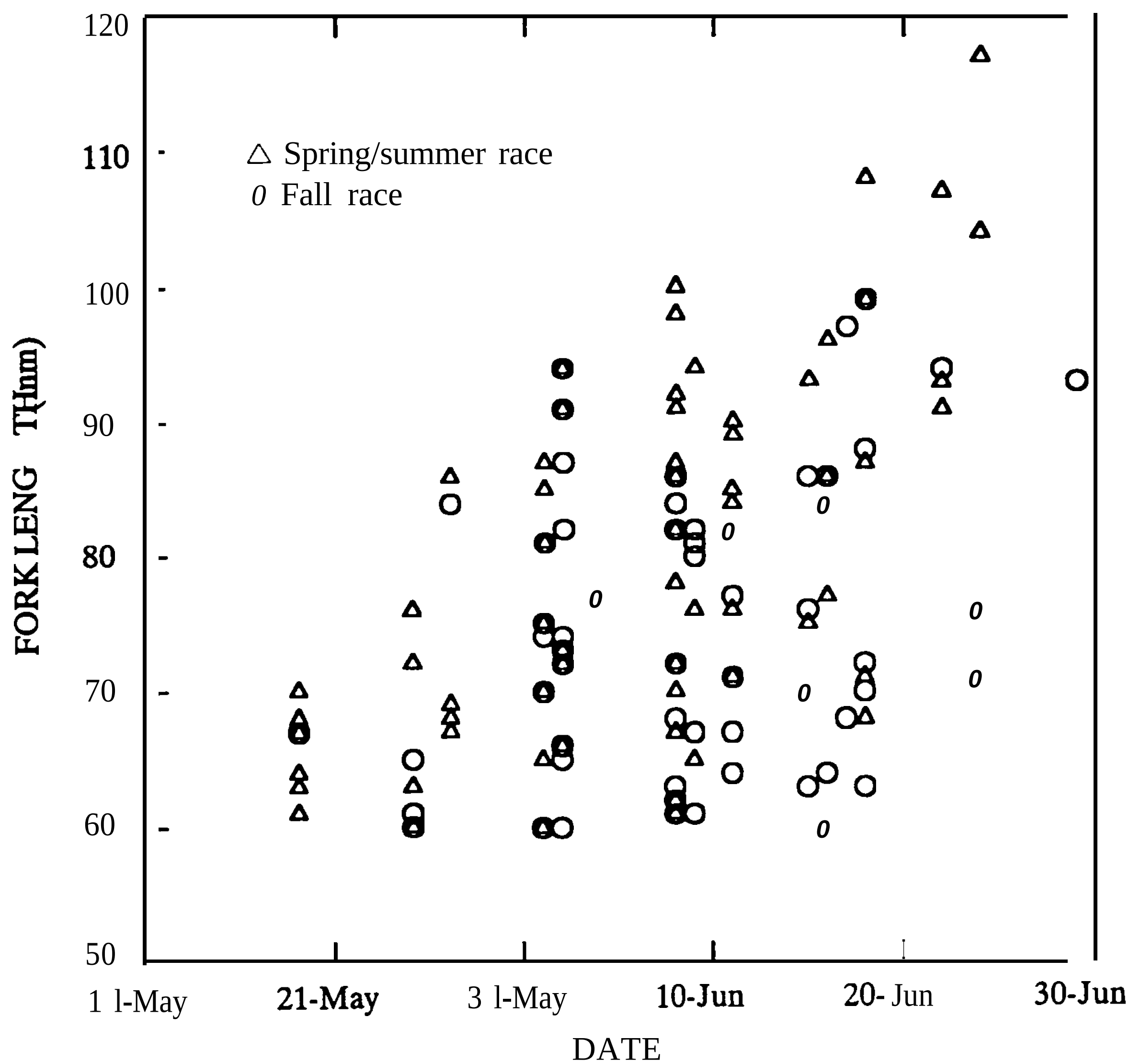

Figure 7.- Fork length of subyearling fall and spring/summer chinook salmon PIT-tagged in the Snake River, 1993.

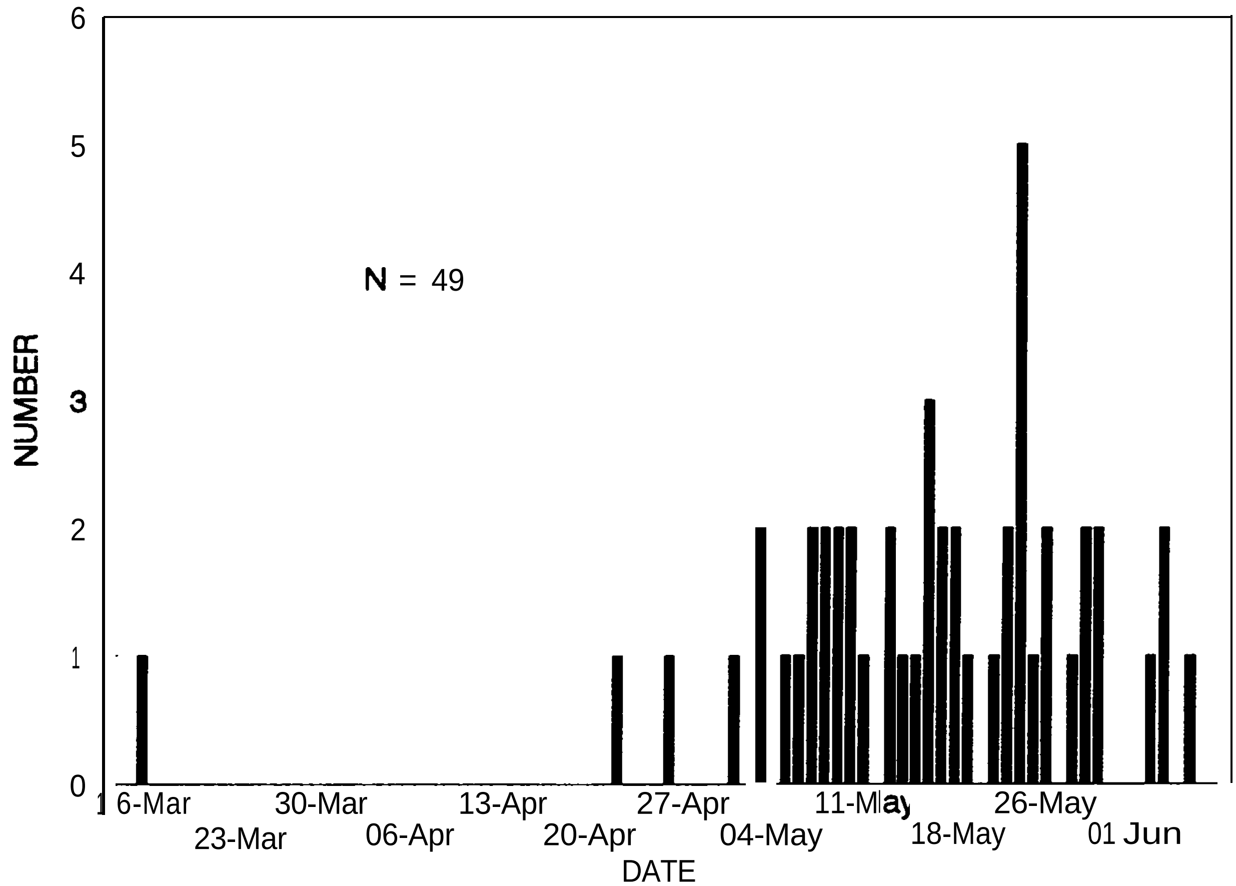

Figure 8.-Snake River fall chinook salmon emergence timing in 1993 back calculated using the release size of each fish and Individual growth rates. Only data from subyearling chinook salmon validated as fall race by electrophoresis were used.

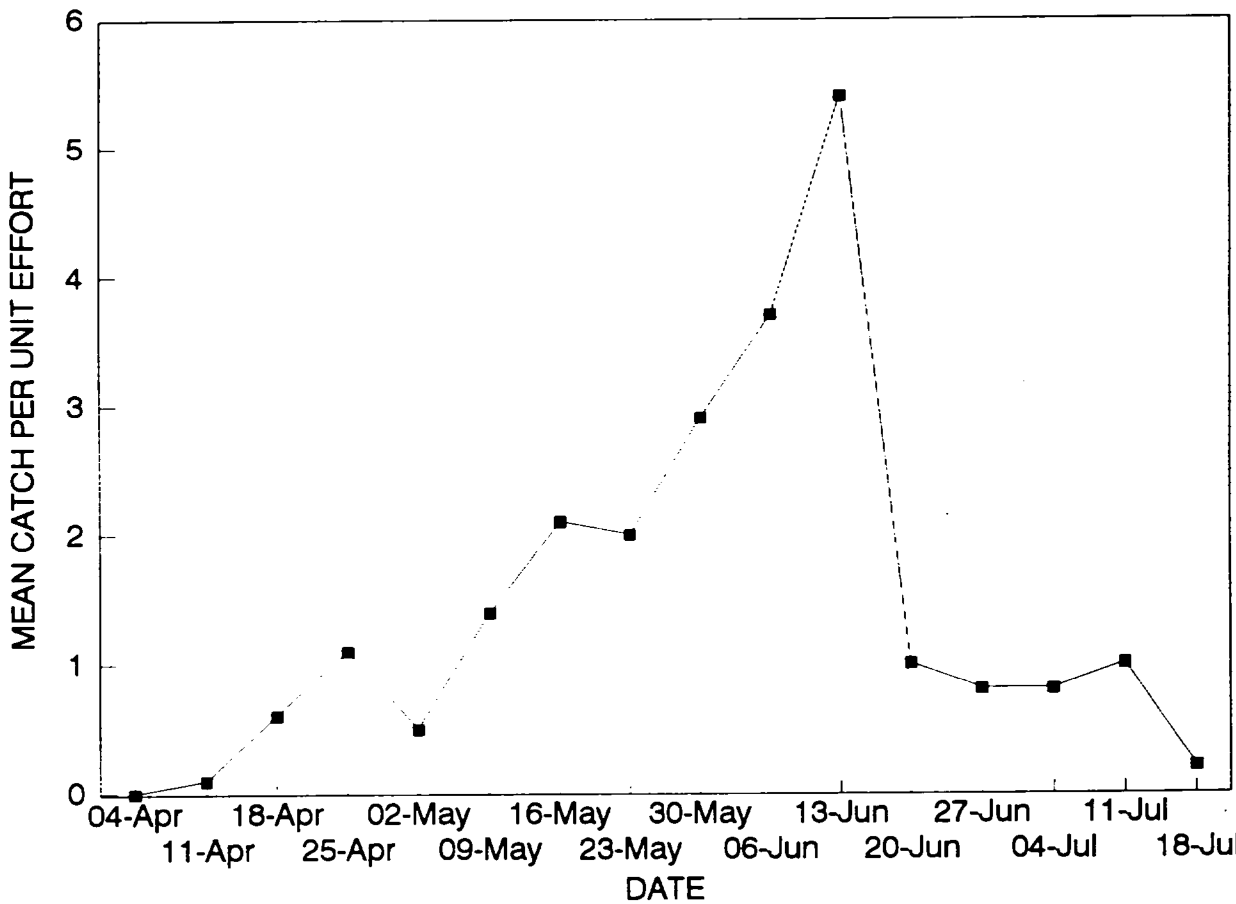

Figure 9.-Mean catch per unit effort of Snake River fall chinook salmon juveniles by sampling week, 4 April - 18 July, 1993. Only data collected below the river kilometer 251 were used.

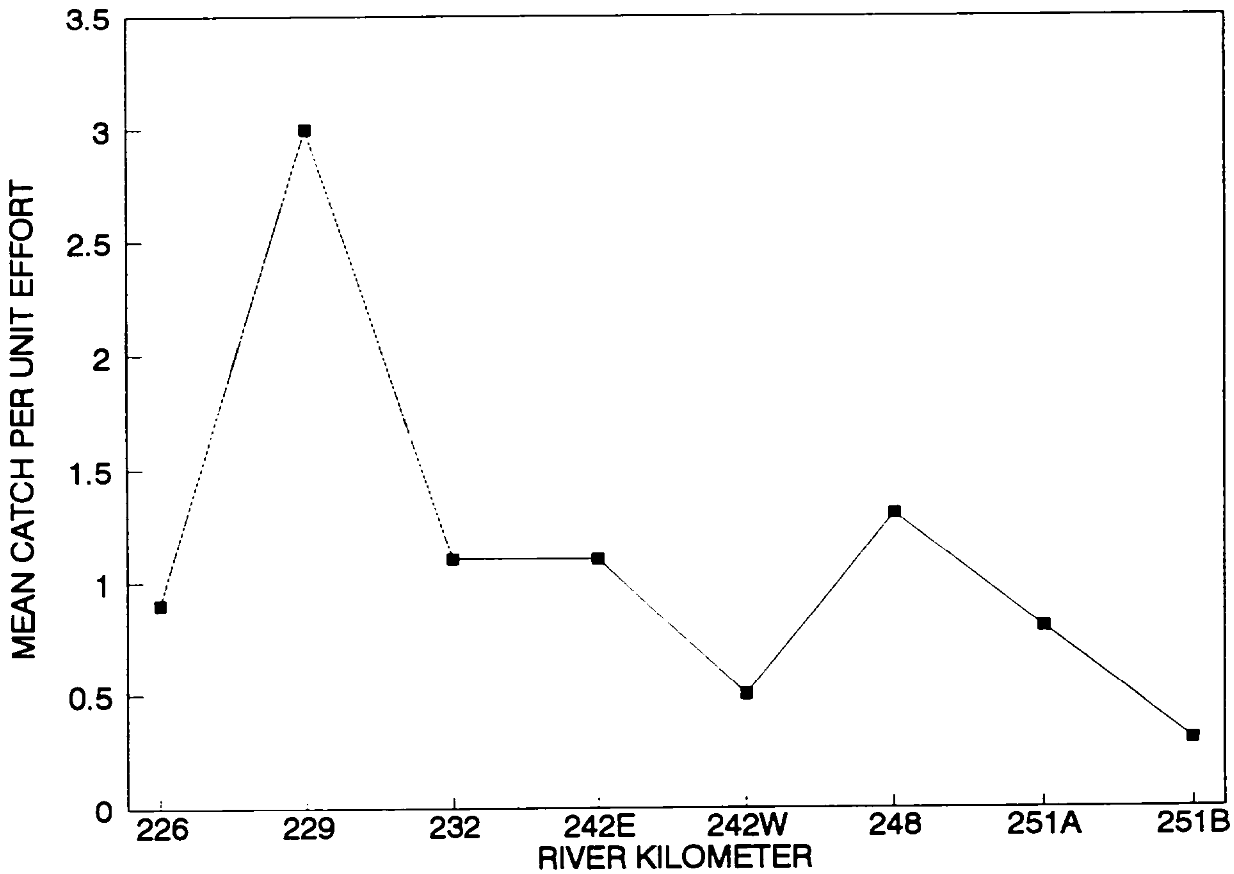

Figure 10.- Mean overall catch per unit effort of Snake River fall chinook juveniles by river kilometer, 4 April - July 18, 1993. Only data collected below the river kilometer 251 were used. There are two sites at both river kilometer 242 and 251 designated by E (East), W (West), A (East downriver) and B (East upriver).

Through combined sampling we recaptured 203 PIT-tagged subyearling chinook salmon (recapture rate = 16.4%; Table 4). The number of times an individual fish was recaptured ranged from one to five. Recapture interval ranged from less than 24 h to 56 d with the most common interval being 7 d. Twenty-five PIT-tagged subyearling chinook salmon were recaptured downstream of their original tagging site and none were recaptured upstream. Downstream movement ranged from 1 to 38 km.

Influence of Flow. Temperature and Size on Emigration Rate

The 49 known fall chinook salmon took from 13 to 81 d to arrive at Lower Granite Dam after they were last seined (average = 36 d; Figure 11). They were detected at Lower Granite Dam between and 25 June and 2 September (Figure 12). Detection of tagged fall chinook salmon at Lower Granite peaked on 20 July (N = 5) and the median date of arrival was 17 July. PIT-tagged fall chinook salmon emigrated to Lower Granite Dam at an average rate of 2.1 km/d (range = 0.7-4.3 km/d; Figure 13).

Pearson correlations (SYSTAT 1990) indicated there was collinearity between emigration flow and emigration temperature (r = -0.930; Table 5). After removing emigration temperature from the analysis, 24% of the variability in fall chinook salmon emigration rate in 1993 could be explained by release size and release temperature (Table 6). The low R^2 value in Table 6 prompted us to group the data in 5 mm FL intervals to allow better predictive ability. Pearson correlation coefficients indicated possible collinearity between emigration flow and emigration temperature, emigration flow and release size, and emigration temperature and release temperature (r = -0.974, -0.952, and 0.944; Table 7). After removing emigration flow and emigration temperature from the analysis, based on the importance of release size and release temperature from the results in Table 6, 89% of the variability in fall chinook salmon emigration rate could be explained by release temperature (Table 8).

The relation of emigration rate to the release temperature fcr 1993 was:

$$RATE = -5.019 + 0.488\ RELTEMP$$

Where: RATE = emigration rate to Lower Granite Dam (km/d) and
RELTEMP = release temperature (°C).

Table 4.- PIT-tagged subyearling chinook salmon juveniles recaptured by beach seine in the Snake River, 1993.

lag code	Times recaptured	Release			Last recapture			lime interval (d)	Distance (km)
		date	length	kilometer	date	length	kilometer		
7F7DDD7772	2	27-May	68	229	18-Jun	87	229	22	0
7F7DOE3D73	1	19-May	60	229	18-Jun	70	229	30	0
7F7DE5336	2	18-May	72	280	26-May	79	280	8	0
7F7DF6573	1	27-Hay	60	229	11-Jun	73	229	15	0
7F7DOF674C	1	19-May	62	229	25-May	64	229	6	0
7F7DOF6B0F	2	27-May	64	229	16-Jun	76	229	20	0
7F7D0F6C1E	1	01-Jun	71	229	18-Jun	87	229	17	0
7F7D0F6D21	1	19-May	62	229	14-Jul	98	226	56	3
7F7D0F7063	1	17-Jun	66	242	14-Jul	86	226	27	16
7F7D0F7328	1	19-May	62	247	08-Jun	80	247	20	0
7F7D100300	3	19-mAY	60	229	18-Jun	79	229	30	0
7F7D1E603A	1	11-Jun	67	224	18-Jun	73	224	7	0
7F7D1E696B	1	11-Jun	72	229	22-Jun	81	229	11	0
7F7D1E696C	1	16-jUN	61	232	22-Jun	68	232	6	0
7F7D1E6A35	1	11-Jun	60	229	18-Jun	63	229	7	0
7F7D1E6F48	1	11-Jun	60	229	18-Jun	67	229	7	0
7F7D247403	1	11-Jun	70	229	18-Jun	74	229	7	0
7F7D280A57	2	17-Jun	74	242	07-Jul	92	242	20	0
7F7D312E28	1	09-Jun	66	251	16-Jul	--	251	7	0
7F7D312E41	1	16-Jun	60	229	18-Jun	61	229	2	0
7F7D312F3E	1	15-Jun	87	261	29-Jun	97	251	14	10
7F7D314165	2	19-May	69	229	11-Jun	92	229	23	0
7F7D336966	2	09-Jun	81	251	29-Jun	94	251	20	0
7F7D34094A	1	02-Jun	64	229	16-Jun	71	229	14	0
7F7D340865	1	02-Jun	68	232	22-Jun	78	232	20	0
7F7D340875	1	25-May	70	229	27-May	72	229	2	0
7F7D340C38	1	09-Jun	63	229	11-Jun	65	229	2	0
7F7D340D08	1	01-Jun	76	229	11-Jun	87	229	10	0
7F7D34131A	2	27-May	61	234	08-Jun	68	234	12	0
7F7D341847	2	02-Jun	69	229	16-Jun	78	229	14	0
7F7D341D1B	2	01-Jun	87	229	22-Jun	110	229	21	0
7F7D342204	2	25-May	60	229	09-Jun	73	229	15	0
7F7D342311	1	25-May	79	229	09-Jun	102	229	15	0
7F7D34245A	1	09-Jun	67	229	16-Jun	68	229	7	0
7F7D342940	1	25-May	67	234	08-Jun	78	234	14	0
7F7D342B79	1	28-Apr	60	248	04-May	64	248	6	0
7F7D342C7B	1	25-May	66	234	27-May	67	234	2	0
7F7D347719	1	30-Jun	90	249	07-Jul	95	242	7	7
7F7D35324A	2	11-Jun	60	229	18-Jun	65	229	7	0
7F7D357C33	1	25-May	70	226	09-Jun	82	226	15	0
7F7D360735	1	25-May	61	234	27-May	62	234	2	0
7F7D36134D	1	25-May	60	234	27-May	61	234	2	0
7F7D364F01	1	16-Jun	91	232	22-Jun	93	232	6	0
7F7D365960	1	11-Jun	67	229	18-Jun	72	229	7	0
7F7D370A2D	1	25-May	70	234	08-Jun	85	234	14	0
7F7D372F1E	1	11-Jun	62	229	18-Jun	67	229	7	0
7F7D380128	1	09-Jun	72	232	16-Jun	74	232	7	0
7F7D39203B	1	08-Jun	71	234	17-Jun	79	234	9	0
7F7D392147	1	09-Jun	71	229	16-Jun	73	229	7	0
7F7D392159	1	08-Jun	61	247	17-Jun	67	247	9	0
7F7D392271	1	02-Jun	69	226	09-Jun	72	226	7	0
7F7D392276	1	02-Jun	60	242	09-Jun	66	242	7	0
7F7D392420	2	25-May	62	229	18-Jun	82	229	24	0
7F7D39270D	1	09-Jun	73	229	16-Jun	77	229	7	0
7F7D39271B	1	09-Jun	65	229	18-Jlm	67	229	9	0
7F7D392742	1	25-May	71	229	11-Jun	91	229	17	0
7F7D392927	1	18-Jun	60	229	18-Jun	60	228	0	1
7F7D392937	1	29-Jun	87	242	20-Jul	100	242	21	0
7F7D392B7B	1	16-Jun	70	229	22-Jun	72	229	6	0
7F7D392C3D	1	01-Jun	76	229	09-Jun	87	229	8	0
7F7D392C3F	2	02-Jun	66	229	18-Jun	75	229	16	0

Table 4. (Continued).

lag code	limes recaptured	Release			Last recapture			lime interval (d)	Distance (km)
		date	length	kilometer	date	length	kilometer		
7F7D392D55	1	27-May	61	229	11-Jun	73	229	15	0
7F7D392D57	1	27-May	67	234	01-Jun	70	234	5	0
7F7D392E2E	2	09-Jun	77	229	18-Jun	79	229	9	0
7F7D392E36	2	01-Jun	62	229	16-Jun	73	229	15	0
7F7D392F3C	1	01-Jun	65	229	11-Jun	73	229	10	0
7F7D392F44	1	23-Jun	107	254	24-Jun	108	254	1	0
7F7D393120	1	09-Jun	60	229	16-Jun	62	229	7	0
7F7D393131	1	02-Jun	70	242	09-Jun	73	242	7	0
7F7D39322F	1	01-Jun	61	234	08-Jun	64	234	7	0
7F7D393234	1	27-May	67	234	08-Jun	76	234	12	0
7F7D393245	1	01-Jun	69	234	08-Jun	76	234	7	0
7F7D39334E	1	09-Jun	77	229	16-Jun	80	229	7	0
7~7~393526	1	02-Jun	64	242	09-Jun	69	242	7	0
7F7D39367D	1	08-Jun	68	242	17-Jun	76	240	9	2
7F7D393739	1	01-Jun	71	229	18-Jun	91	229	17	0
7F7D39380E	1	30-Jun	94	252	14-Jut	97	226	14	26
7~7~393876	1	27-Hay	66	234	01-Jun	68	234	5	0
7F7D39391F	2	01-Jun	60	234	17-Jun	74	234	16	0
7F7D39397A	1	09-Jun	65	229	16-Jun	68	229	7	0
7F7D393A39	1	16-Jun	74	251	29-Jun	84	251	13	0
7F7D393B28	1	15-Jun	70	264	14-Jul	104	226	29	38
7F7D393B35	1	01-Jun	60	229	18-Jun	78	229	17	D
7F7D393B43	1	25-May	64	234	27-May	65	234	2	0
7F7D393C19	1	25-May	67	229	09-Jun	86	229	15	0
7F7D393C49	2	25-May	60	229	16-Jun	80	229	22	0
7F7D393D4A	1	27-May	61	234	08-Jun	72	234	12	0
7F7D394039	2	27-May	70	237	08-Jun	80	234	12	3
7F7D394046	1	16-Jun	86	229	18-Jun	87	229	2	0
7F7D394156	3	02-Jun	71	229	18-Jun	74	229	16	0
7F7D39421C	2	09-Jun	73	229	16-Jun	78	229	7	0
7F7D39425D	2	09-Jun	62	229	18-Jun	65	229	9	0
7F7D394329	1	08-Jun	73	242	17-Jun	79	240	9	2
7F7D39436C	1	02-Jun	68	229	09-Jun	73	229	7	0
7F7D396A4D	1	09-Jun	68	229	11-Jun	73	229	2	0
7F7D396B60	2	25-May	62	229	29-Jun	84	229	35	0
7F7D396E75	1	02-Jun	67	229	09-Jun	69	229	7	0
7F7D396F74	2	09-Jun	63	229	18-Jun	67	229	9	0
7F7D397237	1	24-Jun	78	249	30-Jun	86	249	6	0
7F7D39732C	1	01-Jun	82	234	08-Jun	92	234	7	0
7F7D397337	1	09-Jun	82	229	16-Jun	82	229	7	0
7F7D397343	2	Ol-Jun	62	234	17-Jun	73	234	16	0
7F7D39736A	2	02-Jun	77	237	17-Jun	87	237	15	0
7F7D39736E	2	27-May	68	237	08-Jun	79	237	12	0
7F7D397922	1	25-May	60	234	27-May	60	234	2	0
7F7D397A36	1	27-May	66	234	08-Jun	74	234	12	0
7F7D397A61	1	29-Jun	75	242	07-Jul	81	242	8	0
7F7D397A6F	1	27-May	69	234	02-Jun	72	226	6	8
7F7D397C05	1	02-Jun	64	232	09-Jun	68	232	7	0
7F7D397C60	1	26-May	70	258	10-Jun	87	258	15	0
7F7D397D6B	1	25-May	62	234	01-Jun	64	234	7	0
7F7D397E0A	1	24-Jun	79	249	30-Jun	81	249	6	0
7F7D397E2D	1	09-Jun	68	229	16-Jun	75	229	7	0
7F7D397F4A	1	27-May	60	229	09-Jun	72	229	13	0
7F7D397F77	1	09-Jun	72	229	16-Jun	74	229	7	0
7F7D3A0049	1	01-Jun	63	229	09-Jun	68	229	8	0
7F7D3A0113	1	02-Jun	68	237	08-Jun	73	237	6	0
7F7D3A034A	2	02-Jun	63	242	07-Jul	92	242	35	0
7F7D3A0419	1	08-Jun	72	242	17-Jun	78	240	9	2
7F7D3A0438	1	18-Jun	78	229	14-Jul	94	226	26	3
7F7D3A074A	2	09-Jun	76	229	18-Jun	78	229	9	0
7F7D3A096A	1	01-Jun	76	234	08-Jun	84	234	7	0
7F7D3A0C32	2	01-Jun	62	229	22-Jun	74	229	21	0
7F7D3D6E43	1	16-Jun	74	229	18-Jun	75	229	2	0

Table 4. (Continued).

Tag code	Times recaptured	Release			Last recapture			Time interval (d)	Distance (km)
		date	length	kilometer	date	Length	kilometer		
7F7D3E026A	1	11-Jun	62	229	18-Jun	63	229	7	0
7F7D3E2A49	1	11-Jun	76	229	18-Jun	80	229	7	0
7F7D3F3111	1	09-Jun	69	232	16-Jun	72	232	7	0
7F7D3F3545	1	09-Jun	62	232	16-Jun	64	232	7	0
7F7D3F3F2B	1	16-Jun	73	229	18-Jun	73	229	2	0
7F7D3F4103	1	11-Jun	60	229	16-Jun	65	229	5	0
7F7D3F4A45	1	11-Jun	62	229	18-Jun	67	229	7	D
7F7D413D55	1	07-Jul	64	242	20-Jul	79	242	13	0
7F7D42095B	1	11-Jun	73	229	16-Jun	76	229	5	D
7F7D420A1C	1	11-Jun	61	229	18-Jun	66	229	7	D
7F7D420B03	1	16-Jun	77	229	18-Jun	80	229	2	0
7F7D420C70	1	11-Jun	63	229	18-Jun	65	229	7	0
7F7D434E26	1	09-Jun	79	251	22-Jun	95	226	13	25
7F7D44630F	1	11-Jun	74	224	18-Jun	79	224	7	0
7F7D45114B	5	19-May	60	229	18-Jun	a3	229	30	0
7F7D45136B	1	11-Jun	63	229	18-Jun	69	229	7	0
7F7D45146A	1	16-Jun	72	229	18-Jun	72	229	2	0
7F7D451515	2	02-Jun	69	229	16-Jun	84	229	14	0
7F7D451520	2	11-Jun	66	229	la-Jun	68	229	7	0
7F7D451C78	1	26-May	69	263	15-Jun	86	262	20	1
7F7D453650	1	24-Jun	96	250	30-Jun	102	250	6	0
7F7D453B41	1	16-Jun	102	229	18-Jun	103	229	2	D
7F7D453D0B	1	11-Jun	63	229	18-Jun	65	229	7	0
7F7D453E1B	1	11-Jun	72	229	18-Jun	72	229	7	0
7F7D453E26	1	08-Jun	74	243	07-Jul	93	242	29	1
7F7D453E54	1	11-Jun	74	224	18-Jun	a3	224	7	0
7F7D454076	1	11-Jun	71	224	18-Jun	75	224	7	D
7F7D45416A	2	08-Jun	75	243	20-Jul	99	242	42	1
7F7D454211	1	11-Jun	64	229	18-Jun	66	229	7	0
7F7D454266	1	08-Jun	72	243	17-Jun	75	242	9	1
7F7D454453	1	08-Jun	a3	243	17-Jun	90	242	9	1
7F7D454A15	1	11-Jun	73	229	18-Jun	76	229	7	0
7F7D454D79	1	C8-Jun	65	241	24-Jun	78	239	16	2
7F7D454F61	1	16-Jun	68	229	18-Jun	69	229	2	0
7F7D454F6E	1	11-Jun	a3	224	18-Jun	88	224	7	0
7F7D45501B	1	16-Jun	77	229	la-Jun	77	229	2	0
7F7D455153	1	16-Jun	70	229	18-Jun	70	229	2	D
7F7D45527C	1	16-Jun	62	232	18-Jun	63	229	2	3
7F7D455338	1	11-Jun	65	224	18-Jun	68	224	7	0
7F7D45535E	1	11-Jun	62	224	18-Jun	65	224	7	0
7F7D455374	2	11-Jun	65	229	29-Jun	a5	229	la	0
7F7D45544D	1	16-Jun	80	229	18-Jun	79	229	2	D
7F7D455513	1	16-Jun	79	251	29-Jun	a9	251	13	0
7F7D45562F	1	11-Jun	78	229	18-Jun	a2	229	7	D
7F7D455739	1	11-Jun	72	229	16-Jun	74	229	5	0
7F7D455A74	1	11-Jun	73	224	18-Jun	80	224	7	0
7F7D455A76	1	11-Jun	62	224	18-Jun	69	224	7	0
7F7D455B74	1	11-Jun	66	229	16-Jun	63	229	5	0
7F7D455C1E	1	11-Jun	62	229	18-Jun	65	229	7	0
7F7D455D0F	1	08-Jun	61	243	11-Jun	64	224	3	19
7F7D45755E	1	09-Jun	66	229	16-Jun	70	229	7	0
7F7D457758	1	08-Jun	a2	242	17-Jun	90	240	9	2
7F7D457847	3	27-May	64	229	18-Jun	81	229	22	D
7F7D457A3A	1	02-Jun	66	229	09-Jun	69	229	7	0
7F7D457B79	1	02-Jun	62	229	04-Jun	62	227	2	2
7F7D457D3B	1	02-Jun	62	229	16-Jul	65	229	14	0
7F7D457D3D	1	Dl-Jun	66	229	16-Jun	77	229	15	D
7F7D457D7D	1	27-May	60	234	08-Jun	70	234	12	0
7F7D457E3E	1	09-Jun	79	229	16-Jun	81	229	7	0
7F7D460129	2	02-Jun	64	229	16-Jun	71	229	14	0
7F7D460438	1	02-Jun	68	232	16-Jun	75	229	14	3
7F7D460626	1	01-Jun	63	229	11-Jun	73	229	10	D
7F7D46084C	2	01-Jun	67	229	18-Jun	78	229	17	0

Table 4. (Continued).

Tag code	limes recaptured	Release			Last recapture			Time interval (d)	Distance (km)
		date	Length	kilometer	date	Length	kilometer		
7F7D46091F	2	27-May	69	234	08-Jun	80	234	12	0
7F7D46127B	3	25-May	62	229	18-Jun	81	229	24	0
7F7D461410	1	25-May	63	229	02-Jun	69	229	a	0
7F7D461508	1	25-May	65	229	01-Jun	68	229	7	0
7F7D461611	3	25-May	62	229	la-Jun	77	229	24	0
7F7D472221	1	11-Jun	68	229	la-Jun	68	229	7	0
7F7D47297B	1	16-Jun	70	229	29-Jun	a2	229	13	0
7F7D4A222A	1	08-Jun	63	234	17-Jun	69	234	9	0
7F7D4A232A	1	02-Jun	77	251	29-Jun	103	251	27	0
7F7D4A2514	1	11-Jun	60	229	18-Jun	63	229	7	0
7F7D4A2766	1	11-Jun	68	229	la-Jun	70	229	7	0
7F7D4A2D19	1	16-Jun	75	232	22-Jun	78	232	6	0
7F7D4A3260	2	25-May	67	229	22-Jun	102	229	28	0
7F7D4A332A	1	19-May	67	229	27-May	69	229	a	0
7F7D4A380A	4	19-May	60	229	18-Jun	76	229	30	0
7F7D4A4037	1	16-Jun	68	229	la-Jun	68	229	2	0

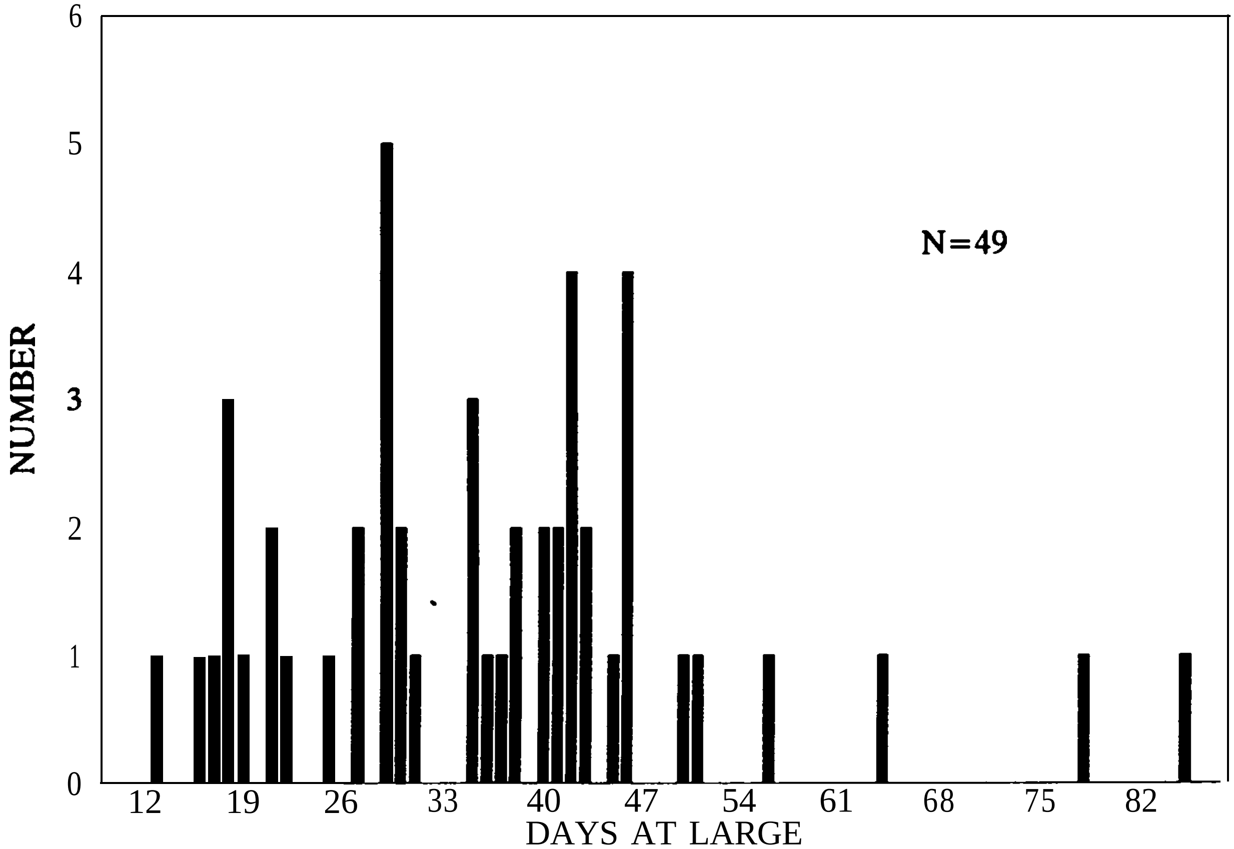

Figure **11.-** Number of days PIT-tagged Snake River fall chinook salmon were at large in 1993 before detection at Lower Granite Dam.

