Preoperational Environmental Monitoring Studies Near WNP 1, 2 and 4 August 1978 Through March 1980

Prepared for:

Washington Public Power Supply System

By:

Beak Consultants Incorporated

WPPSS Columbia River Ecology Studies Vol. 7

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WPPSS COLUMBIA RIVER ECOLOGY STUDIES VOLUME 7
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AQUATIC ECOLOGICAL STUDIES NEAR WNP-1, 2, and 4 AUGUST 1978-MARCH 1980

Prepared for

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FOREWORD

This report has been prepared for the Washington Public Power Supply System by Beak Consultants Incorporated. Data collection, analysis, and presentation were the responsibilities of the following personnel:

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EXECUTIVE SUMMARY

This report supplements previous aquatic ecological studies of the Columbia River near the WNP-1, 2, and 4 intake-discharge structures which commenced in September 1974 and were conducted by Battelle Northwest Laboratories. In addition, fish-power plant investigations were initiated during the present study which encompasses the period August 1978 through March 1980. Results are summarized below.

PHYTOPLANKTON

There was a marked increase in the number of species observed in each month of the study period compared to previous studies. As in past studies, diatoms dominated the phytoplankton community both in numbers of species and in percentage of the total monthly densities. Dominant species were small, centric diatoms.

Diversity indices were highest in summer, fall, and early winter when densities were highest. Diversity indices were higher for most months than previously reported. Unit densities were highest during late spring and lowest in November and December of 1978 and 1979. Chlorophyll a pigment was at highest levels in late spring and early summer, with lowest values occurring in late fall and early winter in both 1978 and 1979.

ZOOPLANKTON AND ICHTHYOPLANKTON

Seasonal variation in zooplankton dominance was similar to past years. Dominant taxa included Diaptomus, Cyclops, and Bosmina; a total of 45 taxa were identified. Maximum zooplankton densities in 1979 were similar to 1978 values, but much lower than the 1977 peaks.

Ichthyoplankton samples contained only a few yolk sac and post-yolk sac larvae. Maximum densities were 0.14 individuals/m^3. These findings suggest low densities

and diversity of fish eggs and larvae in the water column of the area sampled.

BENTHIC MACROFAUNA AND MICROFLORA

Caddisflies (Hydropsychidae) and midges (Chironomidae) were dominant macrofauna numerically. Hydropsychidae and the snail *Lithoglyphus* contributed most to macrofauna biomass. Abundance was highest in September or December and lowest in March. Diversity was generally highest in June and lowest in December.

Statistical comparisons among sampling stations showed the most upriver (station 1) and downriver (station 8) sampling locations were consistently among the bottom three stations in mollusc biomass. One station (11 W) has ranked high in total density since its establishment in September 1977.

Diatoms were the dominant periphyton (attached microflora) taxa. Periphyton densities were highest in winter and diversity was highest in late summer or early fall. No consistent among-station differences were observed.

FISH

A total of 5,503 fish, representing 29 species and 12 families, were collected during the present study. This brings to 38 the grand total of species collected since initial sampling in 1974. The most common species collected were chinook salmon (predominantly fry), largescale sucker, chiselmouth, mountain whitefish, redside shiner, bridgelip sucker, and northern squawfish. These species collectively comprised about 95 percent of the total catch.

Comparison of past and present catch data showed some seasonal but no year-to-year variation. Statistical analysis of data showed highest gill-net catches of minnows (Cyprinidae) occurred at station 4 (crossriver from the intake-discharge structures), while there were no statistical among-station differences for gill-n

catches of suckers (Catostomidae). Largest beach-seine catches of chinook salmon (fry) occurred at stations 1 and 2 located downriver and crossriver, respectively, from the intake-discharge structures.

Chinook salmon fry migrated through the study area from late April through early July with peak movement in late May. An initial estimate of individual fry residence time in the study area was less than 10 - 15 days, which represented the shortest interval between samplings by beach seine.

Food items identified during stomach content examination of selected species included aquatic insect larvae and pupae (primarily caddisflies and midges), molluscs, small fish, algae, and detrital material. The diet was often reflective of the community composition identified during benthic macrofauna studies.

Various life history and population dynamics characteristics were described for selected species.

FISH-POWER PLANT INTERACTIONS

Effects of the WNP-2 intake structures on fish populations appeared negligible. Fish were sometimes observed near the intakes and may have been attracted to areas of reduced velocities. However, they were generally few in number and none were observed to be impinged against the intake pipes. SCUBA divers felt no suction when placing their hands directly on the perforated pipe, indicating intake velocities were quite low. No damage or other irregularities to the structures were noted during the dives.

The absence of fish eggs, larvae, and fry from entrainment samples indicates the flow field had not been modified in a manner that would be detrimental to juvenile recruitment to Columbia River fish populations. These results indicate entrainment is not likely to be a serious problem at WNP-2 with the present intake

design and placement, and that a 12-hour sampling interval with the entrainment cages provides sufficient coverage to detect and measure future entrainment.

Studies to date of the WNP-2 discharge plume indicate no effect of plume discharge on surrounding river velocity patterns.

Turbidity and suspended solids values during placement of the WNP-1/4 intake and discharge lines were well within the temporary water quality standard established by EFSEC.

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1.0 GENERAL

1.1 INTRODUCTION

In July 1978, Beak Consultants Incorporated (BEAK) was awarded a contract to conduct preoperational aquatic monitoring for Washington Public Power Supply System (WPPSS) Nuclear Projects 1, 2, and 4 (WNP-1, 2, and 4). This work represented a continuation of studies begun in September 1974 conducted by Battelle Northwest Laboratories. This report presents data beginning in August 1978 and continuing through March 1980.

1.2 THE SITE

WNP-1, 2, and 4 are located on the west bank of the Columbia River at approximately River Mile 352 (Figure 1.1). Sampling stations, as indicated in Figure 1.1, have been established in the river both upstream and downstream from the plant intake and discharge lines. The river-level in this area fluctuates considerably diurnally and from day to day in response to release patterns at the Priest Rapids Dam alternately exposing and covering large areas of river bottom. The river bottom within the study area varies from exposed Ringold conglomerate to boulders, cobble, gravel, and sand. River velocities at the surface are approximately 2 meters per second in this area of the river, and water temperature varies from approximately 0 to 22^{o}C.

1.3 STUDY OBJECTIVES

The primary objective of the preoperational monitoring program as conducted from 1978 through 1980 was to provide baseline data on the aquatic biological community while documenting potential impacts of construction and preoperational activities such as installation of intakes and water withdrawal to test the

circulating water system. The program was composed of several component areas of study which included planktonic organisms (phytoplankton, zooplankton, and ichthyoplankton), benthic macrofauna and microflora, the fish community, and fish-power plant interactions. Plankton studies are reported in Chapters 2 and 3, benthos studies in Chapter 4, and fish studies in Chapter 5. Results of fish-power plant interaction studies are reported in Chapter 6. Supportive data are contained in the Appendix. Quality assurance activities are governed by a quality assurance manual that provides procedures designed to assure a high degree of reliability in data collection, processing, and reporting. Water chemistry and physical measurement activities have been delayed because of revision of the projected start-up date for WNP-2.

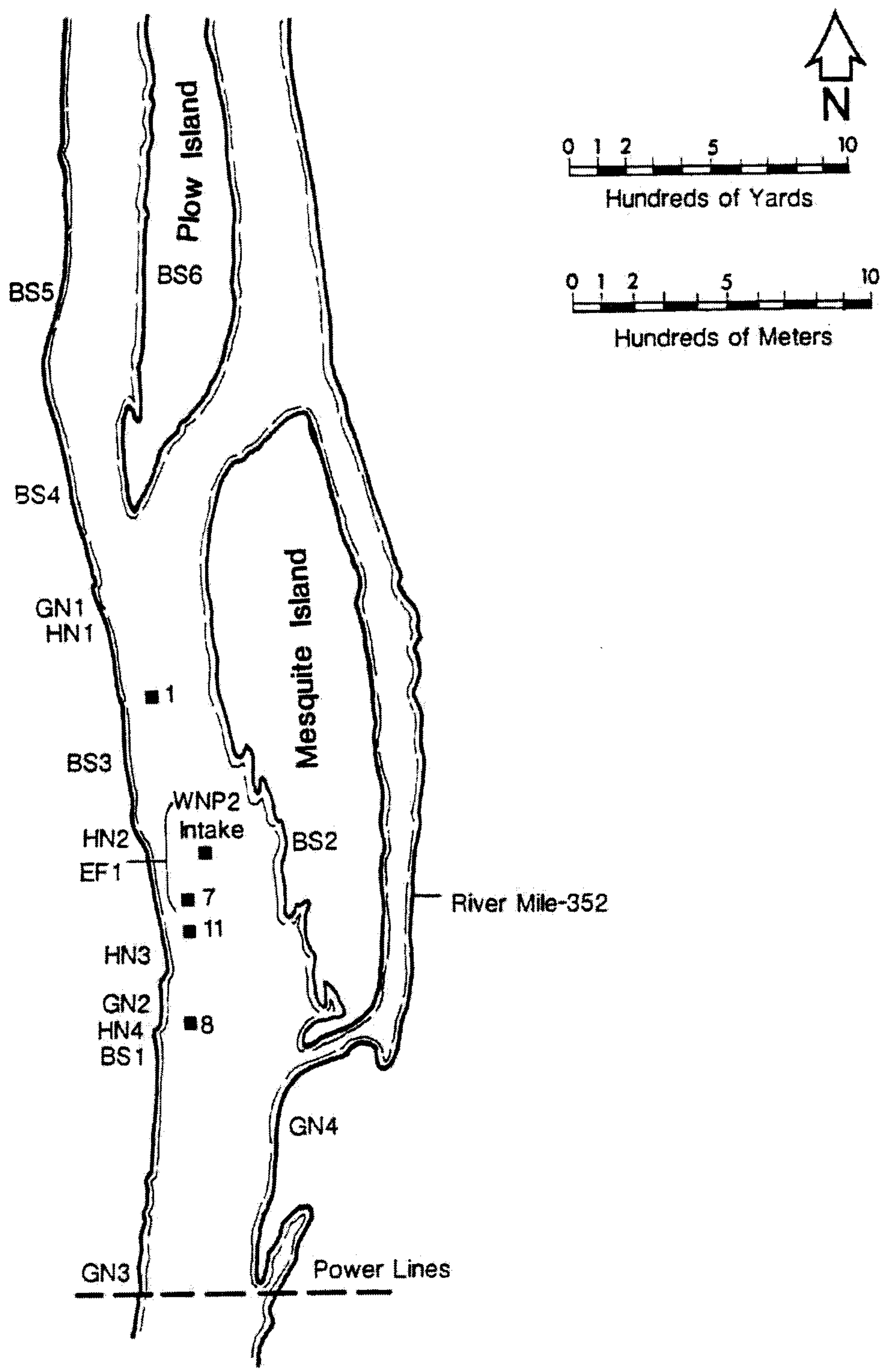

Figure 1.1. Location of sampling stations in the Columbia River.

2.0 PHYTOPLANKTON

2.1 INTRODUCTION

Objectives of this task were to characterize and measure natural changes of phytoplankton in the Columbia River near the WNP-1, 2, and 4 intake and discharge sites. Information was obtained monthly on species composition, density, chlorophyll a (biomass), and diversity.

2.2 METHODS AND MATERIALS

Field and laboratory methods are detailed in Standard Operating Procedures (SOP) B03-03 and B03-06 and described below. Quality assurance/quality control techniques are also described below and detailed in the Quality Assurance Program Document.

Replicate (2) samples were collected monthly from September 1978-March 1980. Samples were collected with a Van Dorn water bottle approximately 300 m (1,000 ft) upriver of the WNP - 1/4 intake structure (Figure 1.1). One liter from each replicate was used for identification and counts and 1-2 liters (depending on phytoplankton abundance) were used for chlorophyll a determinations. Identification samples were preserved as a 3% formalin solution (1.1% formaldehyde solution), and chlorophyll samples were held on ice in the dark and analyzed within 24 hours of collection.

Chlorophyll a, which reflects phytoplankton biomass, was determined by the following laboratory procedure:

1. Sample water was filtered (at 2/3 atmospheric pressure) until membrane filters were clogged. The same amount was filtered for the replicate sample.

2. Filters were placed in a tissue grinder and macerated for one minute in a 2-3 ml acetone solution.

3. This solution was transferred to a graduated centrifuge tube in volume not less than 8 ml. The tube was stoppered and allowed to steep overnight (16 hr) at 4°C in the dark.

4. Steeped samples were removed, shaken, allowed to warm to room temperature in the dark, then centrifuged for 20 minutes at 4,000 rpm.

5. Known volumes of extract solution were measured for absorbance at wavelengths of 750, 663, 645, and 630 mμ.

6. The trichromatic equations from Standard Methods 14th ed. (APHA 1975) were used to determine chlorophyll a.

Quality assurance/control procedures were followed to evaluate and assure the accuracy of chlorophyll a determinations. Comparison of chlorophyll a results, using USEPA standards with the known values of the standards, were made to confirm derived values.

Species composition and abundance were determined by the following laboratory procedure:

1. Sample volumes were measured in a graduated cylinder and a suitable aliquot filtered through a 0.45-μm pore size membrane. The aliquot amount varied with the density of algae so as to avoid a crowded or layered affect.

2. After filtering, the filter was removed and placed on a microslide with three or four drops of immersion oil. The slide was placed on a hot plate with a temperature of 70-80°C. When the filter became transparent, it was removed and covered with a glass slip.

3. Prior to identification, a small portion of each sample was examined in a settling chamber to identify fragile species.

4. Counts of prepared slides were done at a magnification of 400X using phase or brightfield microscopy. Two hundred distinct algal particles were counted and identified along a diameter transect of the circular filtered area. Only units with chloroplasts were counted. The area of the filter surface within which the 200 units occurred was then measured.

5. Once examined and counted, filter slides were stored in trays for future reference.

Taxonomic references most frequently used include Archibald (1972), Drouet (1956, 1968), Geitler (1932), Hustedt (1959, 1961-1966), Patrick and Reimer (1966, 1975), and Prescott (1962).

Quality assurance/control procedures provided independent confirmation of identifications and in-house recounts of randomly selected slides. Algalogists at Oregon State University independently examined and confirmed the identity of dominant species on approximately 21% of samples collected. In-house recounts of individual taxa and total individuals in approximately 10% of the samples confirmed counting accuracy.

The information measure of diversity ($\hat{H}'$) was calculated for each sample (two replicates combined) to numerically summarize data on number of species and number of individuals per species. The expression used to calculate the estimated index of diversity (Shannon's function) was:

$$\hat{H}' = - \sum_{i=1}^{S} p_i \log_2 p_i$$

where S = the number of species observed in the sample and p_i = the number of individuals of species i divided by the total number of individuals in the sample (Pielou 1977). The diversity index ($\hat{H}'$) takes into account both the species richness, which is the total number of species (S) observed in the two sample replicates, and the evenness with which individuals are distributed among species.

An index of evenness ($\hat{J}'$), which is a measure of the relative abundances of the species observed, was also calculated (Brower and Zar 1977):

$$\hat{J}' = \frac{\hat{H}'}{\hat{H}_{max}}$$

where $\hat{H}'_{max}$ = $\log_2$ of the number of species (S) in the sample.

2.3 RESULTS AND DISCUSSION

Data from samples collected during the period September 1978-March 1980 together with analyses and descriptive statistics have been presented in monthly data reports (series DRB03-01) to WPPSS and are summarized below. They are also contained in Appendix A. Samples were collected during each of the nineteen months of study.

2.3.1 Phytoplankton Community Composition and Densities

At least 159 taxa were observed in the nineteen months of sampling (Table 2.1). These included 152 identified species, 2 chrysophyte statospores, and several unidentifiable species in four major algal divisions. The distribution of genera and species among the major algal divisions was:

Algal Division	Genera	Species
Chrysophyta	30	115
Chlorophyta	17	27
Pyrrophyta	3	4
Cyanophyta	5	6
TOTAL	55	152

Diatoms (Chrysophyta: Bacillariophyceae) comprised the largest number of species as well as the highest percentage of the total unit densities among major algal divisions each month (Table 2.2). Dominance of the phytoplankton community by diatoms has been reported for station 1 since 1974 (Page and Neitzel 1978; Page, Neitzel, and Hanf 1979), and was reported at stations approximately 28 miles upstream of station 1 in 1973 (Wolf, Page, and Neitzel 1976). Similar sustained dominance of diatoms has been reported for the lower reach of the Columbia River (BEAK 1977). Generally, in 1976-79 the green algae (Chlorophyta) were second in number of species observed, followed by the pyrrophytes (Pyrrophyta) and blue-green algae (Cyanophyta). The percentage of total density comprised by the pyrrophytes and green algae was similar, with blue-green algae usually the least abundant.

During the nineteen months of sampling, five species of diatoms were most abundant: *Cyclotella glomerata* (September, October and November 1978; August and September 1979); *Stephanodiscus hantzschii* (December 1978; April 1979; January, February and March 1980); *Melosira italica* (May and June 1979); *Cyclotella comensis* (July 1979); and *Cyclotella pseudostelligera* (October 1979). Most of these are very small centric diatoms (c. 5-15 μm diameter by 2-3 μm thickness) which are typically planktonic. The prominence of these species in 1978-1979 samples in contrast to the previously reported frequent prominence of *Asterionella formosa* and *Synedra spp*. (Page and Neitzel 1978; Page, Neitzel, and Hanf 1979) at station 1 may be due to examination of samples at slightly greater magnifications than in past studies. *A. formosa* was present in all samples collected, having highest densities in late spring (April peak), and lowest densities in October 1978 and 1979.

Phytoplankton, as defined here, include all algae drifting with the current. Among these drifting algae are forms typically planktonic and periphytic. In small rivers and streams, periphyton (attached) forms which have washed off stream-bottom surfaces will predominate in the plankton. In the Columbia River at station 1, the periphyton forms comprised 39 to 69% of the monthly species observed; they comprised 50% or less of the species in samples from December 1978, January 1979, May through September 1979, and February 1980. Numerically dominant species in all months were typical planktonic forms.

Total densities during the study ranged from 7.9×10^5 units/liter in November 1979 to 16.0×10^6 units/liter in April 1979 (Figure 2.1). Density values for the year were generally higher than values for preceding years (Figure 2.2). This increase may be related to the observation of samples at a magnification higher than previously employed in counting. This would be consistent with the finding that small centric diatoms were the most abundant species during the study period.

The structure of the monthly phytoplankton assemblages was evaluated by calculating a diversity index ($\hat{H}'$). Two components of the structure, namely the number of species (S) and their relative abundance, influence the diversity index. The values of $\hat{H}'$, S, and the evenness measure, $\hat{J}'$, are reported in Table 2.3. In general, diversity was high during September-December 1978, May-December 1979, and January 1980, and low in late winter 1979 and 1980 and spring (Figure 2.3). Highest diversity, 4.71, occurred in December 1978 and the lowest, 1.02, in February 1979. In general, species richness (S) and evenness ($\hat{J}'$) each varied in agreement with changes in diversity ($\hat{H}'$). Low diversity was related directly to low species richness and low evenness (high dominance by a few species). Low diversities have previously occurred in late spring at the time of highest density (Page and Neitzel 1978; Page, Neitzel, and Hanf 1979). This also occurred in 1979. Generally higher diversity values at station 1 were found in the present study as compared to past work and were probably due to the increased number of species observed in September 1978-March 1980 samples.

2.3.2 Pigment Analysis

Chlorophyll a values ranged from 1.4 mg/m^3 in December 1978 to 25.1 mg/m^3 in May 1979. Levels varied closely with changes in densities, except in March and April when chlorophyll was disproportionately low (Figure 2.1). This lack of agreement between density and chlorophyll a peaks is due to the relationship between amounts of pigment and unit size. Increased numbers of a small centric diatom, such as occurred during March and April when the single-celled *Stephanodiscus hantzschii* was abundant, would have produced less of an increase of chlorophyll a than in May and June when the larger filamentous, colonial diatom *Melosira italica* was abundant. The amount of chlorophyll a reported for 1979 was comparable to that reported for 1978, though notably higher than for the years 1974-1977 (Figure 2.4) (Page and Neitzel 1978; Page, Neitzel, and Hanf 1979).

2.4 SUMMARY AND CONCLUSIONS

There was a greater number of species observed in each month of the study period compared to previous studies at this station. As in past studies, diatoms dominated the phytoplankton aggregation both in numbers of species and in percentage of the total monthly densities. However, during 17 of the 19 months, small (<15μm diameter) centric diatoms were dominant. This is in contrast to the recurring spring dominance by the larger diatom Asterionella formosa in previous years at this station.

Diversity indices were highest in summer, fall, and early winter and lowest in late winter and spring when densities were highest. This pattern is similar to previous reported patterns; however, diversity indices were higher (maximum 4.71) for most months than previously reported (maximum 3.45).

Unit densities were highest during late spring and lowest in November and December in both 1978 and 1979. Densities were generally higher in most months than previously reported. Chlorophyll a pigment was at highest levels in late spring and early summer with a peak slightly higher than reported for 1978. Peak chlorophyll values occurred one month later than the peak monthly density. This was related to the size of the dominant phytoplankton.

Table 2.1. Phytoplankton taxa observed in monthly samples from station 1, September 1978-March 1980.*

Algal Division/Species

CHRYSOPHYTA (BACILLARIOPHYCEAE)

Chrysophyta Unidentifiable
Melosira ambigua
Melosira granulata
Melosira granulata v. angust.
Melosira italica
Melosira varians
Melosira distans v. alpigena
Melosira americana
Stephanodiscus astraea
Stephanodiscus astraea v. min
Stephanodiscus hantzschii
Cyclotella stelligera
Cyclotella pseudostelligera
Cyclotella kutzingiana
Cyclotella meneghiniana
Cyclotella glomerata
Cyclotella atomus
Cyclotella comta
Cyclotella comensis
Rhizolenia eriensis
Tabellaria fenestrata
Diatoma tenue
Asterionella formosa
Opephora martyi
Fragilaria crotonensis
Fragilaria construens
Fragilaria capucina
Fragilaria leptostauron
Fragilaria vaucheriae
Hannaea arcus
Synedra ulna
Synedra ulna v. chaseana
Synedra acus
Synedra delicatissima
Synedra rumpens
Synedra socia
Synedra vaucheriae
Synedra parasitica
Synedra mazamaensis
Synedra pulchella
Synedra radians
Cocconeis placentula
Achnanthes lewisiana
Achnanthes lanceolata
Achnanthes minutissima
Achnanthes trinodis
Achnanthes exigua
Achnanthes linearis
Achnanthes cleveii
Achnanthes deflexa
Diploneis puella
Stauroneis kriegeri
Navicula seminuloides
Navicula circumtexta
Navicula minima
Navicula tripunctata
Navicula cryptocephala
Navicula cryptocephala v. veneta
Navicula mutica
Navicula pupula
Navicula psuedoreinhardtii
Navicula viridula
Navicula decussis
Navicula capitata
Navicula cascadensis
Navicula minuscula
Caloneis hyalina
Gomphonema parvulum
Gomphonema subclavatum
Gomphonema olivacedides
Gomphonema truncatum
Gomphonema ventricosum
Gomphonema olivaceum
Cymbella turgidula
Cymbella sinuata
Cymbella minuta
Cymbella mexicana
Cymbella affinis
Cymbella prostrata
Amphora perpusilla
Amphora ovalis
Epithemia sorex
Rhopalodia gibba
Nitzschia latens
Nitzschia paleacea
Nitzschia silica
Nitzschia palea
Nitzschia dissipata
Nitzschia innominata
Nitzschia perminuta
Nitzschia allansoni
Nitzschia frustulum
Nitzschia osmophila
Nitzschia obsoleta
Nitzschia linearis
Nitzschia intermissa
Nitzschia acicularis
Nitzschia amphibia
Nitzschia oregona
Nitzschia fonticola

Table 2.1. (Continued)

Algal Division/Species

CHRYSOPHYTA (BACILLARIOPHYCEAE)
(Continued)

Nitzschia bacata f. lin.
Nitzschia recta
Nitzschia angustata
Nitzschia holsatica
Nitzschia gracilis
Surirella ovata

CHRYSOPHYTA (CHRYSOPHYCEAE)

Mallomonas alpina
Mallomonas tonsurata
Ochromonas-like
Codosiga #1
Chrysophyte statospore #11
Chrysophyte statospore #14
Rhizochrisis #1
Kephyrion spirale
Kephyrion asper
Kephyrion ovale
Kephyrion gracilis
Chrysococcus rufescens

CHLOROPHYTA

Chlamydomonas-like
Pandorina morum
Tetraspora lacustris, lemm.
Treubaria triappendiculata
Odcystis pusilla
Odcystis lacustris
Sphaerocystis schroeteri
Ankistrodesmus falcatus
Crugigenia quadrata
Kirchneriella obesa
Scenedesmus #2
Scenedesmus denticulatus
Scenedesmus quadricauda
Scenedesmus dimorphus
Scenedesmus abundans
Scenedesmus acuminatus
Scenedesmus longus
Scenedesmus acutiformis
Scenedesmus opoliensis
Schroederia judayi
Schroederia setigera
Chlorella-like #1
Dictyosphaerium ehrenbergianum
Selanastrum minutum
Closterium gracile
Mougeotia #1
Cosmarium #3

PYRROPHYTA

Rhodomonas minuta
Rhodomonas lacustris
Cryptomonas erosa
Glenodinium #1

CYANOPHYTA

Anacystis cyanea
Lyngbya limnetica
Oscillatoria planctonica
Oscillatoria limnetica
Arthrospira jenneri
Schizothrix #2

* Numbered genera could not be identified to species. These taxa have been measured, drawn, and photographed for future identification. Chrysophyte statospores were given numbers to differentiate the forms observed.

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Table 2.2. Total number of phytoplankton species (S) within major algal divisions and the percent of mean monthly phytoplankton density comprised by algal divisions (%) in samples from station 1, September 1978-March 1980.

Algal Division		1978				1979												1980		
		S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
CHRYSOPHYTA	S	49	44	46	52	28	25	22	21	31	37	42	33	35	47	48	53	31	14	20
	%	90.2	70.8	85.0	84.2	96.2	99.9	99.8	98.8	90.9	97.4	83.7	87.2	89.2	83.3	74.2	76.4	82.2	94.4	96.5
CHLOROPHYTA	S	4	8	2	7	2	1	1	1	1	3	7	5	12	5	4	5	2	2	1
	%	2.2	8.7	2.2	14.0	1.8	0.1	0.2	0.5	2.8	1.6	10.6	4.8	5.5	10.1	15.4	8.6	2.5	2.3	0.8
PYRROPHYTA	S	3	2	3		3			1	1	1	2	3	3	1	3	2	2	1	1
	%	7.4	18.1	12.8		2.0			0.7	0.5	0.3	3.9	7.5	5.0	5.9	9.9	15.0	12.5	1.3	2.5
CYANOPHYTA	S	1	2		2					1	2	3	2	1	1	1		1	1	1
	%	0.2	2.4		1.8					5.8	0.7	1.8	0.5	0.3	0.7	0.5		2.8	2.0	0.2
Total Taxa		57	56	51	61	33	26	23	23	34	43	54	43	51	54	56	60	36	18	23

Table 2.3. Values for the species diversity index ($\hat{H}'$), the index of relative abundance ($\hat{J}'$), and species richness (S) for phytoplankton samples from station 1, September 1978-March 1980.

Sample Date	$\hat{H}'$	$\hat{J}'$	S
9-08-78	3.61	0.62	57
10-18-78	4.14	0.71	56
11-13-78	2.95	0.52	51
12-19-78	4.71	0.79	61
1-04-79	1.38	0.27	33
2-26-79	1.02	0.22	26
3-28-79	1.06	0.23	23
4-17-79	1.11	0.24	23
5-30-79	3.12	0.61	34
6-28-79	3.37	0.62	43
7-30-79	4.23	0.73	54
8-28-79	3.28	0.60	43
9-25-79	3.62	0.64	51
10-30-79	4.56	0.79	54
11-12-79	4.48	0.77	56
12-17-79	4.53	0.77	60
1-22-80	3.69	0.64	53
2-19-80	1.87	0.41	24
3-19-80	1.99	0.41	30

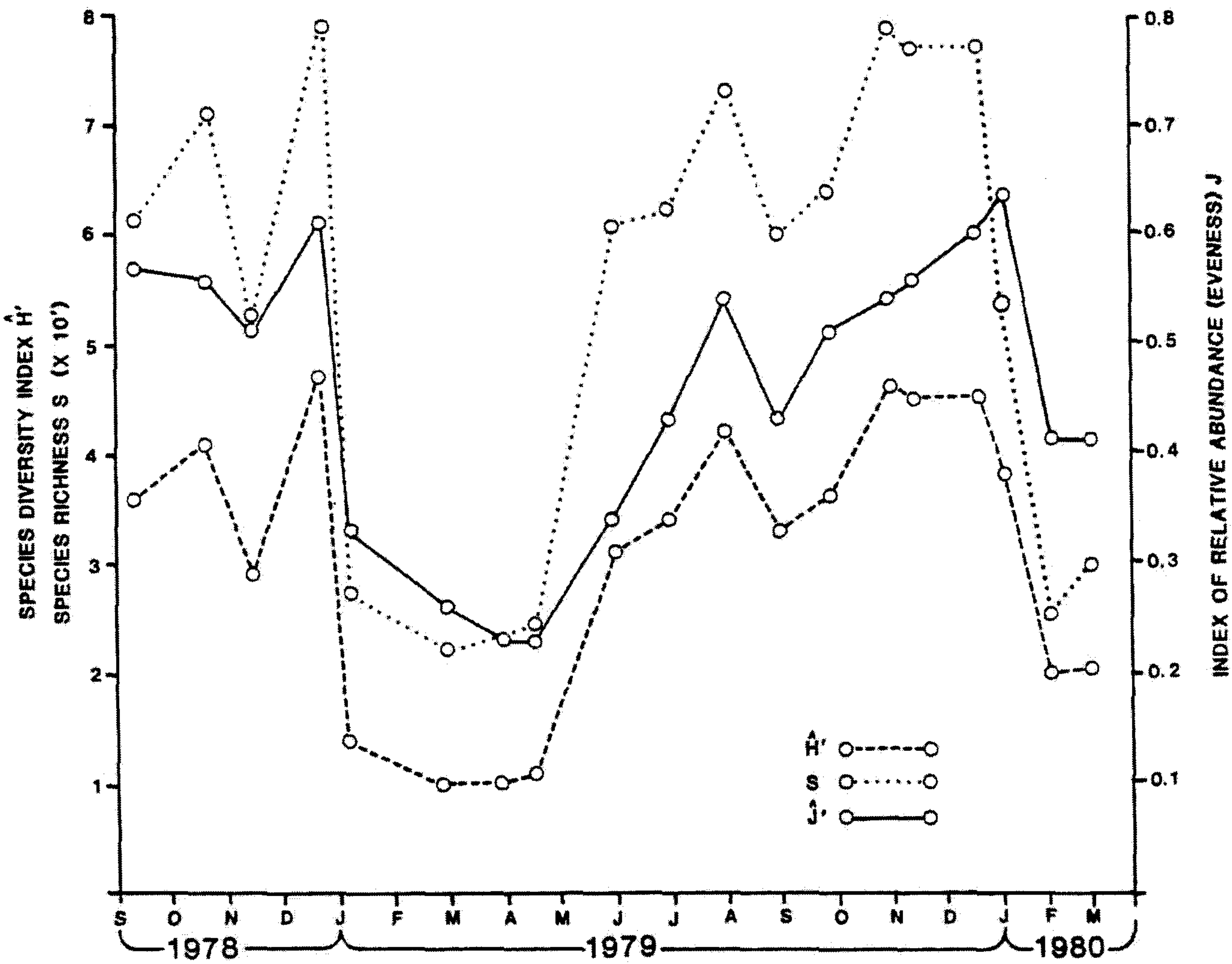

Figure 2.1. Phytoplankton unit density (no./l) and chlorophyll a (mg/m^3) in samples from station 1, September 1978-March 1980.