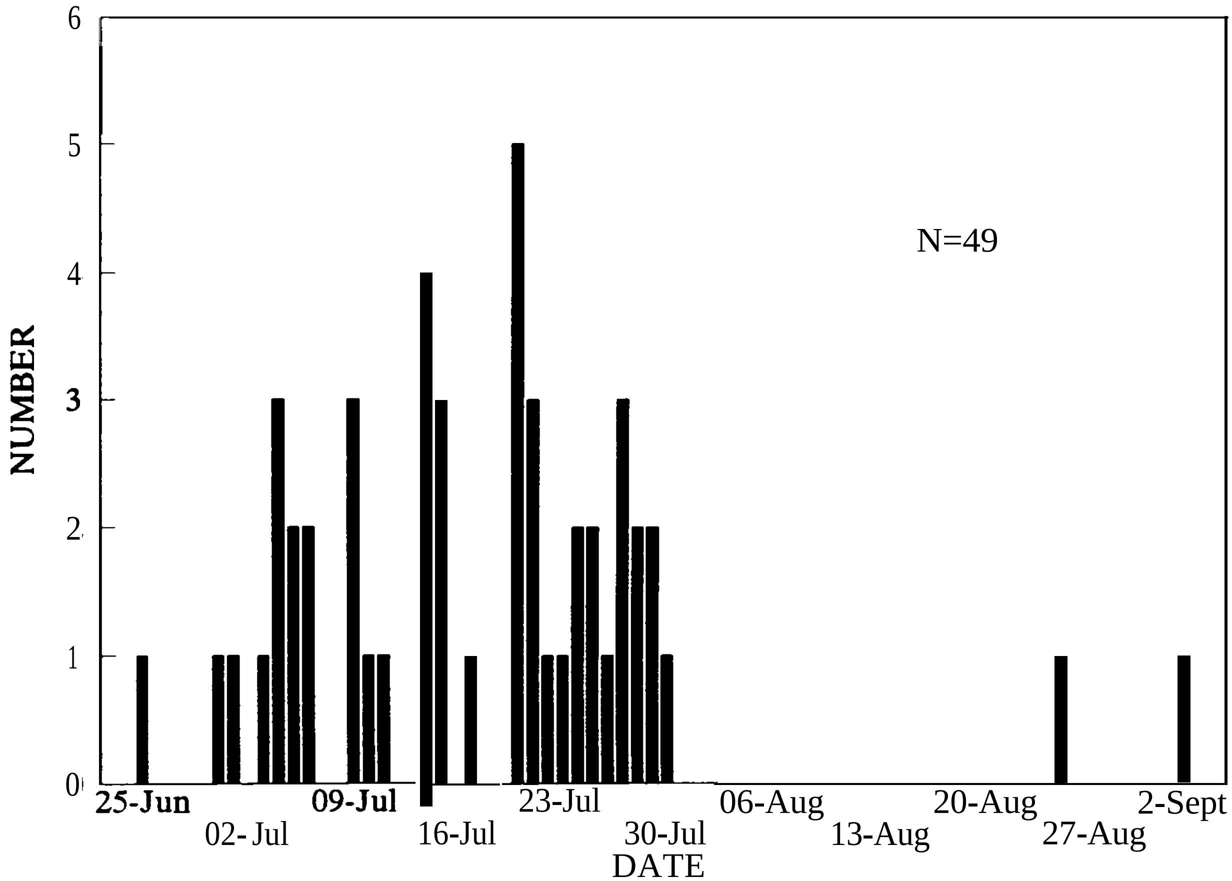

Figure 12.-PIT-tag detection numbers for fall chinook salmon juveniles released in the Snake River, 1993.

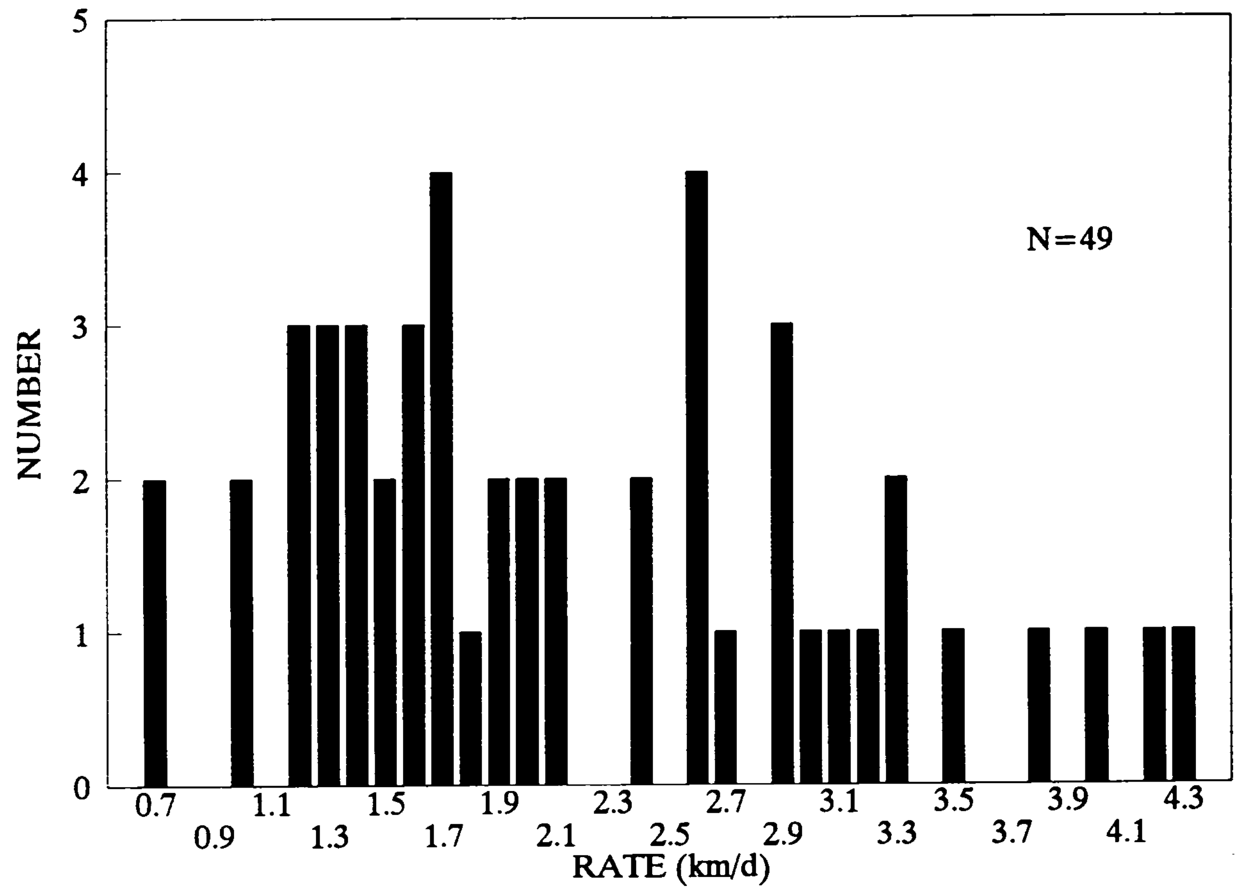

Figure 13.-Emigration rates of PIT-tagged Snake River fall chinook salmon detected at Lower Granite Dam, 1993.

Table S.-Pearson correlation matrix for the emigration rate analysis of Snake River fall chinook salmon juveniles, 1993.

	MIGRFLOW	MIGRTEMP	RELSZ	RELTEMP
MIGRFLO	1.000			
MIGRTEMP	-0.930	1.000		
RELSZ	-0.347	0.309	1.000	
RELTEMP	-0.526	0.521	0.571	1.000

Table 6.-SYSTAT multiple regression output (forward stepwise) for relation among emigration rate (MIGRRATE), release temperature (RELTEMP), and release size (RELSZ). Data were collected by PIT tagging Snake River fall chinook salmon juveniles, 1993.

DEP VAR=RATE N=49 MULTPL R=0.494 SQUARED MULTPL R=0.244
ADJUSTED SQUARED MULTPL R=.211 STD ERROR OF ESTIMATE=0.799

VARIABLE	COEF.	STD ERROR	STD COEF.	TOLERANCE	T	P(2 TAIL)
CONSTANT	-2.531	1.507	0.000		-1.679	0.100
RELSZ	0.021	0.011	0.293	0.674	1.878	0.067
RELTEMP	0.207	0.123	0.264	0.674	1.687	0.098

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	9.468	2	4.734	7.412	0.002
RESIDUAL	29.380	46	0.639		

Table 7.-Pearson correlation matrix for the emigration rate analysis of Snake River fall chinook salmon juveniles using data grouped in 5 mm FL intervals, 1993.

	MIGRFLOW	MIGRTEMP	RELSZ	RELTEMP
MIGRFLO	1.000			
MIGRTEMP	-0.974	1.000		
RELSZ	-0.660	0.562	1.000	
RELTEMP	-0.952	0.944	0.726	1.000

Table 8.-SYSTAT multiple regression output (forward stepwise) for relation among emigration rate (MIGRRATE), release temperature (RELTEMP), and release size (RELSZ). Data were collected by PIT tagging Snake River fall chinook salmon juveniles, 1993.

DEP VAR=RATE N=7 MULTPL R=0.941 SQUARED MULTPL R=0.885
ADJUSTED SQUARED MULTPL R=.862 STD ERROR OF ESTIMATE=0.190

VARIABLE	COEF.	STD ERROR	STD COEF.	TOLERANCE	T	P (2 TAIL)
CONSTANT	-5.019	1.173	0.000		-4.279	0.008
RELTEMP	0.488	0.079	0.941	1.000	6.204	0.002

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	1.396	1	1.396	38.486	0.002
RESIDUAL	0.181	5	0.036		

Discussion

Snake River fall chinook salmon fry emergence was a mid-to-late spring event from 1991-1993. Button-up fall chinook salmon fry have been present in the seine catch from late March to about the second week of June during all three years of sampling. Pre-season emergence estimates in 1991 and 1992 did not account for the entire emergence range seen in the Snake River. Therefore, in 1993, we adjusted the temperature units used in these pre-season emergence estimates to 859 CTUs. This adjusted range provided a reasonable estimate that covered the observed dates of button-up fry capture in 1993. The deviation from 962 CTUs for Snake River fall chinook salmon emergence (Arnsberg et al. 1992) may be due to undetected late spawning or spawning in tributaries (Garcia et al. in this report).

Following emergence in 1993, fall chinook salmon reared in nearshore areas of the Snake River from early March well into July with peak numbers being found in mid-June. The nearshore rearing pattern in 1993 was similar to that of 1991, but was much later than in 1992 when flows dropped sharply in May accompanied by high temperatures and an abrupt drop in CPUE. Fidelity to individual rearing areas prior to emigration was demonstrated in both 1991 and 1992. The recapture of PIT-tagged fall chinook salmon in 1991 and 1992 was about 8% and 7%, respectively. The majority were recaptured at sites where they were initially tagged. In 1993, 16.4% of PIT-tagged subyearling salmon were recaptured, mostly at their original site of tagging. The increase in the percent of fish recaptured in 1993 may be attributed to higher survival during PIT tagging procedures due to cooler temperatures during tagging. In addition, cooler water temperatures during rearing may have increased nearshore residence time or decreased mortality due to predation. At cooler water temperatures, predators such as smallmouth bass *Micropterus dolomieui* may not be **as** active and exert less predation pressure on fall chinook salmon (Curet 1993).

The arrival of fall chinook salmon at Lower Granite Dam was a mid-summer event in 1993 as it was in 1991 and 1992. The 1993 PIT-tag detection pattern for fall chinook salmon at Lower Granite Dam was bell-shaped and distributed mostly through July with a few detections in June, August, and September. This was the result of collecting most of the 124 salmon used for electrophoresis by the beginning of August. Therefore, the fall chinook salmon that were electrophoretically validated represent predominantly early to mid-season migrants. There were numerous detections of mixed race subyearling chinook salmon in August through September but the proportion of those fish that were fall chinook salmon is unknown.

Fall chinook salmon emigration rate was analyzed in 1993 using data only from the 49 known fall chinook salmon. Emigration rate (2.1 km/d) was similar to that of 1991 (2.3 km/d; Connor et al. 1993) but was slower than in 1992 (3.6 km/d; Connor et al. 1994). It is possible that the faster emigration rate in 1992 was due to the truncated detection pattern of PIT-tagged fall chinook salmon at Lower Granite Dam; the 1992 data set lacked late arriving, presumably slow migrants. However, the emigration rate of the first half of the 1991 run, calculated after adjusting for a minimum migration size of 85 mm, was still slower than the overall 1992 average. This finding was somewhat counter intuitive since the 1992 emigration rate was a product of a low flow year. However, the warmer water temperatures in 1992 may have accelerated smoltification or initiated behavioral changes that may have led to increased emigration rates.

Assuming fall chinook salmon emigration behavior evolved under decreasing summer flows when water is warming rapidly, we suggested that the fall race may have evolved to respond to major changes in the pattern of flow and temperature to survive (Connor et al. 1994). However, it remains unclear how and to what degree these variables influence migration behavior and survival. Statistical analyses of the relationships between emigration rate and environmental and biological variables have produced mixed results. The 1993 emigration rate analysis indicated that release temperature had the greatest effect on emigration rate of PIT-tagged fall chinook salmon followed closely by release size. Flow did not appear to have a significant effect on emigration rate in 1993. Conversely, our 1992 analyses suggested under low flow, warm water years that augmenting summer flows to 50 KCFS at Lower Granite Dam increases fall chinook salmon emigration rate (Connor et al. 1994). The low numbers of fish recovered at Lower Granite Dam, unknown fish guidance efficiencies (FGEs), and untested assumptions regarding rearing and emigration act to increase the variability surrounding emigration rate estimates. Collecting additional data under a wider range of environmental conditions may increase the precision of emigration rate estimates and further clarify the relation between fall chinook salmon survival, flow, and temperature.

In summary, we seined 2,396 subyearling chinook salmon in the Snake River, 277 in Lower Granite Reservoir, and 554 in the Clearwater River in 1993. We PIT tagged and released 1,236, 146, and 396 of the above fish in each respective location. We chose to analyze only fall chinook data from the Snake River in this report. Only 42% of the subyearlings tagged in the Snake River and collected at Lower Granite Dam were fall chinook salmon based on electrophoresis. Estimated fall chinook salmon fry emergence ranged from 16 March to 5 June with a 23 May peak. Weekly CPUE of fall chinook averaged 1.2 (range 0.0-5.4) and peaked on 13 June. We tagged fall chinook salmon in the Snake River from 28 April through 21 July with a 9 May peak. About 16.4% of all tagged subyearling chinook salmon were recaptured by beach seine; most at the original site of tagging. Mean emigration rate from release sites in the Snake River to Lower Granite Dam was 2.1 km/d with a 20 July peak passage date and 17 July median passage date. Using multilinear regression we estimated that emigration rate was significantly influenced by release temperature and fish size. It is important to realize that the low population level of Snake River fall chinook salmon dictated small sample sizes for analyses. These preliminary analyses and interpretations will be refined with the collection of additional data in the future.

References

Abbersold, T.D., G.A. Winans, D.J. Tel, G.B. Milner, and F.N. Utter. 1987. Manual for starch gel electrophoresis: A method for the detection of genetic variation. National Marine Fisheries Service, Report No 61, Seattle, Washington.

Arnsberg, B.D., W.P. Connor, and E. Connor. 1992. Mainstem Clearwater River study: Assessment for salmonid spawning, incubation, and rearing. Final Report to Bonneville Power Administration, Contract DE-AI79-87-BP37474, Portland, Oregon.

Connor, W.P., H.L. Burge, and W.H. Miller. 1993. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 86-116 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River Basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Connor, W.P., H.L. Burge, and W.H. Miller. 1994. Rearing and emigration of naturally produced Snake River fall chinook salmon juveniles. Pages 92-119 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River Basin. Annual Report to Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

Curet, T.S. 1993. Habitat use, food habits, and the influence of predation on subyearling chinook salmon in Lower Granite and Little Goose Reservoirs, Washington. Master's thesis, University of Idaho, Moscow.

Fish Passage Center. 1994. Fish passage center 1993 annual report. Annual Report to Bonneville Power Administration, Contract DE-FC79-88BP38906, Portland, Oregon.

Jerald, A. 1983. Age determination. Pages 301-324 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

McCann, J.A., H.L. Burge, and W.P. Connor. 1993. Evaluation of PIT tagging subyearling chinook salmon. Pages 63-85 *in* D.W. Rondorf and W.H. Miller, editors. Identification of the spawning, rearing, and migratory requirements of fall chinook salmon in the Columbia River Basin. Annual Report to

Bonneville Power Administration, Contract DE-AI79-91BP21708, Portland, Oregon.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Final rule, April 22, 1992. Federal Register, Volume 57, Number 78.

NMFS (National Marine Fisheries Service). 1993. Biological opinion on 1993 operation of the federal Columbia River power system. United States Department of Commerce, Silver Springs, Maryland.

PIT Tag Work Group. 1993. PIT tag specification document. Pacific States Marine Fisheries Commission, Portland, Oregon.

Prentice, E.F., T.A. Flagg, and C.S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponders (PIT) tags in salmonids. American Fisheries Society Symposium 7:317-322.

Prentice, E.F., T.A. Flagg, C.S. McCutcheon, and D.F. Brastow. 1990b. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. American Fisheries Society Symposium 7:323-334.

SYSTAT. 1990. SYSTAT for DOS, version 5.02. SYSTAT Inc., Evanston, Ilinois.

NMFS (National Marine Fisheries Service). 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Final rule, April 22, 1992. Federal Register, Volume 57, Number 78.

Zar, J.H. 1984. Biostatistical analysis. Prentice Hall, Englewood Cliffs, New Jersey.

CHAPTER FOUR

Nearshore Habitat Use by Subyearling Chinook Salmon
in the Columbia and Snake Rivers

by

L.O. Key, R. Garland, and E.E. Kofoot
National Biological Survey
Northwest Biological Science Center
Columbia River Research Laboratory
Cook, Washington 98605, USA

Introduction

Currently, little published information exists on habitat requirements for subyearling fall chinook salmon *Oncorhynchus tshawytscha* rearing in the Columbia and Snake rivers. Subyearling chinook salmon have been reported in shoreline areas of the Snake (Mains and Smith 1964) and Columbia rivers (Mains and Smith 1964; Becker 1973; Dauble et al. 1980; Dauble et al. 1989) and in nearshore areas of the Columbia and Snake river reservoirs (Zimmerman and Rasmussen 1981; Bennett et al. 1990, 1991, 1993). Subyearling chinook salmon may reside along river margins where maximum growth is achieved through the interaction of food resources, velocity, and temperature (Becker 1973). The role of these variables in the dispersal, rearing, and migratory stages of subyearling chinook salmon is unknown, but needs to be determined to effectively conserve and enhance fall chinook salmon populations. Furthermore, such information is necessary to protect important rearing habitats during proposed actions to modify reservoir and riverine habitats by dredging, filling, bank stabilization, flow management, and water diversion.

This 1993 study is the continuation of the habitat study initiated in 1992 (Key et al. 1994) to identify and describe the characteristics of rearing habitats used by naturally produced subyearling chinook salmon in riverine reaches and in main-stem reservoirs.

Study Area

The 1993 study area included two reaches in the Columbia River from river kilometer (RK) 508 to RK 538 in McNary Reservoir and from RK 563 to RK 595 in the Hanford Reach (Figure 1). The Snake River was sampled between RK 227 and RK 358 (see Connor et al. in this report for map). River kilometer information was obtained from the National Oceanic and Atmospheric Administration for McNary Reservoir, from the United States Geological Survey (USGS) 7.5 minute topographic maps for the Hanford Reach, and from the U.S. Army Corps of Engineers (COE) navigation charts for the Snake River.

Methods

Methods for the collection and handling of fish captured in the Snake River are described by Connor et al. (In this report). The methods outlined in this chapter describe the procedure for site selection, capture, and handling of fish in the Columbia River reaches. Habitat variables were measured in the same manner for all reaches except where noted.

The sites selected were conducive to beach seining and represent combinations of habitat variables available to

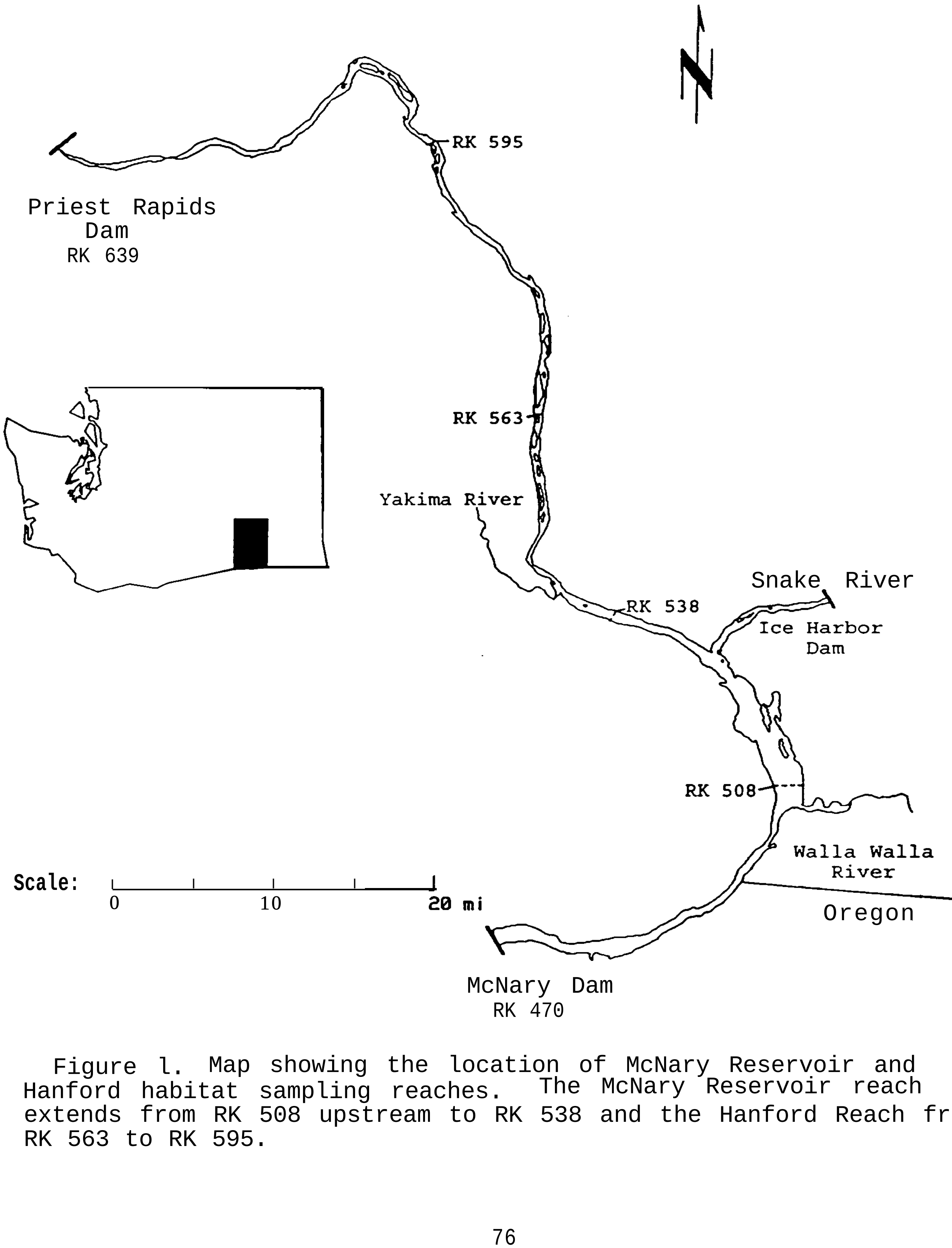

Figure l. Map showing the location of McNary Reservoir and Hanford habitat sampling reaches. The McNary Reservoir reach extends from RK 508 upstream to RK 538 and the Hanford Reach from RK 563 to RK 595.

subyearling chinook salmon. Sites were selected on both banks of the river channel and on side channels. Both linear and complex shorelines were selected in backwater and main channel areas.

All sites in McNary Reservoir (47) and the Hanford Reach (40) were identified by a stake placed above the high water mark. This ensured that the same location would be sampled throughout the season and allowed for measurement of changes in the water elevation at each site. Once all sites were selected, blocks containing six or more sites were established and the sampling order randomized within each block. A single seine haul was made at each site in McNary and Hanford reaches during each week of sampling. All sites were sampled during daylight hours. Sites in McNary and Hanford reaches were sampled from March to July.

Seining

The beach seine used in McNary Reservoir was 30.5 m x 2.4 m with 0.48 cm mesh, 2.4 m^3 bag and 15.2 m leads. A polypropylene rope was wrapped around the leadline to increase its diameter and reduce the incidence of snagging and collecting large substrate. The seine was set from the bow of a 5.5 m boat by backing 15.2 m from shore and then setting the seine parallel to the shoreline in an upstream direction. Once the net was set, both ends of the seine were pulled simultaneously to the shore by the leads. This sampled an area of about 460 m^2 at each site in McNary Reservoir. The beach seine used in the Hanford Reach was of the same design as used in McNary Reservoir except it was 22.9 m long and sampled an area of about 345 m^2.

Catch

Fish caught in each seine haul were processed immediately to minimize stress. If more than 40 subyearling chinook salmon were captured, a subsample of approximately 30 were randomly removed and processed. The subsample was anesthetized with 26 mg/L of tricaine methanesulfonate (MS-222), fork lengths (FL) measured to the nearest millimeter, and weights (W) were recorded to the nearest 0.1 g. Remaining salmonids and incidental fish caught were identified to the lowest taxonomic group possible, enumerated, and released. Based on length frequency information obtained from each week of sampling, subyearling chinook salmon were separated from yearling chinook salmon. Mean catch per unit effort (CPUE) and mean fork length of subyearling chinook salmon were computed per seine haul for each week of sampling. All hauls were used to compute means for the Columbia River reaches. Only hauls made at systematic sites below RK 252 were used to compute mean catch in the Snake River. All Snake River subyearling chinook salmon were used in computations with the exception of those individuals electrophoretically identified as spring chinook salmon by Connor et al. (In this report). Length and weight data obtained from subyearling chinook salmon were plotted and a curve fitted by the power equation, $W=aL^b$ (Ricker 1958).

Because all habitat seining activities were performed during daylight hours, a die1 study was conducted to determine if subyearling chinook salmon catch remained constant in the shoreline areas during day and night. Fifteen sites along a shoreline in Villard Slough (RK 517) in McNary Reservoir were randomly sampled. A total of 58 beach seine hauls were made over a three day period in mid May. Catch and light were analyzed to determine whether they were significantly correlated ($P \leq 0.05$). Mean catches were calculated and grouped into day and night categories, then statistically analyzed using analysis of variance and Tukey's studentized range test (SAS Institute 1988). Differences were considered statistically significant when $P \leq 0.05$.

Habitat Measures

Habitat variables that fluctuated on a daily basis were measured for each seine haul. Light and turbidity were measured before each net set. Light was measured above the water surface and 0.5 m below the water surface using an International Light 1400A light meter. Turbidity of water collected 15 cm below the surface was measured in Nephelometric Turbidity Units (NTU) with a Hach 2100P turbidity meter. After seining each site, distance from the stake to the water line was measured. The midpoint of the seine site was determined by measuring half the seine length upstream from the stake. At midpoint and 1 m from the shoreline, water temperature was measured to 0.1°C. Water velocity at the midpoint was measured 7.6 m and 15.2 m from the shoreline using a Swoffer Model 2100 or Marsh McBirney Model 2000 velocity meter. Temperature and dissolved oxygen at the midpoint were measured 15.2 m from the shoreline and at 1 m below the surface using a YSI Model 59 dissolved oxygen meter.

Thermographs were set to record water temperatures at one hour intervals in a main channel (RK 516.01, side channel (RK 512.0). and backwater area (RK 510.7) of McNary Reservoir. Thermographs were set in a main channel (RK 568.0) and backwater (RK 566.8) area of the Hanford Reach. Thermographs were set 15 m from the shoreline in approximately 2-3 m of water.

The physical characteristics of the seining sites were surveyed after completing beach seining. Depth, substrate, embeddedness, and vegetation were mapped for McNary Reservoir and Hanford Reach sites. Survey equipment was used to measure distances to points where habitat characteristics were measured within the beach seine sites. At each point the substrate was visually assessed and assigned a code according to a Wentworth classification modified from Orth (1983). Descriptions for visually evaluating substrate embeddedness were obtained from Platts et al. (1983). Aquatic vegetation was assessed for species, numbers of plants per meter, and height. Habitat and positional information for each point were entered into a spreadsheet and transferred to a raster based geographic information system (GIS). In GIS, habitat was mapped using 1 m^2 cells. Relative water elevation for each seine haul was calculated from the stake distance. Elevation was used to determine the nearest wetted row of cells which became the beginning point of the beach seine. Once the shoreline point of each beach seine haul was known, the surveyed habitat variables were estimated using the GIS record.

Results

Catch of Subyearling Chinook Salmon

During the habitat study, a total of 14,105 subyearling chinook salmon were captured in McNary Reservoir; 18,452 were caught in the Hanford Reach; and 719 were caught in the Snake River systematic sites. Subyearling chinook salmon made up 98% of the combined salmonid and incidental catch in McNary Reservoir and 96% of the combined catch in the Hanford Reach from March through July. Incidental fish caught in McNary Reservoir and the Hanford Reach are reported in Appendix 3.

A total of 159 beach seine hauls in McNary Reservoir, 103 hauls in the Hanford Reach and 330 hauls in the Snake River were made during the habitat study. Success in capturing one or more subyearling chinook salmon in a haul varied between reaches. In McNary Reservoir, we succeeded in capturing subyearlings in 69% of the hauls (109 hauls), in the Hanford Reach we succeeded in 84% of the hauls (86 hauls), and in the Snake River we succeeded in 40% of the hauls (132 hauls).

The mean weekly CPUE of subyearling chinook salmon in McNary Reservoir, Hanford Reach, and the Snake River peaked during different sampling weeks (Figure 2; Appendix 4). The highest mean CPUE of subyearling chinook salmon (307) occurred in the Hanford Reach during the week of 26 April 1993. Catches were lower in McNary Reservoir than in the Hanford Reach early in the season and the observed CPUE peak of 264 juvenile chinook salmon occurred during the week of 24 May. Peak CPUE of 10 subyearling chinook salmon occurred during the week of 14 June in the Snake River.

Subyearling chinook salmon in the Snake River maintained the highest mean fork length beginning 26 April in comparison to Columbia River reaches (Figure 3; Appendix 5). Mean fork length

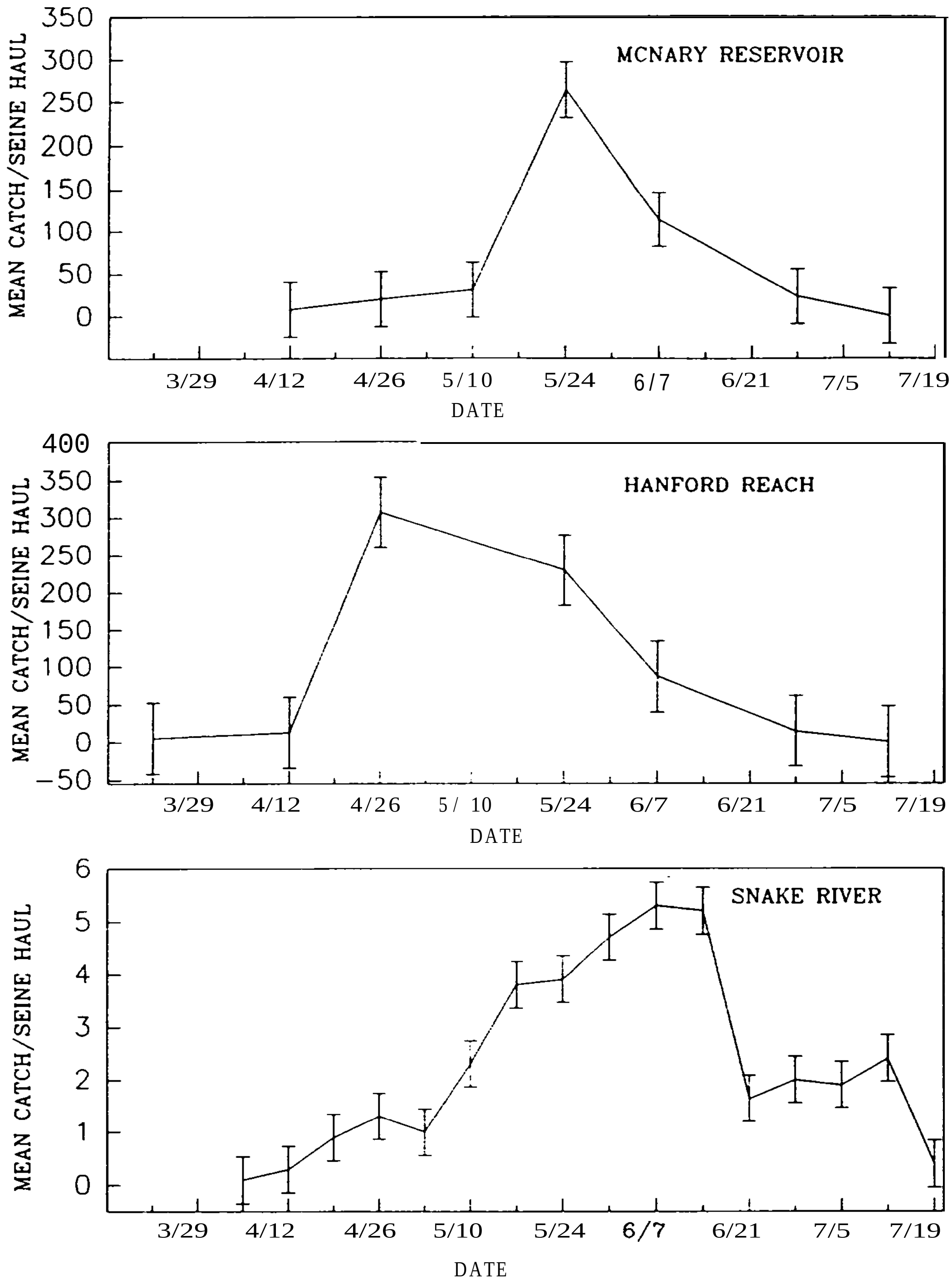

Figure 2.- Mean catch (± se) of subyearling chinook salmon caught by beach seine during one week sampling intervals in McNary Reservoir and the Hanford Reach of the Columbia River, Washington and in the Snake River, Idaho, Oregon, and Washington, 1993.

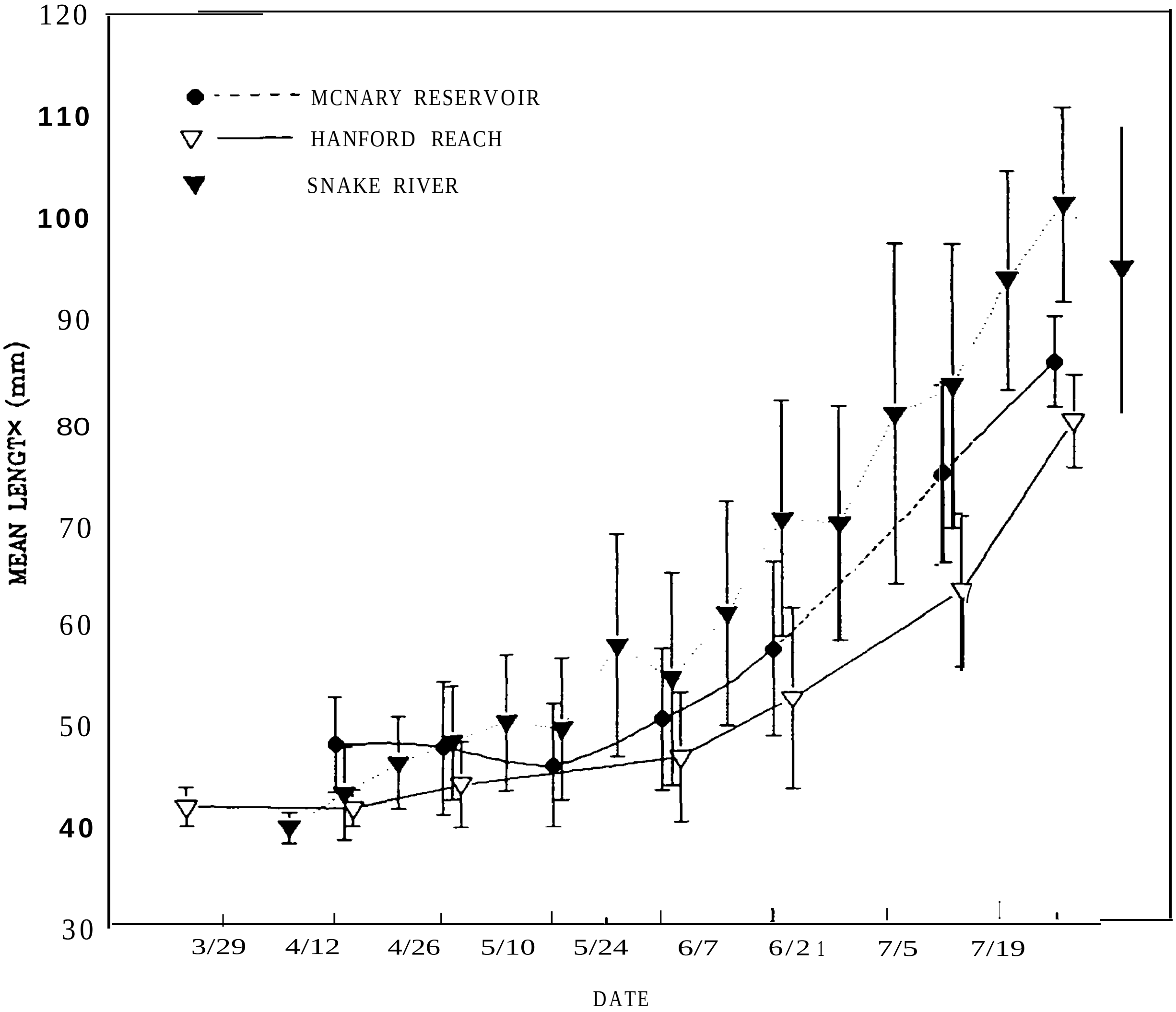

Figure 3.- Mean fork length (+ sd) of subyearling chinook salmon caught in McNary Reservoir and the Hanford Reach of the Columbia River, Washington and in the Snake River, Idaho, Oregon, and Washington, 1993.

of subyearling chinook salmon in McNary Reservoir was consistently higher than mean fork length in the Hanford Reach. The length-weight curves for subyearling chinook salmon were similar for all three reaches (Figure 4).

Die1 Catch

A total of 1,602 subyearling chinook salmon were caught during the die1 study. Low numbers of subyearling chinook salmon were caught during the night (Figure 5). Catch increased immediately following sunrise (0530 hours) and decreased at sunset (2015 hours). Catch was significantly correlated with light (r = 0.59) (Figure 5). Since no significant differences were found between the morning, midday, and evening periods, the habitat data collected during these day periods were combined for analysis. We rejected the hypothesis that mean catch for night and day categories was equal.

Habitat

For each seine haul, a map was created using GIS to define strata for the habitat variables surveyed (Figure 6). Catch of subyearling chinook salmon was compared to the effort associated with various depths, velocities, temperatures, and substrates.

Most effort in McNary Reservoir was expended in shallow water sites where depth was cl.5 m at 7.6 m and <1.75 m at 15.2 m from the shoreline (Figure 7). Few subyearlings were caught insites where water depth 15.2 m from the shore was ≤ 0.25 m. Highest mean catch per seine haul was observed in sites with depths 0.5-1.25 m at 7.6 m from the shoreline, and 0.50-1.75 m at 15.2 m from the shoreline. Highest effort was expended in low velocities (<0.10 m/s) but highest mean catch was in velocities ranging between approximately 0.15-O-25 m/s at 7.6 m and 0.25-0.40 m/s at 15 m from the shoreline (Figure 8). Daily temperature fluctuations measured by thermograph in nearshore areas had a range of 1.5°C (Figure 9). Highest mean catch per seine haul occurred at temperatures between 15.0-18.9°C at 1 m and between 12.0-14.9°C at 15.2 m from the shore (Figure 10). No subyearling chinook salmon were caught when temperatures exceeded 21.9°C at 1 m from the shoreline or 19.8°C at 15.2 m from the shoreline. Catch of subyearling chinook salmon was not related to percent of fine substrate (Figure 11).

In the Hanford Reach, seining effort was highest between 0.51-1.50 m depth at 7.6 m and between 1.01-2.00 m depth at 15 m from the shoreline (Figure 12). In general, the highest number cf subyearlings were caught where effort was highest and this was reflected in the mean catch per seine haul. Highest effort was expended in low velocities (<0.05 m/s) at 7.6 m and 15.2 m from shore and resulted in the highest catch of subyearling chinook

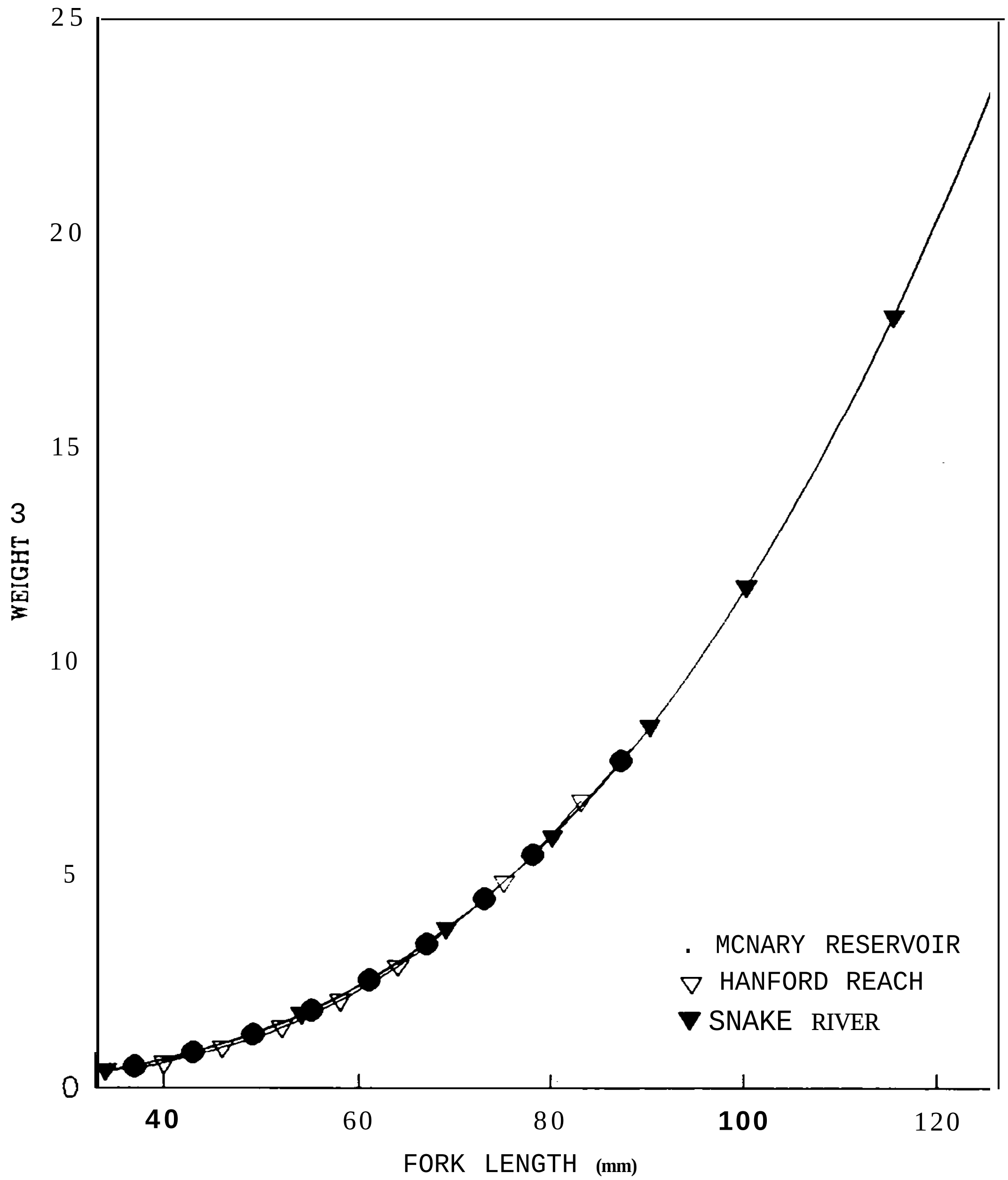

Figure 4.-Fitted curves for length and weight of all subyearling chinook salmon caught during 1993 in McNary Reservoir and the Hanford Reach in the Columbia River, Washington and in the Snake River, Idaho, Oregon, and Washington, 1993.

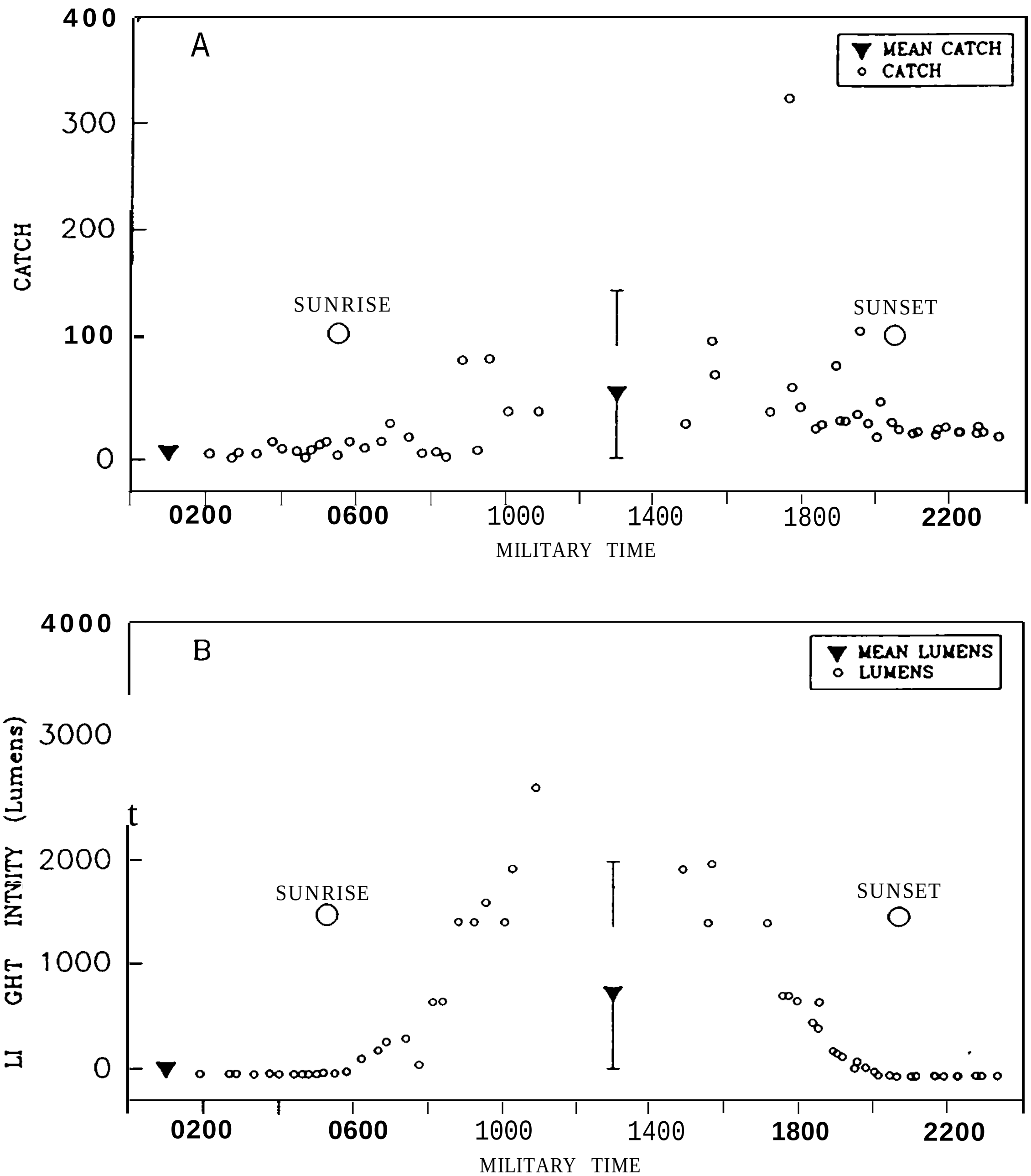

Figure 5.—Catch of subyearling chinook salmon and (B) light intensities in McNary Reservoir, 1993. The catch and light intensities were grouped into two time categories and means calculated. Means are displayed as triangles with corresponding standard deviations.

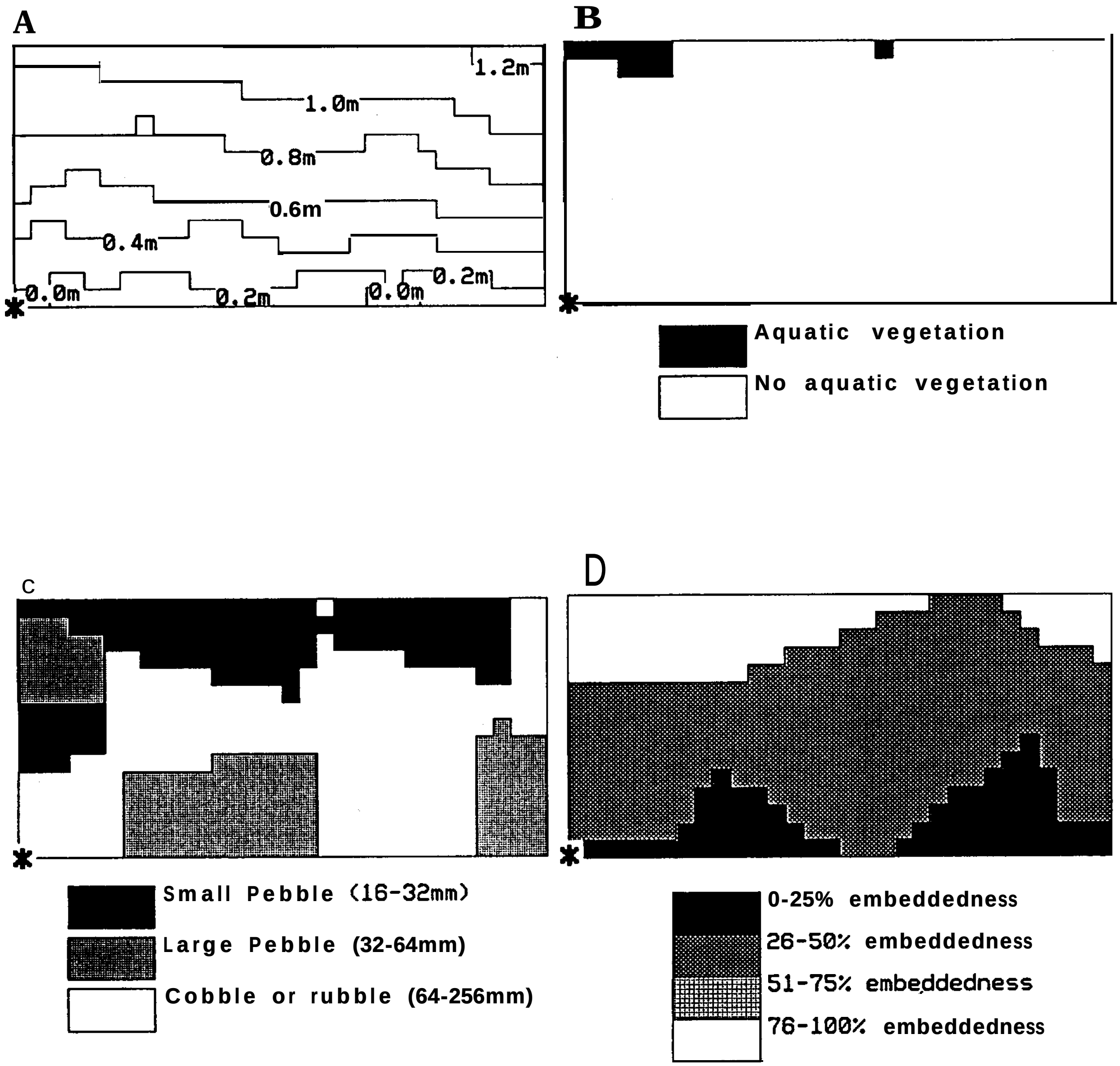

Figure 6.- Example of maps of surveyed habitat data variables (A) depth, (B) aquatic vegetation, (C) dominant substrate, and (D) embeddedness. Star (*) represents position of stake.

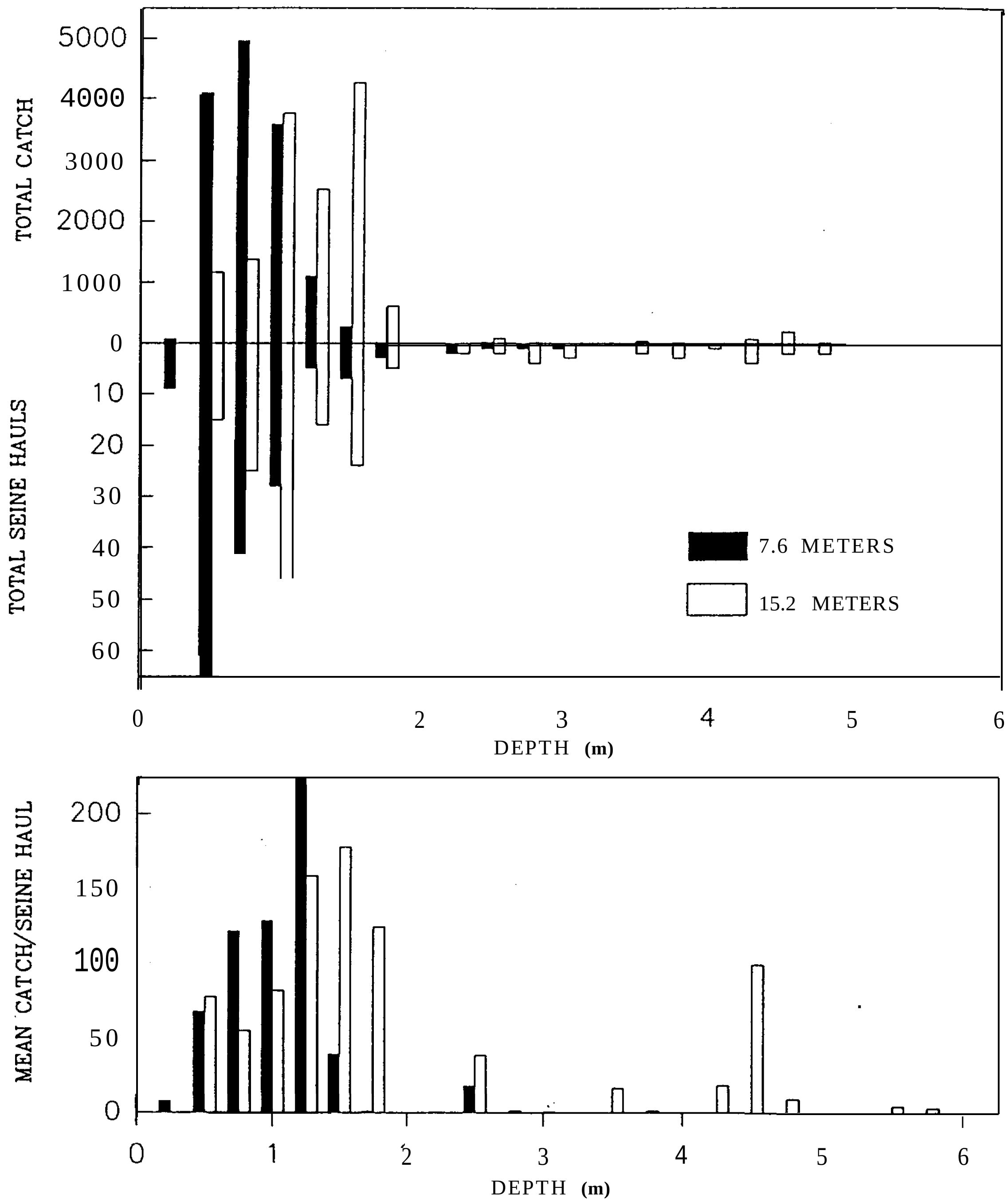

Figure 7.-Total catch, total seine hauls and mean catch/seine haul of subyearling chinook salmon. Depth was measured at 7.6 and 15.2 m from the shoreline in McNary Reservoir of the Columbia River, Washington, 1993.

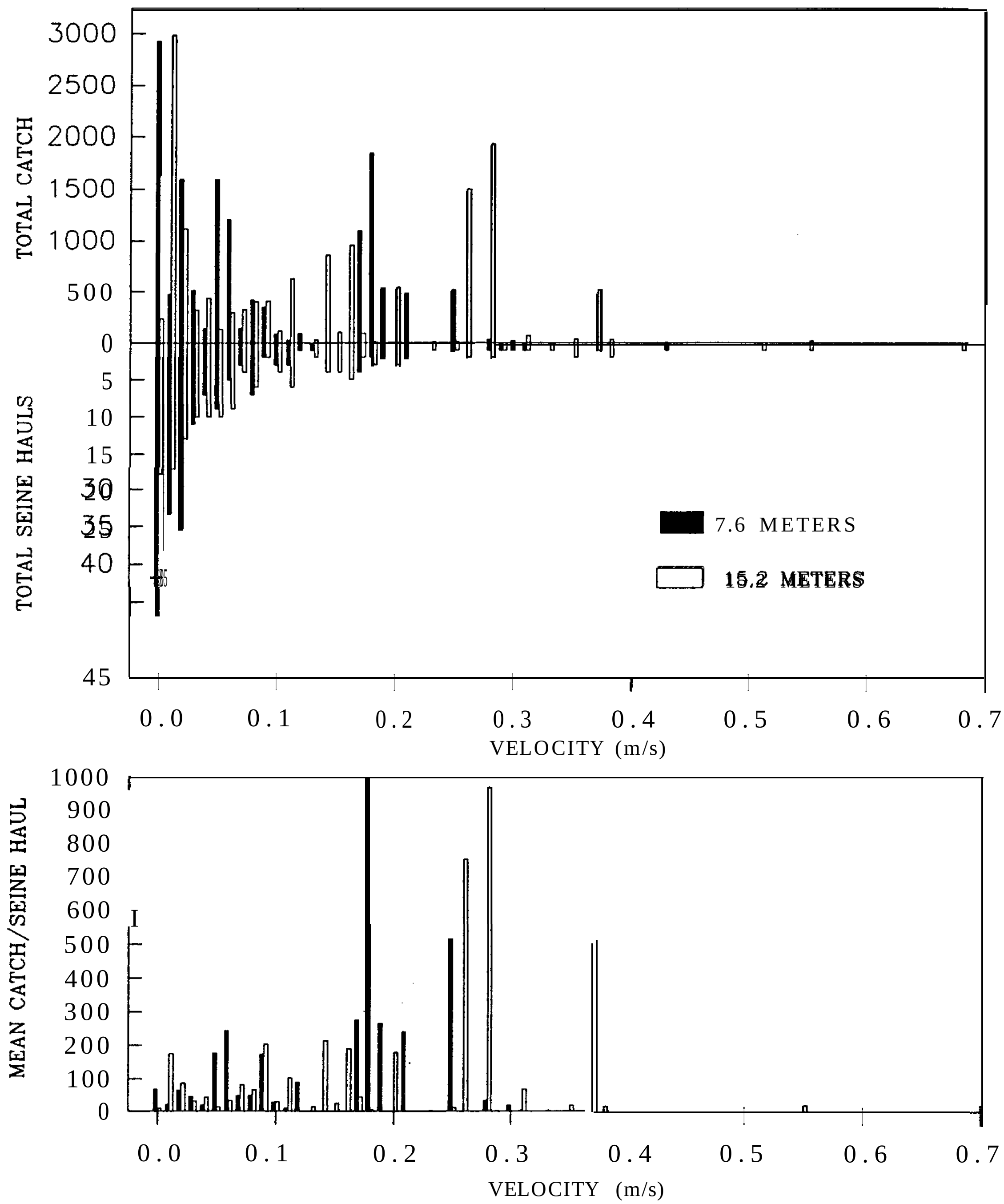

Figure a.-Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Velocity was measured at 7.6 and 15.2 m from the shoreline in McNary Reservoir of the Columbia River, Washington, 1993.

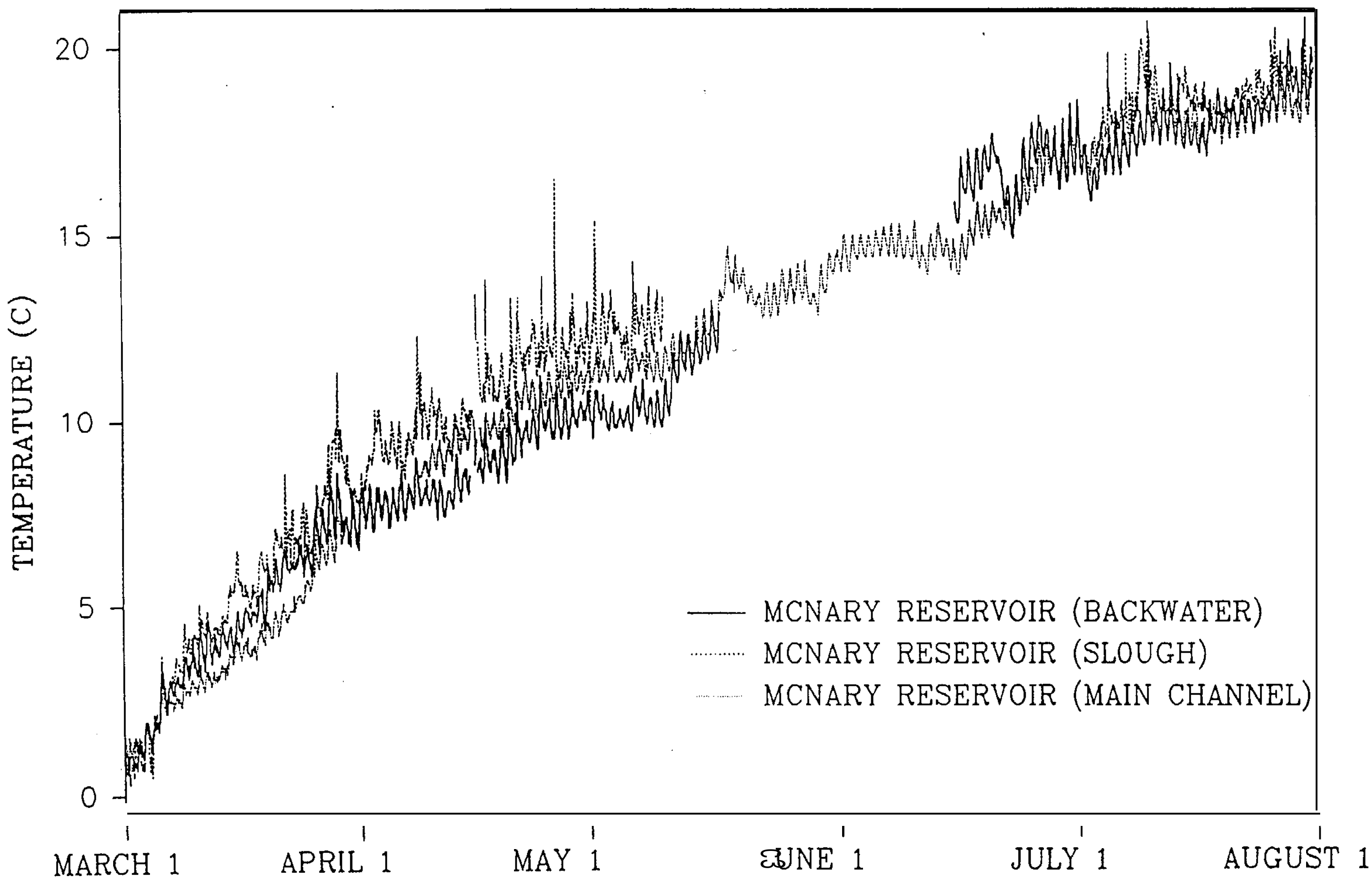

Figure 9.—Hourly temperature fluctuations measured by thermographs in nearshore areas of McNary Reservoir of the Columbia River, Washington 1993.

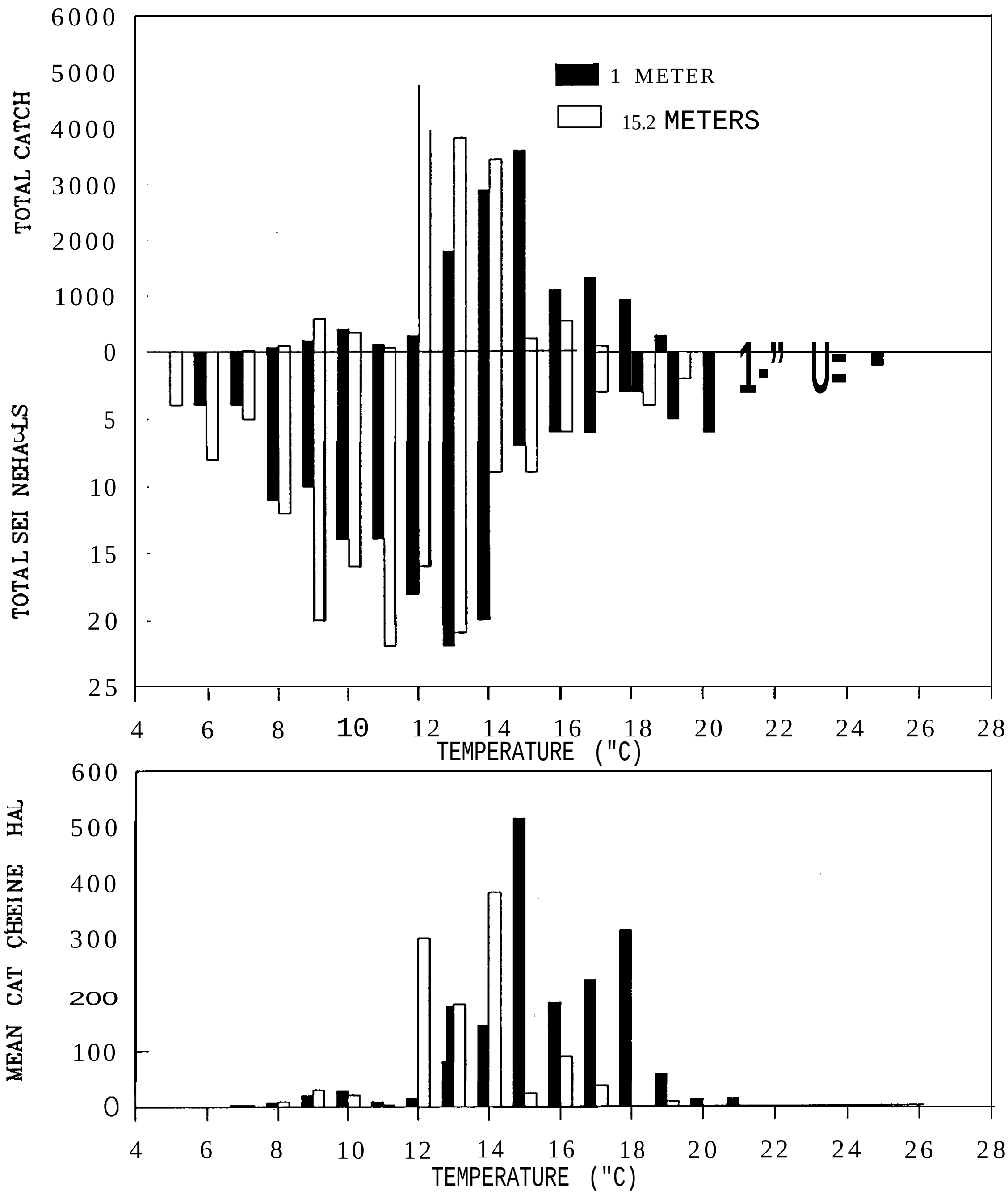

Figure 10.—Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Temperature was measured at 1 and 15.2 m from the shoreline in McNary Reservoir of the Columbia River, Washington, 1993.