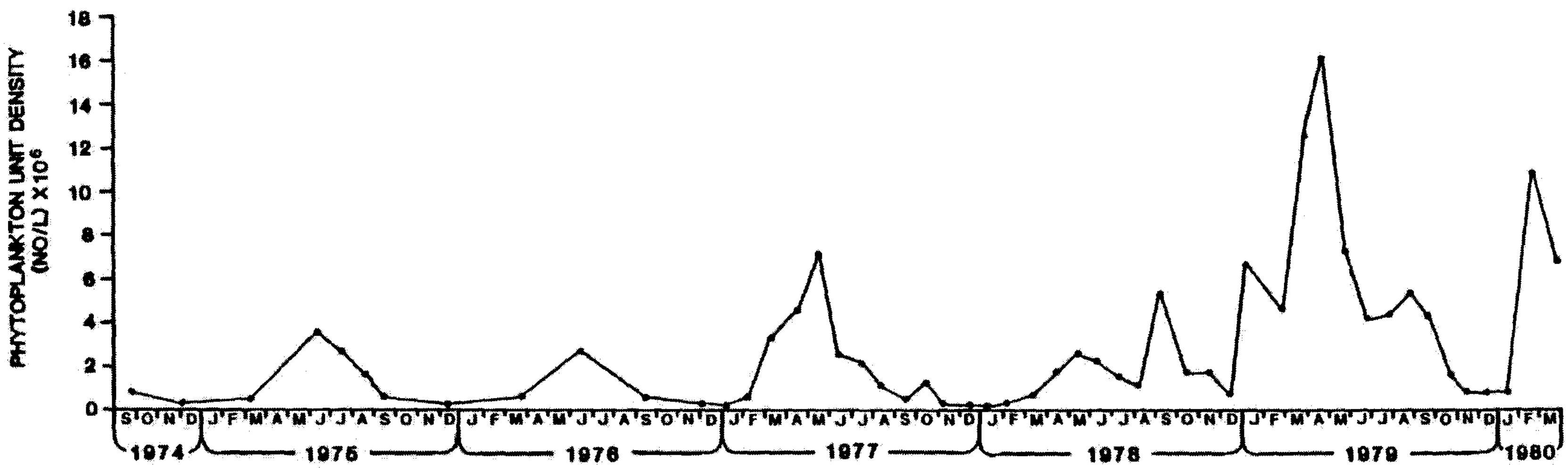

Figure 2.2. Phytoplankton unit densities at station 1, September 1974-March 1980. Data from September 1979 through July 1978 from Page and Neitzel (1978) and Page, Neitzel, and Hanf (1979).

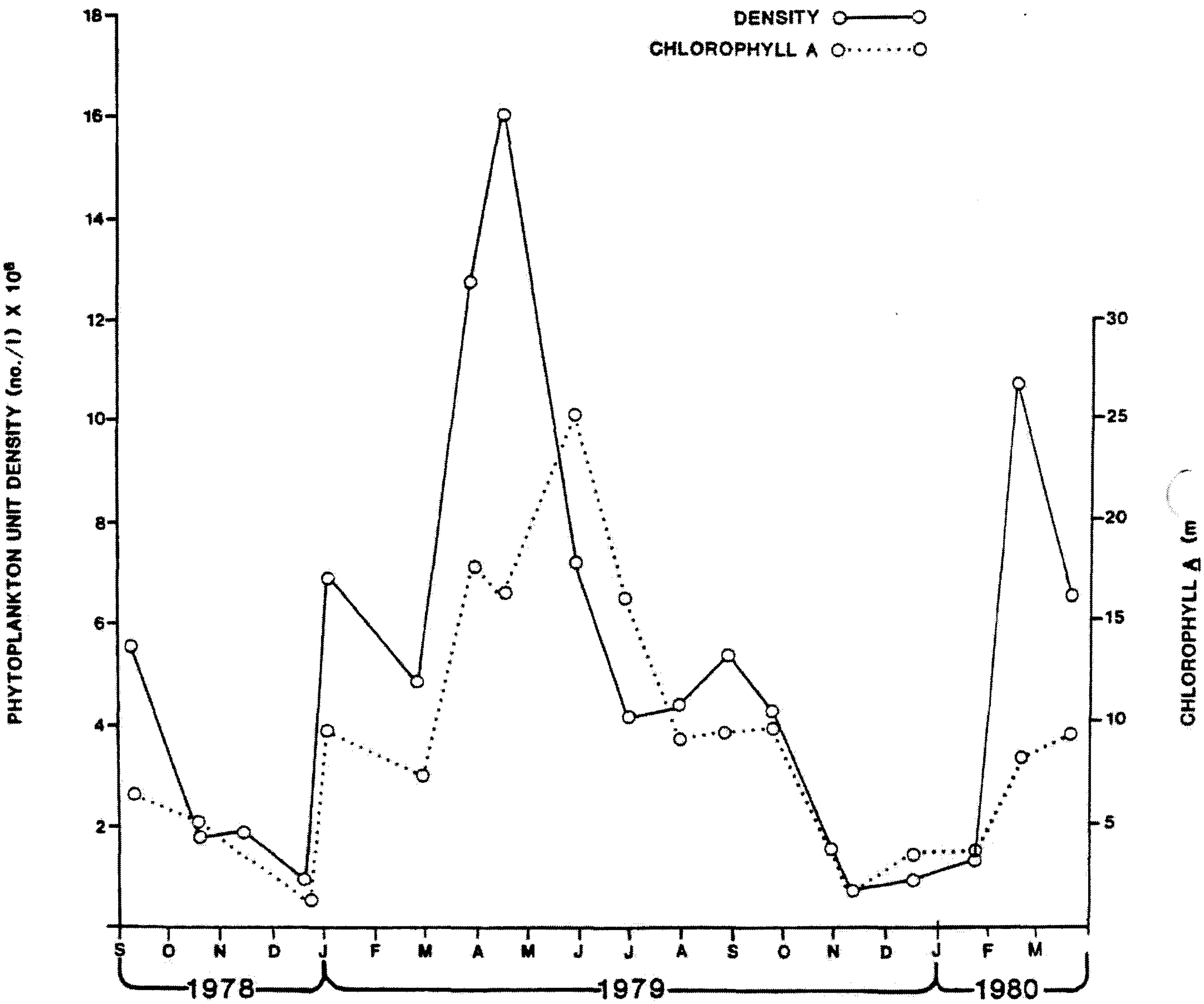

Figure 2.3. Species diversity index ($\hat{H}'$), the index of relative abundance ($\hat{J}'$), and species richness (S) for phytoplankton samples from station 1, September 1978-March 1980.

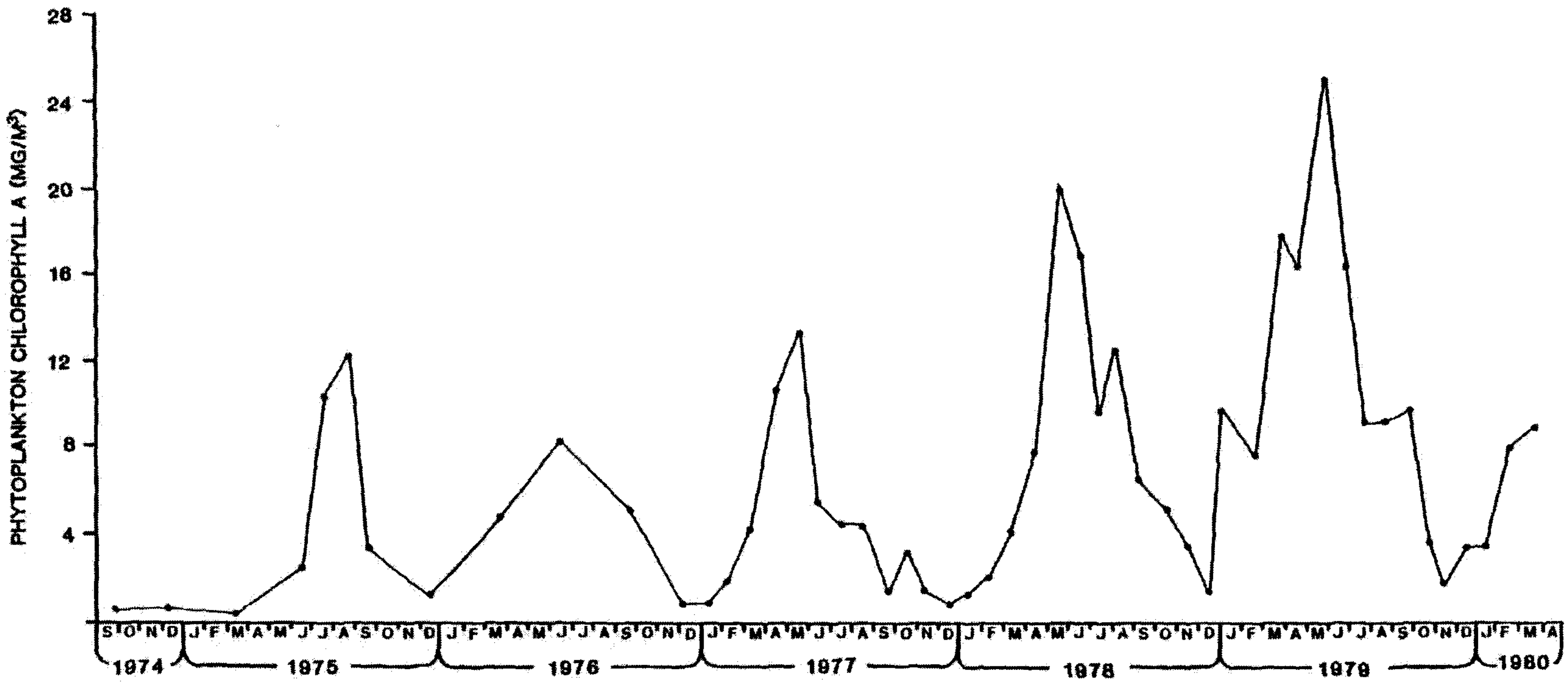

Figure 2.4. Phytoplankton chlorophyll a values at station 1, September 1974-March 1980. Data from September 1974 through August 1978 from Page and Neitzel (1978) and Page, Neitzel, and Hanf (1979).

3.0 ZOOPLANKTON AND ICHTHYOPLANKTON

3.1 INTRODUCTION

Zooplankton and ichthyoplankton study goals were to identify and enumerate taxa found in the Columbia River at station 1 near the WNP-1, 2, and 4 intake-discharge structures (Figure 1.1), and to determine density, community composition (seasonal and relative abundance), and diversity within the community.

Results of zooplankton investigations from September 1978 through March 1980 supplement previous studies in the Hanford Reach of the Columbia River for the interval September 1974 through August 1978 (Page and Neitzel 1976a,b, 1977, 1978a, b; Page, Neitzel, and Hanf 1979). Ichthyoplankton investigations represented the initial, formal, monthly sampling for fish eggs and larvae in the study area.

3.2 METHODS AND MATERIALS

Field and laboratory methods are available in Standard Operating Procedures (SOP) B03-01 and B03-04 and are described briefly below. The sampling station and field and laboratory methodology for zooplankton studies remained the same as employed during previous investigations to provide sampling program continuity and data comparability. Quality assurance/quality control procedures are detailed in the Quality Assurance Program Document and summarized below.

3.2.1 Zooplankton

Replicate (2) zooplankton samples were collected monthly during the day from September 1978 through March 1980. A plankton net with a 0.3 m (1.0 ft) diameter opening and #10 (153 micron) mesh netting was used. Samples were taken by lowering the net into the river while the boat was anchored to a buoy. Flow through the net was measured with a Tsurumi-Seiki Company (TSK) flowmeter mounted in the net

opening. To obtain a representative sample of zooplankton in the water column, a stepped oblique sample was taken. This involved a 30-second exposure at 1 m below the surface and at mid-depth during lowering and retrieval and a 1-minute exposure 1 m above the bottom.

After retrieval, contents of the net were transferred to a labeled sample bottle containing a 10 percent formalin solution and Rose Bengal stain. Duration of net exposure, initial and final flowmeter readings, sample code number and other pertinent data were recorded on standard field data sheets.

In the laboratory, each sample replicate was subsampled with a Folsom No. 31 plankton splitter. The samples were split until the subsample contained from 100-200 organisms. The subsample was then transferred to a petri dish with a grid scribed on the bottom to facilitate accurate counting. All organisms in the petri dish were counted and identified under a Wild M-5 stereo microscope. Identifications were carried to the taxonomic level of previous investigations or lower. Taxonomic keys used were Pennak (1978) and Ward and Whipple (1959). Counts and identifications were recorded directly onto computer data forms.

The number of zooplankton per cubic meter was calculated by relating numbers per subsample to total volume of sample. Total volume of sample filtered was calculated from the following formula: $V = (c)(r)(w) + (t)$,

where: V = total volume filtered (m^3)
c = rotor constant: 0.148 m/rev. from September 1978 to October 1979
0.153 m/rev. from November 1979 to December 1979
r = number of revolutions
w = area of net mouth $0.071 m^2$
t = correction factor 0.014 for rotor resistance

The slight change in the rotor constant after October 1979 was due to a recalibration of the flowmeter in November 1979.

Density was expressed as number of organisms per m^3 of water sampled. Measures of species diversity ($\hat{H}'$) based on information theory and an index of evenness ($\hat{J}'$) were calculated as described in Chapter 2.

Quality control checks were made on field and laboratory procedures as described in the *Quality Assurance Program Document.* All field collection procedures were monitored at least quarterly. Laboratory quality assurance checks were performed by a senior biologist on ten percent of all zooplankton samples to verify the accuracy of the original identifications and enumerations. Zooplankton were also sent to the University of Washington for confirmation of taxa identifications. Following laboratory analysis, all processed samples were archived for future reference and a reference collection of all taxa compiled.

3.2.2 Ichthyoplankton

Replicate (2) ichthyoplankton samples were collected at the same time and location as zooplankton samples. Sampling gear consisted of a Tucker trawl net (0.5 x 0.5 m square mouth and 333 micron mesh) with an attached General Oceanics (GO) flowmeter. Sampling duration and methodology were identical to that described for zooplankton. Following net retrieval, contents of the straining bucket were washed into labeled jars containing a 10 percent formalin solution and Rose Bengal stain.

Flowmeter readings were recorded on field data forms prior to and following each sampling for calculation of volume of water sampled. The formula used for these calculations was:

$$\text{Volume } (m^3) = [\text{net cross-section area } (m^2)] \times \frac{[(\text{Final count} - \text{initial count}) \times (\text{rotor constant})\ (m)]}{999{,}999}$$

where rotor constant = 26,873 and net cross-section = 0.25 m^2.

Samples were examined under magnification and specimens identified with the aid of standard references (Lippson and Moran 1973; Stein 1972). Densities were expressed as number per m^3.

Quality control/quality assurance checks on ichthyoplankton field procedures were performed at least quarterly. All identifications were performed by a senior biologist expert in Columbia River ichthyoplankton. Following analysis, samples were stored for future reference.

3.3 RESULTS AND DISCUSSION

3.3.1 Zooplankton

Zooplankton and ichthyoplankton data are detailed in data reports of the series DRB03-04 and DRB03-05, and in Appendices B and C respectively, and are summarized below. A total of 45 taxa were taken in zooplankton samples at station 1 during the interval September 1978 through March 1980 (Table 3.1). This compares to 27 taxa in 1978, 22 taxa in 1977, and 15 taxa in 1976 (Page and Neitzel 1978a, b; Page, Neitzel, and Hanf 1979). The substantial increase in number of taxa in 1979 was due largely to a refinement in identification which resulted in more organisms being identified to lower taxonomic levels. Also, several new taxa were collected in 1979.

Zooplankton densities (no./m^3) ranged from 22.1/m^3 in November 1979 to 775.8/m^3 in August 1979 (Table 3.2). An earlier but slightly smaller peak of 658.6/m^3 occurred in March 1979. The peak numbers recorded in 1979 are similar to those found in 1978 (Page, Neitzel, and Hanf 1979). However, the 1978 density curve (Figure 3.1) was unimodal and peaked in May; in 1979, the curve was bimodal with peaks of similar density in March and August. Examination of the relative abundance data

for 1979 indicates that similar patterns of relative abundance occurred in both 1978 and 1979 but that the abundance patterns were slightly different. The 3.5 to 6.0 fold density increase reported for 1977 (Page and Neitzel 1976b) was likely influenced by extremely low river discharges that year. Reduced flows can result in higher plankton densities by increasing residence time of the water, permitting more production, and decreasing the export of plankton (Hynes 1972). Similar year-to-year density variation has been reported for the lower Columbia River (BEAK 1978).

The early peak in abundance in March was due primarily to increases in the abundance of cyclopoid copepodids (54 percent of the total) and diaptomid copepodids (23 percent of the total). Diaptomids and cyclopoids were also relatively abundant in 1978 (Page, Neitzel, and Hanf 1979) during the same interval but their numbers did not increase to the level reached in 1979. In 1978, peak abundance occurred in May largely as a result of increased abundance of Bosmina and to some extent cyclopoid copepods. In 1979, zooplankton numbers in May were low relative to 1978 and cyclopoid copepods rather than Bosmina were the dominant components, comprising 55 percent of the total. The August peak in 1979 was brought on by an increase in Bosmina (56 percent of the total). The patterns of abundance observed in 1979 therefore conform to the general pattern seen in previous years with diaptomid and cyclopoid copepodids dominating during the late winter and early spring and Bosmina increasing in abundance during the spring to reach a dominant position during the summer and early fall (Figure 3.2).

Table 3.3 shows the frequency of occurrence for each zooplankton taxa taken at station 1 during the interval September 1978 through December 1979. The taxa found in 50 percent or more of the samples included Alona, Bosmina, Brachionus,

Ceriodaphnia, Chironomidae, *Chydorus*, Copepoda nauplii, *Cyclops*, *Daphnia*, *Diaptomus*, *Epischura*, *Hydracarina*, *Kellicottia*, *Lecane*, Nematoda, Oligochaeta, unidentified Rotifera and Tardigrada. *Bosmina*, Chironomidae, *Cyclops* and *Diaptomus* were found in all samples.

Diversity ($\hat{H}'$) for zooplankton samples for the interval September 1978 through March 1980 ranged from 1.30 in February 1979 to 3.38 in October 1978 (Table 3.4). The 3.38 value for October was the highest diversity value obtained at station 1 since studies were initiated in 1974. High $\hat{H}'$ values were observed in months with the more equitable distribution of individuals among the taxa. Low $\hat{H}'$ values were observed in December 1978, February, March, April, July, and September 1979 when one or two taxa clearly dominated. Evenness ($\hat{J}'$) varied within the same range as observed 1975 through 1978 (Page and Neitzel 1976a,b, 1977, 1978a, b; Page, Neitzel, and Hanf 1979) (Figure 3.3). Richness (S), on the other hand, showed much higher values in September, October, and November 1978 then had been observed previously (Figure 3.3). This can probably be attributed to the refinement in taxonomic identifications which were initiated in September 1978.

3.3.2 Ichthyoplankton

Ichthyoplankton were captured only during the period May through July 1979. Densities ranged from 0 to 0.14 individuals per m^3, indicating sparse populations of eggs or larvae in the water column in this area of the river. A total of two sculpin yolk sac larvae and 25 sculpin post-yolk sac larvae were captured. Highest densities ($0.14/m^3$) occurred in June 1979. Density values are shown in Table 3.5.

3.4 SUMMARY AND CONCLUSIONS

Seasonal variance in zooplankton taxa dominance in 1979 was generally similar to past years. *Diaptomus* spp. were dominant in December 1978 and April 1979, co-

dominant with *Cyclops* in January, and co-dominant with *Bosmina* and *Cyclops* in June and November. *Cyclops* was dominant in February, March, and May 1979. *Bosmina* was dominant in September 1978, and July, August, and September 1979.

Maximum zooplankton densities were about the same in 1979 as in 1978, but were much lower than the peaks which occurred in 1977.

A total of 45 zooplankton taxa were identified during the interval September 1978 through March 1980. This was 18 more taxa than observed in 1978. The increase was attributed primarily to refinement in identification which led to identification to lower taxonomic levels.

Ichthyoplankton studies indicated low densities and diversity of pelagic-oriented fish eggs and larvae at station 1 sampling depths.

Table 3.1. Taxonomic categories of Columbia River zooplankton collected near WNP-1, 2, and 4 at station 1.

Coelenterata
- *Hydra* spp.

Aschelminthes
- Nematoda
- Rotifera
  - Brachionidae
    - *Brachionus* spp.
    - *Euchlanis* spp.
    - *Kellicottia* spp.
    - *Keratella* spp.
  - Lecanidae
    - *Lecane* spp.
  - Synchaetidae
    - *Synchaeta* spp.
  - Testudinellidae
    - *Testudinella* spp.

Bryozoa
- Ectoprocta
  - Paludicellidae
    - *Paludicella* spp.

Annelida
- Oligochaeta

Arthropoda
- Tardigrada
- Crustacea
  - Cladocera
    - Leptodoridae
      - *Leptodora kindtii*
    - Sididae
      - *Sida crystallina*
      - *Latona* spp.
      - *Diaphansoma* spp.
    - Daphnidae
      - *Daphnia* spp.
      - *Ceriodaphnia* spp.
    - Bosminidae
      - *Bosmina* spp.
    - Macrothricidae
      - *Macrothrix* spp.
      - *Ilyocryptus* spp.
    - Chydoridae
      - *Pleuroxus* spp.
      - *Alona* spp.
      - *Chydorus* spp.

Arthropoda (continued)
- Ostracoda
- Copepoda
  - Calanoida
    - Temoridae
      - *Epischura* spp.
      - Temoridae copepodid
    - Diaptomidae
      - *Diaptomus* spp.
      - Diaptomidae copepodid
    - Cyclopoida
      - Cyclopidae
        - *Cyclops* spp.
        - Cyclopoid copepodid
        - Copepoda nauplii
    - Harpacticoida

Insecta
- Collembola
- Ephemeroptera
- Trichoptera
  - Hydropsychidae
  - Rhyacophilidae
- Diptera
  - Chironomidae

Arachnida
- Hydracarina

Table 3.2. Numbers per cubic meter (No./m^3), sample means, and standard deviations for the Columbia River Zooplankton collected at station 1 near WNP-1, 2, and 4 (RM 352).

Date	Replication	No./m^3	Sample Mean	Standard Deviation
September 8, 1978	1	106.0	107.8	± 2.55
	2	109.6		
October 18, 1978	1	110.9	103.8	± 10.04
	2	96.7		
November 13, 1978	1	61.4	61.9	± 0.71
	2	62.4		
December 19, 1978	1	98.1	103.0	± 6.93
	2	107.9		
January 24, 1979	1	125.9	120.3	± 7.99
	2	114.6		
February 26, 1979	1	402.3	420.2	± 25.31
	2	438.1		
March 28, 1979	1	914.0	658.6	± 361.20
	2	403.2		
April 17, 1979	1	466.2	466.0	± 0.35
	2	465.7		
May 30, 1979	1	193.3	217.0	± 33.45
	2	240.6		
June 28, 1979	1	608.6	311.6	± 420.02
	2	14.6		
July 30, 1979	1	300.2	269.50	± 43.42
	2	238.8		
August 28, 1979	1	646.1	775.8	± 183.42
	2	905.5		
September 25, 1979	1	567.4	548.0	± 27.44
	2	528.6		
October 30, 1979	1	22.5	23.4	± 1.27
	2	24.3		
November 12, 1979	1	24.3	22.1	± 3.11
	2	19.9		
December 17, 1979	1	56.7	69.45	± 18.03
	2	82.2		
January 22, 1980	1	281.8	321.7	± 56.43
	2	361.6		
February 19, 1980	1	548.7	588.1	± 55.72
	2	627.5		
March 19, 1980	1	163.8	415.3	± 355.67
	2	666.8		

BEAK

Table 3.3. Frequency of occurence for Columbia River zooplankton taxa at station 1 near WNP-1, 2, and 4.

	Alona	Annelida	Bosmina	Brachionus	Ceriodaphnia	Chironomidae	Collembola	Chydorus	Cladocera	Copepoda nauplii	Cyclops	Cyclopoida	Daphnia
1978													
S	X		X	X	X	X		X		X	X	X	X
O	X		X		X	X		X		X	X		
N	X		X	X	X	X		X	X		X		X
D	X		X			X		X	X	X	X		X
1979													
J			X	X		X		X		X	X		X
F	X		X			X		X		X	X		X
M			X			X		X		X	X		X
A	X		X		X	X		X		X	X		X
M	X		X	X		X		X		X	X		
J	X		X	X	X	X			X	X	X		X
J		X	X			X		X		X	X		X
A	X		X	X	X	X				X	X		X
S	X		X	X	X	X				X	X		X
O	X		X	X	X	X				X	X		X
N	X	X	X			X		X		X	X		X
D	X		X			X	X	X		X	X		
1980													
J		X	X	X						X	X		X
F			X	X						X	X		X
M			X							X	X		X
Total	68	16	100	53	42	84	5	63	16	95	100	5	84

	Diaphanosoma	Diptera A	Diaptomus	Ephemeroptera	Epishura	Euchlanis	Harpactocoida	Hydra	Hydracarina	Hydropsychidae	Ilyocryptus	Kellicottia	Keratella	Latona	Lecane	Leptodora kindtii
1978																
S		X	X	X	X	X		X	X		X				X	X
O	X		X	X		X		X	X							
N		X	X		X	X		X	X		X			X	X	
D		X	X			X			X			X	X			
1979																
J			X			X						X				
F			X									X				
M			X						X							
A			X						X							
M			X						X				X		X	
J			X						X			X	X		X	
J			X		X				X			X	X			
A			X					X	X			X			X	
S			X					X	X			X	X		X	X
O			X	X	X			X	X	X					X	
N			X	X			X	X	X	X		X			X	
D			X						X			X			X	
1980																
J			X		X				X			X	X		X	
F			X									X	X		X	
M			X									X	X			
Total	5	16	100	21	26	26	5	37	79	11	11	63	42	5	58	11

	Macrothrix	Nematoda	Oligochaeta	Ostracoda	Paludicella	Pleuroxus	Rotifera (unidentified)	Rhyacophilidae	Sida crystallina	Syncheata	Tardigrada	Trichoptera L	Temoridae	Testudinella
1978														
S		X	X	X	X	X	X		X		X	X	X	
O		X	X		X	X	X		X		X	X	X	
N		X	X		X				X		X	X	X	X
D	X	X	X		X		X		X	X				
1979														
J	X									X				
F		X	X				X							
M														
A							X	X						
M			X				X				X			
J			X					X			X			
J		X	X				X	X			X			
A			X				X	X						
S		X	X				X	X			X		X	
O		X	X	X			X	X			X			
N		X	X								X		X	
D		X												
1980														
J		X									X		X	
F		X											X	
M														
Total	11	63	63	11	21	11	53	32	21	11	53	16	37	5

Table 3.4. Species diversity ($\hat{H}'$), evenness (J) and richness (S) for Columbia River zooplankton collected near WNP-1, 2, and 4 at station 1.

Date	$\hat{H}'$	J	S
September 8, 1978	3.20	0.66	29
October 18, 1978	3.38	0.76	22
November 13, 1978	2.95	0.63	26
December 19, 1978	2.00	0.46	20
January 24, 1979	2.00	0.56	12
February 26, 1979	1.30	0.36	12
March 28, 1979	1.44	0.48	8
April 17, 1979	1.55	0.43	12
May 30, 1979	2.12	0.56	14
June 28, 1979	2.58	0.63	17
July 30, 1979	1.82	0.45	17
August 28, 1979	2.17	0.56	15
September 25, 1979	1.73	0.40	20
October 30, 1979	3.36	0.78	20
November 12, 1979	3.21	0.76	19
December 17, 1979	2.06	0.58	12
January 22, 1980	2.39	0.61	15
February 19, 1980	2.35	0.68	11
March 19, 1980	2.07	0.74	7

Table 3.5. Densities of ichthyoplankton (number/m^3) by species/life stage and replicate collected in the Columbia River during September 1978 - March 1980.