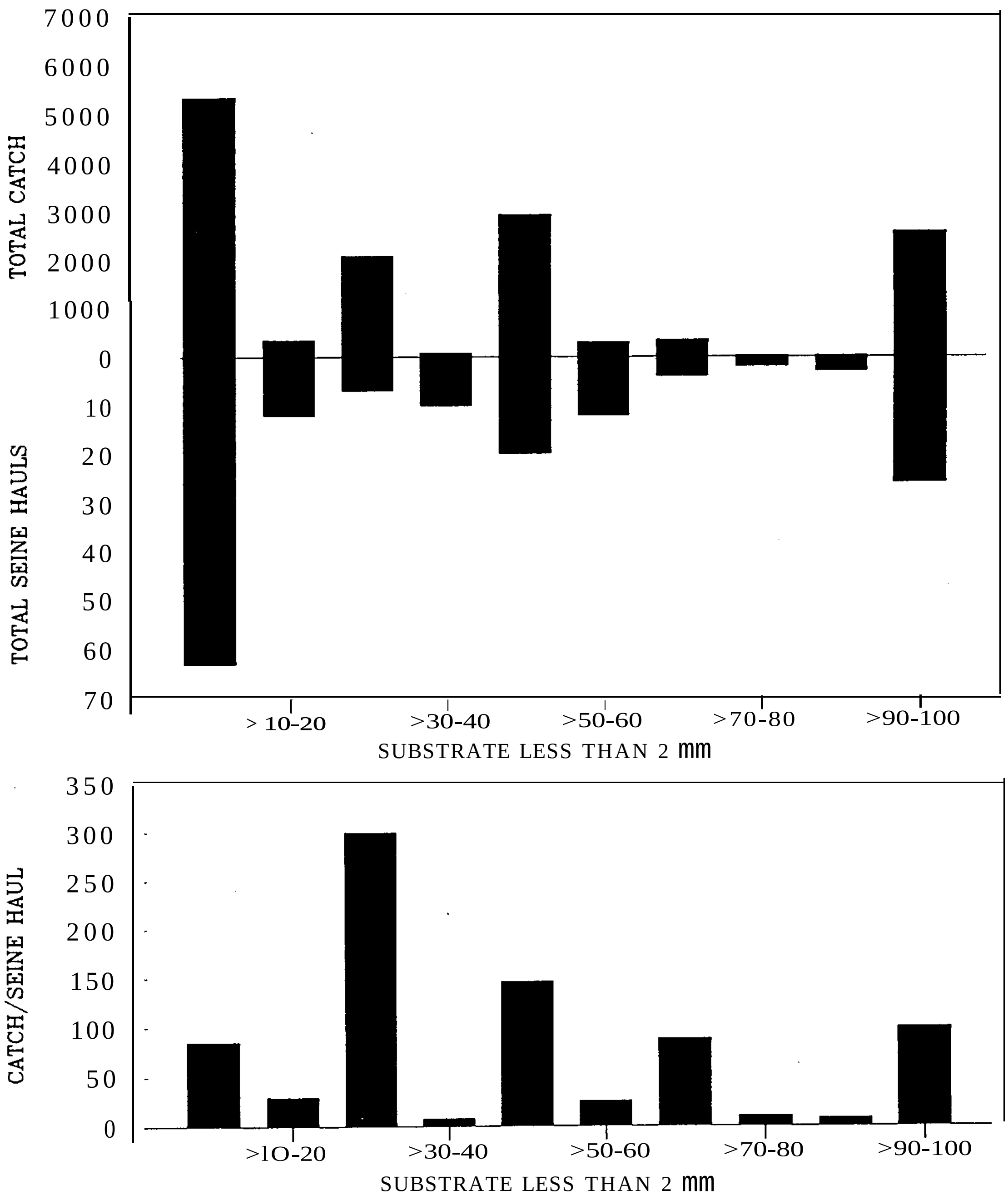

Figure ll.-Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon in McNary Reservoir of the Columbia River, Washinton, 1993. The percent area of the beach seine site was determined for each seine haul where dominant substrate was fines <2 mm in size. Areas were combined into ten percent intervals and graphed.

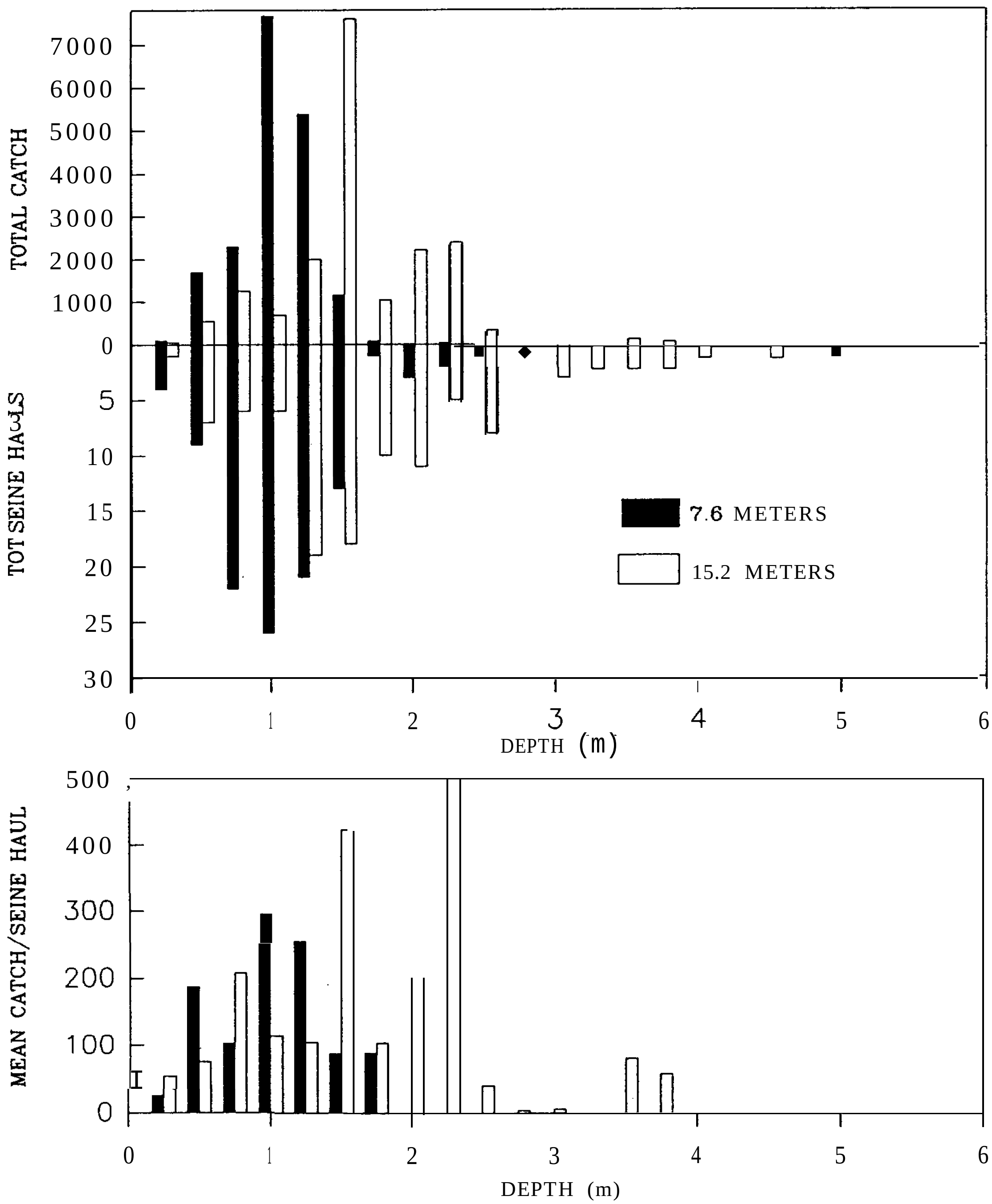

Figure 12.-Total catch, total seine hauls and mean catch/seine haul of subyearling chinook salmon. Depth was measured at 7.6 and 15.2 m from the shoreline in the Hanford Reach of the Columbia River, Washington, 1993.

salmon, excluding the effects of a single haul in which 4,681 subyearlings were caught (Figure 13). No relationship could be discerned between velocity and mean catch. Daily temperature fluctuations measured by thermograph in a nearshore area had a range of 1.5°C and were approximately a degree cooler than those from McNary Reservoir (Figure 14). Effort was highest for sites where water temperature was between 9.0-14.9°C at 1 m and between 9.0-12.9 °C at 15.2 m from shore (Figure 15). Highest mean catch per seine haul occurred at temperatures between 11.0-13.9°C at 1 m and 8.0-12.9°C at 15.2 m from shore. Subyearling chinook salmon were not caught where temperature exceeded 18.2°C at 1 m from shore and 17.0°C measured 15.2 m from shore. Most subyearling chinook salmon were caught, and greatest effort expended in sites that contained a low percent of substrate <2 mm (Figure 16) . Mean catch per seine haul did not appear related to percent of fine substrate.

In the Snake River, seining effort was highest between 0.51 m and 1.25 m depth at 7.6 m from shore and between 1.01-1.50 m at 15.2 m from shore, with no apparent trends in mean catch per seine haul (Figure 17). Effort was highest for velocities between 0.01-0.02 m/s at 7.6 m and 0.25-0.26 m/s at 15.2 m from shore but there were no apparent trends in mean catch per seine haul (Figure 18). Effort was highest for sites where water temperatures were between 11.0-11.9°C at 1 m and between lO.O-10.9°C at 15.2 m from shore (Figure 19). Highest mean catch per seine haul occurred at temperatures between 15.0-15.9°C at 1 m and 15.2 m from the shore. Subyearlings were caught at all temperatures sampled. Effort and catch was highest where the percentage of substrate <2mm was greater than 90% (Figure 20). Catch per seine haul did not reveal any relationship between fall chinook salmon abundance and the amount of sand present at sites.

Discussion

The emergence and peak mean catch per seine haul of subyearling chinook salmon in the Columbia River occurred later in 1993 than in 1992. Emergence of fry from redds in the Hanford Reach began 41 days later in 1993 than in 1992 (Carlson and Dell 1993). The peak mean catch of subyearling chinook salmon per seine haul in McNary Reservoir occurred two weeks later in 1993 than in 1992. The McNary Reservoir peak mean catch occurred four weeks later than the peak mean catch in the Hanford Reach in 1993. Inasmuch as McNary Reservoir sampling sites were about 25-55 km downstream of Hanford Reach sites, this result was not unexpected. In contrast to the Columbia River, emergence of fry in the Snake River in 1993 was similar to fry emergence patterns of 1991 and 1992 (Connor et al. in this report). However, the peak mean catch per seine haul occurred five weeks later in 1993 than in 1992.

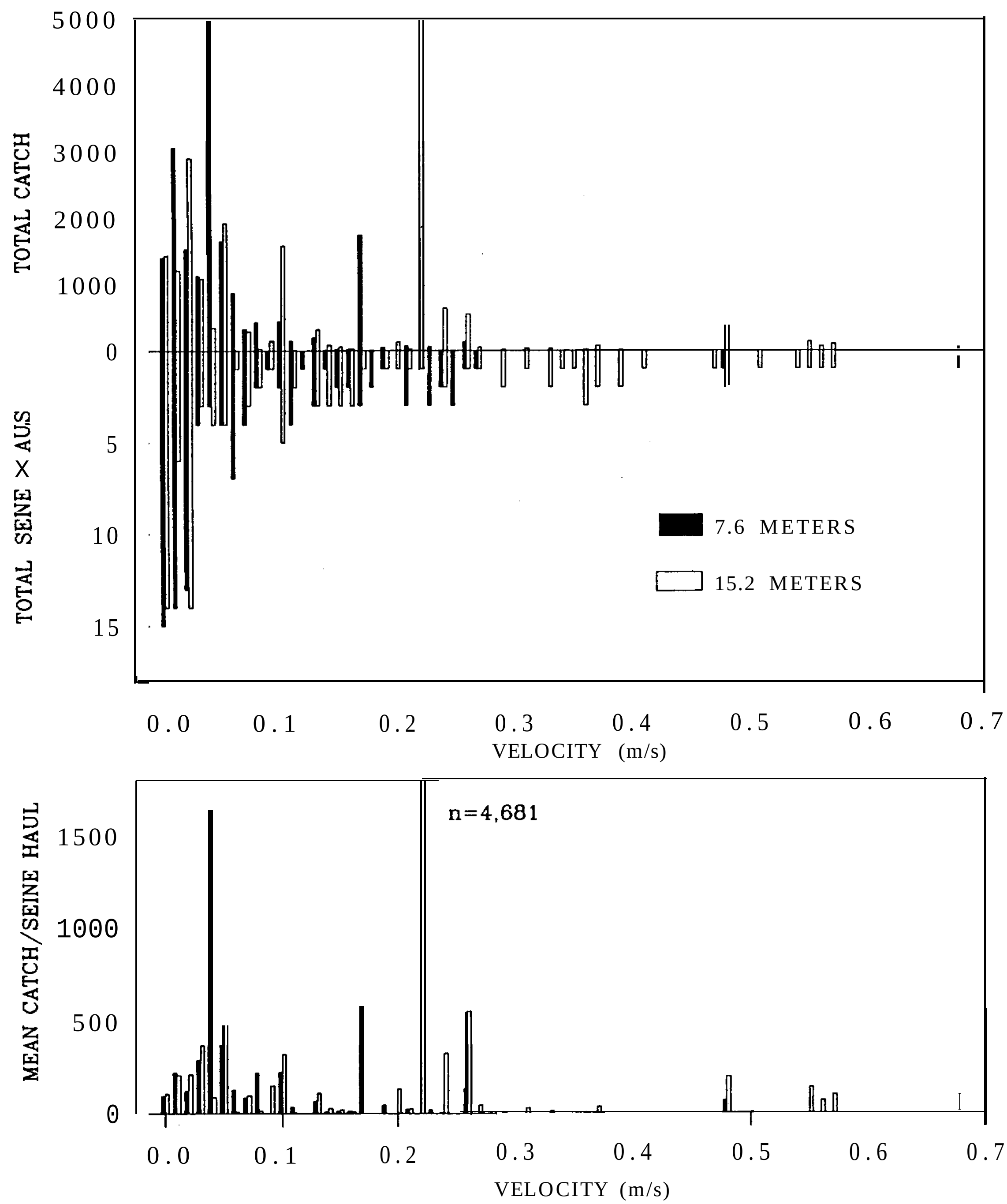

Figure 13.-Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Velocity was measured at 7.6 and 15.2 m from the shoreline in the Hanford Reach of the Columbia River, Washington, 1993.

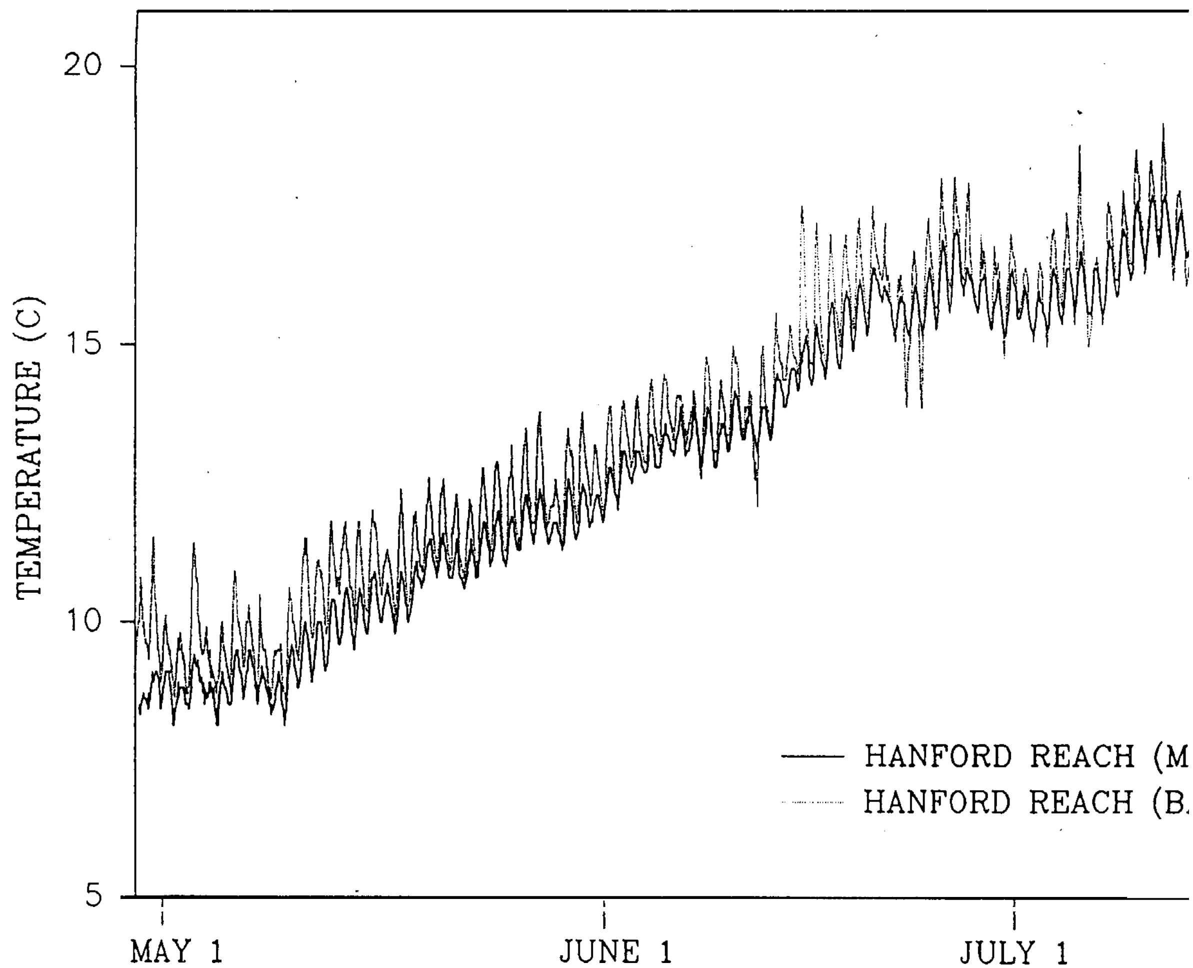

Figure 14.- Hourly temperature fluctuations measured by thermographs in nearshore areas of the Hanford Reach of the Columbia River, Washington 1993.

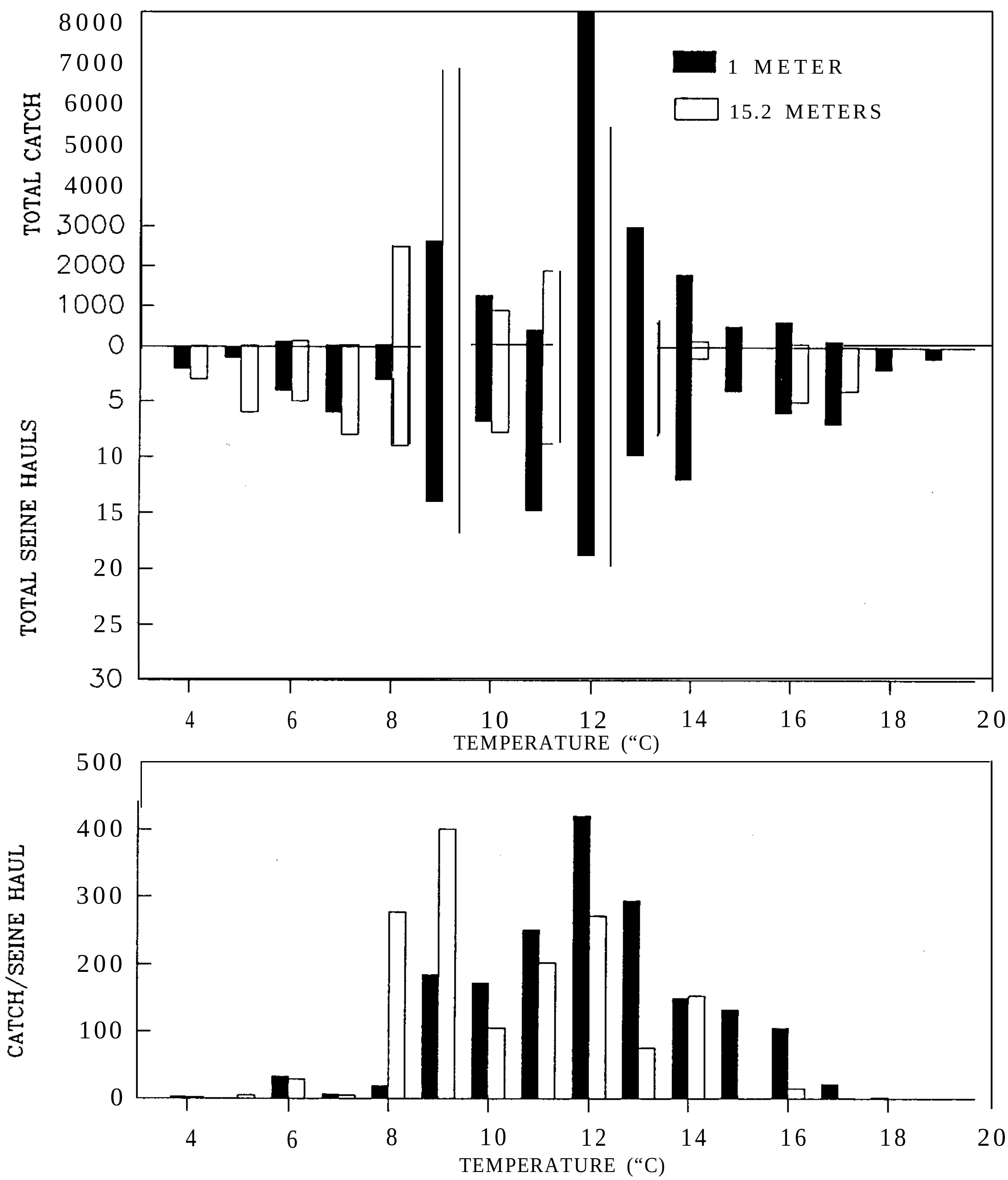

Figure 15.—Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Temperature was measured at 1 and 15.2 m from the shoreline in the Hanford Reach of the Columbia River, Washington, 1993.

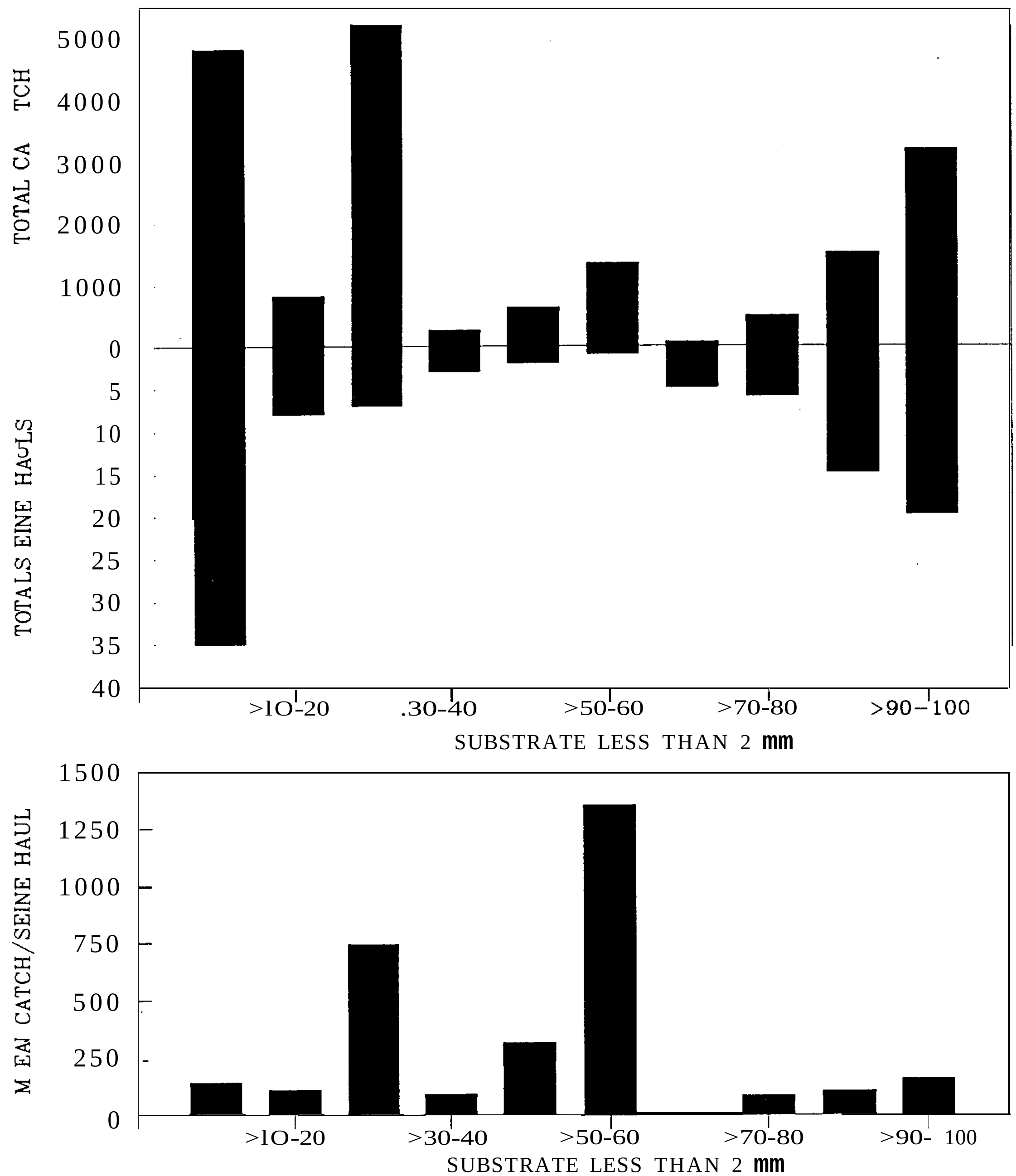

Figure 16.-Total **catch, total seine hauls, and mean** catch/seine haul of subyearling chinook salmon in the Hanford Reach of the Columbia River, Washington, 1993. The percent area of **the beach seine site was determined for each seine haul where** dominant substrate was fines <2 mm in size. Areas were combined into ten percent intervals and graphed.

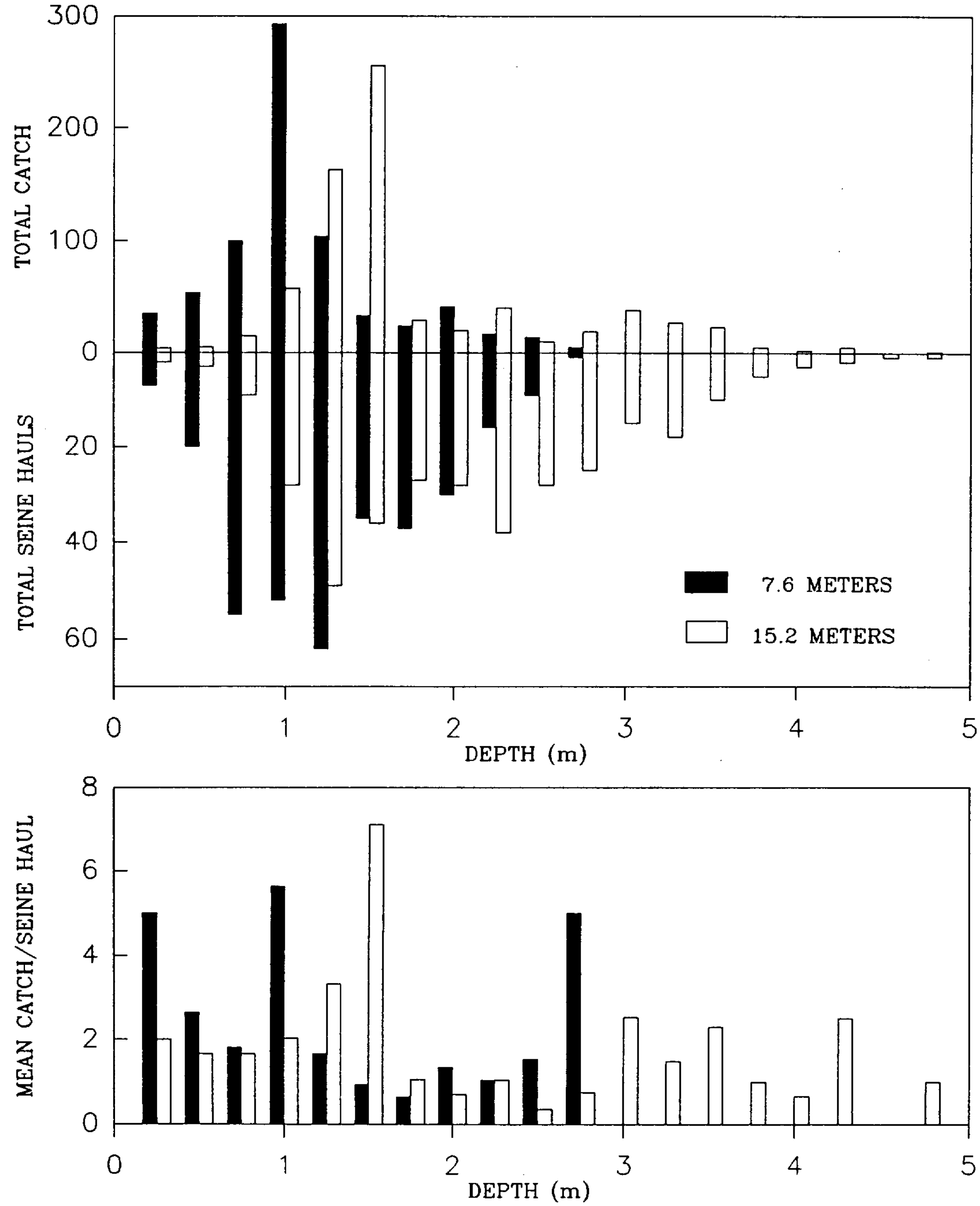

Figure 17.— Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Depth was measured at 7.6 and 15.2 m from the shoreline in the Snake River, Idaho, Oregon, and Washington, 1993.

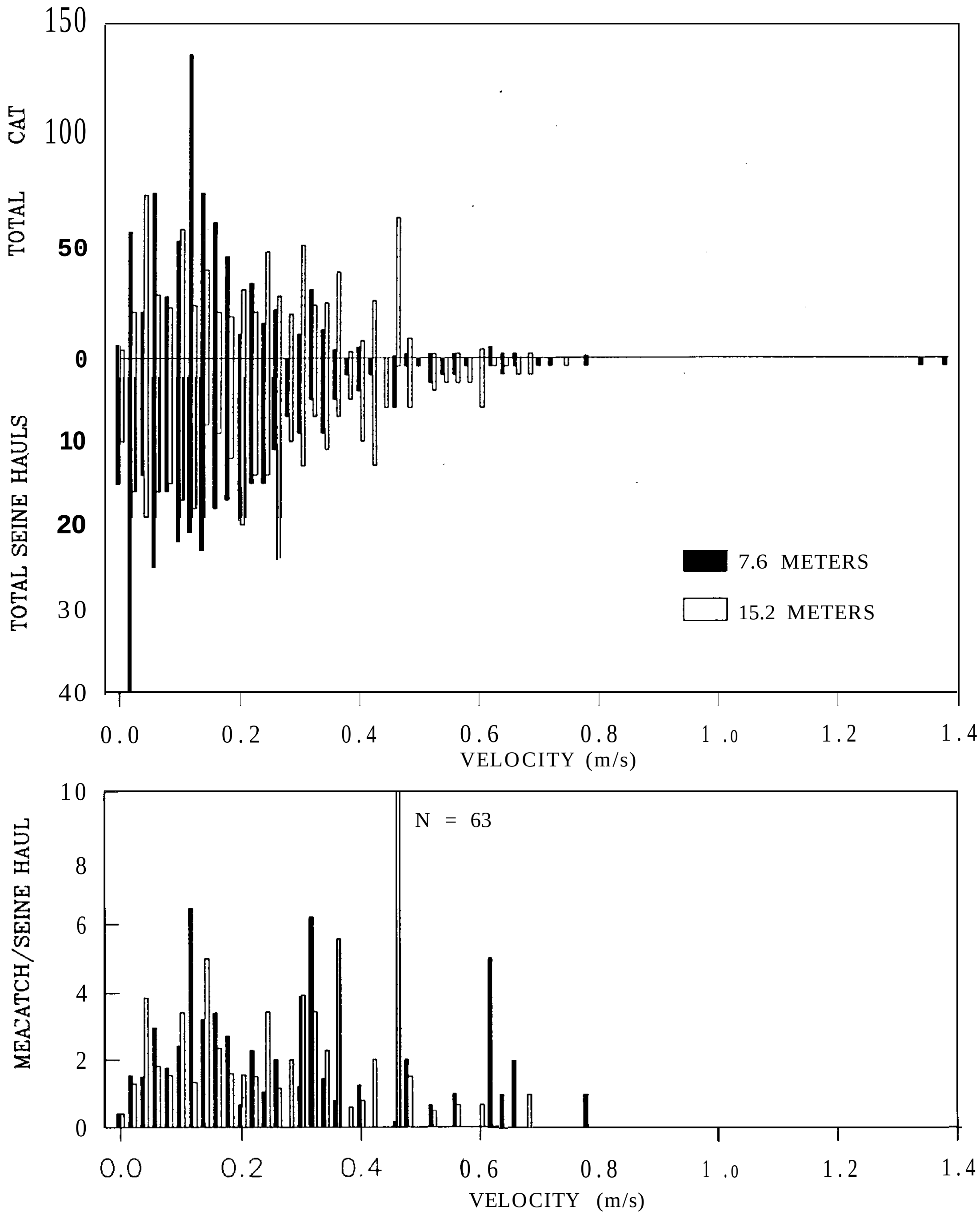

Figure 18.-Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Velocity was measured at 7.6 and 15.2 m from the shoreline in the Snake River, Idaho, Oregon, and Washington, 1993.

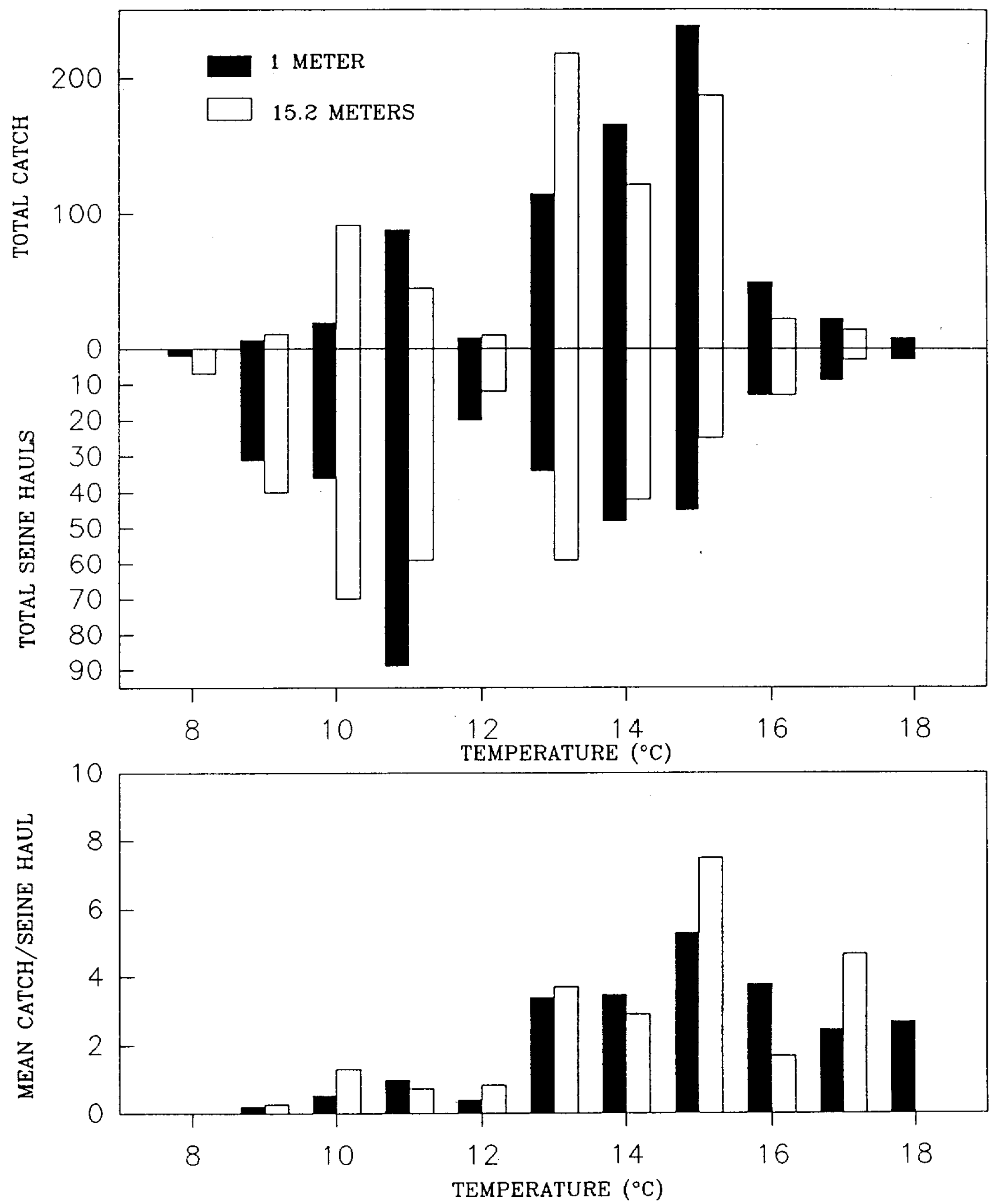

Figure 19.— Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon. Temperature was measured at 1 and 15.2 m from the shoreline in the Snake River, Idaho, Oregon, and Washington, 1993.

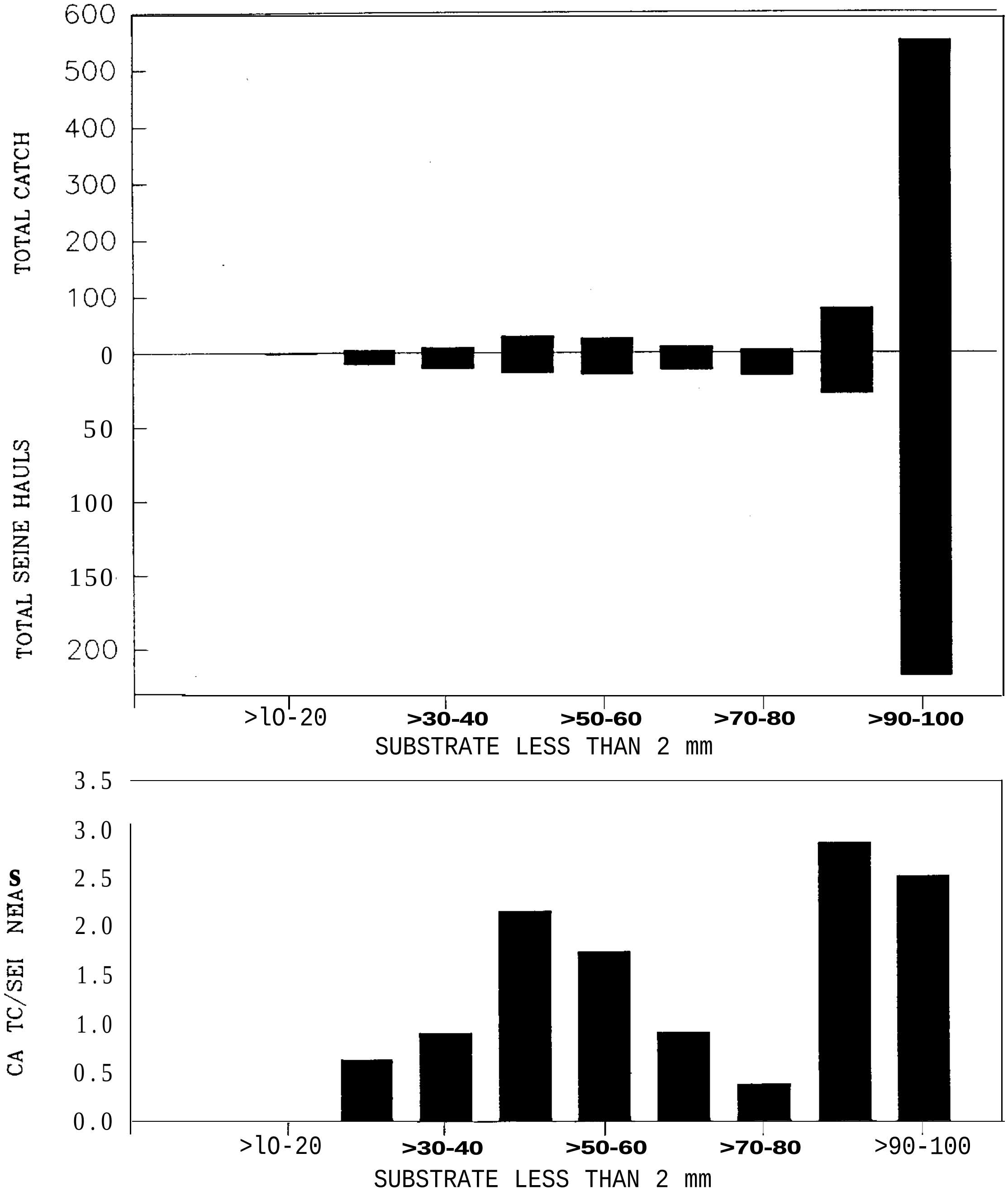

Figure 20.- Total catch, total seine hauls, and mean catch/seine haul of subyearling chinook salmon in the Snake River, Idaho, Oregon, Washington, 1993. The percent area of the beach seine site was determined for each seine haul where dominant substrate was fines <2 mm in size. Areas were combined into ten percent intervals and graphed.

The pattern of increase in fork lengths in 1993 between the three reaches was similar to 1992 results. The mean fork length of subyearling chinook salmon remained lower in the Hanford Reach than in McNary Reservoir. The time required for subyearling chinook salmon to disperse 25 km from the downstream-most sampling point in the Hanford Reach to the upstream-most sampling point in McNary Reservoir may explain their consistently larger mean fork length in McNary Reservoir. Subyearling chinook salmon in the Snake River had higher mean fork length than subyearlings in the Columbia River reaches in both 1992 and 1993. Emergence of fry from redds in the Hanford Reach was reported to occur between 2 April and 24 May 1993 (Carlson and Dell 1993). However, subyearling chinook salmon began emerging earlier in the Hanford Reach as fry were captured during the week of 22 March. In the Snake River, earliest emergence was estimated to occur on 16 March with consistent emergence beginning on 5 May and continuing until 5 June (Connor et al. in this report). Emergence in both reaches appear to have begun and ended within about a week. Fall chinook salmon fry emerged in the Hanford Reach when daily mean water temperatures were between 6°C and 11°C (Carlson and Dell 1993) but in the Snake River they emerged when water temperatures were between 5°C and 14°C (Connor et al. in this report). Water temperatures increased at a higher rate in the Snake River than in the Hanford Reach and may have been the primary contributor to the faster increase in mean length observed in Snake River subyearling chinook salmon.

Although Snake River subyearling chinook salmon may increase in length more quickly, they appear to increase in weight in the same proportion to length as subyearlings in McNary Reservoir and the Hanford Reach. The lack of a difference between the McNary Reservoir subyearlings and the Hanford Reach in 1993 supports the conclusion that in 1992 the difference in the length-weight curve for subyearlings in McNary Reservoir could simply have been a result of hatchery fish released into the Columbia River. Few hatchery fall chinook salmon were caught in 1993 as only 0.5% of the total catch in the Columbia River was obtained after Priest Rapids Hatchery releases as opposed to 6.5% in 1992.

The catch of subyearling chinook salmon was positively correlated with light and was significantly higher during the day than at night. The higher mean daytime catch in this study agrees with our 1992 findings (Key et al. 1994). The lower total number of fall chinook yearlings caught in 1993 as compared to 1992 is attributed to the different time of year, location, and water conditions between the years (Table 1). The similar die1 catch patterns in 1992 and 1993 suggest that die1 catch may be more related to fish behavior than to either fish size or environmental conditions. The low water velocity, shallow depth, small mean fork length, and distance the subyearlings would have to travel from the Villard Slough shoreline to the main channel does not support the theory that subyearlings move into the main

Table l.-Comparison of the sampling conditions between the 1992 and 1993 die1 study in McNary Reservoir, WA.

	1992	1993
Total number of fall chinook salmon caught	10,511	1,602
Mean FL	78 mm	47 mm
Location	Foundation Island	Villard Slough
Type	Main channel island	Backwater shoreline
Date	Mid June	Mid May
Source	Hatchery and Naturally produced	Naturally produced
Temperature	14-18 °C	13-16 °C
Velocity	0.01-0.20 m/s	0.00-0.02 m/s
Distance from main channel	310 m	1,530 m

current and travel downstream at night. Movement during and immediately following dusk would place them in the water column during the time when largemouth bass ***Micropterus** dolomieu,* walleye *Stizostedion vitreum* , northern squawfish *Ptychocheilus oregonensis,* and channel catfish *Ictalurus punctatus* become active and would increase predation risk (Vigg et al. 1991; Petersen and Gadomski in press). The results of the 1993 die1 study further support the hypothesis presented by Key et al. (1994) that subyearling chinook salmon move to the bottom and become torpid during the night. Further study is required before die1 behavior by subyearling chinook salmon in the nearshore can be determined.

Shallow nearshore water depth may be important to subyearling chinook salmon by providing an environment with warmer water temperatures and lower risk of predation from large piscivorous fish. Bennett et al. (1993) found that subyearling chinook salmon in Lower Granite Reservoir were caught most frequently at low gradient sites. However, our findings suggest that there may be a minimum slope that subyearling chinook salmon will inhabit. Extremely shallow water may place small fish at a higher risk to avian predation by reducing escapement into deeper water depths; avian predation was observed daily by workers in the field during daylight hours. In addition, sites with very low slope dewater rapidly as reservoir and river levels fluctuate daily, and sometimes hourly, and may cause stranding.

As juvenile salmon grow they tend to shift to higher velocities and deeper water (Lister and Genoe 1970; Hillman et al. 1987). Subyearlings were observed to feed at increasing distances from the shoreline as the season progressed and mean length increased. In June, when beach seine hauls captured few subyearling chinook salmon, fish were observed feeding beyond the range of the beach seine. These observations suggest that the lack of a relationship between velocity and catch may be an artifact of grouping catches and velocity intervals across the entire sampling season and further study and analysis are required before a definitive conclusion can be reached.

Temperature avoidance may affect movement from nearshore areas. Mean catch dropped when temperatures exceeded 16.9°C in the Hanford Reach and 18.9°C in the Snake River and McNary Reservoir. As in 1992, the mean catch peaked when temperatures were between 12.0-15.9°C in McNary Reservoir and the Snake River. In the Hanford Reach mean catch peaked earlier when temperatures were between 9.0-12.9°C. Because river temperature and subyearling chinook salmon length both increase with time, it is difficult to separate temperature factors from the physical and physiological changes in subyearling chinook salmon that can affect behavior.

Substrate is commonly reported as an important component of the habitat for resident fish in streams and small rivers where it may provide protection from high velocity or predators. In the Snake River, Bennett et al. (1993) reported that of the total subyearling chinook salmon caught, 72% were captured over substrates consisting of >75% fines, however, effort was not reported. In our study, catch of subyearling chinook salmon appeared to be proportional to effort over a range of percent of fine substrate. High effort resulted in high total catch of subyearlings in all three reaches. Since catch appeared dependent on effort, a conclusion regarding association of subyearling chinook salmon with substrate could not be supported. Key et al. (1994) proposed that subyearling chinook salmon are generalistic feeders consuming prey items from the water column and the surface (Becker 1973; Rondorf et al. 1990) and moving freely in the water column as loose aggregates (personal observation). A snorkel study in the Sixes River, Oregon observed subyearling fall chinook salmon inhabiting backwater eddies near shore, distributed throughout the water column, and consuming prey from the drift (Stein et al. 1972). This nondemersal behavior of subyearlings during the day could explain the proportional relationship between effort and catch and a lack of association between substrate and catch.

In conclusion, peak numbers of subyearling chinook salmon were caught later in 1993 than in 1992. As water temperatures increased above 15.9°C, mean catch decreased. The Snake River subyearling chinook salmon attained a larger size more quickly than the Columbia River subyearlings. Subyearlings were caught in significantly greater numbers during the day than during the night. Most subyearlings were caught in water between 0.5 m and 2.0 m deep. Substrate did not appear to have an influence on catch of subyearling chinook salmon in the main-stem Columbia River or Snake River. These results and conclusions are preliminary and may be modified with further analysis.

References

Becker, C.D. 1973. Food and growth parameters of juvenile chinook salmon, *Oncorhynchus tshawytscha* , in central Columbia River. U.S. National Marine Fisheries Service Fishery Bulletin 71:387-400.

Bennett, D.H., J.A. Chandler, and L.K. Dunsmoor. 1990. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic and habitat monitoring program-Year 1 (1988). Completion report to U.S. Army Corp of Engineers, Walla Walla, Washington.

Bennett, D.H., J.A. Chandler, and G. Chandler. 1991. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic and habitat monitoring program-Year 2 (1989). Completion Report to U.S. Army Corp of Engineers, Walla Walla, Washington.

Bennett, D.H., T.J. Dresser Jr., T.S. Curet, D.B. Lepla, and M.A. Madsen. 1993. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic and habitat monitoring program-Year 3 (1990). Completion Report to U.S. Army Corp of Engineers, Walla Walla, Washington.

Carlson, D. and M. Dell. 1993. Vernita Bar monitoring for 1992-1993. Annual Report. Public Utility District of Grant County. Ephrata, Washington.

Dauble, D.D., R.H. Grey and T.L. Page. 1980. Importance of insects and zooplankton in the diet of O-age chinook salmon *(Oncorhynchus tshawytscha)* in the central Columbia River. Northwest Science 52:253-258.

Dauble, D.D., T.L. Page, and R.W. Hanf, Jr. 1989. Spatial distribution of juvenile salmonids in the Hanford Reach, Columbia River. U.S. National Marine Fishery Service Fishery Bulletin 87:775-790.

Hillman, J.W., J.S. Griffith, and W.S. Platts. 1987. Summer and winter habitat selection by juvenile chinook salmon in a highly sedimented Idaho stream. Transactions of the American Fisheries Society 116:185-195.

Key, L.O., J.A. Jackson, C.R. Sprague, and E.E. Kofoot. 1994. Nearshore habitat use by subyearling chinook salmon in the Columbia and Snake rivers. Pages 120-150 *in* Rondorf, D.W. and W.H. Miller, editors. Identification of the spawning, rearing and migratory requirements of fall chinook salmon in the Columbia River Basin. Annual Report to Bonneville Power Administration, Contract DE-AI7991BP21708, Portland, Oregon.

Lister, D.B., and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha and coho *(0. kisutch)* salmon in the Big Wualicum River, British Columbia. Journal of the Fisheries Research Board of Canada 27:1225-1224.

Mains, E.M., and J.M. Smith. 1964. The distribution size, time, and current preferences of seaward migrant chinook salmon in the Columbia and Snake rivers. Washington State Department of Fisheries, Fisheries Research Papers 2(3):5-43, Olympia.

Orth, D.J. 1983. Aquatic habitat measurements. Pages 61-84 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Petersen, J.H., and D.M. Gadomski. in press. Light-mediated predation by northern squawfish *(Ptychocheilus oregonensis)* on juvenile chinook salmon *(Oncorhynchus tshawytscha)* . Journal of Fish Biology.

Platts, W.S., W.F Megaham, and H.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service, General Technical Report INT-138, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 119, Ottawa, Ontario.

Rondorf, D.W., G.A. Gray, and R.B. Fairley. 1990. Feeding ecology of subyearling chinook salmon in riverine and reservoir habitats of the Columbia River. Transactions of the American Fisheries Society 119:16-24.

SAS Institute. 1988. SAS/STAT User's Guide, Release 6.03 edition. SAS Institute Inc., Cary, North Carolina.

Stein, R.A., P.E. Reimers, and J.D. Hall. 1972. Social interaction between juvenile coho *(Oncorhynchus kisutch)* and f al 1 chinook salmon *(0. tshawytscha)* in Sixes River, Oregon. Journal of the Fisheries Research Board of Canada 29:1737-1748.

Vigg, S., T.P. Poe, L.A. Prendergast, and H.C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Zimmerman, M.A. and L.A. Rasmussen. 1981. Juvenile salmonid use of three Columbia River backwater areas proposed for subimpoundment. U.S. Fish and Wildlife Service, Ecological Services, Portland, Oregon.

CHAPTER FIVE

Osmoregulatory Performance and Marking of Subyearling Chinook Salmon at McNary Dam to Estimate Adult Contribution

by

K.F. Tiffan
National Biological Survey
Northwest Biological Science Center
Columbia River Research Laboratory
Cook, Washington 98605, USA

and

P.G. Wagner
Washington Department of Fisheries
Plymouth, Washington 99346, USA

Introduction

Research conducted at McNary Dam from 1981 to 1983 determined 'that subyearling chinook salmon *Oncorhynchus tshawytscha* which emigrated earlier in the summer exhibited greater adult contribution than did those emigrating later in the summer (Giorgi et al. 1990). No physical or biological factor could be isolated as a causal factor for this phenomenon even though a primary objective of the study was to examine the influence of flows on juvenile emigration and survival. Giorgi et al. (1990) attributed this failure to an inability to recover sufficient numbers of marked fish at John Day Dam to estimate their travel time through John Day Reservoir and the interaction among flow, temperature, fish size, physiological development, and origin of the fish.

This study was initiated in an attempt to resolve the questions pertaining to the influence of summer flows on the emigration of subyearling chinook salmon and their contribution as adults. The primary objectives for this third year of study were to mark and release sufficient numbers of subyearling chinook salmon at McNary Dam to estimate their travel time through John Day pool and to determine if released groups remained temporally discrete during emigration. Another objective was to describe the physiological development of fish marked and released at McNary Dam and to relate that to travel time and future adult returns.

Methods

Marking and Release

Juvenile subyearling chinook salmon were collected from the juvenile fish collection facility at McNary Dam. The dam is equipped with traveling screens to divert juvenile fish from the turbine intakes into gatewells and to raceways. Fish entering the collection facility were sub-sampled by operation of a timed gate in the conduit moving fish to the holding raceways. Each group of fish was collected by repeated sub-sampling during a 24 h period starting at 0700 hours. The sub-sample rate ranged from 5% to 20% of the total number of fish diverted.

Subyearling chinook salmon were marked with coded wire tags (CWT) and branded with cold brands (Jefferts et al. 1963; Mighell 1969). Fish were anesthetized with a preanesthetic of benzocaine (ethyl P-aminobenzoate) and an anesthetic of tricaine methanesulfonate (MS-222) similar to that described by Matthews (1986). Juvenile fish were then sorted by species and marked with CWT and cold brands. Three segments of the emigration were marked; early, middle, and late. For each segment of the emigration, three CWT codes were used resulting in a total of nine CWT codes released in 1993. During each day of marking, fish were marked with cold brands using a unique combination of a character, location, and rotation. The cold brand identified the fish for subsequent determination of migration time from McNary Dam to John Day Dam. Marked fish were released into the fish bypass system at McNary Dam between 2200 and 2300 hours on the day of marking. At John Day Dam juvenile salmon were collected using two air-lift pumps (Brege et al. 1990) and the brands on recaptured fish were recorded.

The marking program included measures to ensure the quality of subyearling chinook salmon released at McNary Dam. Fish that were previously branded or adipose fin clipped and CWT tagged, descaled, or had injuries likely to result in mortality were not marked (Wagner 1994). Fish with fork lengths c 55 mm were also not marked. Fifty fish per day were held for 48 h to measure delayed mortality and coded wire tag loss. Fish surviving the delayed mortality test were transported downstream by barge or truck to prevent confounding of migration time estimates to John Day Dam.

Travel time of branded replications of fish was estimated to the nearest day by the method used by the Fish Passage Center i.e., the difference between the median date of release at McNary Dam and the date nearest the median date of recovery based on the passage indices at John Day or Bonneville dams. However, we only estimated travel time to the nearest day and did not interpolate to the nearest tenth of a day. Flow and temperature during travel time was estimated by averaging the discharge and temperature at McNary Dam from the day after fish release at McNary Dam through the median day of recovery at John Day Dam. Mean dates of recapture were weighted by passage index and compared using the Kruskal-Wallis test (SAS 1990) and a Tukey-type multiple comparison test (Zar 1984). Differences were considered statistically significant when $P \leq 0.05$.

Physiology

Samples were collected for gill Na',K'-adenosine triphosphatase (ATPase) analysis from Priest Rapids State Fish Hatchery brand groups and from wild subyearling fall chinook salmon in the Hanford Reach of the Columbia River to assess smoltification of premigrants. Priest Rapids fish were sampled before release and Hanford fish were sampled coincidentally with a Washington Department of Fisheries marking study. Gill samples were collected again from marked Priest Rapids and Hanford fish at McNary Dam to measure ATPase activities of emigrants.

Twenty-four-hour seawater challenges were employed to evaluate the physiological status of emigrating subyearling chinook salmon marked at McNary Dam. The general procedures of the seawater challenges followed Blackburn and Clarke (1987). Recirculating flow-through systems were used for challenged and control fish. The seawater system was composed of eight plastic 80-L containers which drained into a sump reservoir and a pump recirculated salt water from the sump to the plastic containers. The freshwater control system was identical to the seawater system. Chillers were placed in sump reservoirs to maintain water temperature at 18.3°C. Diaphragm pumps and air stones supplied air to each tank.

Actively emigrating subyearling chinook salmon were collected at the McNary Dam fish collection facility coincidentally with marking. Three separate challenges were conducted to characterize the seawater adaptability of migrants during the early, middle, and late portions of the outmigration. Random samples of 10 anesthetized fish were distributed to each tank. Fish were allowed to acclimate for 24 h prior to being challenged.

Artificial sea salt was dissolved and added to the sump reservoir of the seawater system to infuse salt water into the tanks without handling or disturbing the fish. A desired salinity of 30 parts-per-thousand (ppt) was usually achieved within one hour. Unchallenged control fish were maintained in fresh water.

At the end of *a* 24-h challenge, fish were immobilized in their tanks with 30 mg/L MS222. Anesthetized fish were weighed, measured (FL), rinsed in fresh water, and their tails blotted dry before being severed. Blood was collected from the caudal artery in ammonium heparinized Natelson tubes, centrifuged, and the plasma was frozen immediately in liquid nitrogen. Gill filaments were collected for determination of Na',K'-ATPase activity.

In addition to the seawater challenges conducted during the early, middle, and late portions of the outmigration, a serial seawater challenge was conducted in August to characterize the pattern of plasma Na' and gill Na', K^+-ATPase activity of fish exposed to sea water for varying lengths of time. Fish were challenged as described above but were sampled at 1, 4, 7, 12, 24, 31, 36, and 48 h intervals.

Blood plasma *was* analyzed for Na' and K^+ by flame photometry and gill Na', K^+-ATPase activity was measured using a microassay (Schrock et al. 1994). Group means were calculated for control and test fish for the three challenges and the serial challenge. Means were compared between challenges using analysis of variance (ANOVA) and Student-Newman-Kuels (SNK) multiple comparison test while within-challenge comparisons were made using t-tests for plasma Na^+ and K^+ and gill ATPase activity (SAS 1990). The significance level for all tests was $P \leq 0.05$.

Salinity Preference

Salinity preference of subyearling chinook salmon was measured weekly from June to August for run-of-the-river and hatchery fish. Fish were tested in a horizontal gradient similar to that used by Otto and McInerney (1970) with the exception that the gradient was circular thus eliminating any "end" effects characteristic of straight gradients (Figure 1). The preference tank was 1.2 m in diameter and consisted of 16 compartments located around the inside wall of the tank forming a circular trough. Each compartment measured 22.9 cm wide by 20 cm long by 22.9 cm deep. Compartments were formed by baffles extending 7.6 cm from the bottom and the top of the trough leaving a 7.6 cm gap through which fish could freely swim between compartments. Water was pumped continuously through an orifice in the bottom of each compartment and exited through drain holes in the inner wall of the tank. An overhead video camera was used to observe fish behavior and locations in the tank. A gradient was established by infusing 30 ppt seawater into one compartment and allowing it to mix with inflowing freshwater in the remaining compartments. The maximum salinity that could be achieved in the most saline compartment, while still maintaining an opposite freshwater compartment, was 18 ppt. A salinity meter was used to measure the salinity of water siphoned from each compartment which eliminated any disturbance to fish during a test.

Ten fish were used in each test and were introduced into the tank on the day before a test and were allowed a minimum of 16 h to acclimate to the tank. The tank was supplied with fresh water during this time. Each test **was** begun by filming fish behavior in fresh water for 2 h which is referred to as the control period. At the end of the control period, sea water was infused to establish the gradient, which usually took 2 h. Fish were filmed for an additional 2 h after the gradient had become established and is referred to as the test period. At the conclusion of a test, fish were weighed, measured, and gill samples were collected for ATPase activity analysis.

Two replicate tests were conducted each week using new fish in each test. Salinity preference was assessed by making observations of fish locations in the tank every three minutes during both control and test periods for a total of 40 counts during each period. Frequency distributions for control and test periods were compared to each other and to a hypothetical distribution, which assumed no salinity preference, using the Kolomogorov-Smirnov test (Zar 1984).

A

B

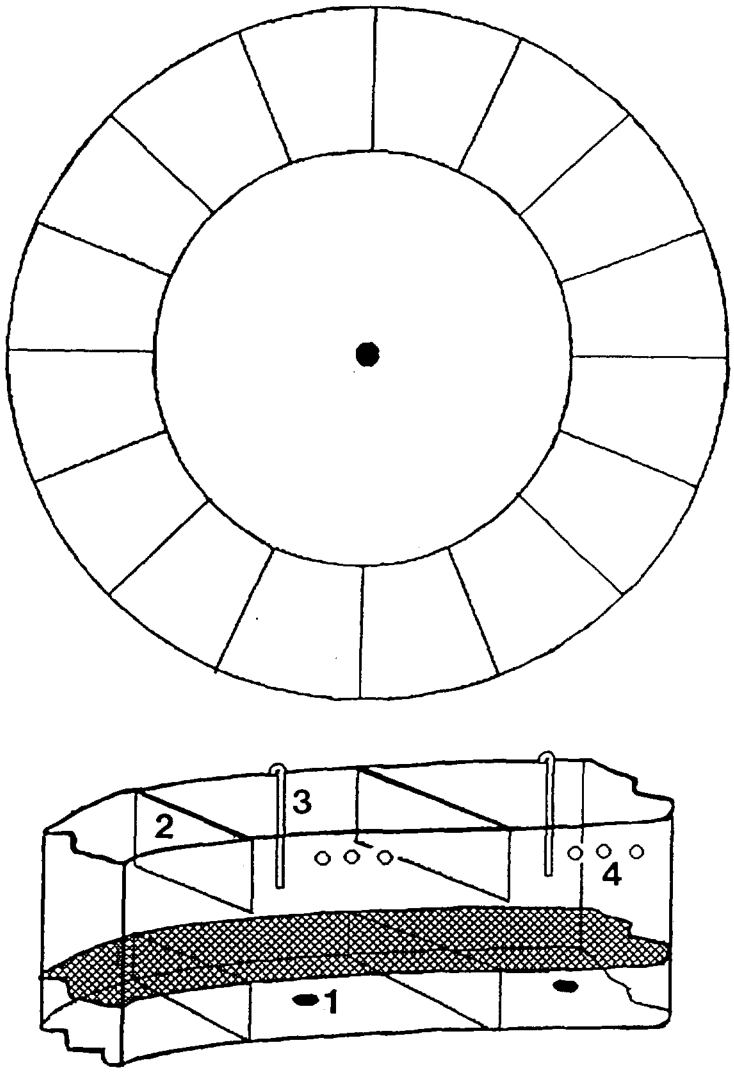

Figure 1. -Schematic overhead (A) and side (B) views of salinity preference tank with (1) water input, (2) baffle, (3) siphon hose and (4) outflow.

Results

Marking, Release, and Recapture

The median date of subyearling chinook salmon emigration past McNary Dam in 1993 was 5 July (Figure 2), which is 4 days later than the 1984-90 median. The 10% passage was 12 days later and the 90% passage was 13 days later than the 1984-90 mean (Fish Passage Center 1994). Based on recaptures of wild subyearling chinook salmon that were tagged with passive integrated transponders (PIT) and released in the Hanford reach on 9 June (median date), 50% passage at McNary Dam occurred on 8 July with a median travel time of 29 days. Since less than 20% of the wild fall chinook salmon in the Hanford Reach were of tagable size, this median date represents only early migrants. The median dates of passage at McNary Dam of branded subyearling fall chinook salmon released from Priest Rapids State Fish Hatchery between 15 and 27 June ranged from 30 June to 7 July. PIT tagged subyearling fall chinook salmon released from Turtle Rock Hatchery on 30 June (median date) had a median passage at McNary Dam on 27 July (Fish Passage Center 1994). The 10, 50, and 90% passage dates of all hatchery and wild fish combined at McNary Dam were 27 June, 5 July, and 2 August. Passage dates at McNary Dam indicate that outmigration timing was similar to the 1991 subyearling outmigration.

A total of 107,077 subyearling chinook salmon collected at McNary Dam were freeze branded, coded wire tagged, and released in the tailrace (Table 1; Appendix 6). An additional 1,400 marked fish were transported after being retained for 48 h to estimate delayed mortality and CWT loss, which was 0.4% and 0.7% respectively. The group of 35,994 early migrants were marked with 9 unique brands from 24 June to 2 July when the cumulative passage index increased from 5% to 20%. The middle group of 35,555 emigrants were marked with 10 unique brands from 9 to 18 July when the passage index increased from 63% to 84%. The late group of 35,578 emigrants were marked with 9 unique brands from 27 July to 4 August when the passage index increased from 94% to 97%.

Columbia River flows at McNary Dam decreased from about 265 thousand cubic feet per second (KCFS) in early June to about 100 KCFS in late August while water temperature increased from 14°C to 21°C (Figure 2). Flows during June and July were about 65% of the 40 year average and in August flows increased to about 83% of the 40 year average.

The number of subyearling chinook salmon recaptured at John Day Dam ranged from 79 to 224 fish for the nine CWT replications and from 297 to 519 for the early, middle, and late groups (Figure 3; Table 2). Estimated travel times were 8, 26, and 16 days for the early, middle, and late groups, respectively. The

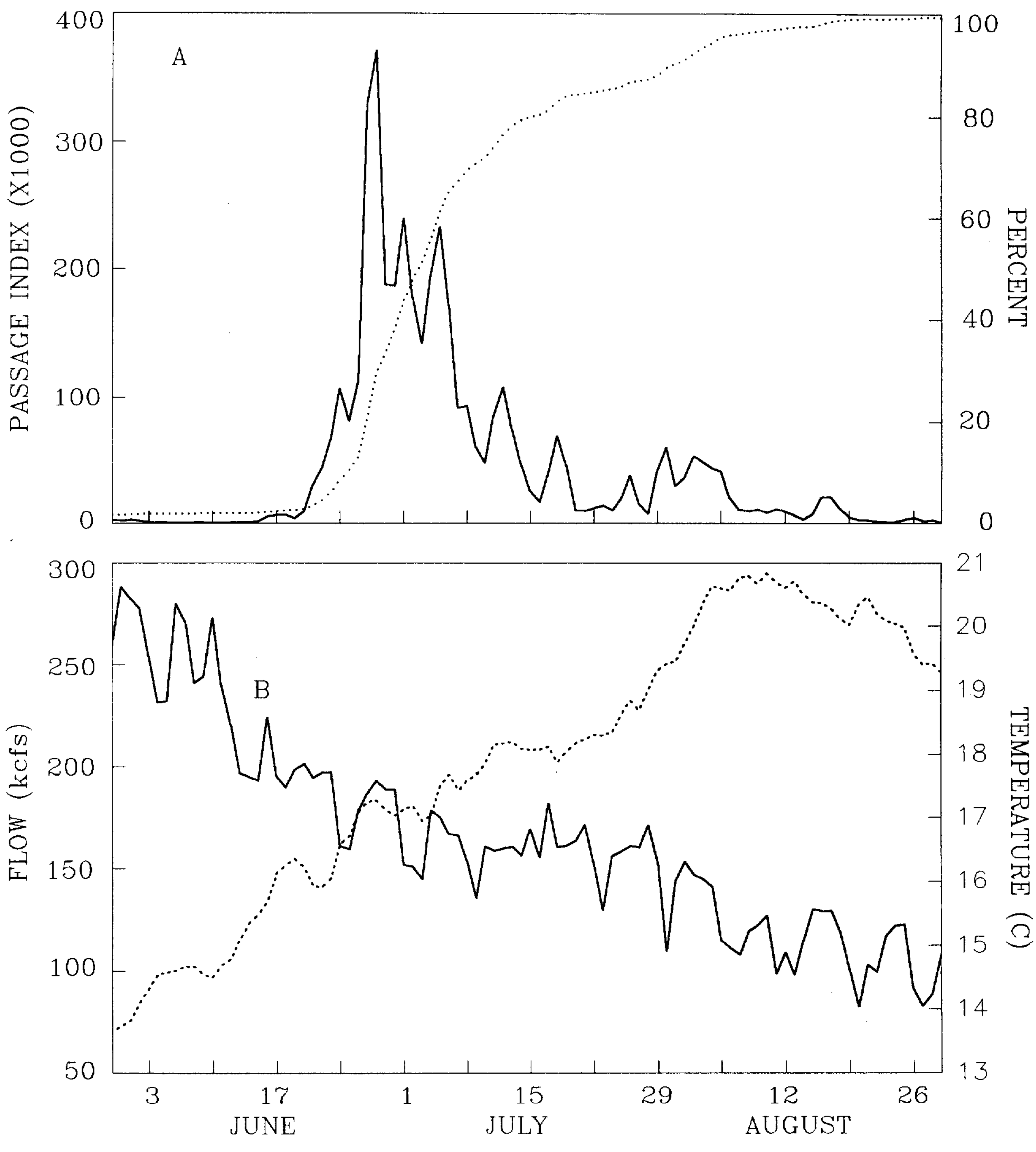

Figure 2.—Daily (solid line) and cummulative (dotted line) passage index (x1000) of subyearling chinook salmon (A) and daily flow (solid line) and temperature (dotted line; B) at McNary Dam, 1993.

Table l.-Date, coded wire tag (CWT) code, and number of subyearling chinook salmon released in the McNary Dam tailrace and the number of fish held for 48 h with their tag loss and mortality prior to transportation, 1993.