Month	Species/Life Stage	Density Replicate 1	Density Replicate 2
May 1979	Sculpin/Yolk Sac Larvae	0	0.03
	Sculpin/Post-Yolk Sac Larvae	0.08	0.05
June 1979	Sculpin/Post-Yolk Sac Larvae	0.14	0.14
July 1979	Sculpin/Post-Yolk Sac Larvae	0	0.01

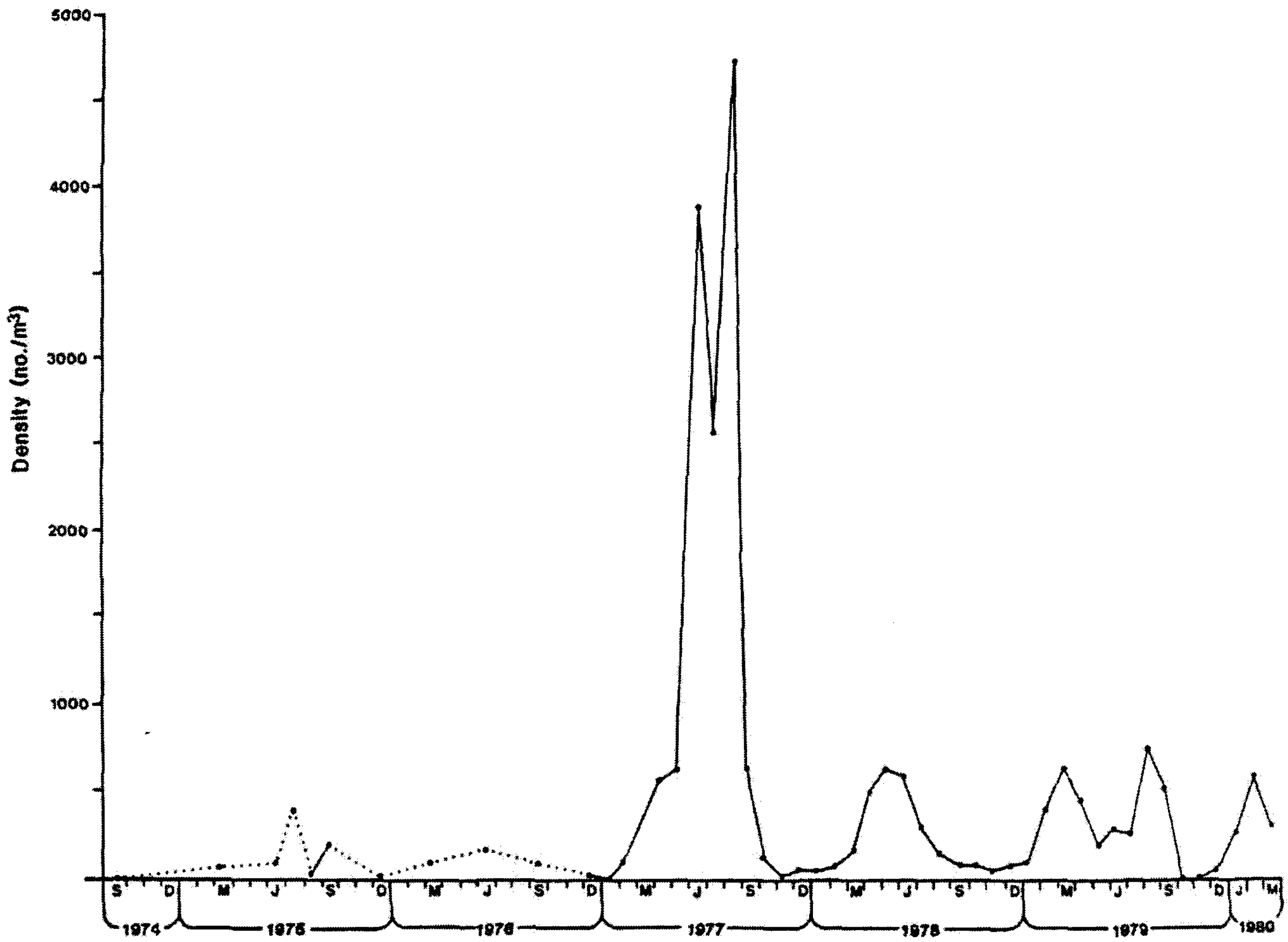

Figure 3.1. Total mean density (no./m^3) for Columbia River zooplankton collected at station 1 near WNP-1, 2, and 4.

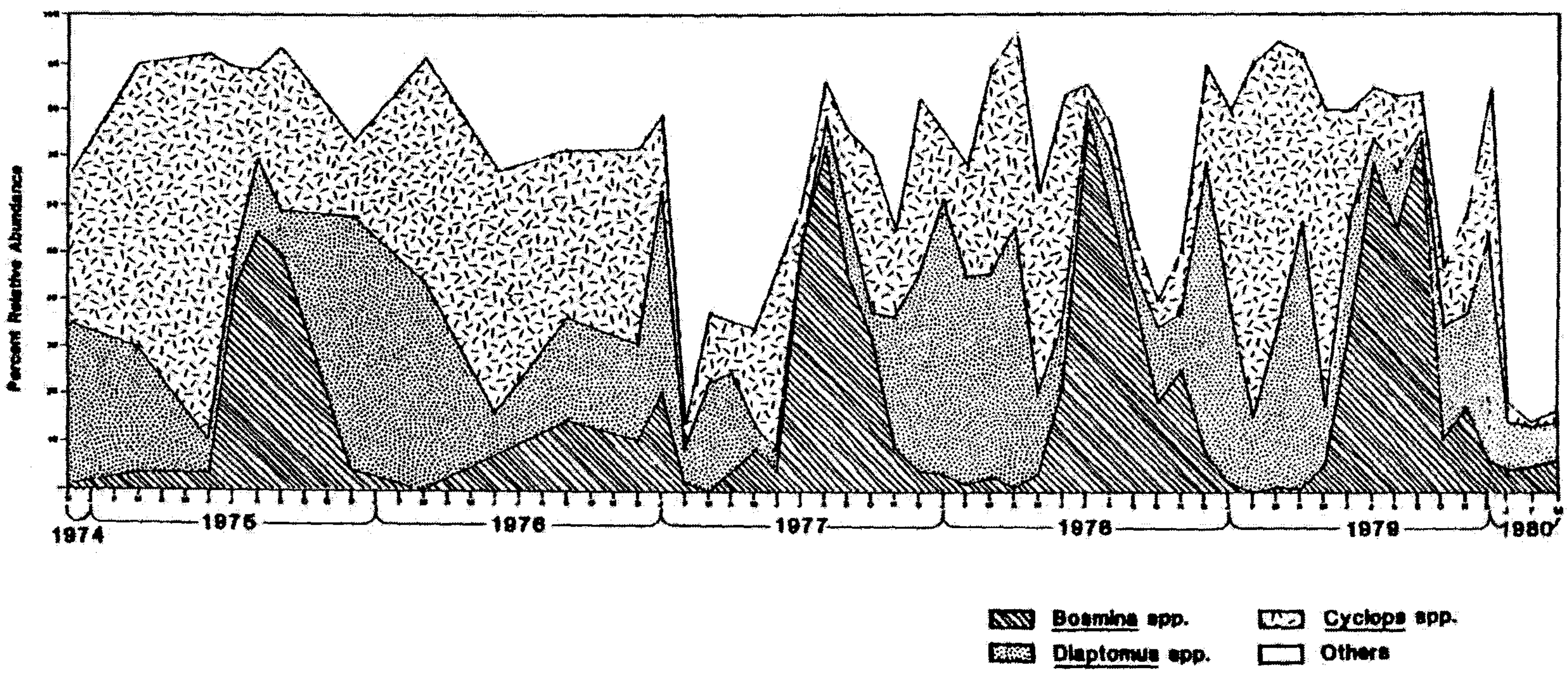

Figure 3.2. Relative abundance (% of mean total number) of the three dominant zooplankton organisms taken at station 1 near WNP-1, 2, and 4, December 1974-March 1980.

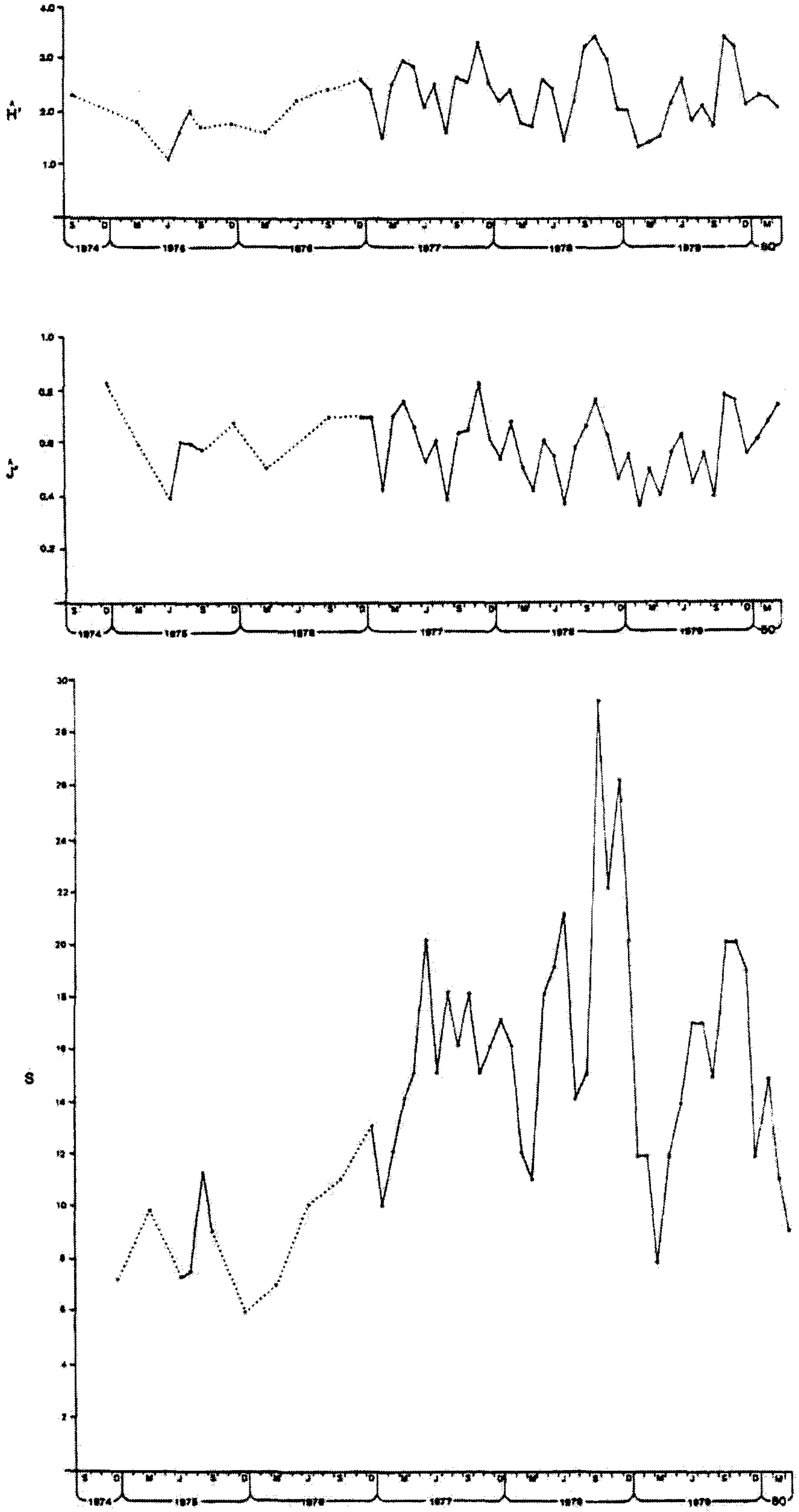

Figure 3.3. Diversity ($\hat{H}'$), evenness ($\hat{J}'$), and richness (S) for Columbia River zooplankton collected at station 1, near WNP-1, 2, and 4.

4.0 BENTHIC MACROFAUNA AND MICROFLORA

4.1 INTRODUCTION

The benthic macrofauna and microflora (periphyton) of the Hanford Reach of the Columbia River are important components of the aquatic biota. These components were studied at established stations in the vicinity of WNP-1, 2, and 4 (Figure 1.1) to determine density, biomass, community composition, and diversity of these organisms. The study was designed as a monitoring program to detect changes in the benthic community which may result from plant operation or construction.

4.2 METHODS AND MATERIALS

Samples of benthic macrofauna and microflora were collected using stations and methods established in a previous survey (Page, Neitzel and Hanf 1979). Rock-filled baskets and diatometers were the primary sampling gear. Detailed field methods are given in Standard Operating Procedures (SOP) B01-01 and B01-02 for macroinvertebrates and microflora, respectively, and are summarized below. Laboratory procedures are contained in SOPB01-03 and SOPB01-04 and data analysis techniques in SOPB01-05, and are also summarized below. Quality assurance/control procedures are contained in the Quality Assurance Program Document and described below.

4.2.1 Benthic Macrofauna

Four sampling sites have been established on the bottom of the Columbia River in the vicinity of WNP-1, 2, and 4. These sites are indicated as sites 1, 7, 8, and 11 in Figure 4.1. Sites 7 and 11 are subdivided into three stations each: 7W, 7M, 7E and 11W, 11M, and 11E. A diagram of the sample layout is provided in Figure 4.1.

Three baskets measuring 20.3 x 20.3 x 7.6 cm and containing 14 cleaned rocks measuring approximately 5-8 cm in diameter were attached to each of the eight stations by divers. Following an exposure period of approximately three months, the baskets were retrieved by divers and new rock-filled baskets were installed. Upon retrieval, baskets were enclosed in a 200 µm or smaller mesh bag to prevent loss of organisms as samples were brought to the surface.

Samples were transported to the laboratory where rocks, bags, and baskets were brushed clean and washed into a U.S. standard 30 mesh (0.59 mm mesh opening) sieving bucket. Sieved contents were then transferred to sample jars, preserved in alcohol, and stained with Rose Bengal. Benthic organisms were picked from each sample, sorted into general taxonomic categories, then identified to the lowest practical taxonomic category and counted. Taxonomic references included Pennak (1978), Usinger (1956), and Ward and Whipple (1959). Organisms in each taxonomic category were subsequently weighed collectively after blotting and air-drying for two minutes. Data were recorded on laboratory data sheets which were then keypunched and entered into computer data files.

Quality assurance/control procedures involved the independent reworking of approximately 10% of the samples. Results of these checks confirmed picking, identification, counting, and weighing accuracy.

Data analysis included calculating densities and biomass for individual taxa, and calculating indices of diversity, evenness, and taxonomic richness (discussed in Chapter 2.0). Seasonal data were compared graphically, and station data by Analysis of Variance and multiple comparisons.

4.2.2 Benthic Microflora

Microflora were obtained at the eight stations described in Section 4.2.1 by placing diatometers on two rock-filled baskets at each station. Diatometers

were similar to those described by Page and Neitzel (1978b), and each contained 8 clean glass slides measuring 25 x 75 mm which were held in a vertical position during the colonization period. Samplers were set in place and retrieved by divers at the same times as macrofauna samples were retrieved. Six of the eight slides from a single diatometer were taken to measure three variables (two slides per variable): taxonomic abundance, ash-free weight, and chlorophyll a. The remaining two slides were spares to be used for these analyses in case of slide loss or breakage.

Species composition and density were determined by microscopic examination of membrane filters prepared from two replicate sample slides from each station. These slides were transported to the laboratory in separate containers in a 3% formalin solution (1.1% formaldehyde solution), scraped clean of microflora, resuspended, and agitated to reduce particle size. After dilution of a suitable sample portion, membrane filters were prepared as described in Chapter 2.0. Taxonomic references are also described in Chapter 2.0.

Ash-free dry weight was determined from two replicate slides from each station. These slides were transported to the laboratory in separate containers on ice in the dark. Macroinvertebrates were removed from slides following the technique adopted by Page, Neitzel, and Hanf (1979) in March 1978. Material on slides was scraped into tared crucibles, dried at 105°C, weighed, ashed at 500°C then weighed to determine both dry and ash-free dry weight (combustible organic matter).

Chlorophyll a was determined by spectrophotometry on material from replicate slides from each station. These slides were transported to the laboratory in separate containers on ice in the dark. Material on the slides was scraped into a tissue grinder with a small amount of acetone:water solution and chlorophyll a determined as described in Chapter 2.0. Comparison of results to USEPA standards

confirmed measurement accuracy. Quality assurance/control procedures provided independent confirmation of identifications and recounts of randomly selected slides. Examination of approximately 15% of slides by algalogists at Oregon State University confirmed identifications of dominant species. Identification accuracy of small centric diatoms was confirmed by USEPA scientists at Cincinnatti, Ohio. In-house recounts of individual taxa and total individuals on approximately 10% of the samples confirmed initial results.

Data analysis techniques were the same as described for benthic macrofauna.

4.3 RESULTS AND DISCUSSION

4.3.1 Benthic Macrofauna

4.3.1.1 Community Composition, Population Density, and Biomass

A rich assemblage of benthic macrofauna was found in the vicinity of WNP-1, 2, and 4 during the period August 1978 through March 1980 (Table 4.1). Most taxa noted in Table 4.1 were collected using the rock-filled baskets; however, the freshwater sponge was collected by hand from the surface of the intake structure. The fauna tended to be dominated by caddisflies of the family Hydropsychidae and flies of the family Chironomidae (midges). These two taxa often comprised more than 80% of the total density at a station. Other major taxa, which may account for more than 10% of the total density at a station, included Simuliidae (blackflies) and Lithoglyphus sp. (a snail, formerly Fluminicola sp.) In terms of biomass, the fauna was generally dominated by the hydropsychid caddisflies. The snails Lithoglyphus and Limnaea, together with Chironomidae and Simuliidae, were major contributors to the biomass, accounting individually for more than 10% of the total biomass at some stations. Data on density and biomass are reported by sample for each taxonomic category in data reports of the series DRB 01-03 for August and December 1978, March, June, September and December 1979, and March 1980, and in

Appendix D.

Total density of macroinvertebrates followed seasonal patterns generally similar to those noted in previous years (Figure 4.2). Abundance was lowest in March and June 1979 and highest in September 1979. Sampling has been approximately quarterly since 1976 at 3 locations but was more frequent in 1975. Most stations have data avilable since the fall of 1977. Certain year to year differences are notable. Timing of peaks and troughs in abundance vary from year to year. Abundance peaked in September for the years 1976, 1977, and 1979 (the 1978 sample was taken on August 21 rather than in September). Highest abundance in 1975 and 1978 was noted in December, although abundance subsequently increased after the 1975 high and declined after the 1978 high. Lowest densities for the years 1976 and 1978 were in June, while the lows in 1977 and 1979 were in March.

Mean total biomass data for each station covering the period August 1978 - March 1980 are presented in Figure 4.3. Biomass showed peaks in December 1978 and September or December 1979. The lowest biomass over the 19-month sampling period was in March 1979 and March 1980 at all stations.

Timing of highs and lows in density and biomass of benthic macroinvertebrates from the basket samplers is not necessarily reflective of seasonal patterns in the benthic community as a whole. For instance, the sharp declines in both density and biomass of the benthic fauna from December 1978 to March 1979 and from December 1979 to March 1980 were primarily due to much lower abundance of hydropsychid caddisfly larvae in the basket samplers. This apparent mid-winter decline in the net-spinning caddisflies is certainly not due to emergence of adult caddisflies, a summertime phenomenon along the Columbia River, and is not likely to be caused entirely by a massive mortality in the larval populations since abundance of these larvae rebounded to some extent in June. The most likely explanation is the noted winter quiescence of some Hydropsyche larvae (Pennak 1978) which may result in a

lower chance of colonizing new substrates during the winter. The peaks of larval abundance noted for September and December follow the major emergence and subsequent egg deposition by adult Hydropsychidae in the summer and early fall. The *situation with Hydropsychidae illustrates the point that what we see in these* benthic data is the result of the births, deaths, immigration, and emigration which occurred during the preceding three months, and as such may not always give an *accurate picture of the adjacent benthic community.*

Results of diversity investigations of the benthic macrofauna are presented in Table 4.2. Richness (S = number of taxa, not species) ranged from 5 to 19 during the sampling interval August 1978 through March 1980. Richness was highest in September 1979 and lowest in March 1979. The diversity index ($\hat{H}'$) ranged from 0.69 to 2.26. The index was highest in March 1980 and lowest in December 1978. The evenness index ($\hat{J}'$) was highest in March 1979 (0.68) and lowest in December 1978 (0.19). The higher diversity and evenness for March was due to much reduced numbers of Hydropsychidae. Expected values for diversity and evenness were calculated, but the bias correction factor in these estimates did not affect either index beyond the third decimal place so these results are not reported here.

While the diversity, evenness, and richness data presented here are not directly comparable to figures reported in previous studies of this region (Page and Nietzel 1976, 1977, 1978 a,b; Page, Neitzel, and Hanf 1979) because of identification to lower taxonomic levels in the present study, seasonal patterns should be comparable. The interpretation of seasonal patterns in diversity from basket sample data is constrained by the same factors which limited the inferences which could be drawn from density or biomass data on seasonal trends in abundance, i.e., the community structure found in a basket of rocks exposed to colonization for a three-month period may be quite different from the community structure found in adjacent substrates with a much longer time of exposure. In fact, there were no consistent

patterns in the seasonal variation of the three measures of community structure. For instance, diversity ($\hat{H}'$) at control station 1 was high in December in one year and low in December in two other years.

4.3.1.2 Station Comparisons

In view of the preceding discussions, Analysis of Variance on the macroinvertebrate density and biomass data was performed using a one-way classification in which comparisons among stations were made on log-transformed data within a single sampling period. Logarithmic transformations were made to stabilize the variances and reduce the dependency between means and standard deviations, thus increasing the validity of the tests of significance in the Analysis of Variance (Steel and Torrie 1960; Snedecor and Cochran 1976). Results of these analyses are included in Table 4.3. Subsequent multiple comparisons were performed, and the results are reported in Table 4.4.

Few consistent patterns were evident. Most stations were not significantly different in terms of either density or biomass. Station 11W tended to rank high in total density. This pattern has continued since September 1977. The lack of significant differences in most comparisons reflected that variability within stations exceeded variability among stations.

4.3.2. Benthic Microflora

4.3.2.1 Community Composition, Population Density, and Biomass

Data from replicated analyses together with descriptive statistics are presented in data reports of the series DRB01-04 for August and December 1978, March, June, September and December 1979, and March 1980, and Appendix E. All samples were collected except at station 7W in August 1978, all stations (except 8) in December 1978, and station 7W in March 1979 where slide breakage occurred.

At least 162 taxa were observed in the seven sets of samples (Table 4.5). These included 155 identified species, 2 chrysophte statospores, and several unidentifiable species in two major algal divisions. The distribution of genera and species among the major algal divisions was:

Algal Division	Genera	Species
Chrysophyta	29	138
Chlorophyta	6	9
Cyanophyta	8	13
Rhodophyta	1	1
Pyrrophyta	1	1
Total	45	162

Diatoms (Chrysophyta: Bacillariophyceae) were the dominant algal forms both in number of species (Table 4.5) and in percent of total density for most sampling dates, as had been reported in previous studies at these stations (Page and Neitzel 1978b; Page, Neitzel, and Hanf 1979). However, the blue-green algae (Cyanophyta) were occasionally dominant, as in June 1979. The only other algal division commonly observed on slides, but at lower densities, was the green algae (Chlorophyta). A species of red algae of the division Rhodophyta which has not been reported previously was observed in September.

Typical planktonic forms were observed together with the benthic microflora (attached algae or periphyton) and often at high density. This occurred especially in June 1979 and March 1980 when the planktonic centric diatoms Stephanodiscus hantzschii and Melosira italica and the planktonic colonial diatoms Asterionella formosa and Fragilaria crotonensis were dominant or very abundant. The planktonic centric diatom Cyclotella glomerata was dominant in August 1978. During their periods of greatest abundance (see Chapter 2.0), these planktonic forms sedimented

out of solution onto the bottom and constituted a larger proportion of the microflora on the slides than at other times of the year when phytoplankton densities were low.

The dominant species for each of the seven sets of samples were as follows: the centric diatom Cyclotella glomerata (August 1978); the diatoms Achnanthes minutissima and Cocconeis placentula (December 1978); the diatom Gomphonema olivaceum (olivaceoides?) (March 1979); the filamentous blue-green Schizothrix #2 (June 1979); Cocconeis placentula (September 1979); the diatom Achnanthes deflexa (December 1979); and the diatoms Gomphonema olivaceoides, Nitzchia frustulum and Stephanodiscus hantzschii (March 1980).

The structure of each of the samples was evaluated by calculating a diversity index ($\hat{H}'$), and index of evenness ($\hat{J}'$) and the number of species per sample, or species richness (S) (Table 4.6). Diversity was generally highest in late summer (August and September) of both years and lowest in early summer and winter. Values ranged from 2.45 (Station 11M, June 1979) to 4.83 (station 1, September 1979). Evenness ranged from 0.50 (station 11M, June 1979) to 0.85 (station 11W, September 1979). An evenness value of 1.0 indicates an equal distribution of numbers of individuals per species in the sample. Species richness ranged from 21 (station 7M, December 1979) to 58 (station 7M, September 1979 and station 1, August 1978). The highest diversity value ($\hat{H}'$) previously reported was 3.1, which occurred in June 1977 at station 8 (Page and Neitzel 1978b). The highest number of taxa per sample previously reported for these stations was 30 at station 7W on September 21, 1977 (Page and Neitzel 1978b). It should be noted that previous and present data are not directly comparable. The microscopic magnification used in the present study (400x - 1000x) was greater than that used in previous studies (200x or less). The lower magnification would have hindered the observation and thus identification of frequently dominant small diatoms such as Cyclotella glomerata.

Total microflora densities tended to be highest in March and December and lowest in June (Figure 4.4). Densities ranged from 18.0 x 10^5 units/l (station 8, March 1979) to 0.2 x 10^5 units/l (station 11E, June 1979). At station 8, for which a complete set of samples has been obtained, the quarterly pattern showed highest densities during winter (December and March) and lowest densities during summer (Figure 4.5). This pattern may be due to at least two factors: availability of colonizing cells and shading. As noted in Chapter 2.0, the lowest proportion of typical periphyton forms in the plankton occurred May through September. Colonization by forms able to exploit surface growth may therefore have been restricted during these months. Shading of the bottom by dense plankton populations and other suspended particulates during freshet from March through September probably is of more importance in restricting benthic microflora development. Phytoplankton productivity studies in 1973-1974 at stations near the present study stations (Wolf, Page, and Neitzel 1976) and in 1974-1975 at present study stations (Page, Neitzel, and Wolf 1976) showed severely decreased productivity of phytoplankton incubated near the river bottom due to shading. During winter when plankton populations are low, more light is available for benthic microflora, even though incident solar radiation is less.

Values of chlorophyll a and total organic matter (ash-free weight), both measures of microflora biomass, were in agreement with density values in being lowest in early summer (June 1979) (Figure 4.5). Values for these two measures for other sampling periods during the present study varied widely. Ash-free weight, or total organic matter, ranged from 0.48 g/m^2 (station 7M, June 1979) to 9.52 g/m^2 (station 8, December 1978). Chlorophyll a ranged from 1.66 mg/m^2 (station 7M, June 1979) to 113.53 mg/m^2 (station 8, March 1979).

Correlation analysis of chlorophyll a versus ash-free weight over all samples from the study period was not significant ($P < 0.05$; 0.150). With March data

from 1979 and 1980 removed from the data correlated, there was a significant ($P<0.05$) correlation of 0.373. A significant ($P<0.05$) correlation was also found in the March 1979 and 1980 data of 0.626. This same pattern of relationships was noted in the correlation of unit density versus ash-free weight. Using all samples from the study period showed no significant correlation ($P<0.05$; 0.279). With March data from 1979 and 1980 removed from the data correlated, there was a significant ($P<0.05$) correlation of 0.427. A significant ($P<0.05$) correlation was also found in the March 1979 and 1980 data of 0.702. Correlations of density versus chlorophyll using all months showed a significant ($P<0.05$) correlation of 0.772. Examination of Figure 4.5 shows the peak ash-free weight generally occurred in August, September or December while the peak chlorophyll values (and unit densities, see Figure 4.4) occurred in March. These differences may reflect seasonal changes in species composition (for example, relatively more green and blue-green algae in the fall) and thus seasonal changes in the amount of chlorophyll per unit algal biomass.

4.3.2.2 Station Comparisons

Analysis of Variance was used to analyze total densities, densities of dominant species, ash-free weight, and chlorophyll a of five sets of samples. Results showed significant differences ($\alpha = 0.05$ or 0.01) among stations for each of these items on different occasions (Table 4.7). Results of multiple comparisons are presented in Table 4.8. In several cases, significant F ratios were observed; however pairwise comparisons among stations showed no significant differences. This result was due to the fact that Analysis of Variance techniques are more powerful in detecting overall differences among stations than are multiple comparison techniques where pairwise differences occur between stations at a comparable α level. In several months, significant differences were detected among stations for the various measures of abundance. However, no consistent pattern through time was

Table 4.3. (Continued)

Month/ Category	Density F	Density df*	Density Significance	Biomass F	Biomass df*	Biomass Significance
September 1979						
Hydropsychidae	0.65	7, 16	-	3.15	7, 16	0.05
Chironomidae	0.83	7, 16	-	1.00	7, 16	-
Simuliidae	1.86	7, 16	-	2.47	7, 16	-
Mollusca	3.79	7, 16	0.05	6.22	7, 16	0.01
Total	0.54	7, 16	-	4.21	7, 16	0.01
December 1979						
Hydropsychidae	6.62	7, 16	0.01	5.66	7, 16	0.01
Chironomidae	3.56	7, 16	0.05	1.89	7, 16	-
Simuliidae	5.54	7, 16	0.01	1.46	7, 16	-
Mollusca	6.51	7, 16	0.01	9.41	7, 16	0.01
Total	7.97	7, 16	0.01	7.68	7, 16	0.01
March 1980						
Hydropsychidae	2.53	7, 16	-	2.04	7, 16	-
Chironomidae	1.74	7, 16	-	1.74	7, 16	-
Simuliidae	2.78	7, 16	0.05	1.37	7, 16	-
Mollusca	4.70	7, 16	0.01	4.21	7, 16	0.01
Total	2.42	7, 16	-	4.06	7, 16	0.01

* First value denotes degrees of freedom in numerator.
  Second value denotes degrees of freedom in denominator.

Table 4.4. Results of multiple comparisons (Newman-Keuls) of benthic macrofauna among stations. Stations connected by the same underline are not significantly different at $\alpha = 0.05$. Stations are ranked in order from highest to lowest.