Date	CWT Code	Marked & Released	Marked & Held	Mortality	Tag Loss	Percent Loss
Jun 24-26	65-33-18	11,872	150	0	0	0
Jun 27-29	05-33-19	12,027	150	0	1	0.7
Jun 30- Jul 2	05-33-20	12,045	150	0	2	1.3
Sub-Total		35,944	450	0	3	0.7
Jul 9-11	05-33-21	11,878	150	3	4	2.7
Jul 12-14	05-33-22	11,858	150	0	0	0
Jul 15-18	05-33-23	11,819	200	1	0	0
Sub-Total		35,555	500	4	4	0.8
Jul 27-29	05-33-24	11,798	150	0	2	1.3
Jul 30- Aug 1	05-33-25	11,850	150	1	0	0
Aug 2-4	05-33-26	11,930	150	1	1	0.7
Sub-Total		35,578	450	2	3	0.7
Total		107,077	1,400	6	10	0.7

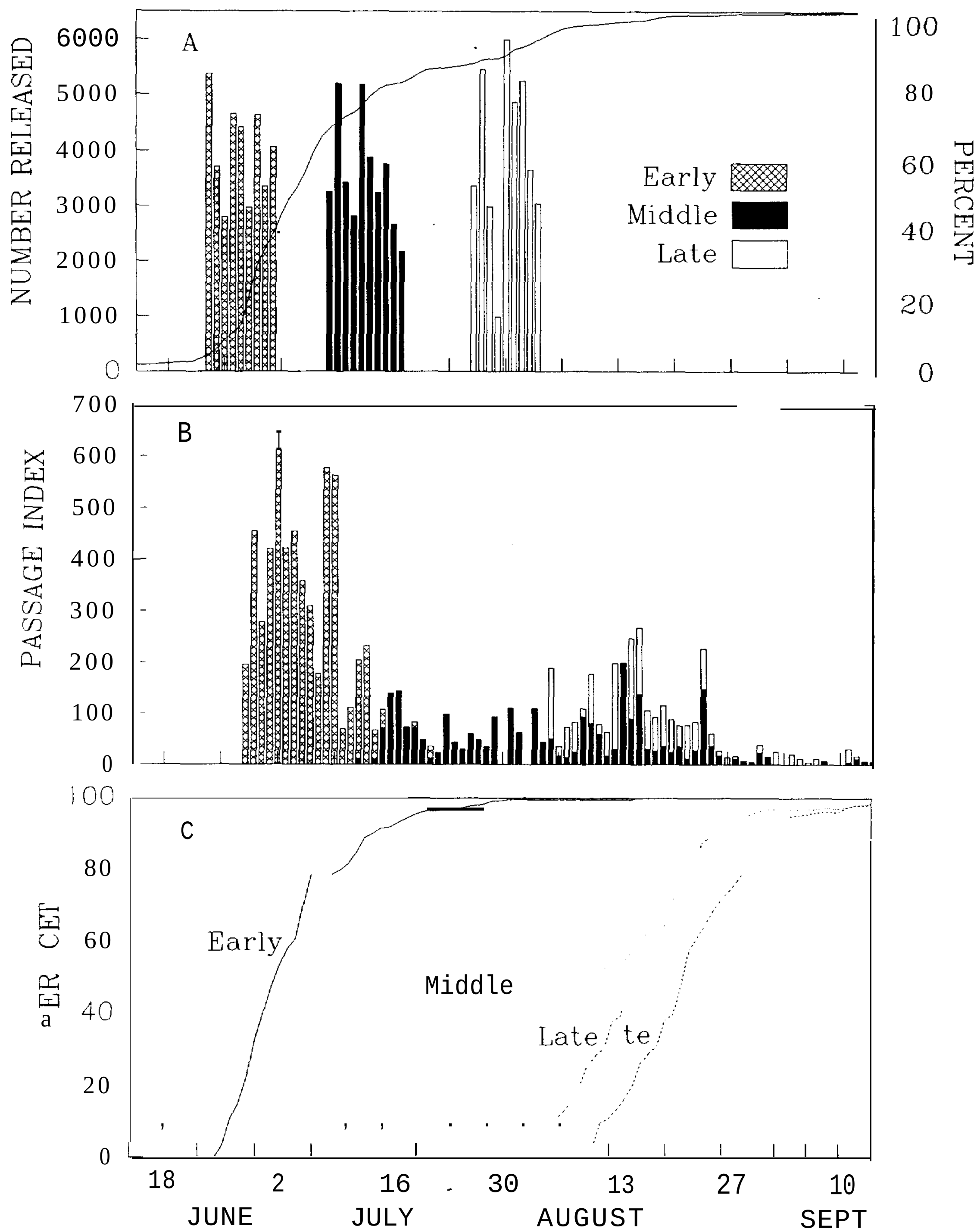

Figure 3.-Number of subyearling chinook salmon marked and released at McNary Dam with cummulative percent passage index (A) and the passage index of early, middle, and late emigrating marked groups (B) and the cummulative percent frequency of each group (C) recovered at John Day Dam, 1993.

Table 2.-Median dates and number of subyearling chinook salmon released at McNary Dam and the number recovered, passage index (PI), and percent detected (%) at John Day and Bonneville dams, 1993.

McNary Dam Release			Recovery at John Day				Recovery at Bonneville			
CWT Group	Med. Date	Num-ber	Med. Date	Num-ber	PI	%	Med. Date	Num-ber	PI	%
33-18	25 Jun	11,872	2 Jul	198	2,436	20.5	5 JuL	15	169	1.4
33-19	28 Jun	12,027	5 Jul	153	1,773	14.7	7 Jul	40	194	1.6
33-20	1 Jul	12,045	10 Jul	168	1,949	16.2	10 Jul	31	160	1.3
Early	28 Jun	35,944	6 Jul	519	6,158	17.1	8 Jul	86	523	1.5
33-21	10 Jul	11,878	27 Jul	95	941	7.9	3 Aug	32	64	0.5
33-22	13 Jul	11,858	4 Aug	100	952	8.0	3 Aug	44	88	0.7
33-23	16 Jul	11,819	15 Aug	102	832	7.0	7 Aug	21	37	0.3
Middle	13 Jul	35,555	8 Aug	297	2,725	7.7	4 Aug	97	189	0.5
33-24	28 Jul	11,798	16 Aug	79	626	5.3	6 Aug	68	138	1.2
33-25	31 Jul	11,850	15 Aug	127	1,007	8.5	8 Aug	62	119	0.9
33-26	3 Aug	11,930	16 Aug	224	1,671	14.0	19 Aug	42	69	0.6
Late	31 Jul	35,578	16 Aug	430	3,304	9.3	8 Aug	172	326	0.9

Kruskal-Wallis test indicated that the time of emigration for the three groups past John Day Dam was significantly different and the mean dates of passage of all three groups were significantly different from each other.

The number of fish recaptured at Bonneville Dam ranged from 21 to 68 for the nine CWT replications and 86 to 172 for the three groups (Table 2). Emigration time for the three groups past Bonneville Dam was significantly different and each group was different from each other. The median dates of recapture for the replications at John Day and Bonneville dams indicated the fish traveled rapidly through the Dalles and Bonneville reservoirs compared to travel time through John Day reservoir. Travel time was not significantly correlated with flow, temperature, gill ATPase activity, median release date, or fork length (Table 3).

Physiology

Gill ATPase activity of premigrants from Priest Rapids State Fish Hatchery and from the Hanford Reach was low but became elevated by the time of recapture at McNary Dam. Mean gill ATPase activities of prerelease brand groups at Priest Rapids on 14 and 21 June were 10.3 and 9.5 μmol Pi/(mg protein)/h, respectively. These same brand groups were recaptured at McNary Dam from 30 June to 9 July and had a mean gill ATPase activity of 20.2 μmol Pi/(mg protein)/h. Subyearling chinook salmon coded wire tagged in the Hanford Reach on 10 and 14 June had mean gill ATPase activities of 14.9 and 9.4 μmol Pi/(mg protein)/h. Since these fish were not branded, 60 coded wire tagged subyearlings were collected at McNary Dam from 21 July to 4 August with the expectation that some would have originated from the Hanford Reach. Coded wire tags revealed that 26 fish were from the Hanford Reach and had a mean ATPase activity of 19.5 μmol Pi/(mg protein)/h. Gill ATPase activities of migrants marked at McNary Dam ranged from 16.4 to 22.3 in 1993 while in 1992 levels ranged from 20.0 to 34.3 and in 1991 levels ranged from 14.6 to 30.3 μmol Pi/(mg protein)/h (Figure 4).

All subyearling chinook salmon used in seawater challenges exhibited the silvery appearance of smolts. Group means of plasma Na' of challenged fish were 153.0 mmol/L for the early challenge, 153.7 for the middle, and 157.2 for the late challenge (Table 4, Figure 5). Of the 380 fish challenged only 3 died during testing.

ANOVA of test plasma Na' values indicated that late challenge values were significantly different than those of the early and middle challenge. The early and middle challenge plasma Na' concentrations were not different from each other. Control values from all challenges were not significantly

Table 3.-Correlation of subyearling chinook salmon travel time from McNary Dam to John Day Dam with median release date, flow, temperature, ATPase activity, and fork length (FL) of coded wire tagged (CWT) groups, 1993.

CWT Group	Travel Time (d)	Median Date	Flow (kcfs)	Temp. (C)	ATPase Activity	FL (mm)
Early						
05-33-18	7	25 June	180	17.0	20.3	106
05-33-19	7	28 June	172	17.1	19.8	100
05-33-20	9	1 July	164	17.3	18.6	99
Middle						
05-33-21	17	10 July	158	18.1	17.6	98
05-33-22	22	13 July	156	18.6	22.2	100
05-33-23	30	16 July	142	19.4	22.2	100
Late						
05-33-24	19	28 July	129	20.2	20.1	115
05-33-25	15	31 July	123	20.4	----	115
05-33-26	13	3 Aug	120	20.6	22.4	121
r		0.501	-0.505	0.578	0.449	-0.097

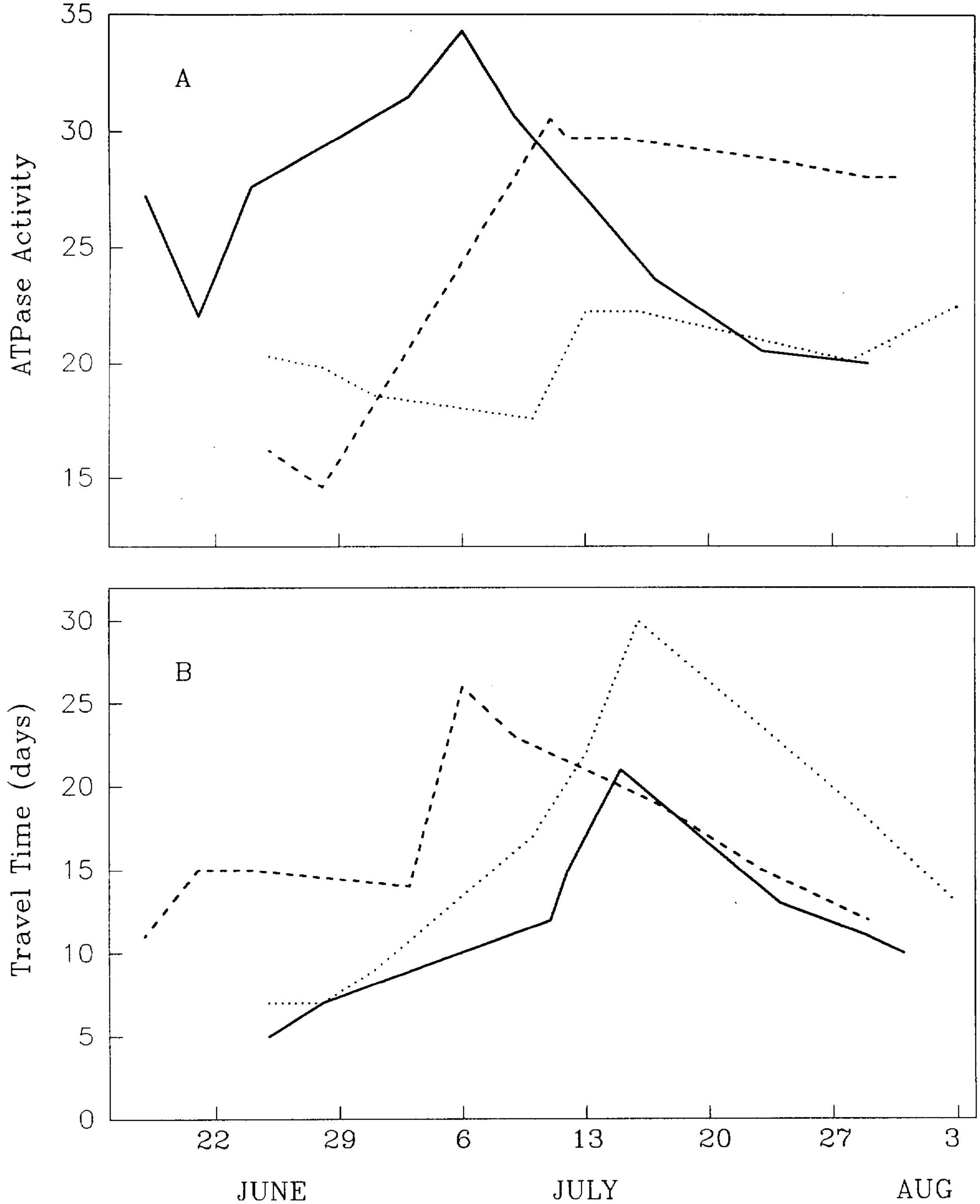

Figure 4.—Gill ATPase activity (A) and travel time to John Day Dam (B) calculated from median date of release of groups of subyearling chinook salmon marked at McNary Dam in 1991 (solid line), 1992 (dashed line), and 1993 (dotted line).

Table 4.-Mean plasma Na' (mmol/L) and gill ATPase activity (μmol Pi/(mg protein)/h) from subyearling fall chinook migrants subjected to 24-h seawater challenges at McNary Dam, 1993.

Date	Test water	Level	N	Std err	cv	Mort
		Plasma Na'				
7-l	seawater	153.0	57	0.522	0.026	0
7-l	fresh	149.3	55	0.660	0.033	1
7-15	seawater	153.7	57	0.722	0.035	0
7-15	fresh	150.2	58	0.918	0.047	2
7-29	seawater	157.2	65	**0.932**	0.048	0
7-29	fresh	149.4	57	1.403	0.071	0
		ATPase				
7-l	seawater	19.9	30	0.758	0.208	0
7-l	fresh	19.8	30	1.016	0.281	1
7-15	seawater	22.5	28	**0.920**	0.216	0
7-15	fresh	21.9	29	0.918	0.226	2

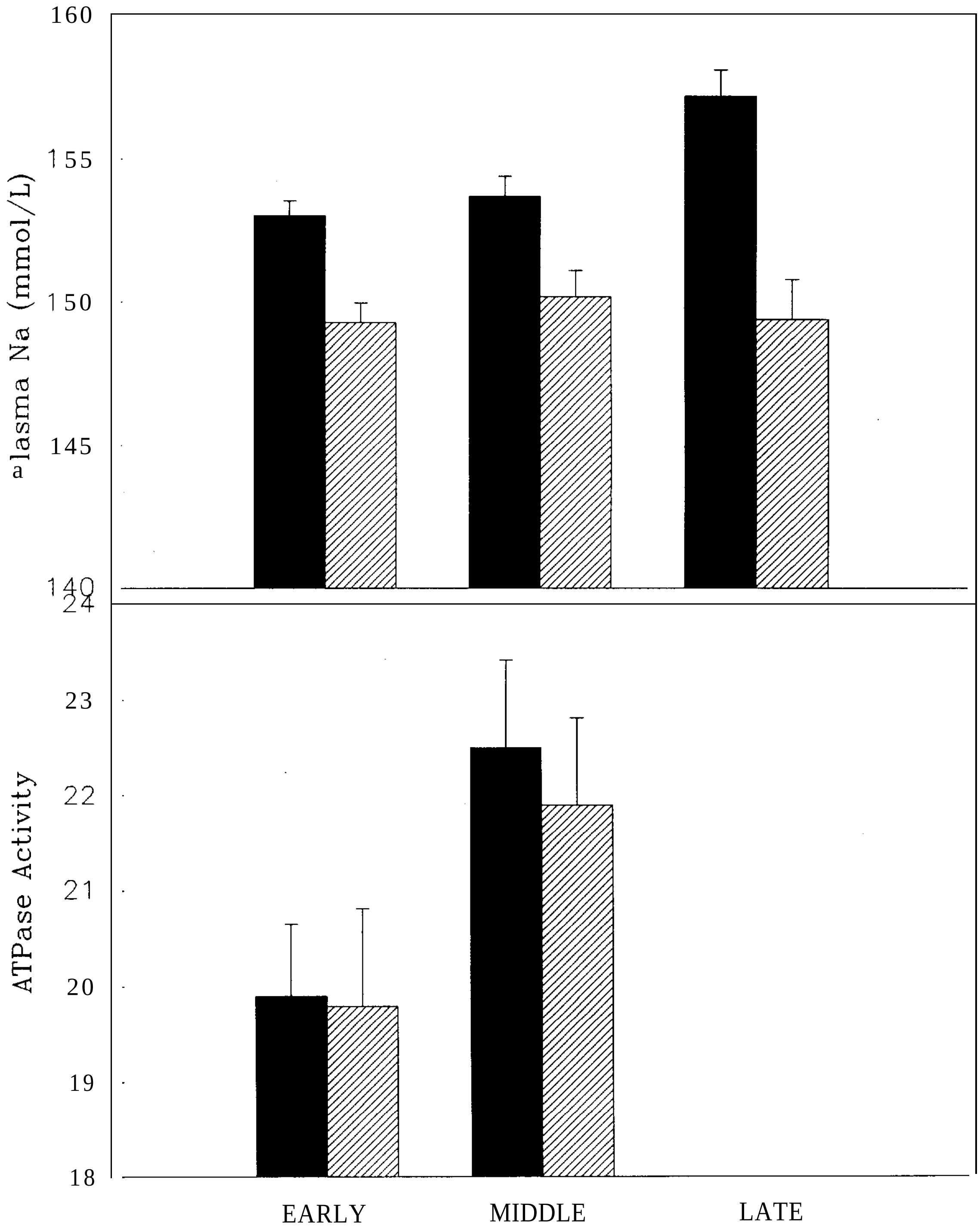

Figure 5.-Physiological responses, with standard error bars, of subyearling chinook salmon exposed to sea water (solid bars) and fresh water (cross hatched bars) at McNary Dam during the early (1 July), middle (15 July), and late (29 July) portions of the 1993 outmigration.

different from each other. In each challenge, plasma Na' values in test fish were significantly higher than in control fish. There was a small decrease in plasma K^+ concentration from the early to late portion of the run but no meaningful differences were found between challenged and control fish. No significant changes in length or weight occurred between test and control fish in any challenge. Plasma sodium was correlated with both length (r=0.227) and weight (r=0.220) in seawater challenged fish.

ATPase activities could only be compared between the first and second challenges because samples from the third challenge were destroyed in a laboratory accident. Seawater challenged fish did not have significantly higher activities than control fish (Table 4, Figure 5) as was observed in 1992. Seawater gill ATPase activities from fish in the second challenge were significantly different than those from the first challenge. In seawater challenged fish, ATPase activity was not significantly correlated with length, weight, plasma sodium, or plasma potassium, however, ATPase activity was correlated with plasma sodium (r=0.375) in control fish.

The response of plasma Na' of fish sampled at various intervals in the serial seawater challenge did not show a distinct pattern. In general, plasma Na' values were not significantly different from each other in seawater challenged fish except for the 31 and 36 h sampling intervals which were different from each other but similar to the other values (Table 5, Figure 6). There were no significant differences in plasma K^+, length; weight, or gill ATPase activity between sampling intervals. Plasma Na' values of seawater challenged fish were significantly higher than those of control fish throughout the serial challenge except for the 1 and 31 h sampling periods. There were no significant changes in plasma K', length, weight, or gill ATPase activity between challenged and control fish except for the 12 h (plasma K^+), 31 h (length and weight), and 36 and 48 h (gill ATPase activity) periods. Gill ATPase activity was negatively correlated with plasma Na' (r=-0.324) when all serial seawater challenged fish were combined.

Subyearling chinook salmon tested for salinity preference did not show any pattern of preference development over time. Fish swam continuously around the tank, usually as a group, during both control and test portions of each preference test. Because of this constant swimming behavior, no meaningful determination of salinity preference could be made. In general, fish swam slightly faster through the higher salinity compartments which resulted in more observations of fish in lower salinities (O-3 ppt). Frequency distributions of locations of fish in test portions were significantly different than control fish distributions in 17 of 20 preference tests where 10 fish

Table 5.-Mean plasma Na^+ (mmol/L), plasma K^+ (mmol/L), gill ATPase activity (μmol Pi/(mg protein)/h), length (mm), and weight (g) of subyearling fall chinook salmon tested in a serial seawater challenge at McNary Dam, 1993.

Variable	Test Water	Sampling interval (h) 1	4	7	12	24	31	36	48
Na	seawater	157.1	163.4	167.6	170.9	162.6	167.9	168.0	163.5
	fresh	153.6	151.2	152.4	152.6	154.1	158.6	148.6	152.1
K	seawater	4.35	4.23	4.81	4.82	4.56	4.78	4.59	4.08
	fresh	4.31	4.41	4.04	4.25	`	4.36	4.28	4.38
ATP	seawter	17.0	21.7	16.3	16.8	19.6	16.2	18.5	18.7
	fresh	15.1	17.6	17.9	18.8	19.2	16.8	13.3	12.7
Length	seawater	122.5	123.2	123.1	120.2	120.8	118.7	120.3	121.7
	fresh	117.9	120.1	117.7	122.0	118.6	124.9	119.4	120.7
Weight	seawater	21.3	21.7	21.3	19.8	19.8	18.6	19.6	20.0
	fresh	18.4	19.8	18.8	21.4	17.8	22.4	19.8	19.8

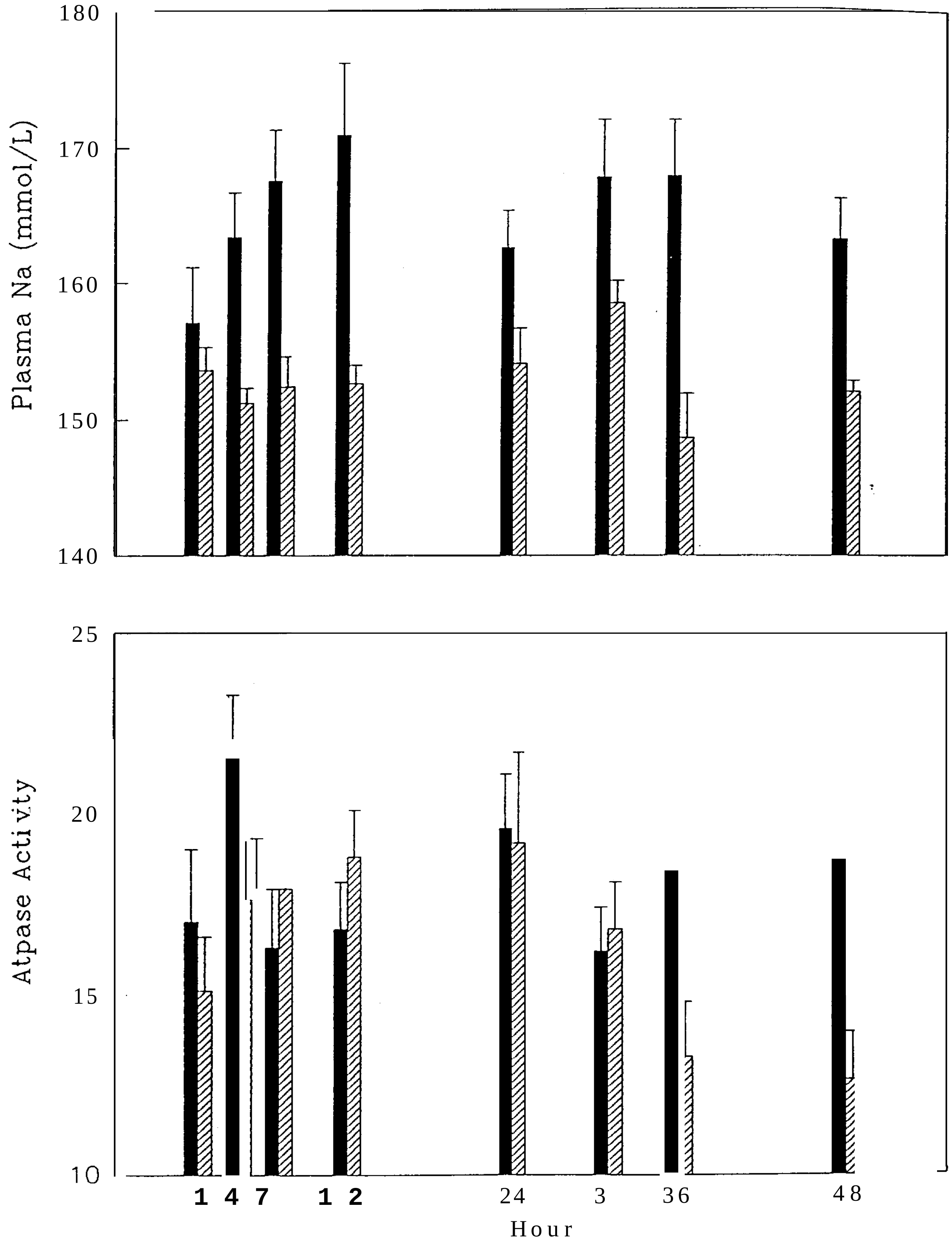

Figure 6. -Physiological responses, with standard error bars, of subyearling chinook salmon exposed to sea water (solid bars) and fresh water (cross hatched bars) in a serial seawater challenge at McNary Dam in August 1993.

were used. In two tests using single fish, test period distributions were not significantly different from random.

Discussion

Travel time from McNary to John Day Dam was not significantly correlated with any of the physical and physiological variables tested in 1993 as **was** true in 1992. The reason for this may be that travel times in 1993 showed no simple pattern of either increasing or decreasing over time. This made the likelihood of obtaining any significant correlations involving travel time improbable, especially given the small sample sizes used in correlation analyses.

Estimated travel times of subyearling chinook salmon from McNary to John Day Dam did not follow the paradigm that travel time decreases with increased flow or the expectation that rapid travel time would be associated with relatively high gill ATPase activities. Travel times increased from the early to middle portions of the outmigration as flows decreased, but then became shorter during the late portion of the run as flows continued to decline. ATPase activity followed a similar trend although the decline in ATPase activity was only slight during the late portion of the outmigration and was elevated on the last sampling date (Figure 4). Both of these trends were also observed in 1991 and 1992 with the exception that the late decline in ATPase activity was more pronounced during these years. During the latter portion of the outmigration several factors such as increased water temperature, increased fish size, and stock differences may have contributed to this phenomenon. The early portion of the run is usually comprised of fish released from Priest Rapids State Fish Hatchery whereas middle and late migrants are a mix of both hatchery and wild fish (Fish Passage Center 1994). Stock differences may account for variable travel times. In addition, Skalski (1989) has shown that various assumptions related to passage index calculation at John Day Dam are often violated due to shifts in dam operations and subsequently may lead to biased travel time estimates. This may explain the seemingly contradictory results obtained in 1993.

Subyearling chinook salmon migrating past McNary Dam during the early, middle, and late portions of the outmigration in 1993 appeared to be fully smolted and were physiologically adapted to sea water. Although statistical differences were found between plasma Na' values, biologically there appeared to be no trend in seawater adaptiveness. Fish in all three seawater tests performed equally well as evidenced by low mortality and ability to regulate plasma Na' below 165 mmol/L, the value given by Clarke and Shelbourn (1985) for characterizing chinook salmon smolts. However, fish challenged in mid-August in the serial seawater challenge had mean plasma Na' values both above and below 165 mmol/L. The gradual rise in plasma Na' values as the outmigration progressed may suggest that late migrants may be migrating after some optimal time of emigration that would ensure successful seawater entry. This may be especially true considering the high water temperatures encountered in late summer and the adverse effects they may have on smolt physiology. The slight increase in plasma **Na'** levels over time as river temperatures increased and flows decreased was the only relationship, albeit weak, that existed between physiology and environmental conditions. Higher plasma Na' values in challenged fish compared to freshwater control groups may be attributed the maintenance of plasma Na' at **a** higher equilibrium in **seawater** (Conte and Wagner 1965) or the requirement of more than,48 h in seawater to further lower plasma Na' as indicated by the serial seawater challenge.

The rise in gill ATPase activity exhibited by Priest Rapids and wild Hanford Reach fish was likely due to physiological change characteristic during emigration (Zaugg et al. 1985). Gill ATPase activity of run-at-large fish sampled at McNary Dam in 1993 were generally lower than in 1991 and 1992. Peak activities were 8-12 units lower than in those in 1992 and 1991, respectively. The cooler water temperatures in 1993 may have retarded or delayed physiological development. Despite the lower gill ATPase activities, fish were still able to adapt to sea water. The loss of gill samples from the late seawater challenge precluded comparison to ATPase activities from the late challenge in 1992. Although ATPase activities were significantly elevated in seawater fish from the late challenge in 1992, this trend **was** not observed until after 36 and 48 h had elapsed in the serial seawater challenge in 1993. The elevation of gill ATPase activity is consistent with the findings of other investigators (see review in Folmar and Dickhoff 1980) relating to sea water's stimulating effect on ATPase activity but may also be dependent on other variables as well.

The relationship of gill **ATPase** activity of run-at-large fish sampled at McNary Dam to travel time in 1993 was not as distinct as in 1991 and 1992. There was a small rise in gill ATPase activity as travel time increased but the insignificant decline that followed did not match the sharp decrease in travel time. This observed trend of increasing gill ATPase activities with increasing travel times was unexpected. The definition and cause for this pattern may be elucidated after collecting additional data in upcoming years.

A meaningful biological preference for different salinities could not be established in 1993 for subyearling chinook salmon. This was due largely to the design of the test apparatus. The circular nature of the tank allowed fish to swim and explore directionally without ceasing and regard to salinity. This strong swimming behavior of both hatchery and run-at-large fish was likely the factor controlling fish distributions and not preference for the available salinities despite observed statistical differences. This swimming behavior was also observed in a different circular tank in 1994. Subyearling fall chinook salmon appear to exhibit strong tendencies to swim, even as premigrants, which may be an adaptive advantage for migrating great distances seaward in their first year of life. The desire to swim may be stronger than selecting a desired salinity in a tank that offers both choices as was the case in this study. An alternative explanation may be that development of a salinity preference may require more time than was allowed in these tests.

References

Blackburn, J., and W.C. Clarke. 1987. Revised procedure for the 24 hour seawater challenge test to measure seawater adaptability of juvenile salmonids. Canadian Technical Report of Fisheries and Aquatic Sciences.

Brege, D.A., W.E. Farr, and R.C. Johnsen. 1990. An air-lift pump for sampling juvenile salmonids at John Day Dam. North American Journal of Fisheries Management 10:481-483.

Clarke, W.C., and J.E. Shelbourn. 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha* in relation to temperature. Aquaculture 45:21-31.

Conte, F.P., and H.H. Wagner. 1965. Development of osmotic and ionic regulation in juvenile steelhead trout *Salmogairdneri.* Comparative Biochemistry and Physiology 14:603-620.

Fish Passage Center. 1994. Fish passage center 1993 annual report. Annual Report to Bonneville Power Administration, Contract DE-FC79-88BP38906, Portland, Oregon.

Folmar, L.C., and W.W. Dickhoff. 1980. The Parr-smolt transformation (smoltification) and seawater adaptation in salmonids: A review of selected literature. Aquaculture 21:1-37.

Giorgi, A.E., D.R. Miller, and B.P. Sanford. 1990. Migratory behavior and adult contribution of summer outmigrating subyearling chinook salmon in John Day Reservoir, 1981-1983. Final Report to Bonneville Power Administration, Contract DE-A179-83BP39645, Portland, Oregon.

Jefferts, K.B., P.K. Bergman, and H.F. Fiscus. 1963. A coded-wire identification system for macro-organisms. Nature (London) 198:460-462.

Matthews, G.M., and D.L. Park, S. Achord, and T.E. Reuhle. 1986. Static seawater challenge test to measure relative stress levels in spring chinook salmon smolts. Transactions of the American Fisheries Society 115:236-244.

Mighell, J.L. 1969. Rapid cold-branding of salmon and trout with liquid nitrogen. Journal of the Fisheries Research Board of Canada 26:2765-2769.

Otto, R.G., and J.E. McInerney. 1970. Development of salinity preference in pre-smolt coho salmon, *Oncorhynchus kisutch*. Journal of the Fisheries Research Board of Canada 27:793-800.

SAS Institute. 1990. SAS/STAT User's Guide, Release 6.04 edition. SAS Institute Inc., Cary, North Carolina.

Schrock, R-M., J.W. Beeman, D.W. Rondorf, and P.V. Haner. 1994. A microassay for gill sodium, potassium · activated ATPase in juvenile salmon. Transactions of the American Fisheries Society (In Press).

Skalski, J.R. 1989. Statistical evaluation_ of the smolt monitoring program at McNary and John Day dams. Report to Pacific Northwest Utilities Conference Committee, Portland, Oregon.

Wagner, P.G. 1994. 1993 McNary Dam smolt monitoring program annual report. Annual Report to Bonneville Power Administration, Project 87-127, Portland, Oregon.

Zar, J.H. 1984. Biostatistical analysis. Prentice Hall. Englewood Cliffs, New Jersey.

Zaugg, W.S., E.F. Prentice, and F.W. Waknitz. 1985. Importance of river migration to the development of seawater tolerance in Columbia River anadromous salmonids. Aquaculture 51:33-47.

CHAPTER SIX

Comparison of Field and *InSitu* Acoustic Target Strengths of Juvenile Fall Chinook Salmon and American Shad

by

E.E. Kofoot, D.H. Feil
and W.S. Stastny
National Biological Survey
Northwest Biological Science Center
Columbia River Research Laboratory
Cook, Washington 98605, USA

Introduction

Subyearling fall chinook salmon *Oncorhynchus tshawytscha* that are naturally produced or released from upriver hatcheries on the Columbia and Snake rivers migrate primarily during the summer. High concentrations of juvenile American shad *Alosa sapidissima* also migrate seaward through lower Columbia River reservoirs during late summer and early fall. Migratory conditions during these times are characterized by increasing water temperatures and decreasing flows and passage of fish through mainstem impoundments is often slow, especially through John Day Reservoir (Miller and Sims 1984). Describing the relationship between juvenile chinook salmon distribution and water velocity will lead to a better understanding of their migratory behavior and their relatively slow migration through mainstem reservoirs. However, with the recent listing of Snake River fall chinook salmon as a threatened species under the Endangered Species Act (ESA; NMFS 1992), **a** non-lethal and non-obtrusive methodology must be employed to study migrating juvenile chinook salmon. Hydroacoustic sampling is such a technique and is useful for defining fish distribution and behavior in reservoir environments.

The acoustic target strengths of fish have been used successfully to estimate relative fish size and abundance in numerous aquatic environments (Dickie et al. 1984; Foote et al. 1986; Jacobson et al. 1990; Mesiar et al. 1990). Many factors can influence the variability of acoustic target characteristics and identification of individual fish including biological and environmental attributes such as size, species, orientation of the fish to the transducer beam, depth, and time (Blaxter and Batty 1990; MacLennan et al. 1990). In addition, gas bubbles in the water column also produce acoustic targets and can interfere with data collection by masking fish targets (Thorne et al. 1992). Target strengths of fish may be determined through controlled experiments in which fish are tethered or confined in small enclosures and rotated on different **axes** while in an acoustic transducer beam (Love 1971, 1977; Miyanohana, et al. 1990). In contrast, *insitu* experiments, in which fish are acoustically sampled while exhibiting normal behavior in a natural environment, (Dawson and Karp 1990; Miinalainen and Eronen 1990) may exhibit different acoustic properties than those of fish that are immobilized or confined (Miinalainen and Eronen 1990).