Month/ Category	Density	Biomass
August 1978		
Hydropsychidae	11W 7W 7E 11E 7M 8 11M 1	11W 7W 11E 7E 7M 11M 1 8
Chironomidae	11W 8 7W 11M 11E 7M 7E 1	11W 8 11E 7W 7E 7M 11M 1
Simuliidae	11W 11E 11M 7E 7W 7M 1 8	11W 11M 11E 7W 7E 8 1 7M
Mollusca	7W 11W 11E 7E 1 8 7M 11M	7W 11W 7M 7E 11E 1 8 11M
Total	11W 7W 8 7E 11E 7M 11M 1	11W 7W 11E 7E 7M 11M 8 1
December 1978		
Hydropsychidae	11W 11M 1 11E 7W 7M 8 7E	11W 11M 7M 11E 7E 7W 1 8
Chironomidae	1 11W 8 11E 11M 7E 7W 7M	1 8 11W 7E 7W 11E 11M 7M
Simuliidae	11E 11M 11W 7E 1 7W 7M 8	11E 11M 11W 7E 7M 7W 1 8
Mollusca	11E 7M 7E 11W 7W 8 11M 1	7E 11E 7M 11W 7W 11M 1 8
Total	11W 11M 1 11E 8 7W 7M 7E	11M 11W 7M 11E 7E 7W 1 8
March 1979		
Hydropsychidae	11W 8 11M 7W 11E 7E 1 7M	11W 11M 7W 11E 7E 1 8 7M
Chironomidae	8 11W 11M 7W 1 7E 7M 11E	8 11W 7W 11M 1 7E 11E 7M
Simuliidae	8 11W 7W 11M 7E 11E 1 7M	11W 8 7W 7E 11E 11M 1 7M
Mollusca	I.D.*	I.D.*
Total	8 11W 7W 11M 7E 1 11E 7M	11W 8 11M 7W 7E 11E 1 7M
June 1979		
Hydropsychidae	7W 11W 11E 7E 1 8 11M 7M	7W 11W 11E 7E 8 1 11M 7M
Chironomidae	11W 8 7W 11E 1 11M 7E 7M	11W 8 7W 11E 1 7E 11M 7M
Simuliidae	11W 11E 7W 1 7E 11M 7M 8	11W 7W 11E 1 7E 7M 11M 8
Mollusca	7E 11M 7W 11E 11W 1 8 7M	7E 11M 11W 11E 7W 7M 8 1
Total	11W 7W 11E 8 7E 1 11M 7M	11W 7W 7E 11E 8 1 11M 7M

Table 4.4. (Continued)

Month/ Category	Density	Biomass
September 1979		
Hydropsychidae	11M 7M 11E 11W 1 7E 7W 8	11E 11M 7M 11W 1 7W 7E 8
Chironomidae	1 7M 8 11E 11W 11M 7W 7E	11E 8 11W 1 7M 11M 7W 7E
Simuliidae	11W 11E 11M 7W 7M 1 8 7E	11W 11E 7W 11M 1 8 7M 7E
Mollusca	11E 7W 11M 7E 7M 8 1 11W	11E 7W 7E 11M 7M 11W 8 1
Total	11M 7M 1 11E 8 11W 7E 7W	11E 11M 7M 7W 11W 7E 1 8
December 1979		
Hydropsychidae	11W 11E 7M 7W 8 11M 1 7E	11E 11W 7W 7M 1 11M 8 7E
Chironomidae	8 7M 1 11M 11W 7E 11E 7W	8 1 7M 11M 11W 11E 7E 7W
Simuliidae	11E 7M 11W 7W 11M 7E 8 1	11W 11E 7M 11M 7W 8 7E 1
Mollusca	11E 7W 7E 11W 7M 1 8 11M	11E 7W 7E 11W 7M 1 8 11M
Total	11W 8 11E 7M 7W 11M 1 7E	11E 7W 11W 7M 1 7E 11M 8
March 1980		
Hydropsychidae	11W 7E 11E 1 7W 7M 8 11M	11W 1 7M 11E 7W 7E 11M 8
Chironomidae	8 7M 11W 1 7E 7W 11E 11M	8 7W 7E 11W 1 7M 11E 11M
Simuliidae	11E 11W 7W 11M 7E 7M 8 1	11E 11W 7E 7M 11M 7W 8 1
Mollusca	7W 11E 7E 11W 11M = 1 8 = 7M	7W 7E 11E 11W 1 11M 8 = 7M
Total	11W 8 7E 11E 1 7W 7M 11M	7W 7E 11W 11E 1 7M 8 11M

* I.D. = Insufficient Data

Table 4.5. Columbia River benthic microflora collected in the vicinity of WNP-1, 2, and 4, August 1978 - March 1980.*

ALGAL DIVISION/SPECIES

CHRYSOPHYTA (BACILLARIOPHYCEAE)

Melosira ambiqua
Melosira granulata
Melosira granulata v. *angust.*
Melosira italica
Melosira varians
Melosira distans v. *alpigena*
Stephanodiscus astraea
Stephanodiscus astraea v. min.
Stephanodiscus hantzschii
Stephanodiscus dubius
Cyclotella stelligera
Cyclotella pseudostelligera
Cyclotella kutzingiana
Cyclotella meneghiniana
Cyclotella glomerata
Cyclotella comta
Cyclotella comensis
Tabellaria fenestrata
Diatoma tenue
Diatoma vulgare
Asterionella formosa
Opephora martyi
Fragilaria crotonensis
Fragilaria construens
Fragilaria capucina
Fragilaria leptostauron
Fragilaria vaucheriae
Hannaea arcus
Hannaea arcus v. *amphioxys*
Synedra ulna
Synedra ulna v. *chaseana*
Synedra acus
Synedra delicatissima
Synedra rumpens
Synedra vaucheriae
Synedra parasitica
Synedra mazamaensis
Synedra cyclopum
Synedra pulchella
Synedra radians
Cocconeis placentula
Achnanthes lewisiana
Achnanthes lanceolata
Achnanthes minutissima
Achnanthes exigua
Achnanthes linearis
Achnanthes flexella
Achnanthes cleveii
Achnanthes deflexa
Achnanthes pergalli
Rhoicosphenia curvata
Funotia pectinalis
Diploneis smithii v. *dilatata*
Diploneis oculata
Navicula seminuloides
Navicula minima
Navicula tripunctata
Navicula cryptocephala
Navicula cryptocephala v. *veneta*
Navicula mutica
Navicula arvensis
Navicula pupula
Navicula reinhardtii
Navicula pseudoreinhardtii
Navicula radiosa
Navicula viridula
Navicula peregrina
Navicula decussis
Navicula menisculus v. *up.*
Navicula capitata
Navicula cascadensis
Navicula bacillum
Navicula vitabunda
Navicula minuscula
Navicula infirmata
Caloneis hyalina
Pinnularia borealis
Amphipleura pellucida
Gomphonema parvulum
Gomphonema subclavatum
Gomphonema olivaceoides
Gomphonema truncatum
Gomphonema ventricosum
Gomphonema olivaceum
Gomphonema olivaceum v. *calcarea*
Cymbella turgidula
Cymbella sinuata
Cymbella cistula
Cymbella minuta
Cymbella mexicana
Cymbella affinis
Cymbella prostrata
Cymbella muelleri
Cymbella microcephala

Table 4.5. (Continued)

ALGAL DIVISION/SPECIES

CHRYSOPHYTA (BACILLARIOPHYCEAE)
(continued)

Amphora perpusilla
Amphora ovalis
Epithemia sorex
Epithemia turgida
Rhopalodia gibba
Hantzschia amphioxys
Cymbellonitzschia diluviana
Nitzschia latens
Nitzschia paleacea
Nitzschia silica
Nitzschia palea
Nitzschia dissipata
Nitzschia innominata
Nitzschia perminuta
Nitzschia allansoni
Nitzschia frustulum
Nitzschia stagnorum
Nitzschia osmophila
Nitzschia obsoleta
Nitzschia linearis
Nitzschia lauenbergiana
Nitzschia amphioxides
Nitzschia sigmoidea
Nitzschia acicularis
Nitzschia subacicularis
Nitzschia amphibia
Nitzschia oregona
Nitzschia accomodata
Nitzschia fonticola
Nitzschia demota
Nitzschia bacata f. lin.
Nitzschia recta
Nitzschia R1
Nitzschia hungarica
Nitzschia angustata
Nitzschia subpunctata
Nitzschia vermicularis
Nitzschia serpenticula
Nitzschia sigma v. diminuta
Nitzschia holsatica
Nitzschia gracilis
Cymatopleura solea
Surirella linearis
Surirella angustata
Chrysophyte statospore #11
Chrysophyte statospore #1

CHLOROPHYTA:

Ankistrodesmus falcatus
Scenedesmus quadricauda
Scenedesmus abundans
Scenedesmus acuminatus
Scenedesmus longus
Schroederia judayi
Chlorella-like #1
Ulothrix zonata
Stigeoclonium R1

CYANOPHYTA:

Anacystis cyanea
Anacystis montana
Entophysalis rivularis
Oscillatoria lutea
Lyngbya limnetica
Oscillatoria limnetica
Arthrospira jenneri
Arthrospira brevis
Schizothrix calcicola
Schizothrix #2
Schizothrix fragilis
Schizothrix friesii
Calothrix parietina

RHODOPHYTA:

Audouinella violacea

PYRROPHYTA:

Rhodomonas minuta

* Numbered genera indicate particular species which were identified to genera but which could not be identified to species. These species have been measured, drawn and photographed for future identification. Chrysophyte statospores were given numbers to differentiate the forms observed.

Table 4.6. Taxonomic richness (S), diversity ($\hat{H}'$), and evenness ($\hat{J}'$) for benthic microflora August 1978 - March 1980.

Month/Category	Station 1	7W	7M	7E	11W	11M	11E	8	Mean
August 1978									
S	58	N.D.	51	57	52	52	52	54	54
$\hat{H}'$	4.27	N.D.	4.31	4.17	3.69	3.80	4.10	4.02	4.05
$\hat{J}'$	0.73	N.D.	0.76	0.72	0.65	0.67	0.72	0.70	0.71
December 1978									
S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	35	35
$\hat{H}'$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	3.55	3.55
$\hat{J}'$	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.69	0.69
March 1979									
S	N.D.	N.D.	28	28	23	24	26	37	28
$\hat{H}'$	N.D.	N.D.	3.37	3.37	3.39	3.32	3.43	3.52	3.40
$\hat{J}'$	N.D.	N.D.	0.70	0.70	0.75	0.72	0.73	0.68	0.71
June 1979									
S	55	36	25	41	34	29	49	37	38
$\hat{H}'$	4.65	3.21	2.56	3.91	2.93	2.45	4.33	3.21	3.41
$\hat{J}'$	0.80	0.62	0.55	0.73	0.58	0.50	0.77	0.62	0.65
September 1979									
S	55	55	58	44	47	42	52	41	49
$\hat{H}'$	4.83	4.48	4.75	4.59	4.69	4.24	4.14	4.22	4.49
$\hat{J}'$	0.84	0.77	0.81	0.84	0.85	0.79	0.73	0.79	0.80
December 1979									
S	29	27	21	33	34	25	50	35	32
$\hat{H}'$	2.88	3.38	2.98	3.52	3.13	3.35	4.56	3.61	3.43
$\hat{J}'$	0.59	0.69	0.68	0.70	0.62	0.72	0.81	0.70	0.69
March 1980									
S	38	30	36	31	36	29	27	42	34
$\hat{H}'$	3.83	3.44	3.87	3.42	3.59	3.41	3.51	3.57	3.58
$\hat{J}'$	0.73	0.70	0.75	0.69	0.70	0.70	0.74	0.66	0.71

N.D. = No data, slides broken

Table 4.7. Results of One-Way Analyses of Variance comparing benthic microflora among sampling stations.

MONTH/CATEGORY	DENSITY F	DENSITY df	DENSITY Sig*	ASH-FREE WEIGHT F	ASH-FREE WEIGHT df	ASH-FREE WEIGHT Sig*	CHLOROPHYLL a F	CHLOROPHYLL a df	CHLOROPHYLL a Sig*
August 1978									
Cyclotella glomerata (= CRI)	4.45	6, 7	0.05						
Total	9.74	6, 7	0.01	7.95	6, 7	0.01	1.99	6, 6	--
December 1978									
Insufficient samples									
March 1979									
Gomphonema olivaceum	0.60	5, 6	--						
Total	2.66	5, 6	--	25.81	5, 6	0.01	3.40	5, 6	--
June 1979									
Schizothrix #2	4.27	7, 8	0.05						
Total	12.18	7, 8	0.01	1.82	7, 8	--	8.43	7, 8	0.01
September 1979									
Cocconeis placentula	23.27	7, 8	0.01						
Total	14.82	7, 8	0.01	9.53	7, 8	0.01	35.45	7, 8	0.01
December 1979									
Acnanthes deflexa	12.06	7, 8	0.01						
Total	20.96	7, 8	0.01	2.26	7, 6	--	3.70	7, 8	0.05
March 1980									
Gomphonema olivaceum	3.46	7, 8	--						
Total	3.56	7, 8	0.05	13.88	7, 8	0.01	3.40	7, 8	--

* Sig = Significance

Table 4.8. Results of multiple comparisons (Newman-Keuls) of benthic microflora among stations. Stations connected by the same underline are not significantly different at $\alpha = 0.05$. Stations are ranked in order from highest to lowest.

MONTH/CATEGORY	DENSITY	ASH-FREE WEIGHT	CHLOROPHYLL a
August 1978			
Cyclotella glomerata	8 11W 11M 11E 7E 7M 1		
Total	8 11W 11E 11M 7E 7M 1	8 11W 1 11M 7E 7M 11E	8 1 11W 7E 11M 11E 7M
December 1978			
Insufficient samples			
March 1979			
Gomphonema olivaceum	11W 7M 8 7M 11M 11E		
Total	8 11W 7E 7M 11M 11E	8 11W 7M 11M 11E 7E	8 11W 11M 7M 11E 7E
June 1979			
Schizothrix #2	8 7M 7W 11M 7E 11W 11E 1		
Total	8 7M 1 7W 7E 11W 11M 11E	11E 8 7W 11W 7E 7M 1 11M	11W 11E 1 11M 8 7W 7E 7M
September 1979			
Cocconeis placentula	7W 8 11M 7E 11W 1 7M 11E		
Total	7W 8 7E 11M 1 11W 11E 7M	11M 7W 1 11W 8 11E 7E 7M	11W 7W 7E 8 1 11M 7M 11E
December 1979			
Acnanthes deflexa	1 11W 7M 7W 11M 7E 8 11E		
Total	7W 7M 11W 1 8 11M 7E 11E	11E 11W 11M 8 7M 7W 7E 1	7M 7W 1 11W 7E 8 11M 11E
March 1980			
Gomphonema olivaceum	7E 7M 11W 11M 11E 7W 1 8		
Total	8 7M 1 7E 11W 11M 11E 7W	8 7M 11W 1 11E 7W 7E 11M	7M 8 1 11W 11E 11M 7E 7W

BEAK

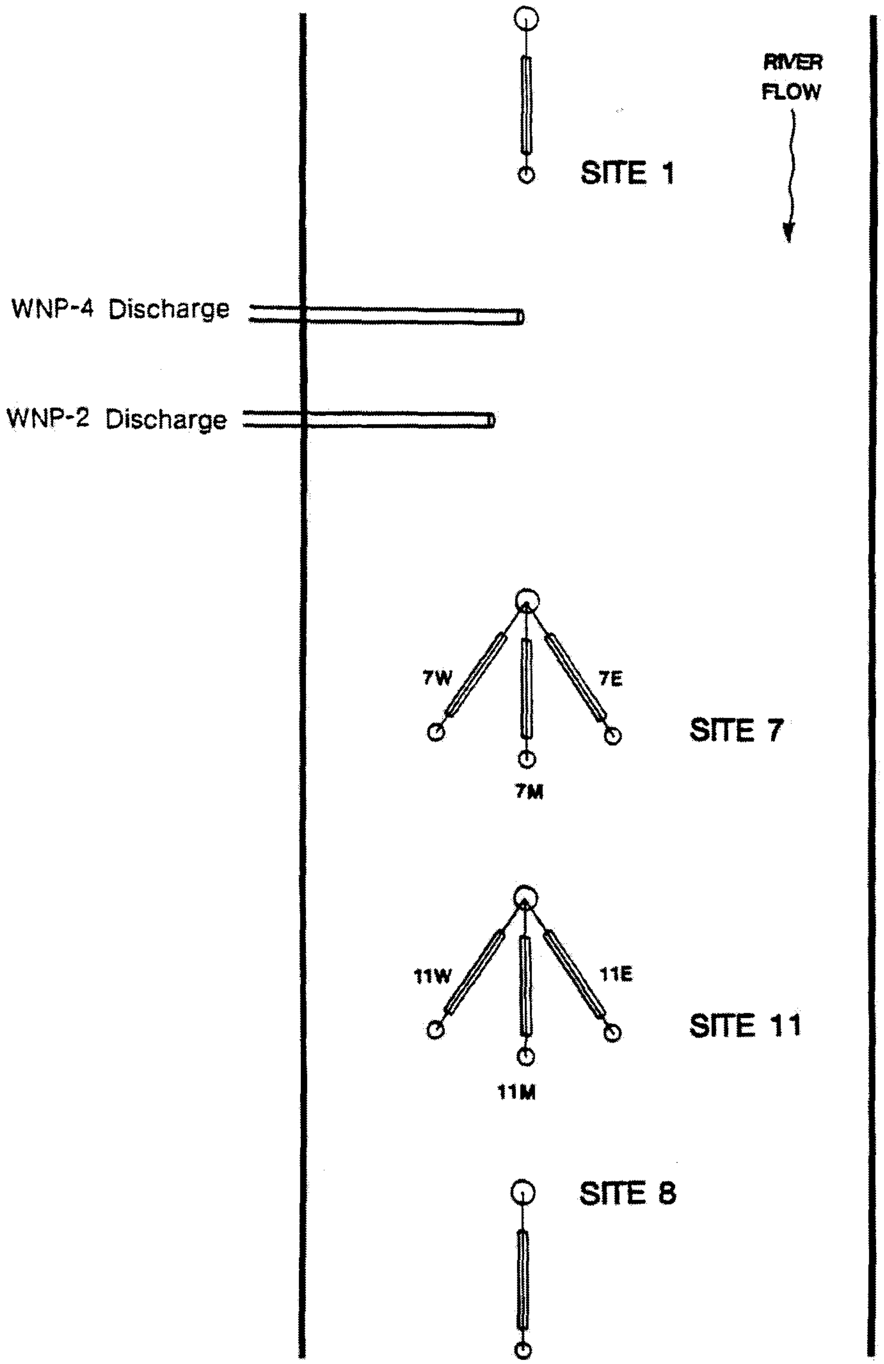

Figure 4.1. Diagrammatic representation of the benthic sampling layout in the Columbia River.

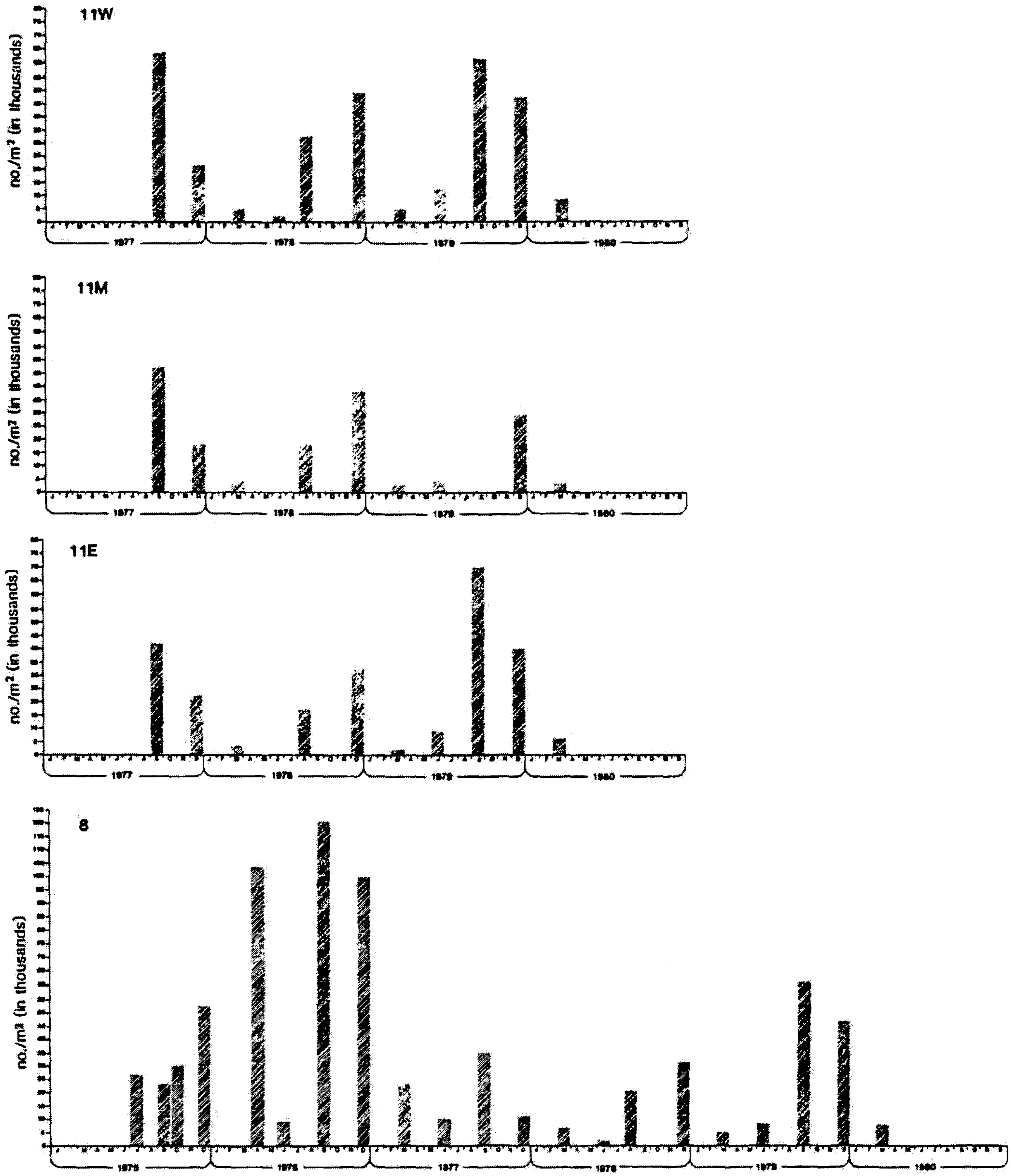

Figure 4.2. Total densities for benthic macrofauna collected at eight stations near WNP-1, 2, and 4 through March 1980. Data for years previous to the present study period from Page and Neitzel (1976, 1977, 1978a, b) and Page, Neitzel, and Hanf (1979).

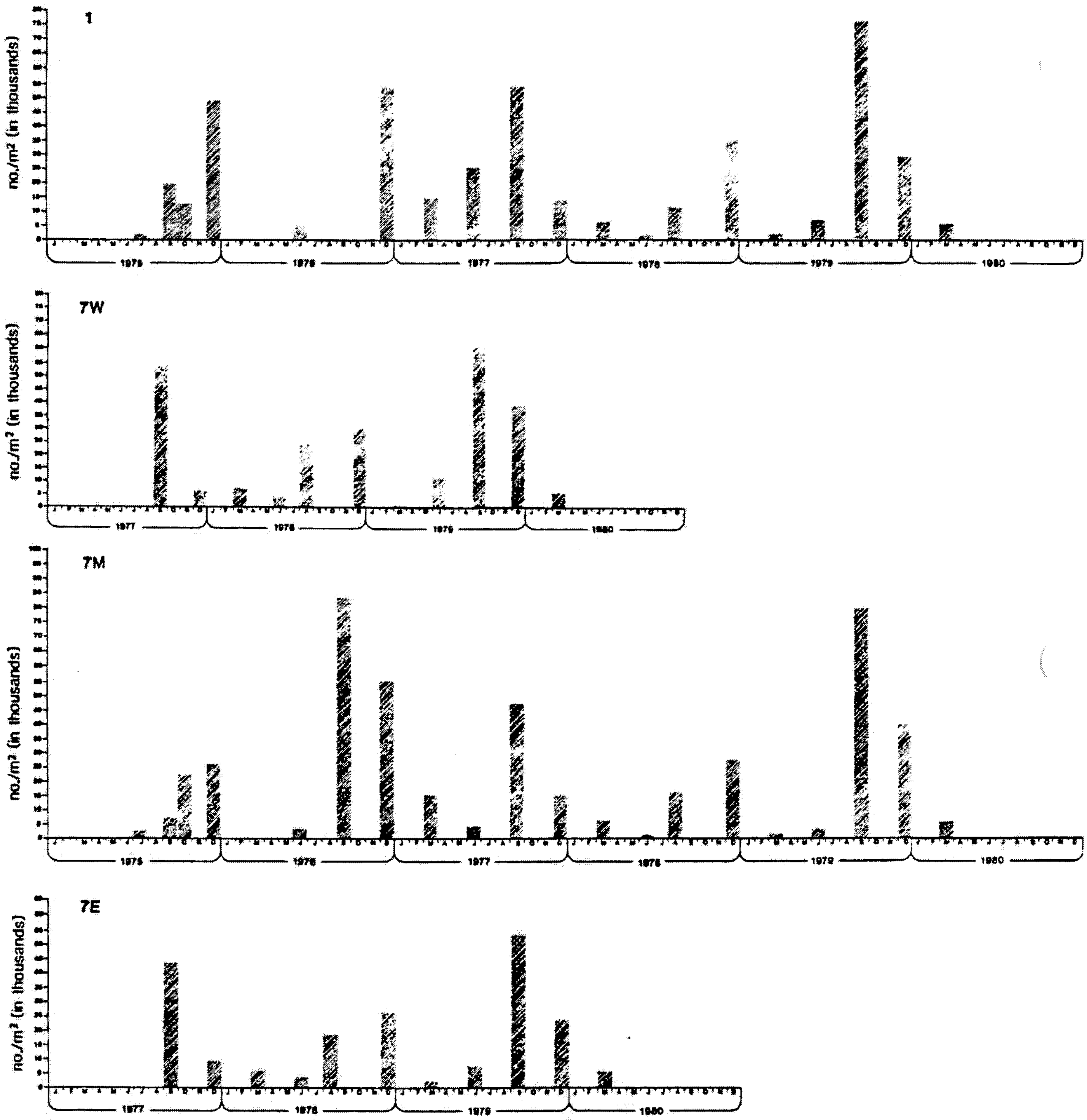

Figure 4.2. (Continued)

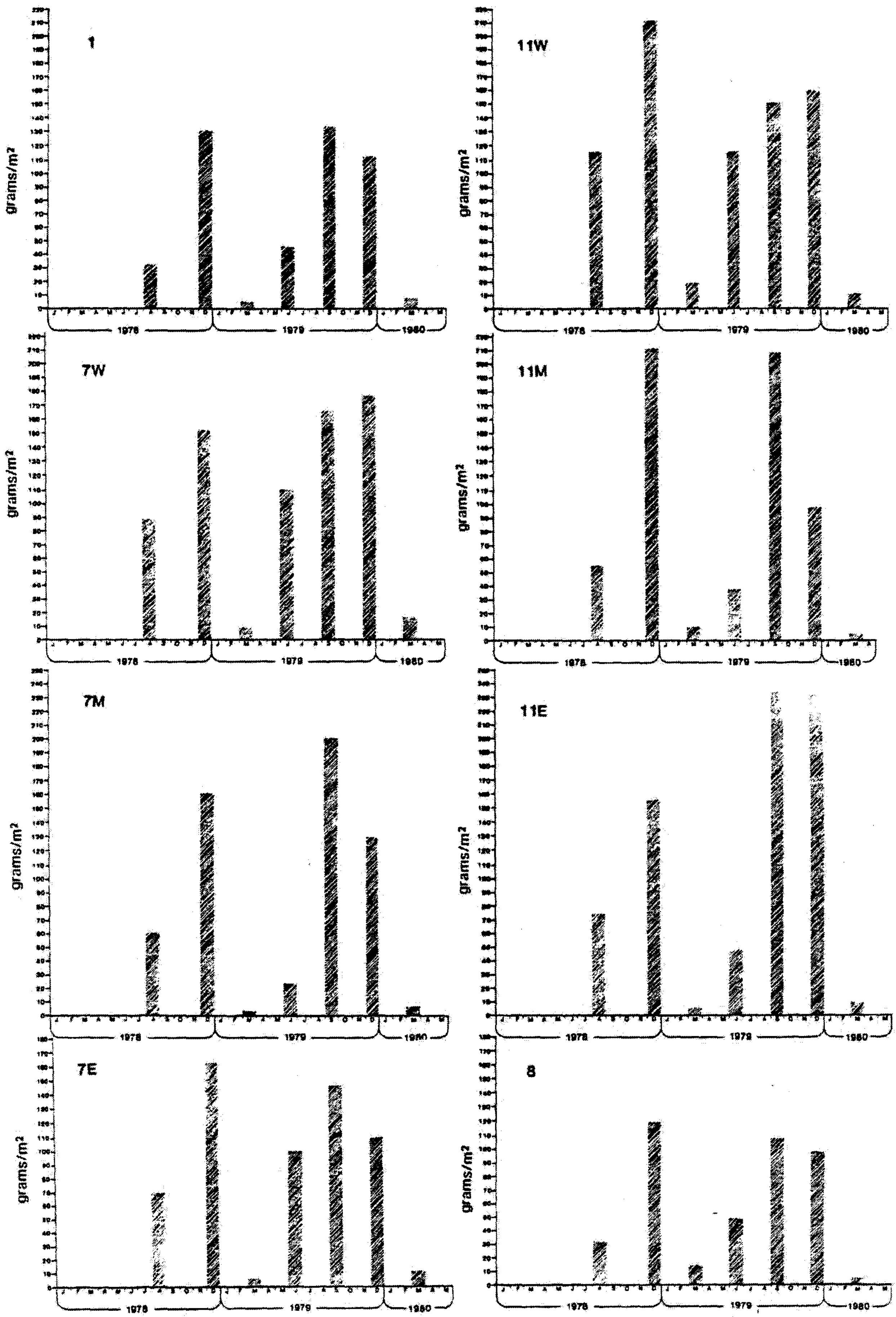

Figure 4.3. Mean total biomass values for benthic macrofauna collected at eight stations near WNP-1, 2, and 4 through March 1980. Data for year previous to the present study period from Page, Neitzel, and Hanf (1979).