The objectives of this study were to measure *insitu* target strengths of juvenile fall chinook salmon and American shad from known length ranges and to compare those to target strengths observed during field hydroacoustic surveys performed in the Columbia River. The findings presented here were used to gather preliminary data to devise the best sampling protocols and analytical approaches for ongoing hydroacoustic sampling.

Methods

Open water hydroacoustic and trawl surveys were conducted on McNary and John Day reservoirs during the summer of 1993. Surveys were conducted on McNary Reservoir from 27 June to 8 August and John Day Reservoir was sampled from 5 August to 28 October. McNary Reservoir was divided into three 6 km reaches based on diversity of hydrologic cross sections. Reach 1 (river kilometer (RK) 477 to 483) was located 8 km above McNary Dam, reach 2 (RK 497 to RK 503) was a mid-reservoir reach, and reach 3 (RK 512 to RK 518) was located 16 km below the confluence of the Snake and Columbia rivers. In John Day Reservoir, **a** single 10 km reach was sampled from RK 386 to RK 396.

Each sampling reach was divided into river kilometers which were further subdivided into 10 fixed cross-sectional river transects. Transects were located 0.1 km apart and oriented perpendicular to the shoreline. A single river reach was sampled each day and is referred to as a hydroacoustic survey. A starting transect was chosen at random within the lowest river kilometer of the selected reach at the start of each day of sampling. A global positioning system (GPS) was used for locating and navigating hydroacoustic transects. Transects were sampled beginning at the most down-river transect and proceeded upstream. This design made it unlikely that fish detected in one transect would be detected in the next upstream transect.

Hydroacoustic data were collected using a Biosonics dual-beam system. Data were processed using the following equipment: a model 105 echo sounder, a 420 KHz (6°/15°) dual-beam transducer oriented vertically and downward, a 151 chart recorder, a Compaq 486 micro computer using ESP V2.0 dual beam-signal processing software, and a model 171 digital tape interface. Ping rate was 5 pings/s, pulse width was 0.4 ms, and receiver sensitivity gain was set at 0 decibels (dB). An echo received from a single ping was referred to as a target. A grouping of targets that matched user defined criteria was classified as **a** tracked fish. Criteria were based on ping density, ping range, and exclusion of all targets < -60 decibels dB. Chart recordings, computer generated echograms, and the target strength of tracked gas bubbles were used to try and differentiate between gas bubbles and fish.

A mid-water trawl made of monofilament mesh was used in the pelagic regions of the McNary and John Day reservoirs to verify species composition and fish size for target strength estimates from hydroacoustic surveys. Three trawls were performed during each hydroacoustic survey at randomly selected mid-river and nearshore locations. Two mid-channel trawls were performed at 5 m and 3/4 of the total depth and a nearshore trawl was performed at 5 m, unless the total nearshore depth was greater than 11 m, in which case a trawl was made at 3/4 depth. An additional trawl was performed at a location of high fish concentration identified during each hydroacoustic survey. Trawling was conducted after all hydroacoustic sampling within a river kilometer had been completed. All trawls were deployed for 10 min at .the designated sampling depth and towed upstream,' parallel to shore. All fish captured were identified to species, measured (fork length), and released. If more than 40 fish were captured in a trawl, a subsample of approximately 30 individuals were randomly removed and processed.

Hydroacoustic data collected from McNary Reservoir were divided into two groups for juvenile chinook salmon target strength analysis. The first group (Group 1) included fish targets identified in hydroacoustic surveys performed from 27 June to 15 July and the second group (Group 2) included fish targets identified from 20 July to 10 August. This grouping was based on the expectation of fish increasing in size during the sampling period. In addition, this grouping facilitated comparison of target strengths from two different sizes of fish from hydroacoustic surveys with the target strengths of two size groups used in net pen tests. Hydroacoustic transects from John Day Reservoir were separated into two groups for juvenile American shad target strength analysis and was also based on the expectation of increasing fish length over time. Group 3 included fish targets identified in surveys performed from 23 September to 10 October and Group 4 included fish targets identified from 26 October to 28 October.

In situ net pen tests were conducted at Drano Lake, which is located adjacent to the Columbia River at RK 261. The net pen was anchored in open water and measured 6m x 6m x 6m and was suspended from a rigid, floating frame. Juvenile fall chinook salmon of two size ranges and a single size class of American shad were tested for target strengths during September 1993. Juvenile fall chinook salmon used in the net pen experiments were Upriver Bright stock raised at the Little White Salmon National Fish Hatchery and held at the Columbia River Research Laboratory. The juvenile American shad were collected at the Bonneville Dam juvenile fish collection facility and transported directly to Drano Lake. The first group of 200 subyearling fall chinook salmon were tested on 8 September and 10 September and a second group of 93 yearling fall chinook salmon were tested on 13 September. Juvenile chinook salmon were allowed to acclimate to the net pen for a minimum of 24 h before hydroacoustic tests were performed. A group of 73 juvenile American shad were tested on 14 September. Because of their fragile nature and problems associated with holding juvenile American shad for an extended period of time, hydroacoustic tests were performed on shad the same day as their release into the net pen.

Acoustic target strength measurements were made by a stationary transducer suspended near the center of the net pen and oriented vertically and downward. In addition, the transducer was also suspended near the periphery and aimed horizontally across the net pen. All groups of net pen fish were sampled with both the vertical (down-looking) and horizontal (side-looking) transducer arrangement. Fork lengths (FL) were measured for each group of experimental fish at the completion of each net pen test.

Results

Hydroacoustic Surveys

Juvenile ChinookSalmon.- A total of 593 juvenile fall chinook salmon were captured in 36 trawls conducted in McNary Reservoir during 1993. Juvenile fall chinook salmon made up 95.6% of the total trawl catch in McNary Reservoir with other fish species comprising the remaining 4.4% (Table 1). The mean fork length of juvenile fall chinook salmon captured in Group 1 trawl surveys in McNary Reservoir was 94 mm (range 68 mm to 114 mm) (Figure 1A). Juvenile fall chinook salmon captured in Group 2 trawl surveys in McNary Reservoir had a mean fork length of 112 mm (range 94 mm to 132 mm) (Figure 1B).

The majority of tracked fish identified in McNary Reservoir were believed to be juvenile fall chinook salmon and is based on fish size and species composition from trawl samples in McNary Reservoir. Hydroacoustic surveys performed in McNary Reservoir from 27 June to 15 July (Group 1) ensonified 740 tracked fish and displayed a mean target strength of -48.0 dB (SD = 7.5 dB; range -60.3 dB to -24.5 dB)(Figure 2A). Hydroacoustic surveys performed in McNary Reservoir from 20 June to 10 August (Group 2) identified 344 tracked fish with a mean target strength of -46.9 dB (SD = 7.7 dB; range -58.3 dB to -29.4 dB) (Figure 2B).

American Shad- A total of 2,334 juvenile American shad were captured in 31 trawls in John Day Reservoir and made up 98.7% of the total catch (Table 2). Juvenile fall chinook salmon made up 1.3% of the total trawl catch in John Day Reservoir with other fish species accounting for less than 1% of the total catch. The mean fork length of juvenile American shad captured in Group 3 trawl surveys in John Day Reservoir was 66 mm (range 44 mm to 84 mm) (Figure 3A). The mean fork length of juvenile American shad salmon captured in Group 4 trawls was 71 mm (range 48 mm to 100 mm) (Figure 3B).

Table l.- Species composition and length data, grouped by day, for trawl surveys conducted in McNary Reservoir, 1993.

Trawl Date	Species[1]	Avg FL (mm)	Length Range (mm)	Total Catch	Percent Catch
6-29-93	CHN	94	68 - 110	126	100.0
6-30-93	CHN	94	74 - 111	108	99.1
	SCH	145		1	0.9
7-13-93	CHN	93	83 - 114	24	100.0
7-14-93	CHN	95	76 - 113	169	100.0
7-21-93	CHN	112	97 - 125	63	98.4
	PEM	Adult		1	1.6
7-22-93	CHN	109	94 - 118	21	95.5
	LSS	> 300		1	4.5
7-27-93	CHN	111	95 - 123	34	97.1
	PEM	Adult		1	2.9
7-29-93	CHN	118	117 - 118	2	100.0
8-04-93	CHN	118	105 - 132	15	51.7
	CRP	> 300		6	20.7
	LSS	> 300		4	13.8
	PEM	Adult		2	6.9
	COT	Adult		1	3.4
	SMB	> 300		1	3.4
8-10-93	CHN	125	122 - 127	5	38.5
	SQF	> 300		5	38.5
	LSS	Adult		1	7.7
	PEM	Adult		1	7.7
	CHM	Adult		1	7.7

'Species abbreviations are CHN: fall chinook salmon *O.tshawyrscha*; COT: Cottidae; CRP: common carp *Cyprius carpio;* LSS: large scale sucker *Catostomus macrocheilus* ; PEM : peamouth *Myfocheilus caurinus;* SCH: Spring chinook salmon *0. rshallytscha;* SMB: small mouth bass *Mcropterussalmoides.*

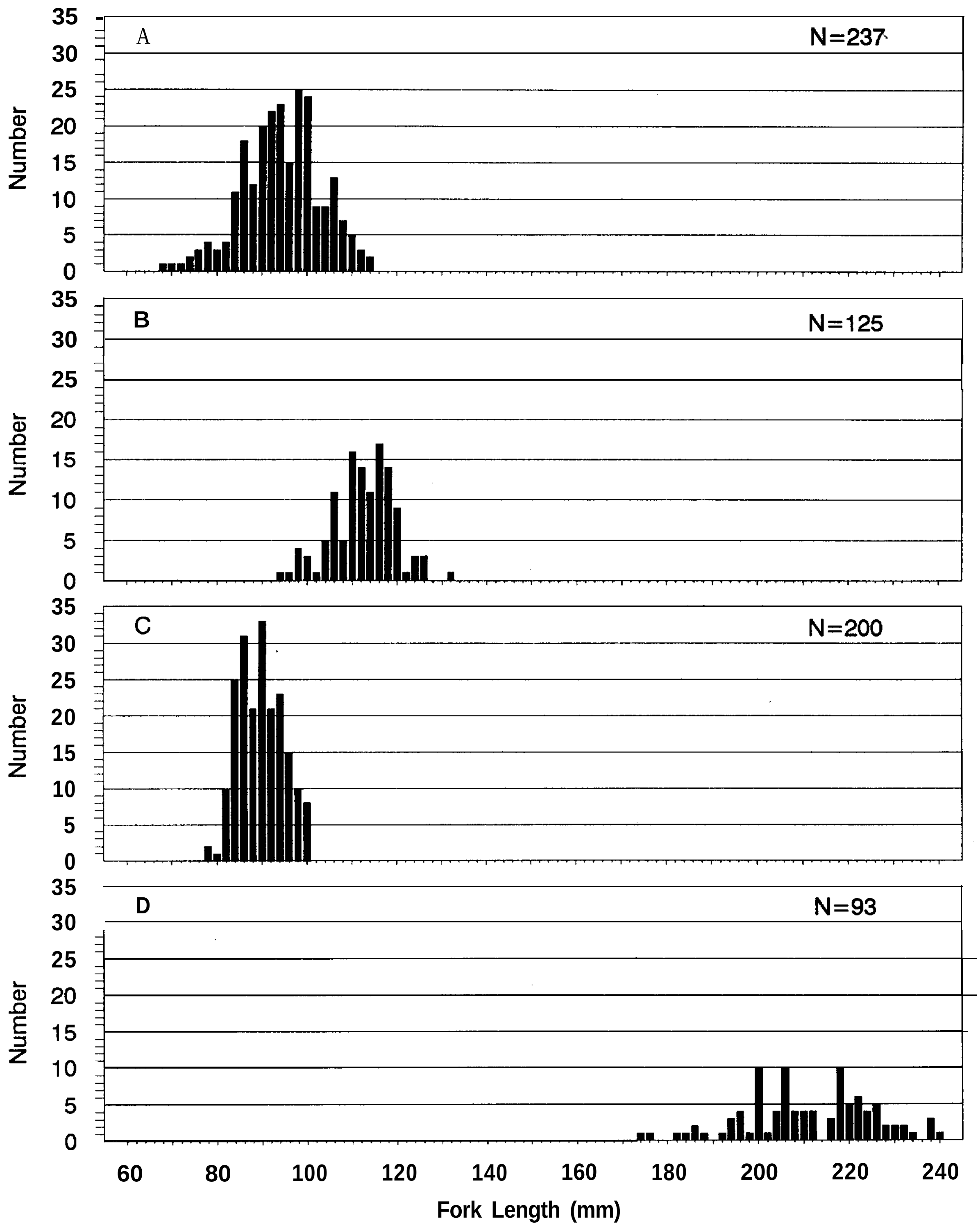

Figure 1.-Length frequency distributions of juvenile fall chinook salmon from trawls performed in McNary Reservoir from 6-29 to 7-14-93 (A) and from 7-21 to 8-4-93 (B) and 1993 net pen evaluations of subyearling chinook salmon (C) and yearling chinook salmon (D).

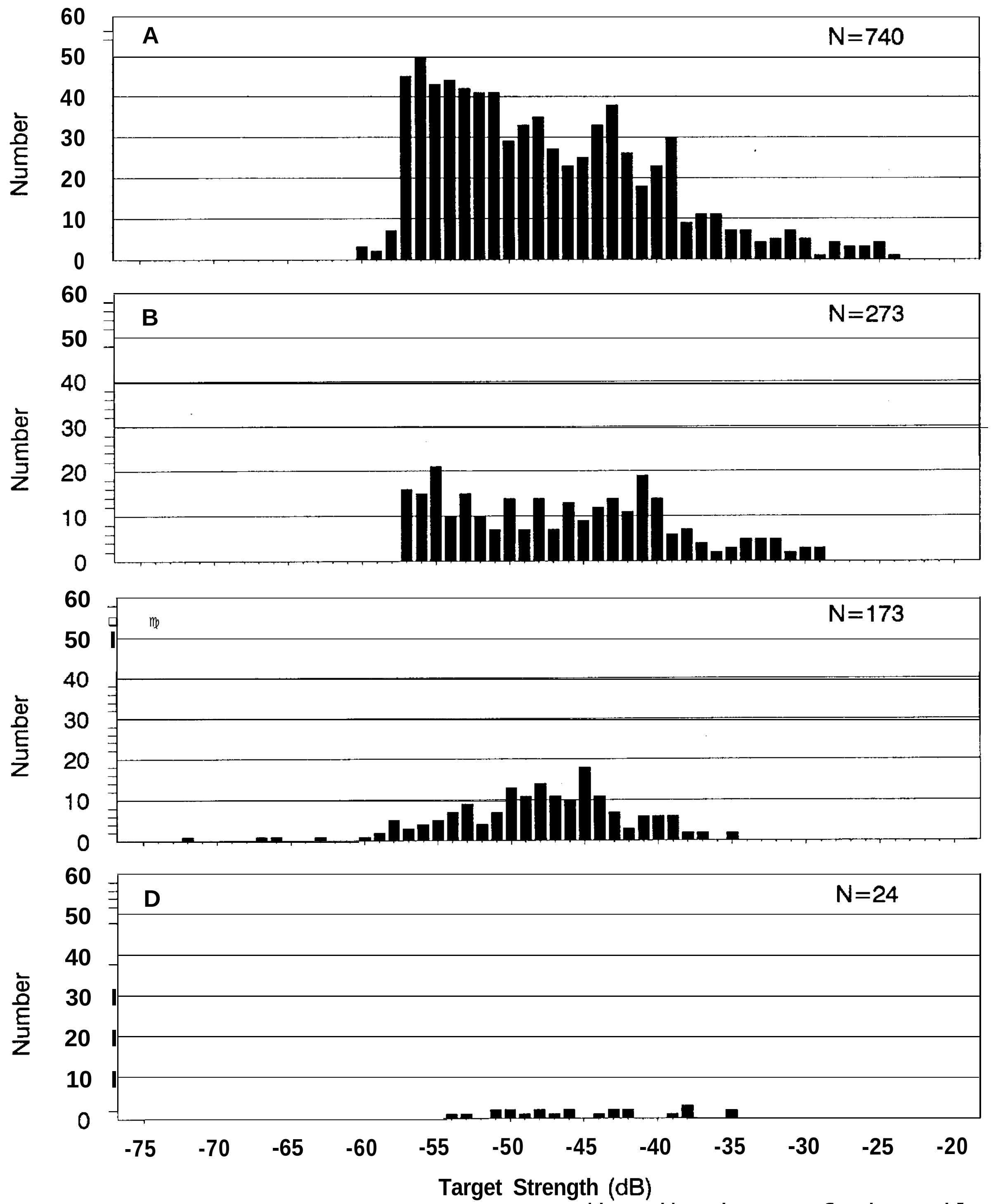

Figure 2.-Target strength frequency distributions of juvenile fall chinook salmon from down-looking hydroacoustic surveys performed in McNary Reservoir from 6-30 to 7-14-93 (A) and from 7-21 to 8-4-93 (B) and 1993 net pen evaluations of subyearling chinook salmon (C; 77-100 mm fl) and yearling chinook salmon (D; 174-239 mm fl).

Table 2.- Species composition and length data, grouped by day, for trawl surveys conducted in John Dav Reservoir, 1993.

Trawl Date	Species[1]	Avg FL (mm)	Length Range (mm)	Total Catch	Percent Catch
8-05-93	CHN	124	119 - 134	21	87.5
	ASH	37	32 - 46	3	12.5
8-25-93	CHN	137		1	0.3
	ASH	38	23 - 66	374	99.7
8-26-93	CHN	135	130 - 139	3	0.3
	ASH	41	26 - 75	624	99.5
9-23-93	CHN	138	133 - 142	2	1.8
	ASH	61	44 - 84	110	98.2
9-24-93	CHN	133		1	3.3
	ASH	69	59 - 80	29	96.7
10-5-93	ASH	70	51 - 83	40	100.0
10-26-93	CHN	170	164 - 175	2	0.2
	ASH	73	62 - 92	925	99.8
10-27-93	No Fish			0	
10-28-93	ASH	70	48 - 100	229	99.6
	COT	Adult		1	0.4

[1]Species abbreviations are ASH: American shad *Alosa sapidissima;* CHM: chiselmouth *Acrocheilus alutaceus;* CHN: fall chinook salmon *O. tshawytscha;* COT: Cottidae; LSS: large scale sucker *Catostomus macrocheilus;* PEM: peamouth *Mylocheilus caurinus ;* SQF : northern squawfish *Ptychocheilus oregonsis.*

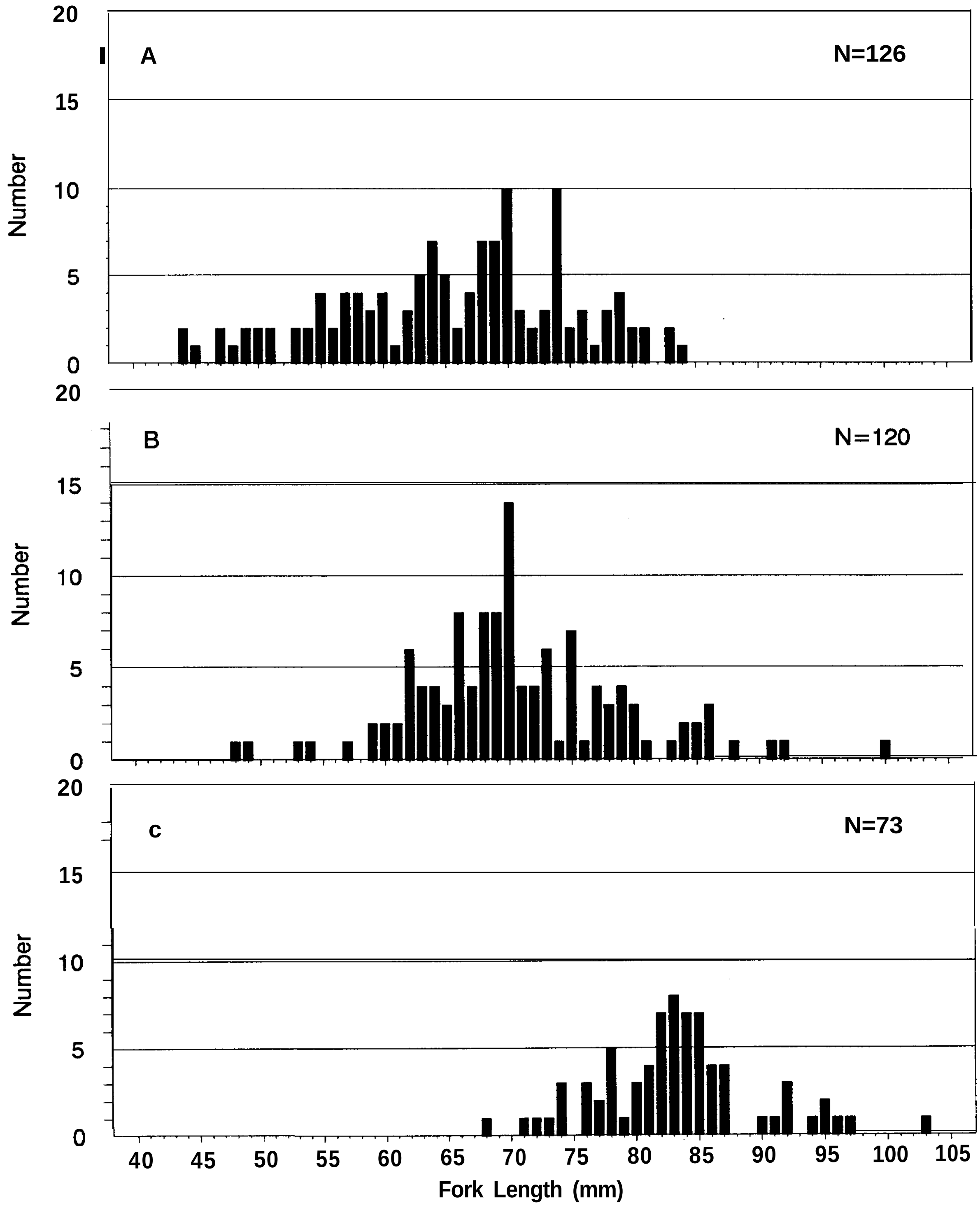

Figure 3.- Length frequency distributions of juvenile American shad from trawls performed in John Day Reservoir from 9-23 to 10-5-93 (A) and from 10-26 to 10-28-93 (B) and 1993 net pen evaluations (C).

The majority tracked fish identified in John Day Reservoir were believed to **be** juvenile American shad. This was based on fish size and species composition from trawl samples in John Day Reservoir. Hydroacoustic surveys performed in John Day Reservoir from 23 September to 5 October (Group 3) ensonified 231 tracked fish which displayed a mean target strength of -43.3 dB (SD = 5.1 dB; range -58.1 dB to -30.1 dB) (Figure 4A). Hydroacoustic surveys performed 26 October to 28 October (Group 4) identified 221 tracked fish with a mean target strength of -41.8 dB (SD = 4.8 dB; range -57.9 dB to -22.3 dB) (Figure 4B).

In Situ Experiments

Juvenile ChinookSalmon.- Subyearling fall chinook salmon used in net pen experiments had an average fork length of 89 mm (range 77 mm to 100 mm) (Figure 1C). The average fork length of yearling fall chinook salmon used in net pen experiments was 211 mm (range 174 mm to 239 mm) (Figure 1D). Target strengths of 173 tracked subyearling chinook ensonified with the down-looking transducer arrangement averaged -48.6 dB (SD = 5.9 dB; range -72.1 dB to -35.3 dB) (Figure 2C). Twenty four targets were ensonified during net pen experiments using yearling fall chinook salmon and had a mean target strength of -44.7 dB (SD = 5.9 dB; range -54.9 dB to -31.4 dB) (Figure 2D).

Side-looking hydroacoustic tests performed using subyearling fall chinook salmon during net pen experiments located 68 tracked fish with a mean target strength of -61.0 dB (SD = 5.9 dB; range -76.6 dB to -45.4) (Figure 5A). Larger yearling fall chinook salmon displayed an average target strength of -48.5 dB (SD = 5.3 dB; range -59.0 dB to 35.3 dB) from 89 tracked fish (Figure 5B).

Juvenile American shad- Juvenile American shad used in net pen experiments on 14 September consisted of 73 fish with a mean fork length of 83 mm (range 68 mm to 103 mm) (Figure 4C). Target strengths of 234 tracked juvenile American shad ensonified with the down-looking transducer arrangement averaged -50.8 decibels dB (SD = 5.3 dB; range -72.6 dB to -36.6 dB) (Figure 5C). Side-looking results from 15 tracked fish of the same group of American shad had a mean target strength of -59.0 dB (SD = 6.6 dB; range -70.7 dB to -45.4 dB) (Figure 5D).

Gas Bubbles.- Gas bubbles rising from the bottom were apparent in many locations in McNary and John Day reservoirs. Concentrations of gas bubbles varied from single ris-ing columns to a multitude of columns. High concentrations of gas bubbles usually appeared as a cloud of tickmarks on the chart recorder (Figure 6A) and masked fish targets which appeared as distinct tickmarks in the absence of gas bubbles (Figure 6B). Target strengths of 533 tracked gas bubbles identified during

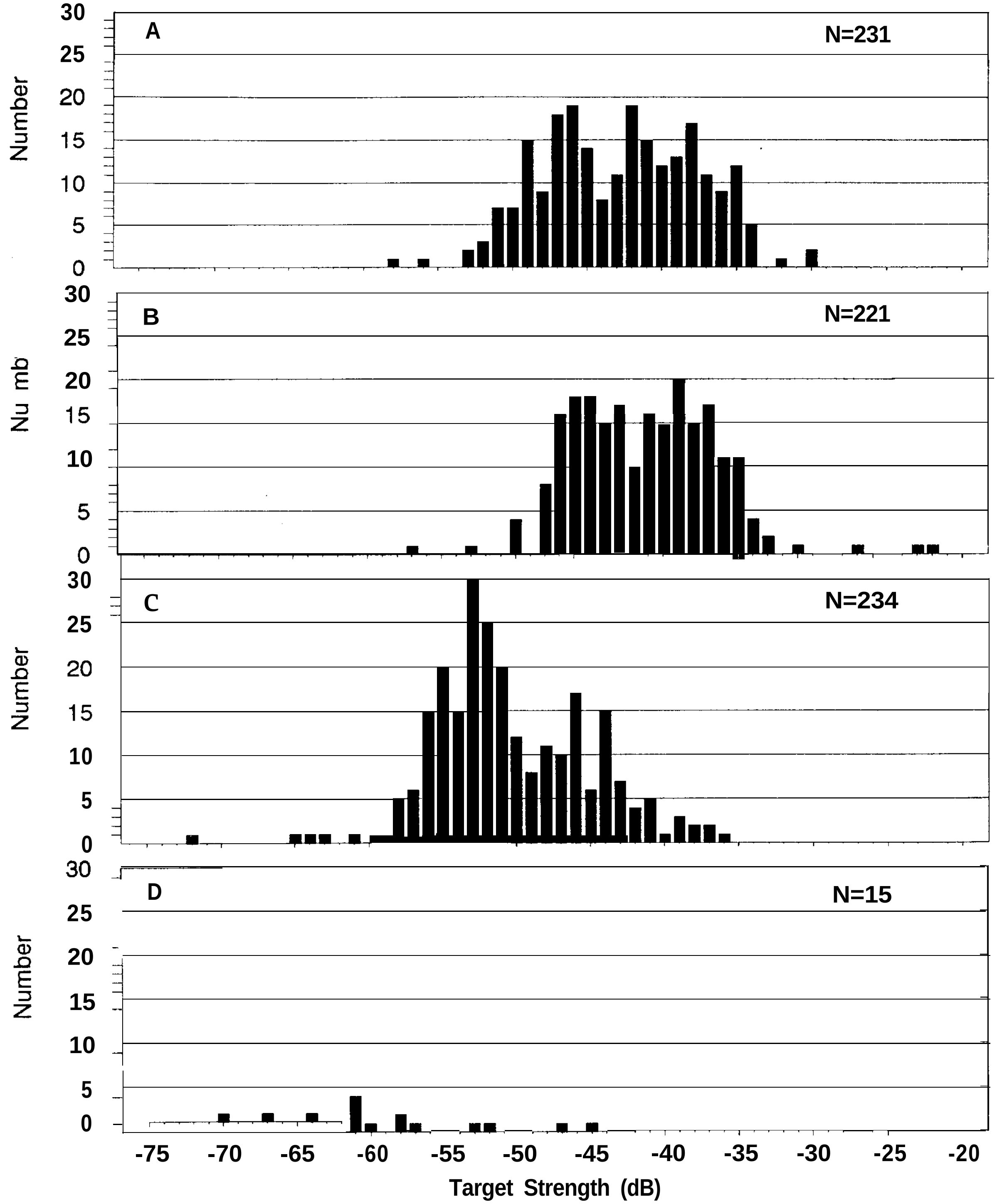

Figure 4.-Target strength frequency distributions of juvenile American shad from down-looking hydroacoustic surveys performed in John Day Reservoir from 9-23 to 10-5-93 (A) and 10-26 to 10-28-93 (B) and 1993 net pen evaluations (C down-looking & D side-looking,

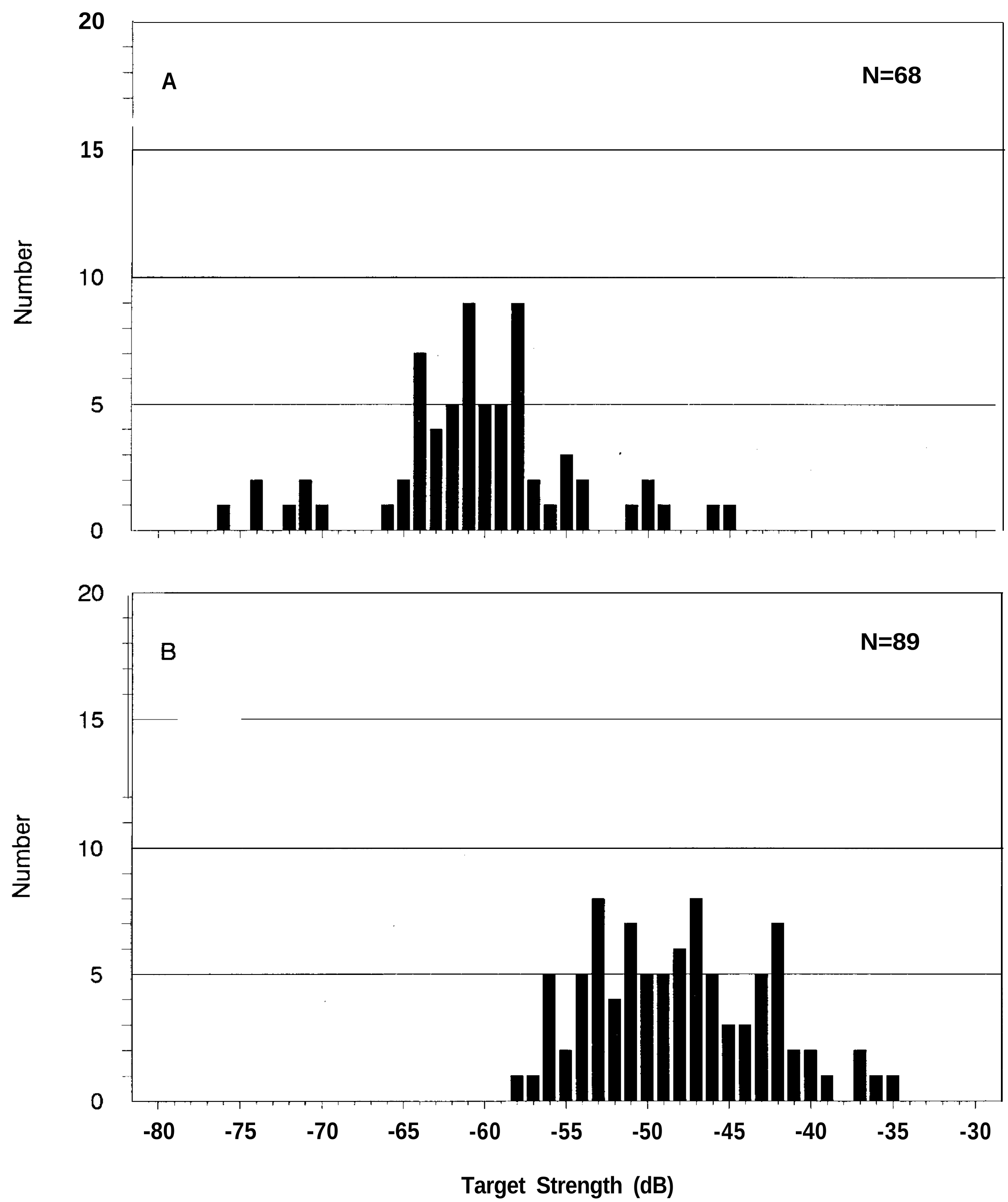

Figure 5. -Target strength frequency distributions of subyearling chinook salmon (A; 77-100 mm FL) and yearling chinook salmon (B; 175-239 mm FL) from side-looking net pen evaluations in 1993.