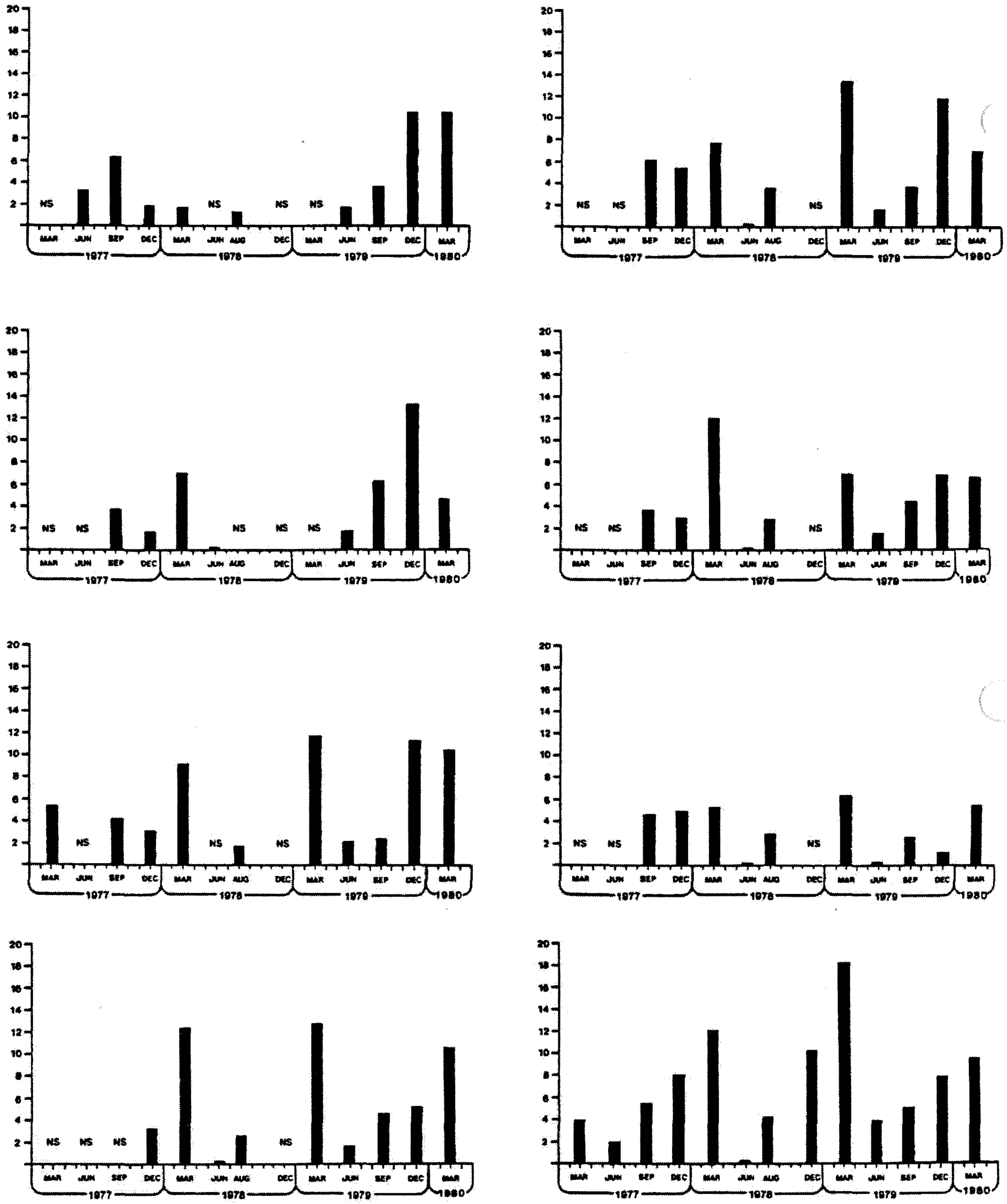

Figure 4.4. Benthic microflora unit densities on colonized artificial substrates (microslides) at end of three month period - March 1977-March 1980 at the eight study stations. Data for years previous to present study period from Page and Neitzel (1978b) and Page, Neitzel, and Hanf (1979). NS = No Sample.

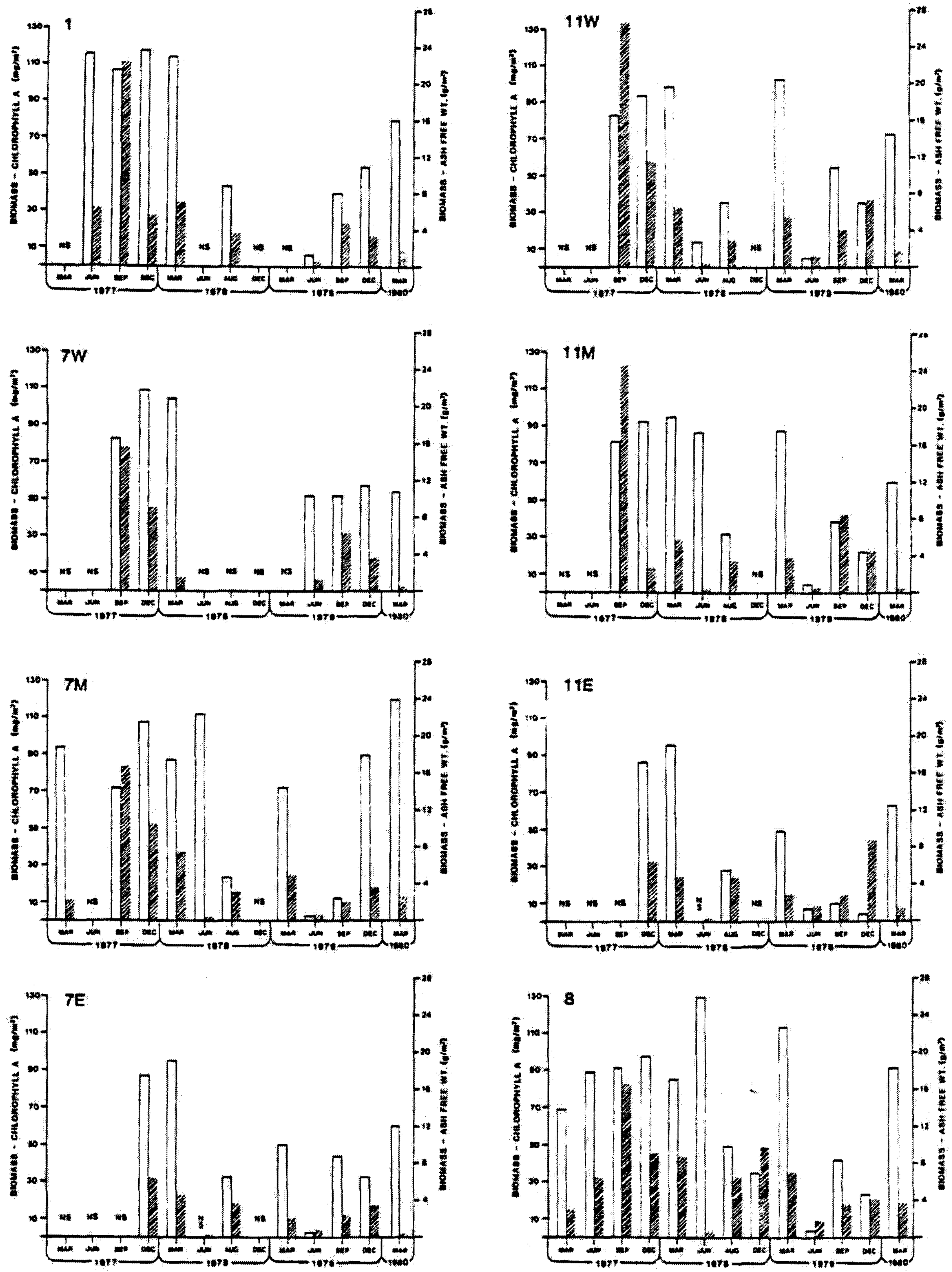

Figure 4.5. Benthic microflora biomass-chlorophyll a (▭) and biomass-ash-free weight (▨) values from study stations March 1977-March 1980. Data for years previous to the present study period from Page and Neitzel (1978b) and Page, Neitzel, and Hanf (1979). NS = No Sample.

5.0 FISH

5.1 INTRODUCTION

Objectives of fisheries studies were to provide baseline, preoperational data on community composition, population residence time, seasonal and spatial abundance, body condition, feeding habits, and species diversity in the Columbia River near the WNP-1, 2, and 4 intake and discharge sites. Data on fish spawning, parasite occurrence, and age-growth characteristics were also gathered.

5.2 METHODS AND MATERIALS

Field, laboratory, and data analysis techniques are described in Standard Operating Procedures B02-01, B02-02, and B02-03, respectively, and discussed briefly below. Quality assurance/quality control procedures for fish studies are described in the Quality Assurance Program Document and summarized below. Continuing field and laboratory tasks were conducted in the same manner as by previous investigators in order to ensure sampling program continuity and data comparability.

5.2.1 Field Collections

Fisheries field activities included beach seining, hoop netting, gill netting, and electrofishing. Sampling locations are shown in Figure 1.1 and sampling frequency in Table 5.1.

5.2.1.1 Beach Seining

Replicate (2) beach-seine samples were taken at each of six sites during the day in each collection period. The seine measured 9.1 x 1.2 m (30 x 4 ft) and was constructed of 3.2 mm (1/8 in.) square mesh nylon. A tow consisted of walking the seine in the shallows parallel to shore for approximately 9.1 m (30 ft). The seine was then bagged and the catch removed for processing.

5.2.1.2 Hoop Netting

Single hoop nets were set overnight at each of four stations during each collection period. The hoop nets consisted of two 3.0 m (10 ft) long fykes of 0.6 m (2 ft) diameter which were connected by a 6.1 m (20 ft) long wing. The nets were set approximately perpendicular to the shore and current with the inshore end anchored firmly at the shoreline. Captured fish were shaken down into the two cod ends, then removed for processing.

5.2.1.3 Gill Netting

Single gill nets were set overnight at each of four stations during each collection period. The gill nets measured 30.5 x 1.8 m (100 x 6 ft) and were constructed of monofilament panels with mesh ranging in size from 12.7 to 63.5 mm (1/2 to 2-1/2 in.) bar mesh. The nets were set approximately perpendicular to the shoreline and current with the smallest mesh anchored nearest to shore. Captured fish were removed from the net and held for processing. Sampling was discontinued after September 1979 as per EFSEC Resolution #157 which was directed at eliminating any impact resulting from the gill netting of sexually mature salmon and steelhead.

5.2.1.4 Electrofishing

Electrofishing samples were taken during day and night of each collection period, except in 1979 when boat engine failure prevented collection of the night early April and the day and night late May samples. Sampling was conducted with a Smith-Root Model SR-16 electrofishing boat. Primary components of this unit were a 5.0 m (16.5 ft) aluminum boat containing a 156 liter (42 gallon) live-well and a Type VI-A Electrofisher powered by a 4 KW generator.

Sampling was conducted using pulsed direct current with one of two boom electrodes serving as anode (attractor) and the other as cathode. One operator netted fish from the bow and the other drove the boat and controlled the generator.

The area electrofished was approximately 12,531 m^2 (15,000 yd^2) and consisted of ten transects measuring approximately 9.1 x 137.1 m (10 x 150 yd) each. The transects extended from approximately 18.2 m (20 yd) offshore of the intake structure to 73.1 m (80 yd) inshore of the intake structure. The intake structure buoy represented the approximate mid-point of transect length. Sampling of each transect was in a downstream direction. The catch was held in the live-well for processing until all transects had been sampled.

5.2.2 Fish Processing

5.2.2.1 Field

Fish captured were identified to species whenever possible and the number of each species counted. Specimens which could not be identified in the field were returned to the laboratory for further examination. Larval fish were not microscopically examined and thus may appear as "unidentified." Any parasites observed on fish were returned to the laboratory for identification.

Each month, a quota of eight individuals per each of three size classes (<100 mm, 100-200 mm, >200 mm) for each species was set for laboratory processing to determine fork lengths (mm) and wet weights (g). The basis for an individual's selection was its length which placed it within one of the three size categories; otherwise, selection was random. Sex and spawning condition of these specimens were also noted and the fish assigned a sequential identification number.

Scale and stomach sample quotas were set for nine selected species: chinook salmon, peamouth chub, largescale sucker, northern squawfish, mountain whitefish, chiselmouth, redside shiner, rainbow trout (steelhead), and white sturgeon (fin ray rather than scale samples). Stomach quotas were eight samples per size class

(<100 mm, 100-200 mm, >200 mm) per species per season (September-November 1978; December 1978-February 1979; March-May 1979; June-August 1979). Scale (or fin) quotas were eight samples per size class (same as above) per species during September 1978-February 1979 and again during September 1979-February 1980. This interval was chosen so as to avoid the period of peak annulus formation. An additional scale quota set for chinook salmon fry was eight samples per size class (same as above) per month.

Fish not used in meeting the above described quotas and which were in satisfactory condition were released to the river. Fish between 50 and 100 mm long were fin-clipped and released to the river. Fin-clips were approved by the Pacific Marine Fisheries Commission in order to avoid any duplication of marks on anadromous salmonids between this and other mark/recapture studies. Fish greater than 100 mm were marked with an external, numbered tag, their fork lengths measured, and released to the river. Condition, sex, and presence of parasites were noted prior to fish release. All specimens present in a catch were examined for marks (recaptures). Any suspected fin-clip recaptures were returned to the laboratory and examined microscopically for verification.

The above data were recorded on standard data sheets together with information on sampling date, location, gear and status, water and air temperature, and personnel. Copies of data sheets were filed at the on-site Richland laboratory. Originals were forwarded to the Portland office for processing and filing.

5.2.2.2 Laboratory

Laboratory work included: processing of scale and stomach samples; completion of any work-up (length, weight, sex, parasites) of fish not identified in the

field; identification of fish parasites; examination of fin-clip recaptures; compilation of a reference collection of various-sized fish of each species; and completion, copying, and filing of data sheets.

Number and volume of each food item in fish stomachs were recorded on standard data sheets together with the number of empty stomachs. Adult insects were identified to order. Larvae, pupae, and nymphs were identified to family, and fish were identified to species unless too badly digested. Volumes were measured by water displacement to the nearest 0.1 ml. Stomach contents were labeled and stored for possible future reference.

Representative, nonregenerated fish scales were examined and the distance (mm) from scale focus to each annulus and/or margin recorded on standard data sheets. If successive, independent age determinations of a scale sample by two biologists differed, that sample was not used in age-growth analysis. In addition, chinook salmon fry scales were examined for information on timing of scale formation and number of circuli as related to body length. Mean length and ranges of fry were further related to date of sampling to provide a general indication of residence time in the Hanford area.

Relative abundance of fishes was calculated as catch-per-unit-effort and expressed as either catch-per-set or catch-per-hour. These data were used to compare abundance among years and seasons. Comparison of stations was accomplished by use of two-way Analysis of Variance and multiple comparisons, as well as with the Friedman Non-parametric Rank Sum Test. Catch data were used to calculate diversity, evenness, and species richness on a seasonal basis according to the methods given in Chapter 2. Mark and recapture data were analyzed to describe movements and to estimate population size using the Petersen estimator (Seber 1973).

Additional data analysis was possible for those species studied in more detail. Food habits were calculated as frequency of occurrence, numerical percentage, and volumetric percentage. Age and length data were used to calculate length frequency and age composition by the age-length-key method (Ricker 1975). Growth history was described by back-calculating body lengths from scale measurements (Carlander 1969). Length-weight relationships were determined using the equation:

$$\log W = \log a + b \log L$$

where W = weight (g)
L = fork length (mm) and a and b are constants.

Sex ratio of fish species and frequency of occurrence of external parasites were determined from a compilation of laboratory data.

5.2.3 Quality Assurance/Quality Control

All field and laboratory procedures under this task were subjected to quality control checks as described in the Quality Assurance Program Document. Each of th procedures was audited at least quarterly by senior personnel. Approximately 10% of field and laboratory samples analyzed for the fisheries studies were re-examined for accuracy. Field and laboratory procedures for which re-examinations were performed included fish length, weight, and general condition measurements, stomach content identification and enumeration, and age determinations derived from scale annuli counts. Further auditing of scale samples to confirm aging accuracy was provided by the U.S. Fish and Wildlife Service in Vancouver, Washington.

In addition to the re-examinations, reference collections of fish species, stomach contents, and parasites encountered during the study were maintained.

5.3 RESULTS AND DISCUSSION

Results of fisheries investigations are discussed below under two section headings, General and Key Species. Within each section, various subsections are presented to facilitate discussion of a particular population characteristic or findings for an individual species.

Much of the following discussion is based on data contained in fish data reports (series DRB02-01) provided to WPPSS. Data from these reports and data not previously reported on are contained in data tables in Appendix F. Tables F1-F3 contain data code lists and catch information. Table F4 contains mark/recapture data and Table F5 a summary of laboratory analyses performed. Table F6 presents back-calculated length data and Table F7 contains food habit data.

5.3.1 General

5.3.1.1 Abundance and Community Composition

A total of 5,503 fish, representing twenty-nine species and 12 families, were collected by beach seining, electrofishing, gill netting, and hoop netting during the period September 1978 through March 1980 (Tables 5.2 and 5.3). No sampling occurred in November and December 1979, or January 1980. The dominant species collected was chinook salmon (Oncorhynchus tshawytscha). Fry of this species accounted for 41.9 percent of the total catch (all gears combined) while older chinook salmon accounted for only 0.5 percent (Table 5.3). The next most common species, in order of decreasing percentage of the total catch, were largescale sucker (13.1 percent), chiselmouth (8.5 percent), mountain whitefish (8.5 percent), redside shiner (7.5 percent), bridgelip sucker (7.3 percent), and northern squawfish (5.0 percent).

All other species comprised less than 5 percent of the total catch. These data do not include an atypically large catch of peamouth, northern squawfish, and redside shiner juveniles made in August 1979 at beach seine station 1 with a large, nonstandard sweep (increased effort) of the seine.

Total catch for each of the 29 species is listed by gear type in Table 5.3. Catch-per-unit-effort values for several dominant species collected in gill nets and beach seines and total species collected in gill nets and beach seines are presented in Figures 5.1 through 5.10.

As expected, each of the four gear types employed during the study was selective for different fish species and size groups. Beach-seine catches generally consisted of small, shore-oriented fishes such as young-of-the-year chinook salmon, mountain whitefish, minnows, and suckers or adult three-spine stickleback and sculpin. A total of 11 different species were captured in beach seines.

The electrofishing catch was represented by 14 species and composed primarily of larger-sized fishes. Mountain whitefish, bridgelip sucker, and largescale sucker were particularly prominent in the catch (Table 5.4).

Twenty species were captured in gill nets. The catch was dominated by chiselmouth, northern squawfish, peamouth chub, largescale sucker, bridgelip sucker, and redside shiner. The net mesh-sizes favored capture of larger individuals, although smaller members of several species were collected in the small-meshed end panels.

Catch-per-unit-effort comparisons among gill-net stations were made on a fish family basis using a Friedman rank sum analysis and multiple comparison (Hollander and Wolfe 1973). Only those catch data for cyprinids (minnows) and catostomids (suckers) were analyzed since these species comprised 71.2 percent and 18.3 percent

respectively, of the total gill-net catch; salmonids accounted for only 7.0 percent and other families only 3.5 percent of the total gill-net catch. No significant difference ($\alpha = 0.05$) among stations was observed for catostomids. A significant difference ($\alpha = 0.05$) among stations was observed for cyprinids. The multiple comparison on ranks indicated the largest catches consistently occurred at station 4 which is located downriver and cross-river from the intake-discharge structures.

A total of 13 species were collected in hoop nets, with the catch composed principally of bluegill, smallmouth bass, yellow perch, black crappie, prickly sculpin, and yellow bullhead. Numbers captured were generally very low considering the overnight sampling duration. Most of these species were generally expected to inhabit the near-shore, slack-water areas in which hoop nets were used.

Catch data were compared to data reported for previous years (Gray and Dauble 1978b, 1979) where gear and station location were comparable. Comparisons are presented in Figures 5.1 through 5.10 for chinook salmon fry, northern squawfish, peamouth chub, redside shiner, chiselmouth, largescale sucker, and for all species combined.

Diversity indices for each of the four sampling gears and four time periods (fall 1978, spring-summer 1979, late summer-fall 1979, winter-early spring 1980) are shown in Table 5.5. Lowest diversity ($\hat{H}'$), evenness ($\hat{J}'$), and species richness (S) values were observed for the beach-seine catches which consisted predominately of northern squawfish and redside shiner in the fall and chinook salmon fry in the spring. Likewise, but to a lesser degree, electrofishing catches were dominated by few species, namely mountain whitefish, largescale sucker, and bridgelip sucker. With this gear, the diversity, evenness, and species richness were similar each season, and higher than noted for beach seines. The gill-net catch contained more

species each season than any other gear. Gill-net diversity and evenness values were similar among seasons and higher than those for either beach-seine or electrofishing gears since gill-net catches were dominated by individual species less frequently. Hoop-net catches had the highest diversity and evenness values, because the 13 species caught with this gear were each represented by low and similar numbers of individuals.

5.3.1.2 Age and Growth

Age and growth information is presented graphically as mean age versus mean observed fork length (mm) for mountain whitefish, chiselmouth, northern squawfish, redside shiner, and peamouth chub (Figure 5.11). Mean back-calculated fork lengths, based on the numerical relationship between body length and scale radius, were derived for these same five species and are presented in Appendix F. Species analyzed for age and growth were chosen on the basis of abundance, adequate distribution of length and age-classes, reliability of aging by scale annulus count, and adequate sample size.

Age distributions for mountain whitefish, chiselmouth, northern squawfish, and redside shiner are presented in Table 5.6. Percentage distributions are presented for fall 1978 and 1979 since these were the seasons scale samples were collected as noted previously. Information for these species was derived on the basis of adequate sample sizes and distribution of age and length-groups. Medium-aged fish (approximately 3 to 5 years) tended to dominate these sample populations. This was attributed primarily to (1) the overall gear catchability favoring the capture of moderate to large-sized fishes versus young-of-the-year or juveniles, and (2) expected higher natural mortality rates in increasingly older year classes. Differences between years in the age composition structure of chiselmouth as well as northern squawfish may be an artifact of sample size, particularly during the 1979 collection period, rather than a shift in a predominant age class.

Length-frequency data are presented in histograms by season for chinook salmon fry, mountain whitefish, bridgelip sucker, largescale sucker, chiselmouth, peamouth chub, northern squawfish, and redside shiner by the gear type in which they were most frequently captured (Figures 5.12 through 5.19).

Seasonal length-weight relationships were derived for representative sample populations of several species in the study area (Table 5.7). Seasonal determinations of length-weight relationships were made since time-of-year variations are probable, particularly for larger fish undergoing gonadal development. Intercept values are shown in Table 5.7 as the antilog value of the intercept calculated with the linear regression analysis. In all cases, ordinate intercepts were near the origin. Values for the regression line slopes ranged between 2.12 and 4.03, approximating isometric growth conditions (slope = 3). Correlations (r values) were also uniformly high, being below 0.9 in only two instances. Representative graphical presentations are expressed for mountain whitefish, largescale sucker, bridgelip sucker, chiselmouth, and northern squawfish (Figures 5.20 through 5.24) using the linear regression equations followed by conversion of the resulting predicted weights for a given length back to their original nontransformed state. This conversion produces the nonlinear curves given in the figures.

5.3.1.3 Population Estimates and Movements

From September 1978 through March 1980, a total of 1,131 fish representing 15 species were marked with an external tag or fin clip (Table 5.8). Ninety-four percent of the marks (tags, clips) were placed on individuals from the following five species: largescale sucker (440 fish), bridgelip sucker (193 fish), chinook salmon fry (161 fish), mountain whitefish (153 fish), and chiselmouth (109 fish). From these marked fish, only largescale sucker and mountain whitefish were

recaptured. Recaptures of largescale sucker occurred during fall months and those of mountain whitefish during spring, summer, and fall months. Recapture data for these two species are presented in Table 5.9 and discussed in the appropriate individual species subsections.

5.3.1.4 Sex Ratios and Spawning Seasons

Sex ratios for six individual species are shown in Table 5.10. There were insufficient data on the remaining species to determine sex ratios. A male to female ratio of approximately 1:1 was observed for mountain whitefish and bridgelip sucker, 2:3 for largescale sucker and peamouth chub, and 3:7 for chiselmouth and northern squawfish.

Spawning times were estimated for those species observed in a gravid or spawned-out gonadal condition by noting the dates of first and last capture of ripe and/or spent individuals. Mean fork lengths and the range for spent and gravid fish were calculated by species and are presented in Table 5.11.

5.3.1.5 Parasites

Most species of fish had few external parasites (Table 5.12). Chinook salmon, mountain whitefish, bridgelip sucker, carp, redside shiner, and peamouth chub each had less than 10 percent infestation. The mean number of parasites/fish for these species ranged from 0.001 to 0.163. Approximately 14 percent of largescale sucker, chiselmouth, and northern squawfish had parasites. Their mean number of parasites/fish varied from 0.206-0.244. Coho salmon and bluegill had the greatest occurrence of parasite infestation, over 30 percent for each species. The mean number of parasites/fish for coho salmon and bluegill was 0.308 and 0.375, respectively. Parasites observed were the copepods, Salmincola and Lernaea; leeches of the family, Piscicolidae; the fungi, Saprolegnia; and protozoans.

5.3.1.6 Food Habits

Food habit data for individual species are discussed under the appropriate subsection. Results of frequency of occurrence and numerical and volumetric analyses are presented by species, size class, and season in Appendix F. Data were analyzed by season where fall = September-November 1978; spring = March-May 1979; and summer = June-August 1979. No designated specimens were collected in winter.

5.3.2 Key Species

5.3.2.1 Chinook Salmon (*Oncorhynchus tshawytscha*)

Chinook salmon were captured in September and October 1978 and from April through July 1979 (Table 5.3). They accounted for 42% of the total catch of all species collected during the study. The entire beach-seine catch of chinook salmon consisted of fry. Figure 5.9 illustrates the similarity between beach-seine catch data from this study and data reported by Gray and Dauble (1978b, 1979). Highest gill-net catch-per-unit-effort values (0.03 fish/hr) occurred in June and July 1979. Monthly catch data for the nine chinook salmon collected by electrofishing are contained in Table 5.4.

Six returning adult chinook salmon were collected. A ripe male measuring 450 mm was taken by electrofishing in late September 1978 and represented the only capture made of the locally spawning fall chinook population near WNP-1, 2, and 4. The remaining five adults, consisting of one female and four males still undergoing gonadal maturation, were spring chinook captured by gill net between late April and mid-June 1979. Spring and summer chinook salmon are only transitory in the Hanford Reach of the Columbia River (Gray and Dauble 1976).

The timing of the chinook salmon fry movement through the Hanford Reach of the Columbia River was from late April until early July with the peak movement occurring in late May. Of the 1,872 chinook salmon fry collected during 1979, over fifty percent were captured on May 25.

During May and June, a total of 161 chinook salmon fry were fin-clipped. Many fish were less than 50 mm fork length and were therefore not marked. Sample catch and marking totals were as follows:

Date	Total Catch	Number Marked
4/26/79	4	-
5/10/79	216	11
5/25/79	998	77
6/04/79	502	19
6/19/79	151	54
7/03/79	1	-
	1,872	161

None of the marked fry were recaptured. The lack of recaptures can primarily be attributed to the movement of marked fish out of the area during the 10 to 15 days between sampling periods. Also, the low number of marked fish released in relation to the potential population size of fry would contribute to the absence of recaptured fry. Field observations at time of fish release indicated no mortalities associated with fin-clipping fry.

Attempts to determine residence time of chinook salmon fry in the study area by fish scale examination were largely unsuccessful. This was due primarily to the relatively large proportion of young which had not formed scales at time of capture. In addition, while there was a generally linear relationship between fish length and number of circuli for individuals bearing scales, there was no indication in either circuli number or pattern that appeared to reflect residence time in the study area.

Based on mark/recapture data there was no indication of chinook fry remaining in the area longer than 10-15 days. The general similarity in fish sizes together with recruitment of smaller-sized individuals to beach-seine catches as depicted in length-frequency histograms for chinook salmon (Figure 5.12) also suggests that residence time in the study area is not extended. Increased mark/recapture efforts during the 6 to 8-week period when young appear to migrate through the study area could be used to refine this initial estimate of residence time.

A statistical comparison of chinook salmon fry abundance (as measured by the index of catch-per-set) among the six beach-seine stations was conducted for the May and June surveys. Beach-seine catches were logarithmically transformed (i.e., log (x + 1)) to stabilize variances and reduce the positive correlation between means and standard deviations. A two-way factorial Analysis of Variance was performed on the transformed data. No significant station by date interaction nor difference among sampling dates was observed (α = 0.05). A significant difference (α = 0.05) among stations was observed. A multiple comparison test (i.e., Newman-Keuls method) indicated beach-seine catches at stations 1 and 2 were significantly higher than at station 5. The overall result was as follows in descending order (geometric mean values in parenthesis):

BS01	BS02	BS06	BS03	BS04	BS05
(27)	(24)	(6)	(4)	(3)	(2)

Beach-seine stations 1 and 2 are located downstream and across-stream, respectively, from the WNP-1, 2, and 4 discharge structures. The remaining stations are located upstream of the structures.

Scale measurements were taken and age determinations made for 18 chinook salmon. Of these, six were yearling smolts captured in September, one was a 2-age smolt collected in June, ten were young-of-the-year fry taken in June, and one was a 2+ adult male taken in September. With the exception of the single 2+ male, the adult spawners captured during the study could not be aged due to resorption of scales.

Seasonal availability of and/or preference for food items was reflected in the 22 stomachs of chinook salmon <100 mm long collected during spring and summer seasons. Of the thirteen stomachs collected during spring, 15% were empty. Diptera (flies) and Hemiptera (true bugs) adults and Chironomidae (midges) pupae accounted for over 80% of the numerical composition while unidentified animal parts and Diptera adults comprised the majority of the volume during spring. Stomach contents of chinook salmon <100 mm captured during summer were dominated by Chironomidae larvae, also one of the dominant benthic taxa, both numerically and volumetrically. None of the nine stomachs collected during summer were empty.

Little seasonal variation in food habits was evident from analyzing the stomach contents of eight chinook salmon 100-200 mm in length. Adult and larval Trichoptera (caddisflies), which dominated the benthic community, occurred most frequently in the diet during all three sampling seasons. Gray and Dauble (1979) reported chinook fry were a food item of chinook smolts (FL 120-337 mm), although this was not observed in the present study.

Seventy-eight percent of the chinook salmon with lengths greater than 200 mm had empty stomachs. The most frequently occurring items in stomachs containing food were Hemiptera adults (40%), Trichoptera adults (40%), and unidentified animal parts (40%). A wide variety of other aquatic and terrestrial invertebrates was also ingested.

Stomach content data for chinook salmon are presented in Appendix Table F7.

5.3.2.2 Largescale Sucker (*Catostomus macrocheilus*)

A total of 590 largescale sucker, about 13% of the total catch of all species, were collected between September 1978 and March 1980. Of these, 469 were taken by electrofishing and 121 by gill net (Table 5.3). Largescale sucker were

collected each month sampling occurred. No adults were taken by beach seine, although many of the unidentified fry listed in Table 5.3 are believed to be from the family Catostomidae. Little numerical difference between day and night electrofishing catches of largescale sucker was observed (Table 5.4), indicating this species consistently inhabits the area in the vicinity of WNP-1, 2, and 4 intake-discharge structures.

Results of tagging studies show four largescale sucker were recaptured. Three recaptures occurred within 32 days following release while the fourth occurred exactly one year following release (Table 5.9). All recaptures were made while sampling with electrofishing gear in the same area where the original capture and release occurred. Although these data show several recaptures at the same site during the two fall seasons, no firm conclusions can be drawn as to the mobility of largescale sucker in the Hanford Reach.

Reproductively mature (gravid and spent) largescale sucker were collected from mid-May to early October. Most gravid individuals were captured in June and July, although one ripe male was taken in early October. Previous reports indicate spawning in the study area was concentrated from May through July (Gray and Dauble 1976; 1978a, b; 1979). Similar timing of spawning has been reported for populations in British Columbia (Scott and Crossman 1973) and northeastern Washington (BEAK 1980), and was shown in most cases to be associated with water temperatures of 7.8-8.9^{o}C.

Fourteen largescale sucker were aged by scale analysis. Specimens ranged in length from 302 mm to 539 mm and in age from III to IX. Age-growth determinations for these fish using back-calculation techniques were felt to be unreliable based on (1) the small sample size and inadequate distribution of length and age groups,

and (2) the questionable accuracy of sucker age determination by scale annuli count (Scott and Crossman 1973, Beamish 1973). Mean observed fork lengths at various ages were generally greater than those previously reported for the study area (Gray and Dauble 1979) and compare to rapid-growing populations reported by Beamish (1973).

The mathematical relationship between length and weight for largescale sucker was formulated using regression analysis and is presented in Figure 5.21.

Stomach data for largescale sucker are presented in Appendix Table F7. The sample consisted of 24 individuals, all >200 mm long. Diversity of food items was greatest during spring with Hydropsychidae (caddisflies) and Chironomidae larvae, the dominant families in benthic studies, prevalent in numerical abundance, and unidentified plant material clearly dominant in volume. Like bridgelip sucker (discussed below), the largescale sucker is largely dependent on bottom-dwelling organisms and plant material for food and its diet appears to vary seasonally. Gray and Dauble (1977) report the utilization of adult caddisflies for food in late summer, indicating the possibility of some surface feeding by largescale sucker.

5.3.2.3 Chiselmouth (*Acrocheilus alutaceus*)

Chiselmouth were collected primarily with gill nets (354 of 381 specimens) and were most abundant June through September. Figure 5.4 shows the peak catch occurred in August 1979, similar to previous study area data reported by Gray and Dauble (1978b). Chiselmouth were also collected by electrofishing (25 individuals) and hoop nets (2 individuals) (Table 5.3).

Spent adult chiselmouth were collected from early June to mid-October 1979. A single gravid female was captured in mid-May. Similar observations on chisel-

mouth spawning condition have been reported for the study area (Gray and Dauble 1976 1978a, b; 1979). Mean fork length of mature adults (gravid and spent combined) was 265.5 mm and the range was 210 to 320 mm (Table 5.11).

Although no chiselmouth were observed spawning, the above data together with peak gill-net and hoop-net catches during July and August may reflect a shore-oriented, spawning activity during this time. Scott and Crossman (1973) report chiselmouth spawn in late June and July in British Columbia.

Age-growth relationships were determined for 18 chiselmouth to age VII. Growth was greatest during year I with a mean length increment of 93 mm (Appendix Table F6). A uniform series of smaller increments was indicated in subsequent years. Mean fork length versus age (Figure 5.11) appears consistent with previous data for the study area (Gray and Dauble 1976; 1978a, b).

The mathematical relationship between length and weight was derived from a representative sample population of 22 chiselmouth captured during summer 1979 and is shown in Figure 5.23.

Stomachs from seven chiselmouth 100-200 mm long were analyzed; 57% contained the aquatic insects Chironomidae and Trichoptera commonly found in the benthic community in addition to unidentifiable animal parts. By volume, insects and animal parts accounted for 81% and plant material (algae) 19% of the total. In larger chiselmouth (>200 mm), plant material occurred in 71% of the stomachs. Additional food items included Chironomidae larvae and detritus. Only 13% of all chiselmouth stomachs were empty. These findings are generally similar to reports by Scott and Crossman (1973) that chiselmouth feed mostly on plant and animal material attached to bottom substrates. Appendix Table F7 contains tabular data for chiselmouth stomach contents.

5.3.2.4 Mountain Whitefish (*Prosopium williamsoni*)

A total of 383 mountain whitefish were collected during the study; 96% of these were taken by electrofishing (Table 5.3). Mountain whitefish were collected during all sampling months except November 1978 through February 1979 when sampling gear was limited to gill nets and beach seines. Peak electrofishing catches occurred in late April and June 1979 with night catches dominating day catches each sampling period. Catch-per-unit-effort values for mountain whitefish fry in beach-seine samples were 0.50 fish-per-set in June 1979 and 0.08 fish-per-set in July 1979. Gill net catches occurred from March through June 1979 and in September 1979. Catch-per-unit-effort for gill nets ranged from 0.01 to 0.03 fish-per-hour.

Ten mountain whitefish were recaptured from spring 1979 through spring 1980 (Table 5.9). Of interest is the fact that nine of these recaptures were from a group of 78 fish tagged during spring 1979. These nine fish accounted for over 10 percent of spring season releases and were recaptured in the same location they were released. One specimen was recaptured a second time in January 1980 in the Yakima River. Tag-recapture data for mountain whitefish indicate little movement by these fish during spring through fall following spawning.

If one assumes minimal movement of mountain whitefish spring (1979) through fall (1979) and restricts analyses to fish >200 mm to reduce effects of recruitment, then a preliminary Petersen estimate of population size (Seber 1973) near the discharge structures is approximately 2,225 fish (78 marks, 168 caught, and 5 recaptures) with a 95% confidence interval of 844-6,722. Since the electrofishing surveys sample about 45,000 square feet (approximately 1 acre), the average density of mountain whitefish spring through fall is approximately 2,225 fish/acre.

Fourteen gravid mountain whitefish were collected between early September and mid-October during the study period. A single spent male was collected in late September 1979. Reduced or discontinued gill-netting and electrofishing sampling efforts in November, December, and January of 1978 and 1979, and January of 1980, prevented verification of previously reported spawning peaks in December and January (Gray and Dauble 1976; 1978a, b). Scott and Crossman (1973) report the spawning time of mountain whitefish is highly variable through fall and winter months and may be activated by several differing environmental conditions (i.e., water temperature, discharge).

Age-growth relationships for 19 mountain whitefish to age VI were determined using back-calculation techniques (Appendix Table F6). Growth was rapid during the first year of life with a mean length of 96 mm attained. Annual growth increments from ages II to V averaged about 50 mm, then declined to 23 mm at age VI. Growth data were similar to those reported by previous investigators in the study area (Gray and Dauble 1979) and for other mountain whitefish populations (Scott and Crossman 1973).

The mathematical relationship between length and weight was determined for 32 mountain whitefish captured during summer 1979 and is presented in Figure 5.20.

Microscopic examination of seven mountain whitefish (<100 mm) stomachs showed Chironomidae larvae and pupae comprised nearly 100% of food items numerically and over 80% volumetrically. Chironomidae is one of several dominant families of benthic fauna occurring near the WNP-1, 2, and 4 structures. The remainder of the diet consisted largely of unidentified animals and nematodes. No empty stomachs were found.

Larger whitefish ranging from 100-200 mm fork length also ingested primarily Chironomidae larvae during all three sampling seasons. The remaining stomach contents of the five specimens analyzed were quite diverse and included four families of Trichoptera larvae, Trichoptera adults, Pyralidae (aquatic caterpillars) larvae, Ephemeroptera (mayfly) nymphs, and Diptera pupae.

Whitefish >200 mm long also exhibited a diverse diet. Chironomidae larvae dominated numerically while Hydropsychidae larvae, unidentified animals, and detritus accounted for the largest volumetric values in the 24 stomach samples analyzed. Mountain whitefish occasionally feed on small fish (Scott and Crossman 1973), although none were encountered in this study. Tabular data listing food items by sampling season and length class are presented in Appendix Table F7.

5.3.2.5 Redside Shiner (*Richardsonius balteatus*)

Some 267 redside shiner were collected by beach seining during August 1979 and September 1978 and 1979. They were absent from beach-seine hauls during all other months. Gill-net catches contained 65 redside shiner with highest catch-per-hour values occurring in September 1978 (0.26) and June 1979 (0.17). Shiner were absent from gill-net catches between December 1978 and March 1979. Few individuals of this species were collected by electrofishing (2 individuals) or hoop nets (1 individual). Overall, catch-per-hour values for gill-net and beach-seine sampling (Figures 5.2 and 5.7) were lower than those reported previously (Gray and Dauble 1978b, 1979); however, the general seasonal pattern of highest catches occurring between May and September was consistent with previous data.

Only three mature redside shiner were observed during laboratory examination; these were a gravid female captured in early June and two spent females collected

in late August. Spawning periods ranging from May through August have been reported both locally (Gray and Dauble 1976; 1978a, b) and throughout the redside shiner's range (Scott and Crossman 1973).

Age and growth data, including back-calculated mean lengths, were obtained from 19 redside shiner and were consistent with previously reported growth rates (Gray and Dauble 1976; 1978a, b; 1979). Growth appeared most rapid during the first year of life when a mean length of 62 mm was attained (Appendix Table F6). Subsequent years showed reduced growth rates. The oldest specimen was age VI and had a length of 183 mm. This probably represents near maximum age and length attained by this species on the basis of past studies (Scott and Crossman 1973, Gray and Dauble 1979).

Stomach analysis of 16 redside shiner <100 mm long showed 13% were empty. Unidentified animal parts (63%), detritus (31%), and Hydropsychidae larvae (13%) were the most frequently occurring food items. Stomachs from 25 redside shiner 100-200 mm in length were analyzed and 36% were found to be empty. Food items consisted mostly of unidentified animal parts and adult insects, including Trichoptera. Unidentified animal parts accounted for 55% of the volume of all food items. Detailed data for redside shiner food habits are found in Appendix Table F7.

Redside shiner appeared to be opportunistic feeders, taking advantage of available organisms like Hygrobatidae (aquatic mites) and amphipods (scuds, sideswimmers) in addition to aquatic insects. Redside shiner are also known to consume terrestrial insects which may be present on the water's surface (Scott and Crossman 1973).

5.3.2.6 Bridgelip Sucker (*Catostomus columbianus*)

A total of 329 bridgelip sucker were collected during the study, all by electrofishing or gill nets (Table 5.3). Electrofishing catches were made in all eleven scheduled sampling months with the highest catches occurring from June through October 1979; 58% of bridgelip sucker collected by electrofishing were taken during daytime shocking (Table 5.4). Although this species was not collected from November 1978 through February 1979 and November 1979 through February 1980, Gray and Dauble (1978b) report its year-round presence in the vicinity of the WNP-1, 2, and 4 intake-discharge structures.

Mature bridgelip sucker were captured from late April through mid-October. Most ripe fish were captured in August and early October, but single gravid individuals were also collected in April, May, and June. The sporadic occurrence of ripe individuals in the catch has been similarly indicated by previous findings in the study area (Gray and Dauble 1976; 1978a, b); however, Dauble (1980) reported spawning occurred primarily between mid-April and mid-June.

The relationship between length and weight for a representative sample of 16 bridgelip sucker is presented in Figure 5.22.

Bridgelip sucker stomachs collected during summer 1979 contained only detritus, contents indicative of their bottom orientation. Gray and Dauble (1977) reported bridgelip sucker in the study area ingest mainly periphyton in addition to some aquatic insect larvae. Food habits noted for the present study are contained in Appendix Table F7.

5.3.2.7 Northern Squawfish (*Ptychocheilus oregonensis*)

A total of 226 northern squawfish, comprising 5% of the total catch of all species, were collected (Table 5.3). Specimens were captured each month sampling occurred. Gill nets were the most efficient collection method capturing 133 fish followed by beach seining (85 fish), electrofishing (5 individuals), and hoop nets (3 individuals). Peak gill-net catches occurred during summer which was consistent with previous data (Gray and Dauble 1976; 1978a, b; 1979) (Figure 5.1). Beach-seine catches of northern squawfish fry increased during summer months indicating some reproduction is probably occurring in the study area (Figure 5.8). The presence of adult northern squawfish decreased markedly in October of 1979 as in previous years, possibly reflecting offshore movements corresponding to reduced water temperatures and reduced near-shore food supplies. Scott and Crossman (1973) report northern squawfish commonly move to deeper waters in fall and winter.

Gravid adults were captured during June, July, and August with spawned-out individuals first taken in mid-July. Spawning appeared to occur primarily from mid-July to mid-August, although sample sizes were small and limited precise delineation of peak spawning time. This agrees generally with findings from previous years (Gray and Dauble 1979). Fork lengths of gravid and spent northern squawfish averaged 342.4 mm (Table 5.11). Scott and Crossman (1973) report most northern squawfish attain sexual maturity at lengths of approximately 305 mm.

Back-calculated fork lengths at annulus formation were derived for 23 northern squawfish to age VII (Appendix Table F6). Growth increments were uniform through age V and only slightly reduced in subsequent years. Growth rates of these fish are consistent with data previously reported for the study area (Gray and Dauble 1979) and for other northern squawfish populations (Scott and Crossman 1973).

A regression formula was derived for length versus weight for a representative sample population of 24 northern squawfish captured during the spring 1979 sampling period. The regression is displayed in Figure 5.24 and has a high correlation value (r = 0.925).

Stomachs of eight northern squawfish <100 mm long contained large numbers of Cladocera (zooplankton) in addition to insect and unidentified animal parts. Food volume was composed primarily of insects, inorganic matter, unidentified animal parts, and detritus. Half of the ten northern squawfish stomachs in the 100-200 mm length class were empty while those containing food items had ingested mostly insect and unidentified animal parts each season. Larger squawfish (>200 mm) consumed aquatic insects (Trichoptera larvae and adults and Chironomidae larvae), small fish, and crayfish. Of the 26 stomachs in this length class, 39% were empty. The contents of northern squawfish stomachs were similar to food habits reported by Gray and Dauble (1976, 1977, 1979) and are presented in Appendix Table F7.

5.3.2.8 Peamouth Chub (*Mylocheilus caurinus*)

Peamouth chub were collected primarily by gill net with highest catch-per-unit effort values (0.16 fish-per-hour) occurring in June 1979. Gill-net catch/effort data for this species from 1977 through September 1979 is shown in Figure 5.5. Only one peamouth chub was collected in standard beach-seine tows during August 1979 (Table 5.3). Eight peamouth chub were captured by electrofishing with equal numbers taken during day and night sampling (Table 5.4).

Five mature (gravid and spent) females were collected from early June through August and a single mature male was captured in September 1979. The few mature individuals captured did not allow for a precise delineation of peak spawning times;

however, the months during which mature or spent peamouth chubs were collected were consistent with previous data for the study area (Gray and Dauble 1979). Mean observed fork lengths of these mature specimens was 297.7 mm (Table 5.11).

Back-calculated length determinations were made for 13 peamouth chub to age VI (Appendix Table F6). Growth was most rapid during the first four years of life with the first year's increment greatest. Data for mean length versus age (Figure 5.11) is consistent with that reported earlier for the study area (Gray and Dauble 1976; 1978a, b).

Peamouth chub, although mainly insectivorous, also consume molluscs, crustaceans, and occasionally small fish (Scott and Crossman 1973). Stomach samples of specimens collected in this study reflect these habits although the diet appeared to vary with fish size. Peamouth chub <100 mm long consumed small insects, detritus, and Chironomidae larvae most frequently. These were also major foods by volume.

Larger peamouth chub (100-200 mm) also consumed insects and detritus together with molluscs and Trichoptera larvae which were present in 20% of the stomachs sampled. In peamouth chub longer than 200 mm, molluscs and Trichoptera adults and larvae occurred more frequently in the diet than in the previous length class. Molluscs and unidentified animal parts accounted for most of the volume for fish >200 mm long. Detailed food habit data are presented in Appendix Table F7.

5.3.2.9 Rainbow Trout (*Salmo gairdneri*)

A total of 16 rainbow trout were collected during the study. Nine individuals were taken in gill nets, six by electrofishing, and one in beach seines. Highest catches occurred in the August gill-net sets. This species was absent from December 1978 through February 1979 catches, October 1978 and May 1979 catches, and November 1979 through March 1980 catches.

Five of the 16 rainbow trout captured were aged by scale annuli counts. These included two age II juveniles, one age III (294 mm fork length) and one age IV (342 mm fork length) trout, and one age V female steelhead 570 mm long.

Four of the 16 trout captured were returning adult steelhead. Three of these were captured by gill net between mid-March and mid-April and consisted of a ripe female measuring 706 mm, a ripening female measuring 686 mm, and a spent male measuring 780 mm. The remaining steelhead was a ripening female measuring 570 mm and was captured by electrofishing in late September 1979.

The contents of 11 adult rainbow trout (>200 mm) stomachs showed a wide diversity of organisms, except during spring when Hydropsychidae larvae and inorganic matter comprised the bulk of the diet. Stomach contents during fall were dominated by Chironomidae pupae, Diptera adults and unidentified animal parts while summer samples contained large numbers of Trichoptera adults, unidentified animal parts, and assorted aquatic and terrestrial invertebrates. Taxa found in spring and summer samples are similar to those reported by Gray and Dauble (1976, 1977, 1978a, b). Appendix Table F7 contains detailed information on rainbow trout food habits.

5.3.2.10 White Sturgeon (Acipenser transmontanus)

One white sturgeon, 1,178 mm long, was captured by electrofishing in April, 1979. Stomach analysis showed Chironomidae larvae, Hydropsychidae larvae, and unidentified fish were the most numerous food items while detritus, sculpins, unidentified fish, and decapods (crayfish) comprised the majority of stomach volume. Scott and Crossman (1973) report the white sturgeon is extremely predaceous and piscivorous in addition to having a diverse invertebrate diet. Food habit data for this species are presented in Appendix Table F7. Examination of a pectoral fin cross-section showed this specimen's age was 16 years.

5.4 SUMMARY AND CONCLUSIONS

A grand total of 38 species representing 12 families were collected in the study area during the period September 1974 through March 1980. A total of 5,503 fish representing 29 species and 12 families were collected by all gear types during the present study period, September 1978 through March 1980. The most common species, in order of decreasing percentage of the total catch, were chinook salmon (predominantly fry), largescale sucker, chiselmouth, mountain whitefish, redside shiner, bridgelip sucker, and northern squawfish. These seven species collectively comprised over 95% of the total catch. Walleye (Stizostedion vitreum) were collected for the first time. As expected, gear types were selective for fish species and size groups which inhabited the specific areas sampled. Catch data were compared to previous years where gear used and locations sampled were similar. Variation was evident between seasons but not between years.

Between-station comparisons of gill-net catch-per-unit-effort revealed a significantly greater catch ($\alpha = 0.05$) of Cyprinidae (minnows) at station 4. No significant station differences were observed for Catostomidae (suckers). Between-station comparisons of chinook fry beach-seine catches revealed significantly higher catches ($\alpha = 0.05$) at stations 1 and 2 than at station 5.

The timing of chinook fry movement through the study area was from late April until early July with peak movement in late May. Residence time for fry was estimated to be approximately 10-15 days based on mark/recapture studies. Age-growth, reproductive maturity, length-weight, and length-frequency characteristics of sample species populations were described and found to be generally consistent with previous data.

Food items identified from stomach analysis included larval and pupal aquatic insects (mainly caddisflies and midges), molluscs, zooplankton, small fishes, algae, and detritus. The kinds and abundance of benthic macroinvertebrates in diets were

generally reflective of the community composition identified in macroinvertebrate sampling (Section 4.3.1).

Table 5.1. Fish sampling frequency by gear from September 1978 through March 1980 in the Columbia River near the WNP-1, 2, and 4 intake and discharge sites. (D = day, N = night, O = overnight, NS = not scheduled.)

MONTH	Beach Seining	Hoop-Netting	Gill-Netting	ElectroFishing
September 1978	D	O	O	D, N, D, N
October	D	O	O	D, N, D, N
November	NS	NS	O	NS
December	NS	NS	O	NS
January 1979	NS	NS	O	NS
February	D	NS	O	NS
March	D	NS	O	D, N, D, N
April	D, D	NS	O, O	D, *, D, N
May	D, D	O, O	O, O	D, N, *, *,
June	D, D	O, O	O, O	D, N, D, N
July	D	O	O	D, N, D, N
August	D	O	O	D, N, D, N
September	D	O	O	D, N, D, N
October	D	O	NS	D, N, D, N
November	NS	NS	NS	NS
December	NS	NS	NS	NS
January 1980	NS	NS	NS	NS
February	D	NS	NS	NS
March	D	NS	NS	D, N, D, N

* Boat engine failure prevented sampling.

Table 5.2. List of fish species by family collected in the vicinity of WNP 1, 2, and 4 from September 1978 through March 1980.

Family	Scientific Name	Common Name
Petromyzonidae-lampreys	Entosphenus tridentatus	Pacific lamprey
Acipenseridae-sturgeons	Acipenser transmontanus	White sturgeon
Clupeidae-herrings	Alosa sapidissima	American shad
Salmonidae-trouts	Oncorhynchus kisutch	Coho salmon
	Oncorhynchus nerka	Sockeye salmon
	Oncorhynchus tshawytscha	Chinook salmon
	Prosopium williamsoni	Mountain whitefish
	Salmo gairdneri	Rainbow trout/steelhead
Cyprinidae-minnows and carps	Acrocheilus alutaceous	Chiselmouth
	Cyprinus carpio	Carp
	Mylocheilus caurinus	Peamouth
	Ptychocheilus oregonensis	Northern squawfish
	Richardsonius balteatus	Redside shiner
Catostomidae-suckers	Catostomus columbianus	Bridgelip sucker
	Catostomus macrocheilus	Largescale sucker
Ictaluridae-freshwater catfishes	Ictalurus melas	Black bullhead
	Ictalurus natalis	Yellow bullhead
	Ictalurus punctatus	Channel catfish
Percopsidae-trout-perches	Percopsis transmontana	Sand-roller
Gasterosteidae-stickleback	Gasterosteus aculeatus	Threespine stickleback
Centrarchidae-sunfishes	Lepomis gibbosus	Pumkinseed
	Lepomis macrochirus	Bluegill
	Micropterus dolomieui	Smallmouth bass
	Micropterus salmoides	Largemouth bass
	Pomoxis nigromaculatus	Black crappie
Percidae-perches	Perca flavescens	Yellow perch
	Stizostedion vitreum vitreum	Walleye
Cottidae-sculpins	Cottus bairdi	Mottled sculpin
	Cottus asper	Prickly sculpin
	Cottus sp.	Unidentified sculpin

Table 5.3. Numerical abundance of fish species collected in the Columbia River near WNP-1, 2, and 4 from September 1978 through March 1980.

	Total Number	(% relative abundance)	Beach Seine	Electro-Fishing	Gill Net	Hoop Net
Pacific lamprey	1	(<0.1)	0	1	0	0
White sturgeon	1	(<0.1)	0	1	0	0
American shad	21	(0.5)	0	17	4	0
Coho salmon	19	(0.4)	1	0	18	0
Sockeye salmon	7	(0.2)	0	0	7	0
Chinook salmon	1908	(42.4)	1884	11	13	0
Mountain whitefish	383	(8.5)	7	367	9	0
Rainbow trout	16	(0.4)	1	6	9	0
Chiselmouth	381	(8.5)	0	25	354	2
Carp	40	(0.9)	0	3	37	0
Peamouth	97	(2.2)	1 (233)[a]	8	88	0
Northern squawfish	226	(5.0)	85 (1374)[a]	5	133	3
Redside shiner	335	(7.5)	267 (175)[a]	2	65	1
Bridgelip sucker	329	(7.3)	0	270	59	0
Largescale sucker	590	(13.1)	0	469	121 (1)[a]	0
Black bullhead	2	(<0.1)	0	0	0	2
Yellow bullhead	7	(0.2)	0	0	0	7
Channel catfish	2	(<0.1)	0	0	2	0
Sand roller	3	(<0.1)	0	0	2	1
Threespine stickleback	9	(0.2)	9	0	0	0
Pumkinseed	5	(0.1)	0	0	0	5
Bluegill	24	(0.5)	1	0	0	23
Smallmouth bass	23	(0.5)	0	0	8	15
Largemouth bass	2	(<0.1)	0	0	1	1
Black crappie	14	(0.3)	0	0	5	9
Yellow perch	21	(0.5)	4	2	4	11
Walleye	2	(<0.1)	0	0	2	0
Prickly sculpin	14	(0.3)	2	0	2	10
Mottled sculpin	1	(<0.1)	1	0	0	0
Unidentified sculpin	12	(0.3)	6	6	0	0
Unidentified[b]	1008	0	1008	0	0	0
TOTALS	5503	(100)	3277	1193	943	90

a Numbers in parenthesis are additional fish collected in nonstandard catch.

b Consisted largely of unidentified species of Cyprinid (minnows) and Catostomid (suckers) fry. *This group of fish was not considered in percent relative abundance calculations.*

Table 5.4. Monthly numbers of fish collected by electrofishing along transects in the vicinity of WNP-1, 2, and 4 from September 1978 through March 1980.

	September 1978		October 1978		March 1979		April 1979		May 1979		June 1979		July 1979		August 1979		September 1979		October 1979		March 1980		Totals	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Pacific lamprey																			0	1			0	1
White sturgeon							0	1															0	1
American shad																	3	0	14	0			17	0
Chinook salmon	0	6	0	1							2	0										2	2	9
Rainbow trout					0	1	1	1					1	0			0	1	1	0			3	3
Mountain whitefish	1	10	3	30	13	17	21	39	6	14	28	29	15	17	4	21	3	15	8	30	20	23	122	245
Largescale sucker	8	36	27	28	23	16	25	8	8	3	20	21	32	18	22	29	24	44	23	33	8	13	220	249
Bridgelip sucker	2	17	11	10	1	0	4	2	2	0	6	13	25	10	33	20	28	20	42	19	4	1	158	112
Carp	0	1	2	0																			2	1
Chiselmouth	0	4	0	2							4	0			1	1	0	9	1	3			6	19
Northern squawfish							0	1			0	1	1	0			0	1				1	1	4
Redside shiner	0	2																					0	2
Peamouth chub			1	0					1	0			2	0			0	3	0	1			4	4
Yellow perch			2	0																			2	0
Sculpin	4	1	1	0																			5	1
Totals	15	77	47	71	37	34	51	52	17	17	60	64	76	45	60	71	58	93	89	87	32	40	542	651
	92		118		71		103		34		124		121		131		151		176		72		1193	

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Table 5.5. Richness, diversity, and evenness indices for fish collected near WNP-1, 2, and 4 during three seasons and for four types of gear.

Gear	Season	Richness (S)	Diversity (Ĥ')	Evenness (Ĵ')
Beach seine	Sep-Oct, 1978	3	0.22	0.14
	Apr-Jul, 1979	7	0.13	0.05
	Aug-Oct, 1979	5	1.03	0.44
	Jan-Mar, 1980	4	1.34	0.67
Electrofishing	Sep-Oct, 1978	10	2.15	0.65
	Mar-Jul, 1979	9	1.72	0.54
	Aug-Oct, 1979	9	1.97	0.62
	Jan-Mar, 1980	5	1.46	0.63
Gill Net	Sep-Nov, 1978	15	2.77	0.71
	Mar-Jul, 1979	18	3.00	0.72
	Aug-Sep, 1979	13	2.17	0.59
Hoop Net	Sep-Oct, 1978 May-Oct, 1979 (combined)	13	3.13	0.85

Table 5.6. Age composition of mountain whitefish, chiselmouth, redside shiner, and northern squawfish populations captured during fall, 1978 and 1979 near the WNP-1, 2, and 4 intake-discharge structures.

Species/Gear	Age	Proportion Fall 1978	Fall 1979
Mountain whitefish		(N=39)	(N=34)
Electrofishing	1	0.0000	0.0000
	2	0.0400	0.0200
	3	0.2400	0.1600
	4	0.3600	0.4200
	5	0.2400	0.2800
	6	0.1100	0.1300
	7	0.0000	0.0000
Chiselmouth		(N=28)	(N=14)
Gill netting	1	0.0000	0.0000
	2	0.0000	0.0000
	3	0.1875	0.5925
	4	0.1300	0.2150
	5	0.6125	0.1225
	6	0.0467	0.0467
	7	0.0233	0.0233
Redside shiner		(N=19)	(N=0)
Gill netting	1	0.0513	-
	2	0.4620	-
	3	0.2567	-
	4	0.1725	-
	5	0.0000	-
	6	0.0575	-
Northern squawfish		(N=13)	(N=7)
Gill netting	1	0.0000	0.0000
	2	0.2150	0.0000
	3	0.2150	0.0000
	4	0.1633	0.0943
	5	0.1192	0.0825
	6	0.2525	0.4646
	7	0.0350	0.3586

Table 5.7. Parameters of length-weight relationships based on regression analysis for several common fish species collected near WNP-1, 2, and 4 by season.

Year	Season[1]	Species	Upstream/ Downstream[2]	Sample Size	Intercept (x10-5)	Slope	r
1978	Fall	Chiselmouth	Downstream	18	1.83	2.95	.975
		Northern squawfish	Downstream	13	2.48	2.86	.998
		Redside shiner	Downstream	7	3.72	2.81	.990
		Redside shiner	Upstream	13	5.03	2.75	.971
		Chinook salmon	Upstream	8	1.07	3.03	.998
		Mountain whitefish	Upstream	10	1.12	2.99	.999
		Largescale sucker	Upstream	9	1.38	2.95	.985
1978	Winter	Coho salmon	Downstream	11	0.23	2.78	.990
1979	Spring	Coho salmon	Downstream	11	0.23	3.23	.990
		Mountain whitefish	Upstream	28	0.24	2.85	.966
		Largescale sucker	Downstream	7	36.74	2.42	.945
		Largescale sucker	Upstream	18	90.45	2.27	.805
		Bridgelip sucker	Downstream	14	0.57	3.14	.981
		Chiselmouth	Downstream	16	55.35	2.36	.797
		Chiselmouth	Upstream	10	2.06	2.92	.995
		Northern squawfish	Downstream	24	1.70	2.94	.962
		Peamouth chub	Upstream	14	1.71	2.93	.991
1979	Summer	Chinook salmon	Downstream	5	3.86	2.82	.999
		Chinook salmon	Upstream	10	4.87	2.80	.958
		Sockeye salmon	Downstream	6	2.16	2.89	.999
		Largescale sucker	Downstream	5	0.16	3.32	.983
		Largescale sucker	Upstream	19	0.35	3.18	.977
1979	Summer	Bridgelip sucker	Downstream	10	1.27	2.97	.968
		Bridgelip sucker	Upstream	16	1.07	3.00	.968
		Chiselmouth	Downstream	22	1.68	2.97	.992
		Chiselmouth	Upstream	7	2.75	2.48	.973
		Northern squawfish	Downstream	33	73.15	2.28	.995
		Redside shiner	Upstream	18	3.42	2.40	.997
		Redside shiner	Downstream	9	123.68	2.16	.999
		Peamouth chub	Downstream	32	18.90	2.49	.996
		Peamouth chub	Upstream	6	25.08	2.45	.968
		Yellow perch	Downstream	9	8.80	2.62	.989
		Mountain whitefish	Upstream	32	17.26	2.52	.996
1979	Fall	Mountain whitefish	Upstream	32	2.04	2.90	.983
		Largescale sucker	Upstream	16	3.24	2.82	.986
		Bridgelip sucker	Upstream	16	59.84	2.35	.949
		Chiselmouth	Upstream	9	1.14	3.04	.992
		Northern squawfish	Downstream	15	50.33	2.36	.999
		Northern squawfish	Upstream	9	24.37	2.47	.997
		Peamouth chub	Downstream	6	92.51	2.22	.954
		Bluegill	Downstream	5	171.55	2.12	.934
		Bluegill	Upstream	5	0.08	3.72	.987
		Smallmouth bass	Downstream	8	1.29	3.06	.997
		Smallmouth bass	Upstream	6	0.06	3.70	.972
		American shad	Upstream	15	0.01	4.03	.981
1980	Winter	Mountain whitefish	Upstream	8	100.55	2.20	.936
		Bridgelip sucker	Upstream	5	5.17	2.76	.984
		Largescale sucker	Upstream	8	1.38	2.96	.987

1 Fall: September, October, November
Winter: December, January, February
Spring: March, April, May
Summer: June, July, August

2 Captured upstream or downstream relative to the WNP 2 intake structures.

Table 5.8. Number of fish of dominant species tagged during each 3-month season from September 1978 through March 1980.