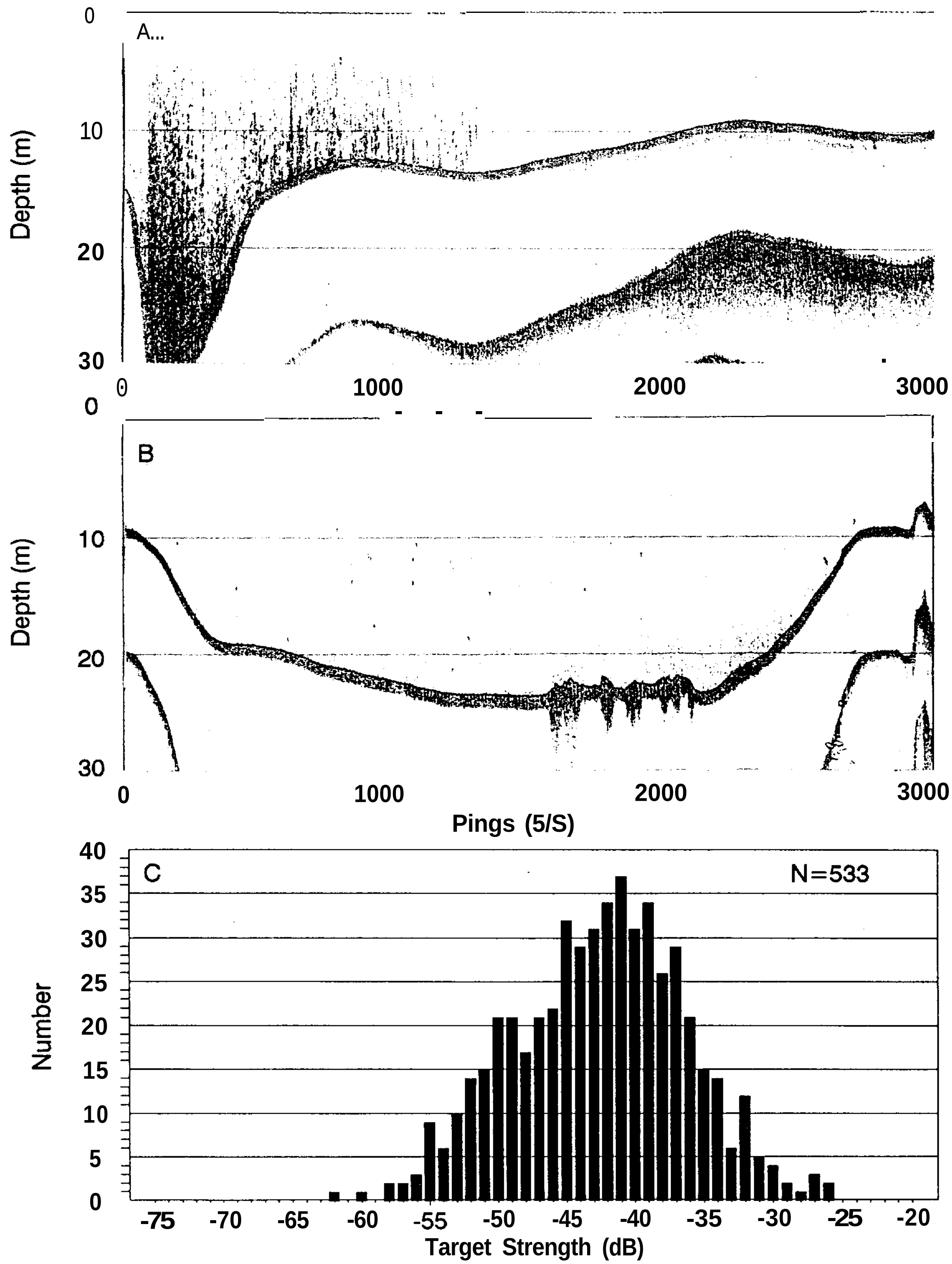

Figure 6.-Example of cross-sectional hydroacoustic chart recording showing rising columns of gas bubbles, which appear as a dense collection of tick marks (A). Example of cross-sectional hydroacoustic chart recording showing individual fish, which appear

hydroacoustic surveys conducted on McNary Reservoir from 29 June to 30 June exhibited a mean target strength of -43.1 dB (SD = 6.3 dB; range -62.6 dB to -26.2 dB) (Figure 6C).

Discussion

Hydroacoustic target strength is directly related to fish size and will increase as fish size increases. It is also expected that multiple fish of the same species and within the same size range will display similar acoustic properties. This is evident in the comparison of target strengths of juvenile fall chinook salmon from Group 1 trawl surveys in McNary Reservoir and subyearling fall chinook salmon used during *insitu* experiments. The mean target strengths of these two groups differed by only 0.6 dB as is not unexpected given the small difference between average fork lengths and the complete overlap in fork length ranges. Although the average target strengths of tracked fish recorded for Group 1 are similar to those recorded for subyearling fall chinook salmon during *insitu* experiments, the overall range of target strengths between the two groups is quite distinct. The greater number of tracked fish in Group 1 with higher target strengths was likely due to some larger fish that were ensonified during the hydroacoustic surveys.

The relationship of increasing target strength with increasing fish size is not evident when yearling and subyearling fall chinook salmon net pen tests are compared. The average fork length of yearling fall chinook salmon used during *insitu* experiments was 211 mm, which is more than double that of the subyearling fall chinook salmon tested (89 mm). Although the size difference was considerable, the disparity between the mean target strength of yearling and subyearling fall chinook salmon (-44.7 dB and -48.6 dB, respectively) was not **as** great as expected for down-looking tests. In side-looking tests, the separation of target strength ranges for tracked subyearling and yearling chinook salmon is slightly more apparent, but still not as great as expected. In both cases, these unexpected results may be due to behavioral differences duringinsitu experiments and/or their orientation or location in the transducer beam.

The average target strengths recorded for American shad tracked during hydroacoustic surveys in John Day Reservoir were higher than those obtained from shad in net pen tests. This result is especially confusing considering the mean fork length of fish in John Day Reservoir was smaller than that of net pen fish. The opposite result should have been obtained if target strength increases with increasing fish size. However, the target strengths recorded for tracked fish during American shad net pen tests are believed to be accurate for the size of fish used. This is based on the close agreement between target strengths and fork lengths of American shad when 1993 net pen data is compared with 1994 field data from John Day Reservoir (unpublished data) . The counterintuitive 1993 John Day Reservoir results may have been due to errors in calibration or suboptimal equipment settings. Hydroacoustic equipment was returned to the factory for recalibration at the end of the 1993 field season. Further investigation and analysis of 1993 and 1994 data will enhance the interpretation of 1993 results.

The limits of using hydroacoustics to distinguish different fish species of similar size is apparent when examining the results of *insitu* experiments using subyearling fall chinook salmon and juvenile American shad. The similarity in sizes and target strengths of these two species makes them acoustically indistinguishable from each other. Without the distinct separation in migration timing of juvenile fall chinook salmon and American shad, the use of hydroacoustics would not be a beneficial tool for assessing differences in migration behavior and distribution.

The average target strength of tracked gas bubbles were compared with that of tracked fish to determine if separation of fish from gas bubbles was possible using automated processing parameters. Although the average target strength of tracked bubbles was -43.1 dB, which was only slightly higher than the average target strengths recorded for tracked juvenile chinook salmon and American shad, the overall range of target strengths for tracked gas bubbles was large and overlapped all ranges of tracked fish targets recorded during hydroacoustic surveys and net pen experiments. This extensive overlap of target strengths and the dense concentrations encountered in many areas of the reservoirs made the task of separating gas bubbles from fish impractical. Thorne et al. (1992) attempted a similar analysis using Lower Granite Reservoir data and concluded that this was a laborious and inaccurate task.

In summary, hydroacoustic and trawl surveys of McNary and John Day reservoirs revealed that the majority of the fish tracked in McNary Reservoir were juvenile fall chinook salmon while juvenile American shad dominated John Day Reservoir samples. Target strengths of juvenile fall chinook salmon tracked in McNary Reservoir were similar to those of both subyearling and yearling fall chinook salmon used in net pen tests. The target strengths of yearling chinook salmon in net pens were lower than expected given they were almost twice as large as all other juvenile fall chinook salmon surveyed or tested. A comparison of field surveyed and net pen tested juvenile American shad did not support the relationship that target strength increases with an increase in fish size. This counterintuitive finding may have been due to suboptimal equipment performance.

References

Blaxter, J.H.S., and R.S. Batty. 1990. Swimbladder "behaviour" and target strength. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:233-244.

Dawson, J.J., and W.A. Karp. 1990. *In situ* measures of target-strength variability of individual fish. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:264-273.

Dickie, L.M., R.G. Dowd, and P.R. Boubreau. 1984. Acoustic estimates of demersal fish using a dual-beam transducer in laboratory and field. Journal of the Acoustical Society of America 76(4):1175-1183.

Foote, K.G., A. Aglen, and 0. Nakken. 1986. Measurement of fish target strength with a split-beam echo sounder. Journal of the Acoustical Society of America 80(2):612-621.

Jacobson, P.T., C.S. **Clay,** and J.J. Magnuson. 1990. Size, distribution, and abundance of pelagic fish by deconvolution of single-beam acoustic data. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:304-311.

Love, R.H. 1971. Dorsal-aspect target strength of an individual fish. Journal of the Acoustical Society of America 49:816-823.

Love, R.H. 1977. Target strength of an individual fish at any aspect. Journal of the Acoustical Society of America 62:1397-1403.

MacLennan, D.N., A.E. Magurran, T.J. Pitcher, and C.E. Hollingworth. 1990. Behvioural determinants of fish target strength. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:245-253.

Mesiar, D.C., D.M. Eggers, and D.M. Gaudet. 1990. Development of techniques for the application of hydroacoustics to counting migratory fish in large rivers. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:223-232.

Miialainen, O.H.J., and T. Eronen. 1990. A least-squares method for *insitu* estimation of fish target strength with a single transducer sonar. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:312-316.

Miller, D.R., and C.W. Sims. 1984. Effects of flow on the migratory behavior and survival of juvenile fall and summer chinook salmon in John Day Reservoir. Report to Bonneville Power Administration, Contract DE-A179-83BP39645, Portland, Oregon.

Miyanohana, Y., K. Ishii, and M. Furusawa. 1990. Measurements and analyses of dorsal-aspect target strength of six species of fish at four frequencies. Rapport et Proces-verbaux des Renunions du Conseil Permanent Internationale pour L'Exploration de la Mer 189:317-324.

National Marine Fisheries Service. 1992. Threatened status for Snake River spring/summer chinook salmon, threatened status for Snake River fall chinook salmon. Final rule, April 22, 1992. Federal Register, Volume 57, Number 78.

Thorne, R.E., C.J. McClain, J. Hedgepeth, E.S. Kuehl, and J. Thorne. 1992. Hydroacoustic surveys of the distribution and abundance of fish in Lower Granite Reservoir, 1989-1990. Report to U.S. Army Corps of Engineers, Contract DACW68-C-0022, Walla Walla, Washington.

LIST OF APPENDICES

Appendix 1. Data used in the 1993 emigration rate analysis.

TAG-FILES	TAG_ID$	REL_SZ	LN_SZ	MGR_FLOW	LN_FLOW	MGR_TEMP	LN_TEMP	REL_TEMP	LN_REL_T	MIGR_RATE
WPC93139.G51	7F7D251179	60	4.0943	107.2	4.6749	14.5	2.6731	14	2.6391	1.7
WPC93145.G29	7F7D393F52	65	4.1744	85.5	4.4483	15.5	2.7434	13.2	2.5802	1
WPC93145.A51	7F7D360E75	60	4.0943	98.0	4.5854	14.8	2.6917	15	2.7081	1.9
WPC93145.G34	7F7D4A3667	61	4.1109	81.7	4.4029	15.9	2.7639	14.8	2.6946	1
WPC93147.G53	7F7D393D72	a4	4.4308	109.8	4.6985	14.3	2.6598	15.3	2.7279	2.8
WPC93152.G29	7F7D457E3A	74	4.3041	87.2	4.4684	15.1	2.7178	14.7	2.6878	1.5
WPC93153.G33	7F7D39715B	74	4.3041	61.8	4.1233	17.7	2.8732	15	2.7081	0.7
WPC93154.254	7F7D341F0D	a2	4.4067	80.9	4.3926	15.6	2.7441	13	2.5649	2
WPC93155.G30	7F7D341269	77	4.3438	76.6	4.3382	15.9	2.7677	15	2.7081	1.2
WPC93159.W37	7F7D3A0B0E	86	4.4543	76.1	4.332	15.9	2.766	13	2.5649	1.7
WPC93159.W34	7F7D357A4A	63	4.1431	76.8	4.3415	15.8	2.7625	13	2.5649	1.7
WPC93159.W42	7F7D393448	63	4.1431	72.9	4.2889	16.2	2.7859	14	2.6391	1.6
WPC93159.W42	7F7D39327C	62	4.1271	69.9	4.247	16.5	2.8055	14	2.6391	1.4
WPC93159.W41	7F7D394035	a4	4.4308	85.8	4.4516	15.3	2.7283	15	2.7081	2.5
WPC93159.W41	7F7D393E63	72	4.2767	84.7	4.4385	15.3	2.7307	15	2.7081	2.4
WPC93159.W34	7F7D3A033B	68	4.2195	93.8	4.5414	15.2	2.718	13	2.5649	2.8
WPC93159.E41	7F7D453A31	61	4.1109	73.4	4.2959	16.2	2.7822	14	2.6391	1.6
WPC93160.A51	7F7D3F3C61	67	4.2047	68.6	4.228	16.7	2.8133	14	2.6391	1.6
WPC93160.226	7F7D394335	81	4.3944	70.3	4.2535	16.4	2.7996	14	2.6391	1.2
WPC93160.226	7F7D3A0543	80	4.382	69.9	4.2468	16.5	2.8019	14	2.6391	1.2
WPC93160.G42	7F7D392276	66	4.1897	69.9	4.2468	16.5	2.8019	14	2.6391	1.5
WPC93160.G32	7F7D364E30	61	4.1109	72.4	4.2816	16.2	2.787	15	2.7081	1.4
WPC93160.226	7F7D397C28	a2	4.4067	80.5	4.3885	15.6	2.7471	14	2.6391	1.7
WPC93162.W24	7F7D454234	64	4.1589	81.1	4.396	15.6	2.7444	13.5	2.6027	2.1
WPC93162.E29	7F7D4A2B72	67	4.2047	86.7	4.4622	15.5	2.7418	14	2.6391	2.7
WPC93162.E29	7F7D455054	77	4.3438	68.4	4.2249	16.6	2.8069	14	2.6391	1.3
WPC93162.E29	7F7D3F3E56	a2	4.4067	68.8	4.2311	16.5	2.8044	14	2.6391	1.3
WPC93166.E62	7F7D101D4C	63	4.1431	67.1	4.2066	16.3	2.7929	14	2.6391	3
WPC93166.E61	7F7D38154F	76	4.3307	64.7	4.1695	16.6	2.8108	14.5	2.6741	2.5
WPC93166.E66	7F7D472D38	70	4.2485	64.3	4.1637	16.7	2.8142	15	2.7081	2.6
WPC93166.E63	7F7D0F6819	86	4.4543	66.6	4.1981	16.4	2.7961	15	2.7081	3.1
WPC93167.A51	7F7D3A0429	86	4.4543	61.5	4.1192	16.9	2.8295	16	2.7726	2
WPC93167.229	7F7D397E2D	75	4.3175	65.3	4.1785	16.4	2.7994	15	2.7081	1.9
WPC93167.A51	7F7D347539	a4	4.4308	65.8	4.1867	16.4	2.7962	16	2.7726	2.8
WPC93167.232	7F7D393E60	60	4.0943	75.5	4.3245	15.9	2.7682	15	2.7081	3.4
WPC93167.229	7F7D3E2B10	64	4.1589	48.5	3.8813	18.6	2.9216	16	2.7726	0.7
WPC93168.W40	7F7D39367D	76	4.3307	72.3	4.2806	16.0	2.77	14	2.6391	3.9
WPC93168.W47	7F7D0E332C	97	4.5747	61.4	4.118	16.8	2.8238	15	2.7081	2.1
WPC93169.W24	7F7D0F617F	70	4.2485	70.2	4.2509	16.0	2.7726	15.5	2.7408	3.2
WPC93169.E29	7F7D34293A	63	4.1431	58.3	4.0663	17.2	2.8468	15	2.7081	1.3
WPC93169.E29	7F7D34217D	72	4.2767	59.1	4.0784	17.1	2.8374	15	2.7081	1.4
WPC93169.E28	7F7D0E2834	88	4.4773	66.3	4.1946	16.1	2.7818	16	2.7726	2.6
WPC93173.229	7F7D4A3A0A	94	4.5433	59.5	4.0854	16.3	2.7881	16.9	2.8273	3.2
WPC93175.W34	7F7D392E60	71	4.2627	56.2	4.0293	16.5	2.8011	14.5	2.6741	3.7
WPC93175.E36	7F7D392650	76	4.3307	53.9	3.9875	17.1	2 .a395	16	2.7726	2.4
WPC93175.E36	7F7D393268	71	4.2627	53.3	3.9767	17.5	2.8596	16	2.7726	1.8
WPC93180.A51	7F7D396C04	93	4.5326	50.6	3.923	17.1	2.8362	16.8	2.8214	4.3
WPC93181.E54	7F7D3A0A1F	91	4.5109	51.1	3.9338	17.6	2.8693	16.7	2.8154	2.9
WPC93195.226	7F7D3D7462	122	4.804	52.0	3.9518	18.3	2.9048	18.6	2.9232	4.2

Appendix 2. Data for chinook salmon juveniles that were PIT tagged in the Snake and Clearwater rivers, diverted at Lower Granite Dam, and analyzed by etectrophoresis, 1993.

Tag code	Release date	Release length (mm)	Release site	Detection date	Detection length	Days at large	Race	Age
7F7D3A070C	02-Jun	91	Snake	17-Jun	107	15.6	Spring/Sumner	0
7F7D446310	01-Jun	86	Snake	20-Jun	112	18.8	Spring/Sumner	0
7F7D397D16	02-Jun	87	Snake	20-Jun	106	17.9	Spring/summer	0
7F7D4A3943	08-Jun	87	Snake	22-Jun	105	14.2	Spring/summer	0
7F7D42462B	18-May	75	Snake	24-Jun	120	37.6	Spring/summer	0
7F7D393739	18-Jun	71	Snake	25-Jun	99	6.8	Spring/Sumner	0
7F7D4A4517	25-May	76	Snake	25-Jun	110	30.7	Spring/summer	0
7F7D454000	16-Jun	93	Snake	26-Jun	105	10.3	Spring/Sumner	0
7F7D396F17	08-Jun	86	Snake	26-Jun	108	17.7	Spring/Sumner	0
7F7D39732C	07-Jun	82	Snake	27-Jun	120	19.4	Spring/summer	0
7F7D34286F	01-Jun	81	Snake	27-Jun	116	25.7	Spring/summer	0
7F7D0E154F	IS-May	66	Snake	27-Jun	109	39.9	Spring/summer	0
7F7D0E3615	17-Jun	96	Snake	27-Jun	108	9.8	Spring/summer	0
7F7D0F3843	19-May	70	Snake	27-Jun	115	38.9	Spring/summer	0
7F7D392D0C	01-Jun	60	Snake	28-Jun	71	27.2	Spring/summer	0
7F7D394141	02-Jun	94	Snake	28-Jun	125	25.6	Spring/summer	0
7F7D0E1446	01-Jun	85	Snake	28-Jun	120	26.4	Spring/summer	0
7F7D10083C	18-May	64	Snake	29-Jun	113	42.2	Spring/summer	0
7F7D393C5A	08-Jun	92	Snake	29-Jun	120	21	Spring/Sumner	0
7F7D39254B	08-Jun	98	Snake	30-Jun	120	21.9	Spring/Sumner	0
7F7D392742	II-Jun	71	Snake	30-Jun	114	19	Spring/summer	0
7F7D394300	01-Jun	75	Snake	30-Jun	107	28.4	Spring/Sumner	0
7F7D39747F	27-May	68	Snake	30-Jun	107	33.8	Spring/summer	0
7F7D393A16	08-Jun	78	Snake	03-Jul	112	24.8	Spring/Sumner	0
7F7D4A3038	22-Jun	108	Snake	03-Jul	119	10.7	Spring/Sumner	0
7F7D364F01	22-Jun	91	Snake	04-Jul	107	12	Spring/Sumner	0
7F7D0D766C	24-Jun	104	Snake	04-Jul	122	10.5	Spring/Sumner	0
7F7D340D60	02-Jun	73	Snake	05-Jul	114	33.1	Spring/Sumner	0
7F7D340D51	25-May	64	Snake	06-Jul	122	42.1	Spring/Sumner	0
7F7D392C04	02-Jun	66	Snake	06-Jul	91	34	Spring/summer	0
7F7D3F2A3D	18-Jun	99	Snake	06-Jul	116	17.9	Spring/Sumner	0
7F7D461502	25-May	72	Snake	06-Jul	114	41.7	Spring/Sumner	0
7F7D397322	02-Jun	65	Snake	06-Jul	104	33.7	Spring/Sumner	0
7F7D394046	16-Jun	86	Snake	07-Jul	120	19.4	Spring/summer	0
7F7D460C3A	25-May	68	Snake	08-Jul	126	43.6	Spring/summer	0
7F7D1E6D23	22-Jun	93	Snake	09-Jul	120	17.1	Spring/summer	0
7F7D340D08	10-Jun	76	Snake	09-Jul	132	28.4	Spring/summer	0
7F7D392C3D	09-Jun	76	Snake	09-Jul	132	30	Spring/summer	0
7F7D360E46	08-Jun	78	Snake	09-Jul	119	30.8	Spring/summer	0
7F7D4A3A60	18-Jun	87	Snake	IO-Jut	115	21.8	Spring/summer	0
7F7D397F2B	27-May	69	Snake	IO-Jul	128	45.2	Spring/summer	0
7F7D472A1F	16-Jun	75	Snake	11-Jul	115	24.8	Spring/summer	0
7F7D0E3E04	19-May	63	Snake	12-Jul	123	53.8	Spring/summer	0
7F7D0E3F5B	19-May	67	Snake	13-Jul	129	54.6	Spring/summer	0
7F7D4A2B2E	II-Jun	89	Snake	13-Jul	131	31.8	Spring/summer	0
7F7D452A15	08-Jun	75	Snake	13-Jul		35.2	Spring/summer	
7F7D0F7328	08-Jun	62	Snake	14-Jul	136	36	Spring/summer	0
7F7D39257E	27-May	67	Snake	14-Jul	128	47.7	Spring/summer	0
7F7D461378	25-May	60	Snake	14-Jul	117	49.6	Spring/summer	0
7F7D357C33	01-Jun	70	Snake	15-Jul	127	43.6	Spring/Sumner	0
7F7D4A323C	25-May	60	Snake	16-Jul	121	52.1	Spring/summer	0
7F7D370A2D	07-Jun	70	Snake	18-Jul	143	40.3	Spring/summer	0
7F7D393002	29-Jun	117	Snake	19-Jul	147	19.7	Spring/summer	0
7F7D453E4E	08-Jun	91	Snake	19-Jul	138	41.3	Spring/summer	0
7F7D454D3D	11-Jun	84	Snake	19-Jul	137	37.9	Spring/summer	0
7F7D392635	25-May	63	Snake	19-Jul	146	54.7	Spring/summer	0
7F7D342940	07-Jun	67	Snake	19-Jul	148	41.3	Spring/summer	0
7F7D394005	08-Jun	100	Snake	21-Jul	146	43.3	Spring/summer	0
7F7D453D4E	II-Jun	85	Snake	21-Jul	140	40	Spring/Sumner	0
7F7D2B6305	02-Jun	72	Snake	21-Jul	126	48.6	Spring/summer	0
7F7D457844	08-Jun	72	Snake	23-Jul	143	45.5	Spring/summer	0
7F7D393A5A	08-Jun	70	Snake	26-Jul	138	48.3	Spring/Sumner	0
7F7D0F3466	15-Jun	90	Snake	26-Jul	142	41	Spring/summer	0

Appendix 2. (Continued).

Tag code	Release date	Release Length (mm)	Release site	Detection date	Detection length	Days at large	Race	Age
7F7D457C33	19-May	61	Snake	27-Jul	153	68.6	Spring/summer	0
7F7D401A62	IO-Jun	65	Snake	28-Jul	113	48.3	Spring/summer	0
7F7D393D4A	08-Jun	61	Snake	30-Jul	145	51.9	Spring/summer	0
7F7D420B03	16-Jun	77	Snake	25-Aug	166	68.6	Spring/summer	0
7F7D393D72	27-May	84	Snake	25-Jun	121	28.5	Fall	0
7F7D3A033B	08-Jun	68	Snake	30-Jun	91	22	Fall	0
7F7D4A2B72	11-Jun	67	Snake	01-Jul	97	20.5	Fall	0
7F7D393E60	16-Jun	60	Snake	03-Jul	87	17.4	Fall	0
7F7D251179	19-May	60	Snake	04-Jul		45.7	Fall	
7F7D0F617F	18-Jun	70	Snake	04-Jul	95	15.7	Fall	0
7F7D39367D	16-Jun	68	Snake	04-Jul	113	17.3	Fall	0
7F7D394035	08-Jun	84	Snake	05-Jul	115	26.8	Fall	0
7F7D360E75	25-May	60	Snake	05-Jul	120	40.9	Fall	0
7F7D393E63	08-Jun	72	Snake	06-Jul	104	28.1	Fall	0
7F7D454234	II-Jun	64	Snake	06-Jul	90	24.8	Fall	0
7F7D0E2834	18-Jun	88	Snake	09-Jul	122	21	Fall	0
7F7D457E3A	01-Jun	74	Snake	09-Jul	133	37.5	Fall	0
7F7D397C28	09-Jun	82	Snake	09-Jul	124	30.3	Fall	0
7F7D4A3A0A	22-Jun	94	Snake	10-Jul	121	17.7	Fall	0
7F7D392E60	24-Jun	71	Snake	11-Jul	99	16.4	Fall	0
7F7D101D4C	15-Jun	63	Snake	14-Jul	107	29.2	Fall	0
7F7D347539	16-Jun	84	Snake	14-Jul	129	28.1	Fall	0
7F7D357A4A	08-Jun	63	Snake	14-Jul	121	35.9	Fall	0
7F7D341F0D	03-Jun	82	Snake	14-Jul	144	41	Fall	0
7F7D397E2D	16-Jun	68	Snake	15-Jul	122	28.9	Fall	0
7F7D3A0B0E	08-Jun	86	Snake	15-Jul	143	37.2	Fall	0
7F7D0F6819	15-Jun	86	Snake	15-Jul	131	29.5	Fall	0
7F7D396C04	29-Jun	93	Snake	17-Jul	121	18.1	Fall	0
7F7D393F52	25-May	65	Snake	20-Jul	142	56	Fall	0
7F7D341269	04-Jun	77	Snake	20-Jul	125	45.8	Fall	0
7F7D364E30	09-Jun	61	Snake	20-Jul	123	41.2	Fall	0
7F7D453A31	08-Jun	61	Snake	20-Jul	121	41.8	Fall	0
7F7D38154F	15-Jun	76	Snake	20-Jul	120	34.9	Fall	0
7F7D393448	08-Jun	63	Snake	21-Jul	129	42.7	Fall	0
7F7D472D38	15-Jun	70	Snake	21-Jul	125	36.2	Fall	0
7F7D392650	24-Jun	76	Snake	21-Jul	107	26.8	Fall	0
7F7D0E332C	17-Jun	97	Snake	22-Jul	157	34.9	Fall	0
7F7D3F3E56	II-Jun	82	Snake	23-Jul	144	41.8	Fall	0
7F7D455054	II-Jun	77	Snake	24-Jul	142	42.7	Fall	0
7F7D394335	09-Jun	81	Snake	24-Jul	149	44.7	Fall	0
7F7D3A0543	09-Jun	80	Snake	25-Jul	137	45.6	Fall	0
7F7D392276	02-Jun	60	Snake	25-Jul	132	45.9	Fall	0
7F7D3A0429	16-Jun	86	Snake	26-Jul	145	40	Fall	0
7F7D4A3667	25-May	61	Snake	27-Jul	146	63.3	Fall	0
7F7D3D7462	14-Jul	122	Snake	27-Jul	131	12.7	Fall	0
7F7D34217D	18-Jun	72	Snake	27-Jul	135	39.2	Fall	0
7F7D39327C	08-Jun	62	Snake	28-Jul	131	49.8	Fall	0
7F7D3A0A1F	30-Jun	91	Snake	28-Jul	126	28.1	Fall	0
7F7D393268	24-Jun	71	Snake	29-Jul	125	34.6	Fall	0
7F7D3F3C61	09-Jun	67	Snake	29-Jul	141	50.3	Fall	0
7F7D34293A	18-Jun	63	Snake	30-Jul	132	41.6	Fall	0
7F7D39715B	02-Jun	74	Snake	25-Aug	177	84.4	Fall	0
7F7D3E2B10	16-Jun	64	Snake	02-Sep	171	77.8	Fall	0
7F7D1B5E74	16-Jun	86	Lower Granite R.	21-Jul	140	35.2	Spring/summer	0
7F7D454D16	09-Jun	61	Lower Granite R.	24-Jun	71	15.4	Spring/Sumner	0
7F7D454F7D	09-Jun	79	Lower Granite R.	22-Jul	142	43.5	Spring/summer	0
7F7D0E1913	16-Jun	67	Lower Granite R.	16-Jul	106	30.3	Fall	0
7F7D453B54	02-Jun	62	Lower Granite R.	23-Jul	138	51.4	Fall	0
7F7D392251	01-Jut	68	Clearwater	25-Jul	98	23.72	Spring/summer	0
7F7D44607D	15-Jul	82	Clearwater	20-Jul	81	5.36	Spring/summer	0
7F7D3A0148	01-Jul	75	Clearwater	14-Jul	78	13.36	Fall	0

Appendix 3. -Total number of incidental fish caught by beach seine in McNary Reservoir and the Hanford Reach of the Columbia River, Washington, 1993.

Common Name	Scientific Name	Total Catch	
		McNary	Hanford
Carp	Cyprinus carpio	3	21
Chisel mouth	Acrocheilus alutaceous	1	0
Crappie	Pomoxis spp.	0	3
Largemouth bass	Micropterus salmoides	2	0
Largescale sucker	Catostomus macrocheilus	54	23
Mountain whitefish	Prosopium williamsoni	18	9
Northern squawfish	Ptychocheilus oregonensis	19	195
Peamouth	Mylocheilus caurinus	20	129
Rainbow trout	Oncorhynchus mykiss	2	32
Redside shiner	Richardsonius balteatus	0	84
Salmon	Oncorhynchus spp.	1	0
Sculpins	Cottidae	35	11
Smallmouth bass	Micropterus dolomieui	33	2
Spring chinook	Oncorhynchus tshawytscha	53	27
Suckers	Catostomus spp.	5	5
Threespine stickleback	Gasterosteus aculeatus	13	283
Walleye	Stizostedion vitreum	3	0
Yellow perch	Perca flavescens	5	11
Unidentified		1	18

Appendix 4.-Mean catch/seine haul (CPUE) of subyearling chinook salmon caught by beach seine during one week sampling intervals in McNary Reservoir and the Hanford Reach of the Columbia River, Washington and in the Snake River, Idaho, Oregon, and Washington, 1993.

Week Beginning With	McNary Reservoir Mean CPUE	Hanford Reach Mean CPUE	Snake River Mean CPUE
3/22		6	
3/29			
4/5			<1
4/12	8	13	Cl
4/19			1
4/26	20	307	1
5/3			1
5/10	31		2
5/17			4
5/24	264	229	4
5/31			5
6/7	114	87	5
6/14			5
6/21			2
6/28	24	15	2
7/5			2
7/12	1	1	2
7/19			<1

Appendix 5.- Mean'fork length (FL) and standard deviation (SD) of subyearling chinook salmon caught by beach seine during one week sampling intervals in McNary Reservoir and the Hanford Reach of the Columbia River, Washington and in the Snake River, Idaho, Oregon, and Washington, 1993.

Week Beginning With	McNary Reservoir FL	McNary Reservoir SD	Hanford Reach FL	Hanford Reach SD	Snake River FL	Snake River SD
3/22			41.9	1.9		
3/29						
4/5					39.7	1.5
4/12	47.8	4.7	41.5	1.8	43.0	4.6
4/19					45.9	4.5
4/26	47.4	6.6	43.7	4.2	47.9	5.6
5/3					49.8	6.7
5/10	45.6	6.1			49.1	7.0
5/17					57.3	11.0
5/24	50.0	7.0	46.2	6.4	54.0	10.5
5/31					60.3	11.1
6/7	56.8	8.6	51.9	8.9	69.6	11.6
6/14					69.1	11.5
6/21					80.0	16.7
6/28	73.9	8.8	62.4	7.6	82.5	13.9
7/5					93.1	10.8
7/12	85.0	4.4	79.3	4.5	100.6	9.7
7/19					94.2	14.3

Appendix 6.-Summary of the number of subyearling chinook salmon marked with coded wire tags and brands or considered not suitable for marking at McNary Dam during 1993.

			MARKED			48 HOUR DELAYED MORTALITY AND TAG LOSS				UNMARKABLE				
Date	CWT Code	Brand	Marked & Bypassed	Held & Trans.	Total Mark.	#Morts	%Mort	#Lost Tags	%Tag Loss	Prev. Branded	Desc.	Under-Size	Other Unmark.	Total Unmark.
Jun 24	33-18	RAW1	5,374	50	5,424	0	0.0	0	0.0	15	194	144	1,533	1,886
Jun 25	33-18	RAW2	3,706	50	3,756	0	0.0	0	0.0	22	110	77	637	846
Jun 26	33-18	RAW3	2,792	50	2,842	0	0.0	0	0.0	43	47	93	288	471
Jun 27	33-19	RAW4	4,647	50	4,697	0	0.0	1	2.0	51	60	167	419	697
Jun 28	33-19	LAW1	4,405	50	4,455	0	0.0	0	0.0	58	50	114	309	531
Jun 29	33-19	LAW2	2,975	50	3,025	0	0.0	0	0.0	53	34	28	133	248
Jun 30	33-20	LAW3	4,635	50	4,685	0	0.0	0	0.0	76	44	54	204	378
Jul 1	33-20	LAW4	3,349	50	3,399	0	0.0	0	0.0	50	27	86	154	317
Jul 2	33-20	RA2J1	4,061	50	4,111	0	0.0	2	4.0	79	50	37	204	370
	Subtotal		35,944	450	36,394	0	0.0	3	0.7	447	616	800	3,881	5,744
Jul 9	33-21	RA2T1	3,249	50	3,299	1	2.0	1	2.0	46	44	52	182	324
Jul 10	33-21	RA2T3	5,201	50	5,251	1	2.0	2	4.0	106	50	63	291	510
Jul 11	33-21	LA2T1	3,428	50	3,478	1	2.0	1	2.0	52	35	5	205	297
Jul 12	33-22	LA2T3	2,811	50	2,861	0	0.0	0	0.0	55	32	7	212	306
Jul 13	33-22	RA2P1	5,176	50	5,226	0	0.0	0	0.0	66	45	3	269	383
Jul 14	33-22	RA2P3	3,871	50	3,921	0	0.0	0	0.0	33	27	7	222	289
Jul 15	33-23	LA2P1	3,228	50	3,278	0	0.0	0	0.0	28	25	6	230	289
Jul 16	33-23	LA2P3	3,752	50	3,802	0	0.0	0	0.0	33	143	3	330	409
Jul 17	33-23	RA9U1	2,662	50	2,712	0	0.0	0	0.0	24	30	0	290	344
Jul 18	33-23	RA9U3	2,177	50	2,227	1	2.0	0	0.0	8	39	1	331	379
	Subtotal		35,555	500	36,055	4	0.8	4	0.8	451	370	147	2,562	3,530
Jul 27	33-24	RA2V1	3,365	50	3,415	0	0.0	0	0.0	22	99	3	270	394
Jul 28	33-24	RA2V3	5,451	50	5,501	0	0.0	1	2.0	17	114	0	338	469
Jul 29	33-24	LA2V1	2,982	50	3,032	0	0.0	1	2.0	10	82	0	206	298
Jul 30	33-25	LA2V3	982	50	1,032	0	0.0	0	0.0	4	26	0	113	143
Jul 31	33-25	RA2L1	6,003	50	6,053	1	2.0	0	0.0	14	120	0	380	514
Aug 1	33-25	RA2L3	4,865	50	4,915	0	0.0	0	0.0	32	59	2	301	394
Aug 2	33-26	LA2L1	5,251	50	5,301	0	0.0	0	0.0	31	103	0	292	426
Aug 3	33-26	LA2L3	3,649	50	3,699	0	0.0	1	2.0	10	70	0	285	365
Aug 4	33-26	RA2C1	3,030	50	3,080	1	2.0	0	0.0	18	54	2	229	303
	Subtotal		35,578	450	36,028	2	0.4	3	0.7	158	727	7	2,414	3,306

SUMMARY	MARKED			48 HOUR DELAYED MORTALITY AND TAG LOSS				UNMARKABLE				
	Marked & Bypassed	Held & Trans.	Total Mark.	#Morts	%Mort	#Lost Tags	%Tag Loss	Prev. Branded	Desc	Under-Size	Other Unmark.	Total Unmark.
TOTAL	107,077	1,400	108,477	6	0.4	10	0.7	1,056	1,713	954	8,857	12,580