Species	Season	Number Tagged	Recaptures — Season of Initial Tagging: Fall '78	Spring '79	Summer '79	Fall '79
Bridgelip sucker	Fall '78	37				
	Spring '79	6				
	Summer '79	85				
	Fall '79	65				
Largescale sucker	Fall '78	89	2			
	Spring '79	67				
	Summer '79	182				
	Fall '79	89	1			1
	Spring '80	13				
Chiselmouth	Fall '78	15				
	Summer '79	84				
	Fall '79	10				
Mountain whitefish	Fall '78	29				
	Spring '79	78	1	3		
	Summer '79	24		3		
	Fall '79	0		2		
	Spring '80	22		1		
Chinook fry	Spring '79	88				
	Summer '79	73				
All other species[a]	Fall '78	24				
	Spring '79	33				
	Summer '79	18				

[a]Northern squawfish, black crappie, bluegill, carp, largemouth bass, pumpkinseed, redside shiner, sculpin, smallmouth bass, yellow perch

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Table 5.9. Tag recapture history for largescale sucker and mountain whitefish during 1978-80.

Species	Tag Number	Recapture Date	Recapture Sample	Tagging Date	Tagging Sample	Length	Duration at Large
Largescale sucker	16	9/25/78	EF0004	9/25/78	EF0003	430	0
"	173	10/31/78	EF0007	10/17/78	EF0006	427	14
"	373	10/29/79	EF0039	9/27/79	EF0035	395	32
"	20	10/31/79	EF0040	10/31/78	EF0007	436	365
Mountain whitefish	624	4/12/79	EF0013	3/29/79	EF0012	306	14
"	46	4/12/79	EF0013	10/31/78	EF0008	294	163
"	94	4/27/79	EF0015	3/14/79	EF0010	365	44
"	211	5/08/79	EF0017	4/28/79	EF0016	292	10
"	204	6/22/79	EF0023	4/28/79	EF0016	347	55
"	204	1/24/80	Yakima R.	(second recapture)			216[a]
"	649	6/22/79	EF0024	4/12/79	EF0013	270	71
"	267	8/08/79	EF0030	5/09/79	EF0018	307	91
"	245	9/27/79	EF0035	4/27/79	EF0015	280	153
"	633	10/29/79	EF0039	4/12/79	EF0013	258	200
"	232	3/13/80	EF0042	4/27/79	EF0015	281	321

[a]Duration at large since first recapture date

Table 5.10. Sex ratio of predominant species of fish analyzed in the laboratory (minimum number sexed > 30).

Species	Number			Percentage	
	Male	Female	Unknown	Male	Female
Mountain whitefish	40	43	30	48.2	51.8
Largescale sucker	35	44	3	44.3	55.7
Bridgelip sucker	33	31	4	51.6	48.4
Chiselmouth	21	45	21	31.8	68.2
Northern squawfish	13	36	54	26.5	73.5
Peamouth chub	19	24	26	44.2	55.8

Table 5.11. Length at reproductive maturity for predominant species of fish captured near WNP 1, 2, and 4.[1]

	n	Mean Length @ Maturity (mm)	Range Lower	Range Upper	S.D.
Mountain whitefish	17	304.0	160	382	50.2
Largescale sucker	35	464.8	338	620	63.0
Bridgelip sucker	30	385.1	225	441	42.2
Chiselmouth	14	265.5	210	320	39.3
Northern squawfish	15	342.4	307	395	29.4
Redside shiner	3	180.3	178	183	2.5
Peamouth chub	6	279.7	265	302	13.2

[1] Based on fork lengths taken for both gravid and spent fish.

Table 5.12. Number of parasites observed on the predominant species of fish during field tagging and laboratory analysis (minimum number of fish checked ≥ 30 unless parasites observed with smaller sample sizes).

Species	Sample Size	Proportion of fish with following number of parasites				Mean parasites per fish
		None	1	2	3-9	
Coho salmon	26	.692	.308			.308
Chinook salmon	1670	.999	.001			.001
Mountain whitefish	246	.947	.049	.004		.057
Largescale sucker	517	.865	.083	.033	.019	.244
Bridgelip sucker	257	.907	.062	.019	.012	.163
Carp	40	.975	.025			.025
Chiselmouth	197	.858	.112	.005	.025	.239
Northern squawfish	126	.865	.103	.024	.008	.206
Redside shiner	61	.984	.016			.016
Peamouth chub	80	.963	.025	.013		.050
Bluegill	16	.688	.250	.063		.375

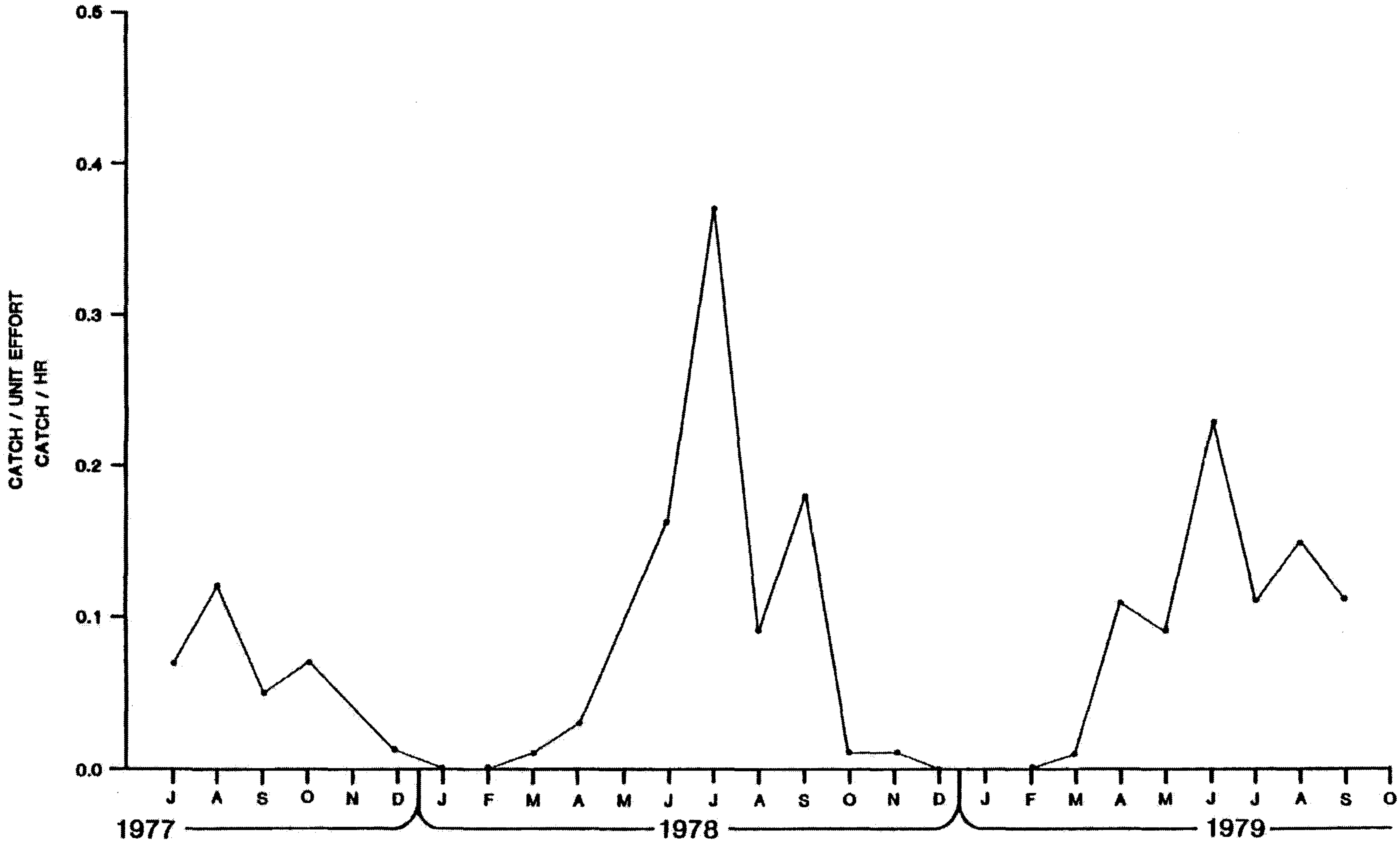


Figure 5.1. Catch-per-unit-effort (catch/hr) for northern squawfish (*Ptychocheilus oregonensis*) collected in gill nets near WNP-1, 2, and 4 from January 1977 - October 1979. Data prior to present study from Gray and Dauble (1978b, 1979)

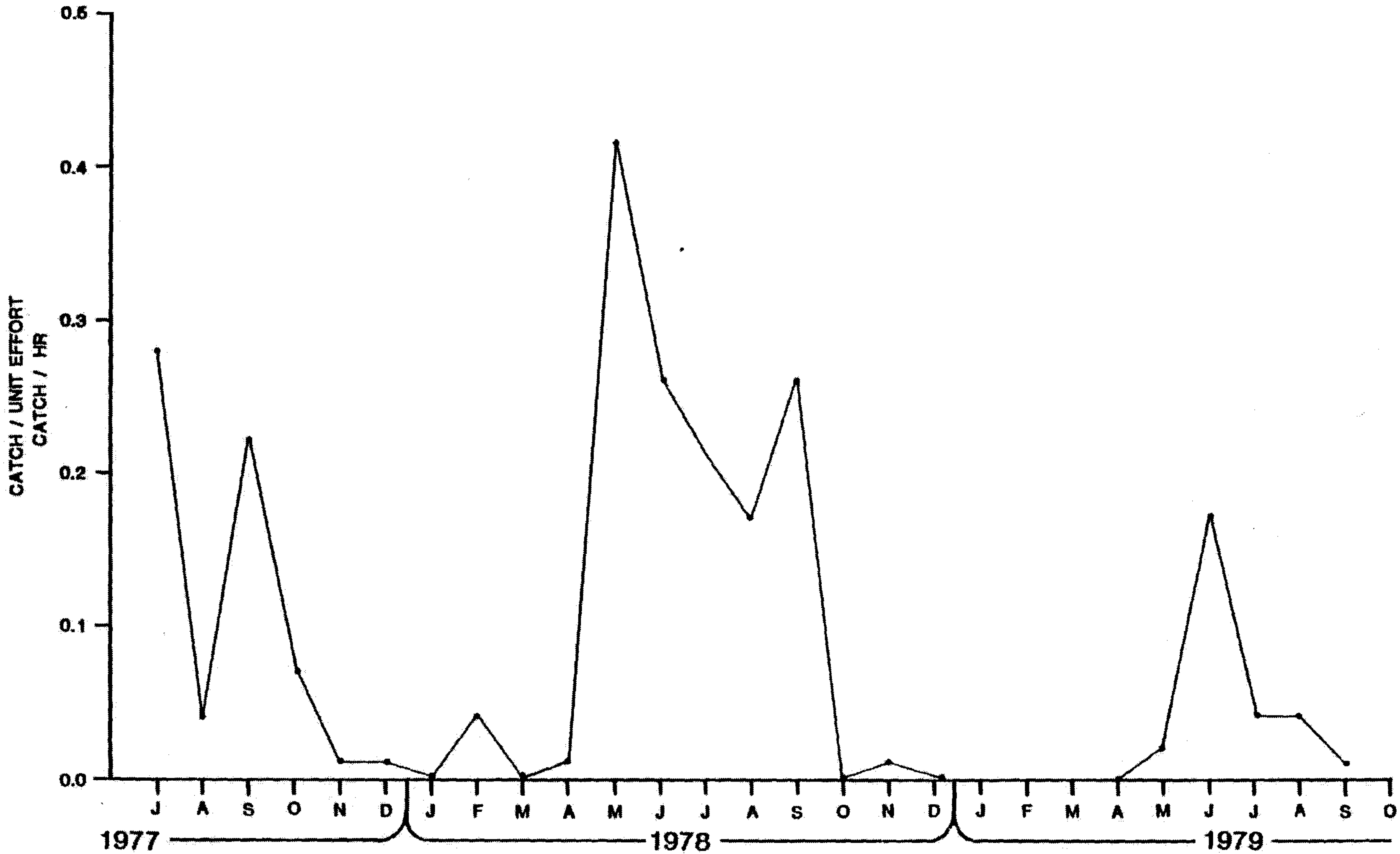


Figure 5.2. Catch-per-unit-effort (catch/hr) for redside shiner (*Richardsonius balteatus*) collected in gill nets near WNP - 1,2 and 4 from January 1977 - October 1979. Data prior to the present study period from Gray and Dauble (1978b, 1979).

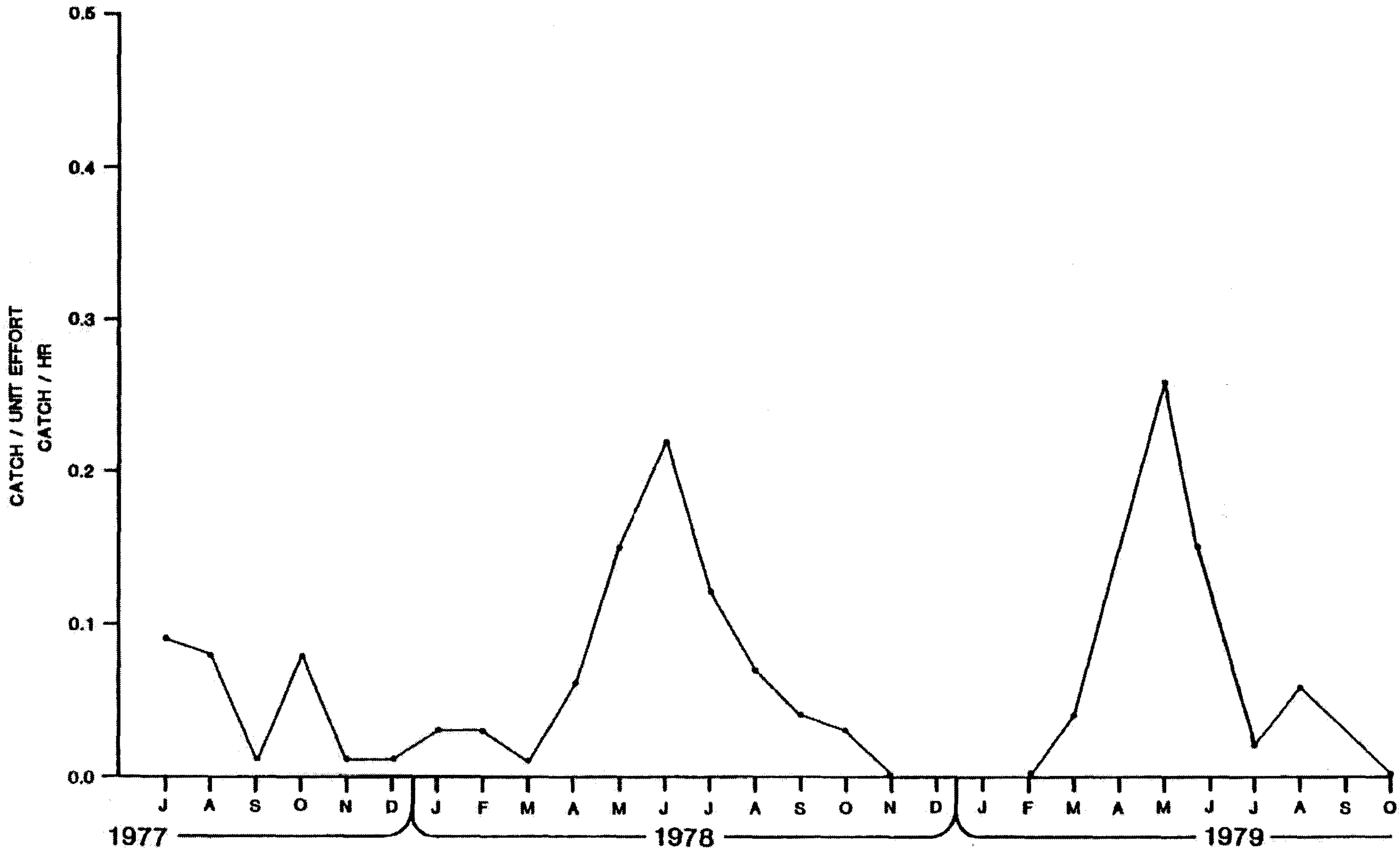


Figure 5.3. Catch-per-unit-effort (catch/hr) for largescale sucker (*Catostomus macrocheilus*) collected in gill nets near WNP - 1,2 and 4 from January 1977 - October 1979. Data prior to present study period from Gray and Dauble (1978b, 1979).

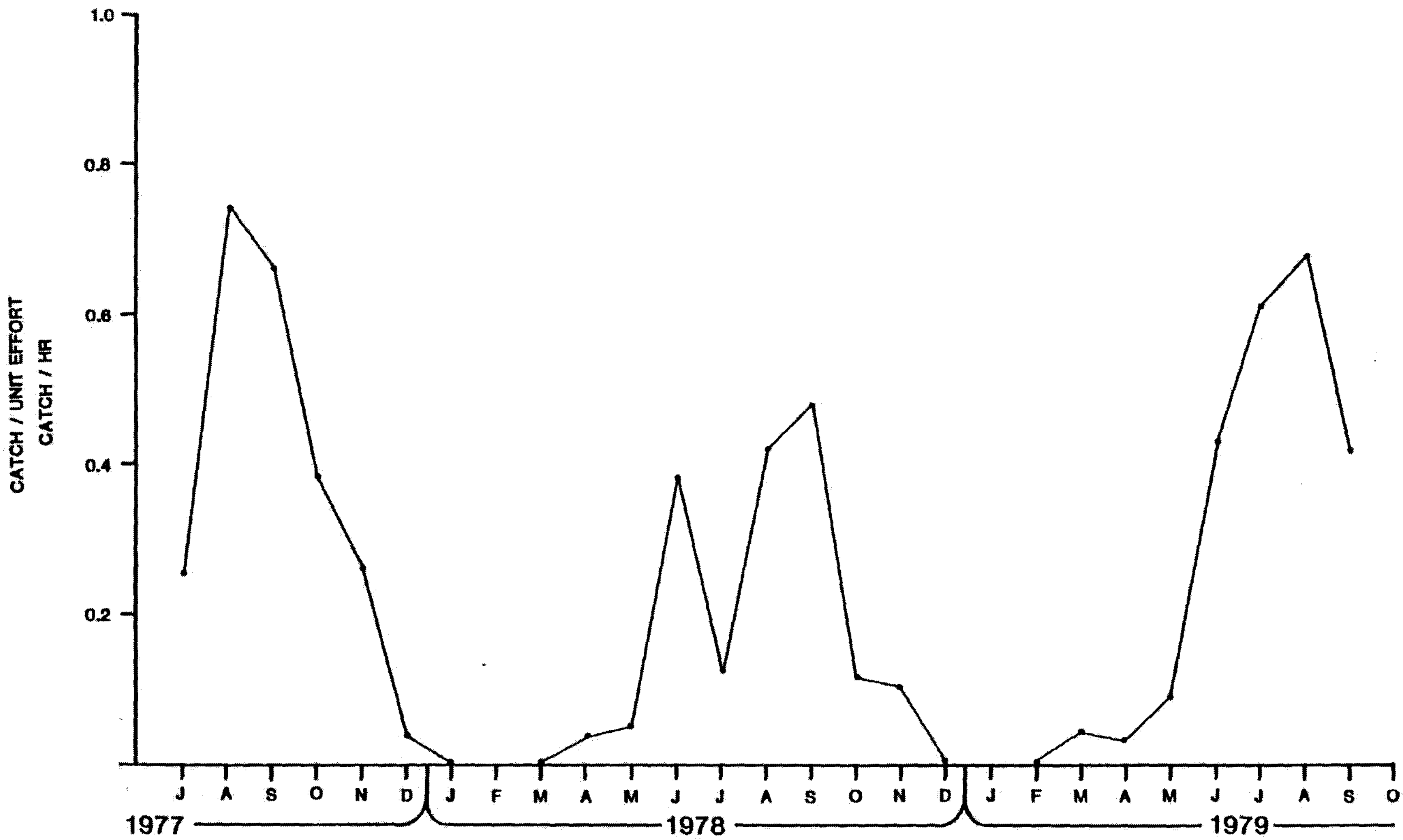


Figure 5.4. Catch-per-unit-effort (catch/hr) for chiselmouth (Acrocheilus alutaceus) collected in gill nets near WNP - 1,2 and 4 from January 1977 - October 1979. Data prior to present study period from Gray and Dauble (1978b, 1979).

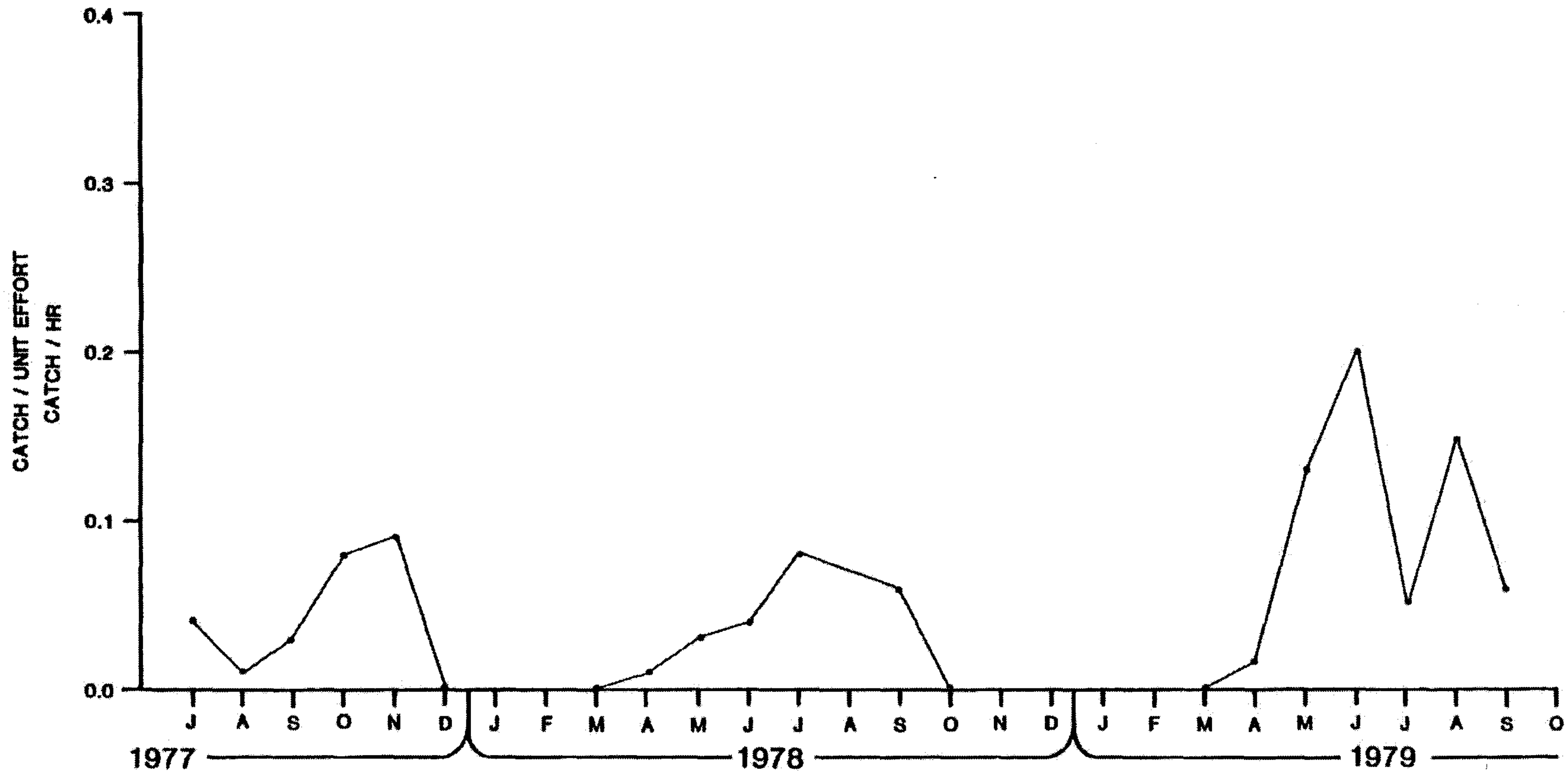


Figure 5.5. Catch-per-unit-effort (catch/hr) for peamouth chub (Mylocheilus caurinus) collected in gill nets near WNP - 1,2 and 4 from January 1979 through October 1979. Data prior to present study period from Gray and Dauble (1978b, 1979).

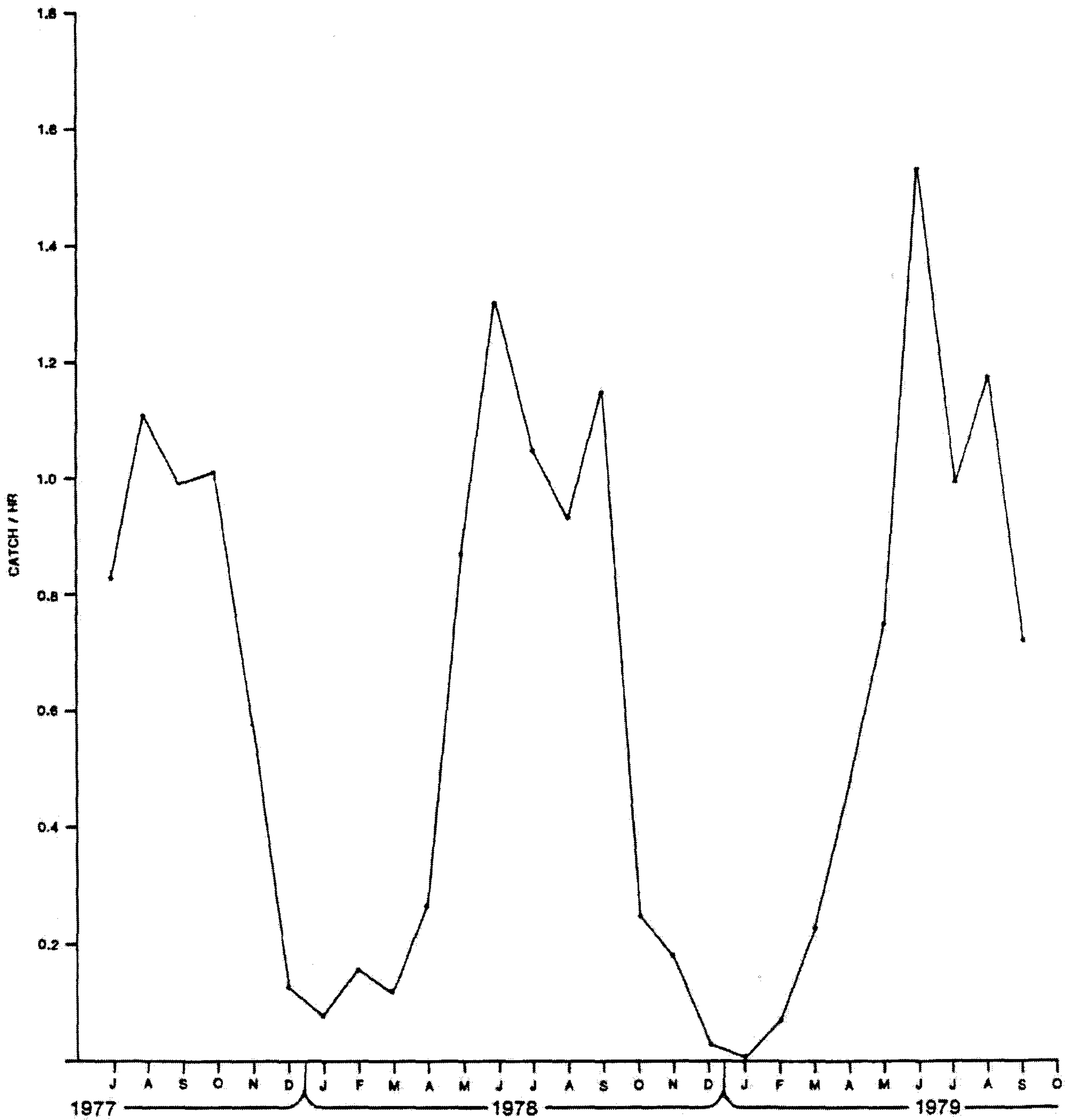


Figure 5.6. Catch-per-unit-effort (catch/hr) for all species collected in gill nets near WNP - 1,2 and 4 from January 1977 - October 1979. Data prior to present study period from Gray and Dauble (1978b, 1979).

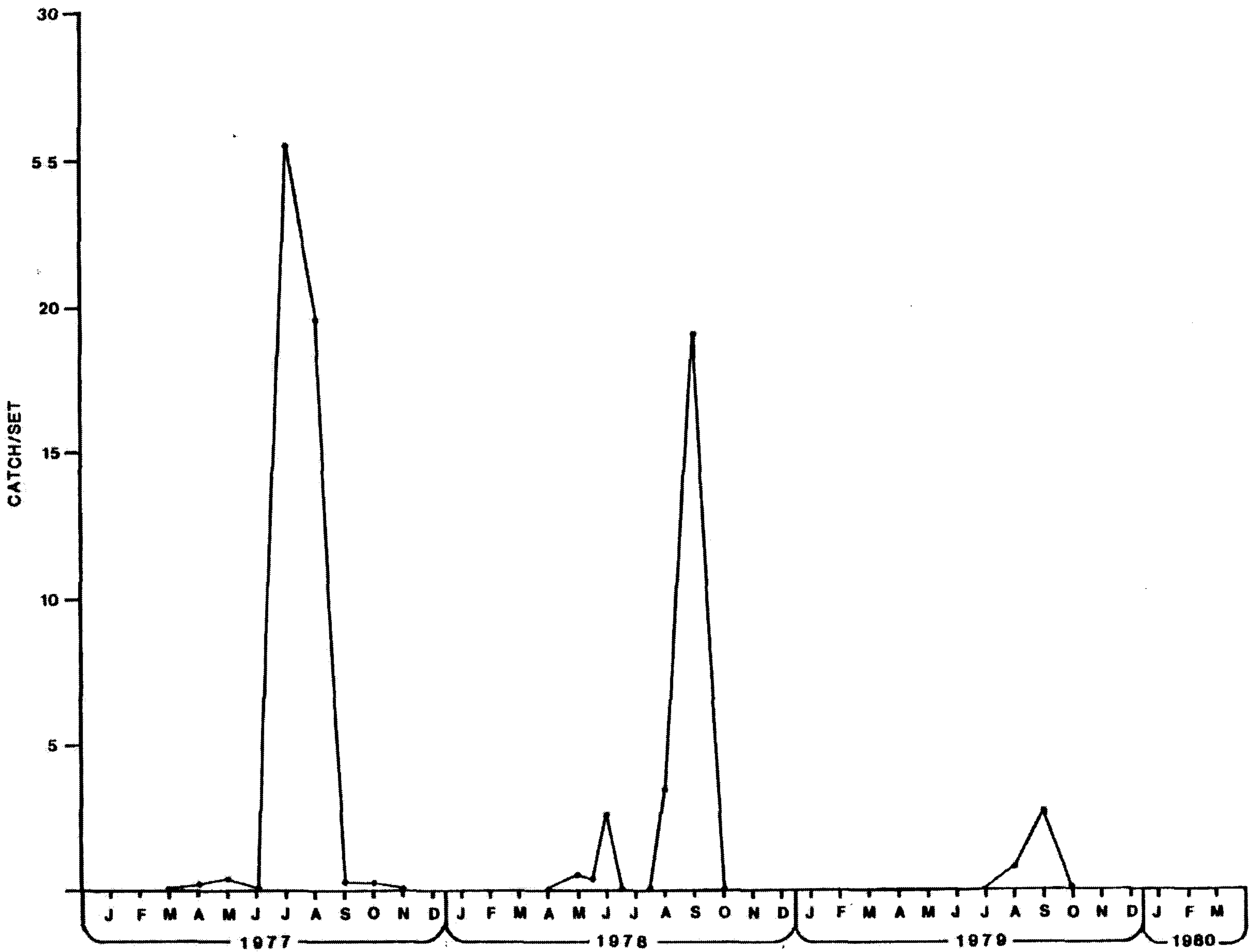


Figure 5.7. Catch-per-unit-effort (catch/set) for redside shiner (*Richardsonius balteatus*) collected in beach seines near WNP-1, 2, and 4 from January 1977-March 1980. Data prior to the present study period from Gray and Dauble (1978b, 1979).

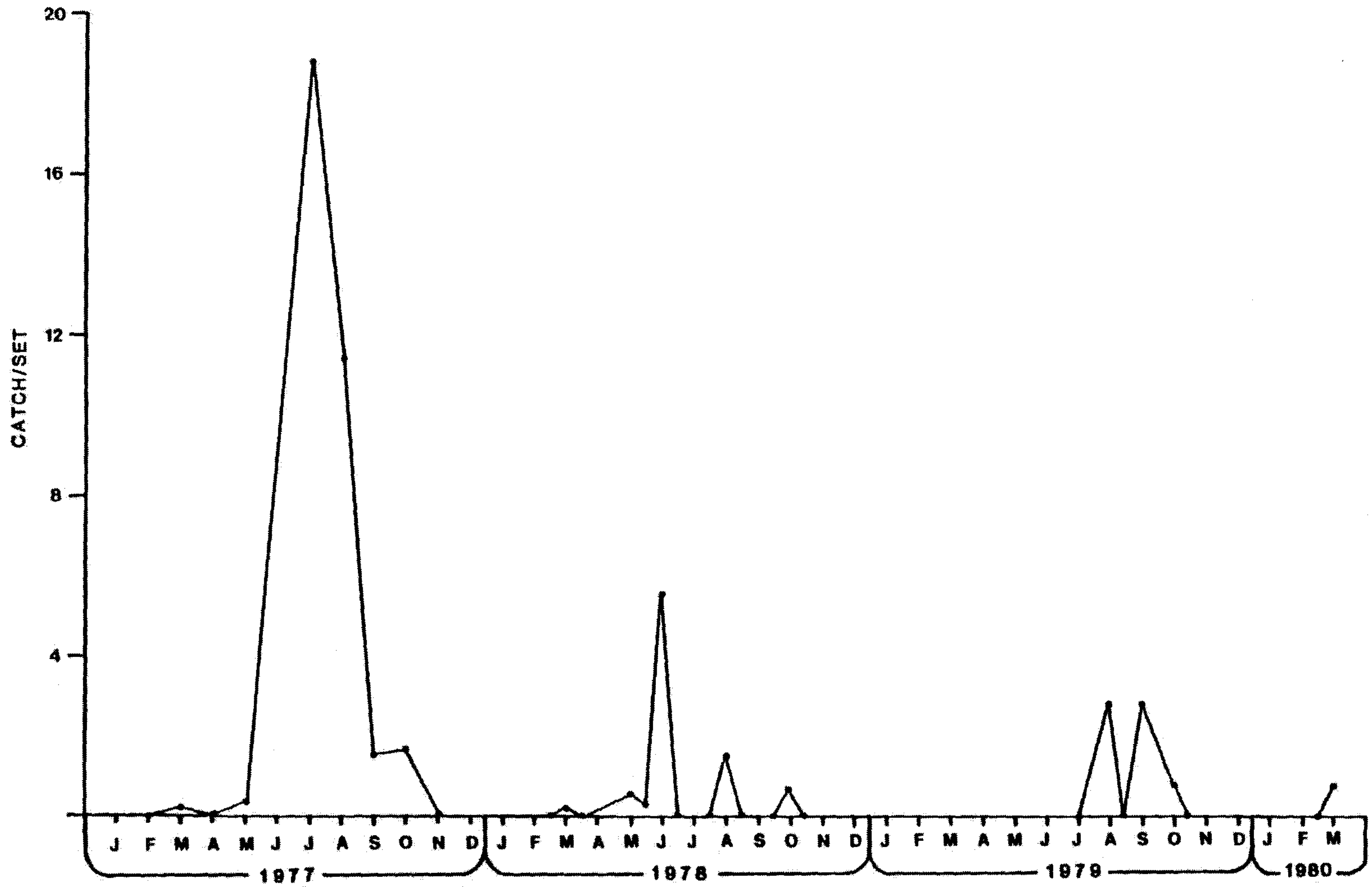


Figure 5.8. Catch-per-unit-effort (catch/set) for northern squawfish (*Ptychocheilus oregonensis*) collected in beach seines near WNP-1, 2, and 4 from January 1977-March 1980. Data prior to the present study period from Gray and Dauble (1978b, 1979).

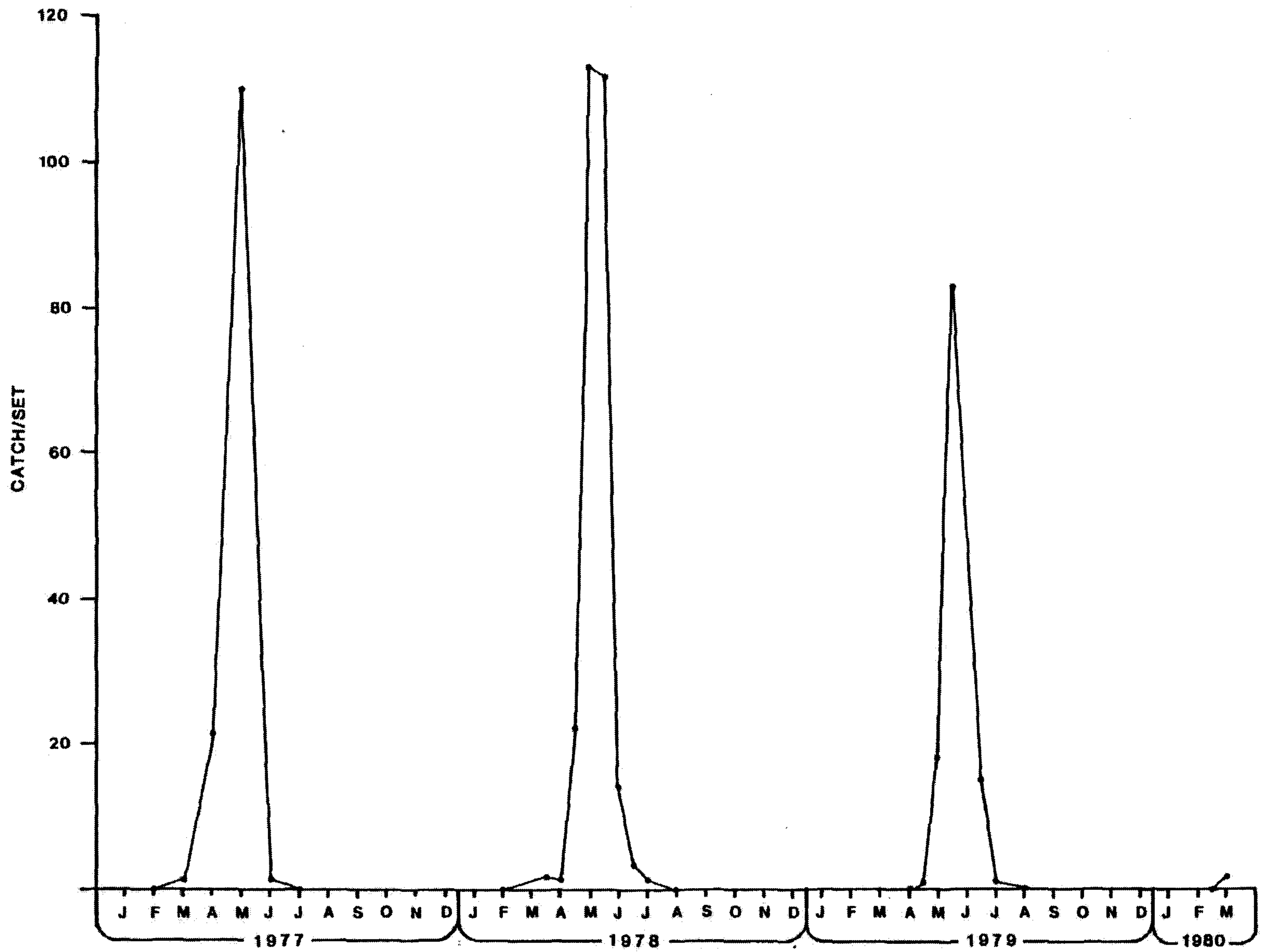


Figure 5.9. Catch-per-unit-effort (catch/set) for chinook salmon (Oncorhynchus tshawytscha) collected in beach seines near WNP-1, 2, and 4 from January 1977-March 1980. Data prior to the present study period from Gray and Dauble (1978b, 1979).

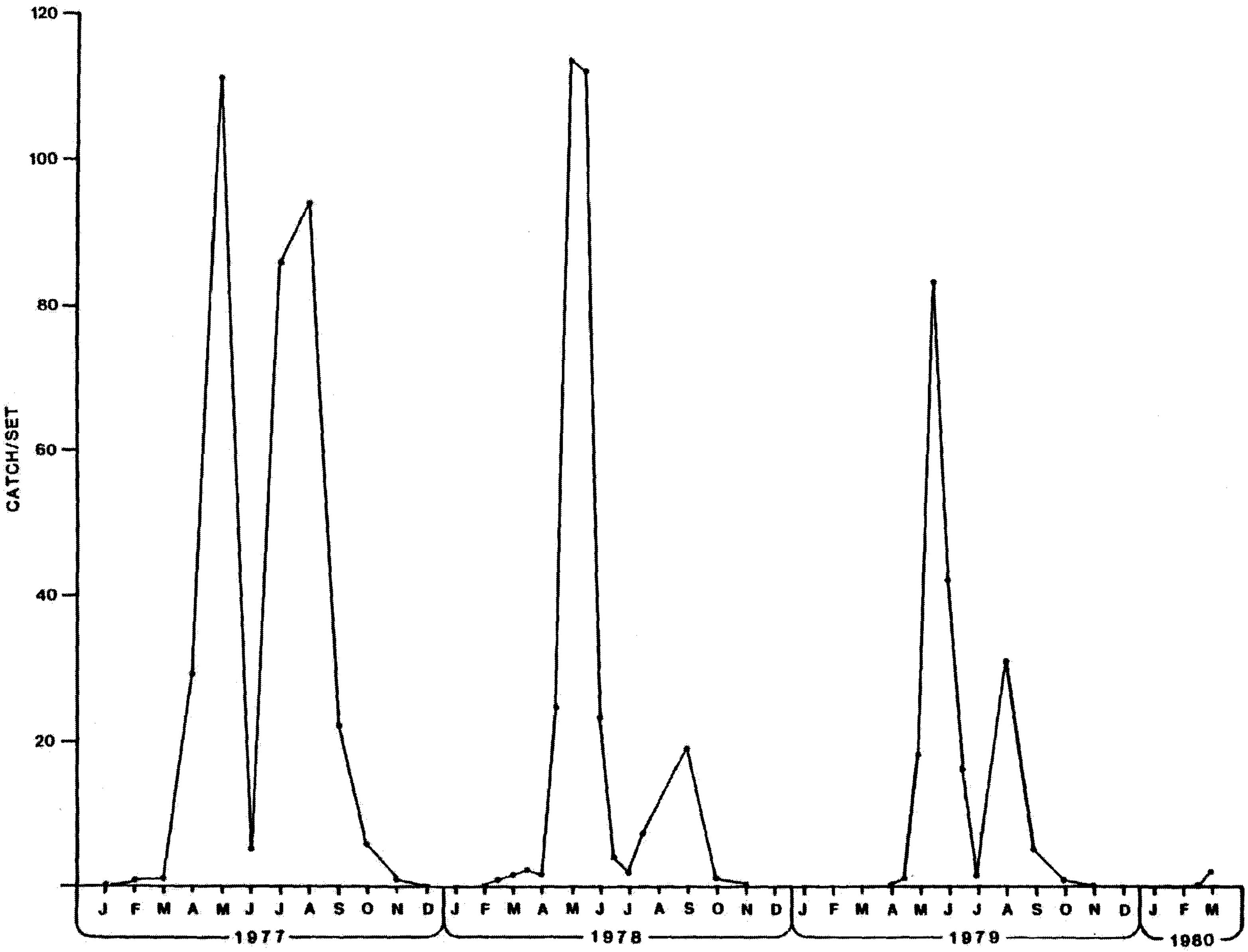


Figure 5.10. Catch-per-unit-effort (catch/set) for all species collected in beach seines near WNP-1, 2, and 4 from January 1977-March 1980. Data prior to the present study period from Gray and Dauble (1978b, 1979).

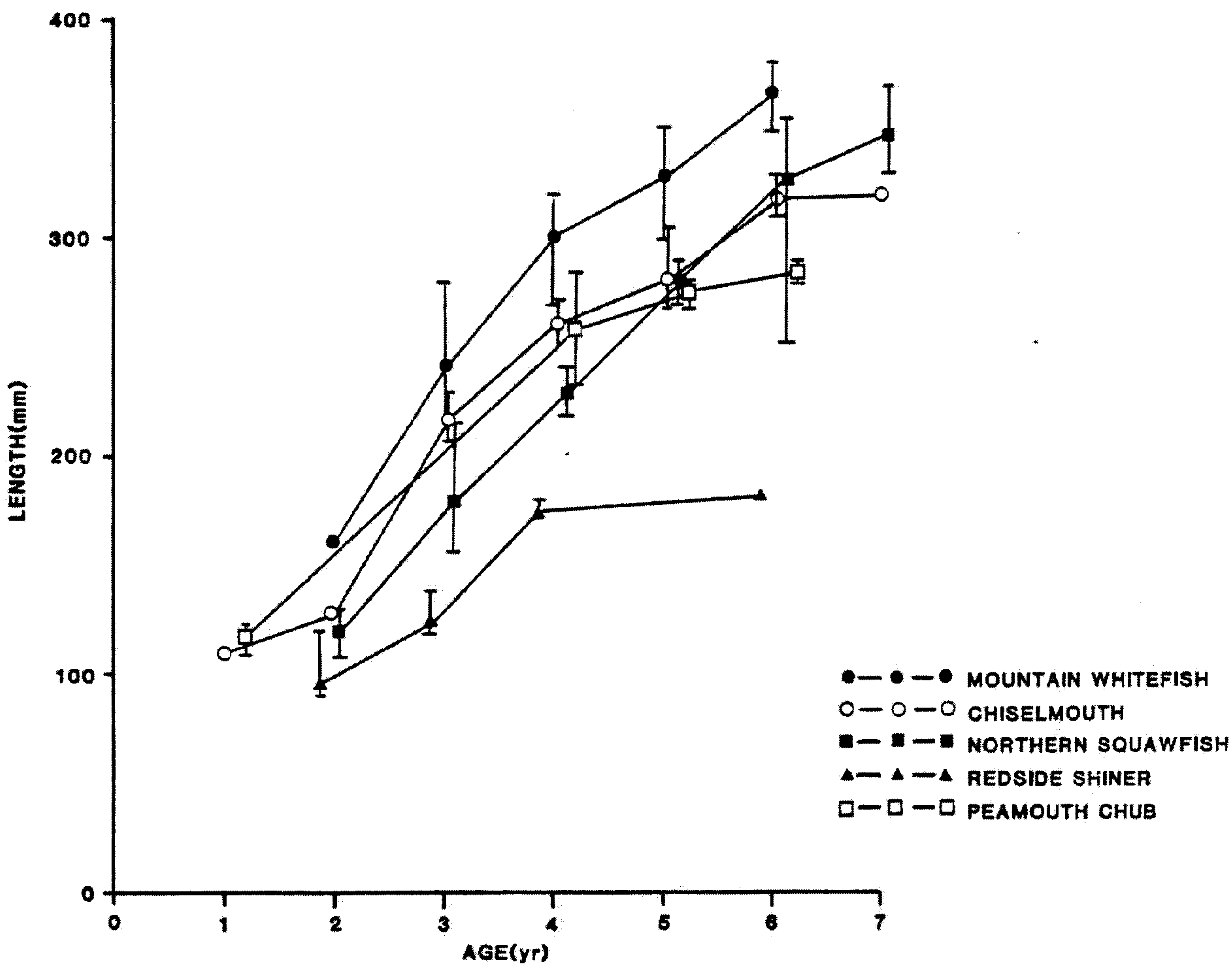


Figure 5.11. Mean fork lengths (m m) and ranges at age (years) for five common species collected near WNP - 1,2, and 4, September 1978 through December 1979.

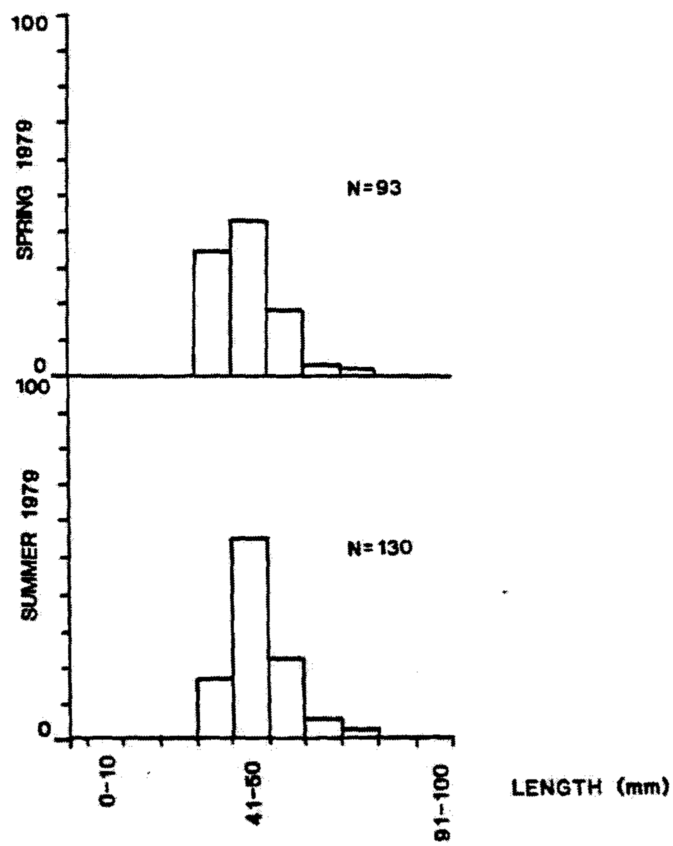


Figure 5.12. Length-frequency of chinook salmon fry (Oncorhynchus tshawytcha) collected in beach seines near WNP-1, 2, and 4 during spring and summer 1979.

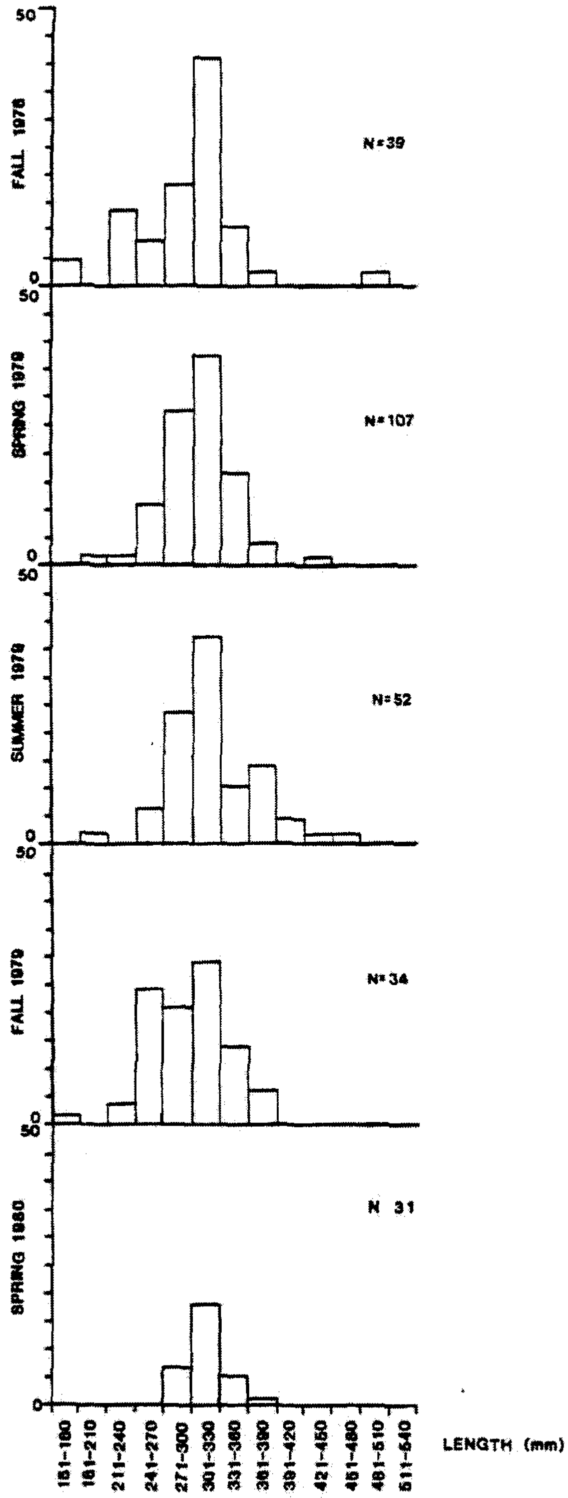


Figure 5.13. Length-frequency of mountain whitefish (<u>Prosopium williamsoni</u>) collected by electrofishing near WNP-1, 2, and 4 by season.

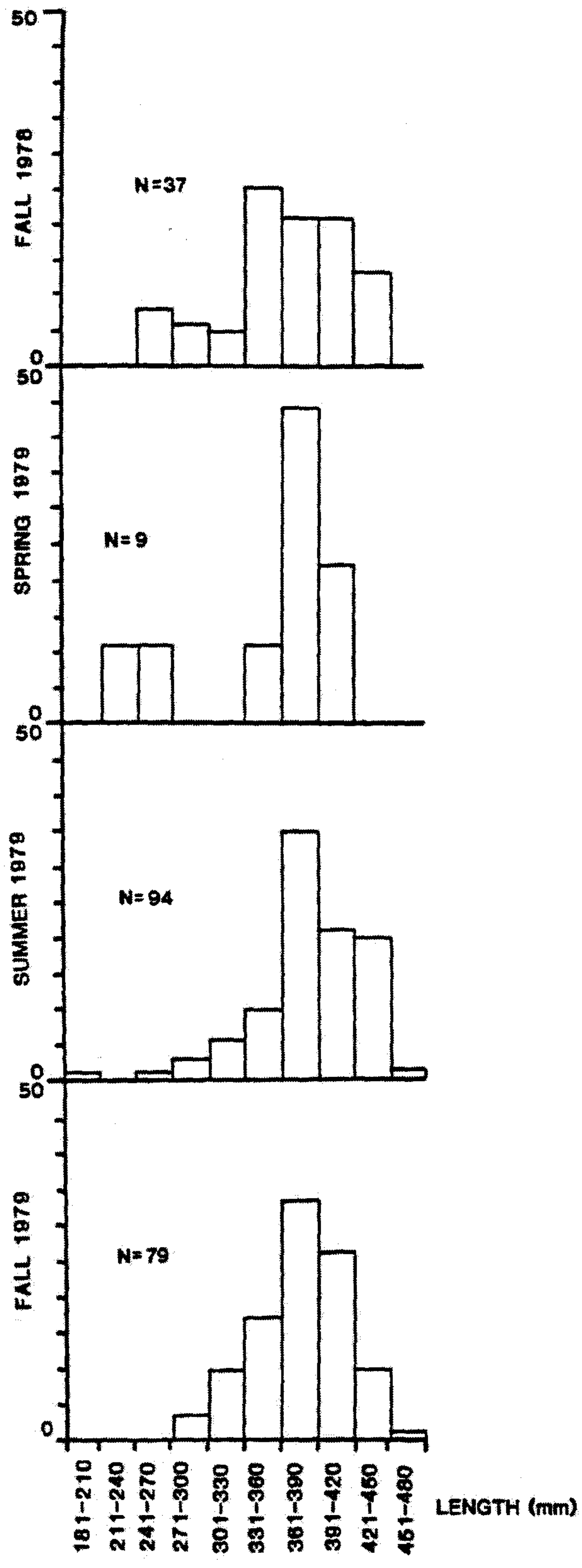


Figure 5.14. Length-frequency of bridgelip sucker (*Catostomus columbianus*) collected by electrofishing near WNP-1, 2, and 4 by season.

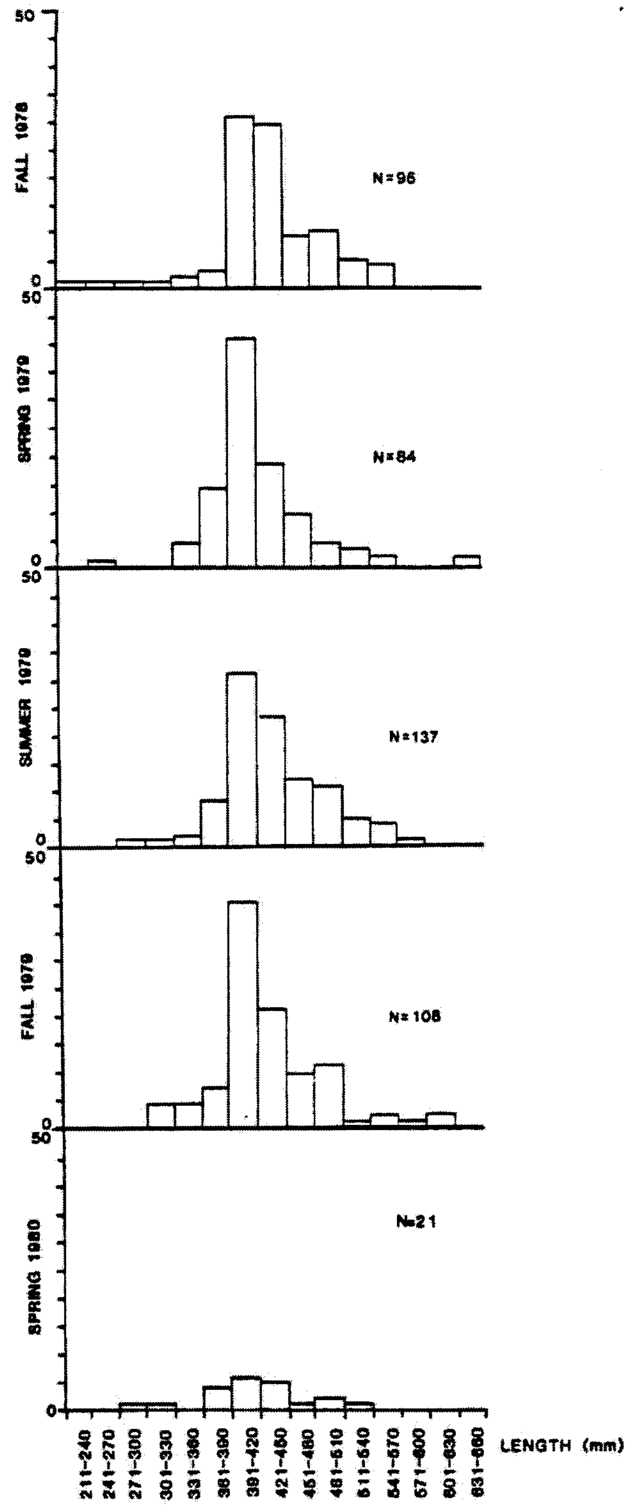


Figure 5.15. Length-frequency of largescale sucker (Catostomus macrocheilus) collected by electrofishing near WNP-1, 2, and 4 by season.

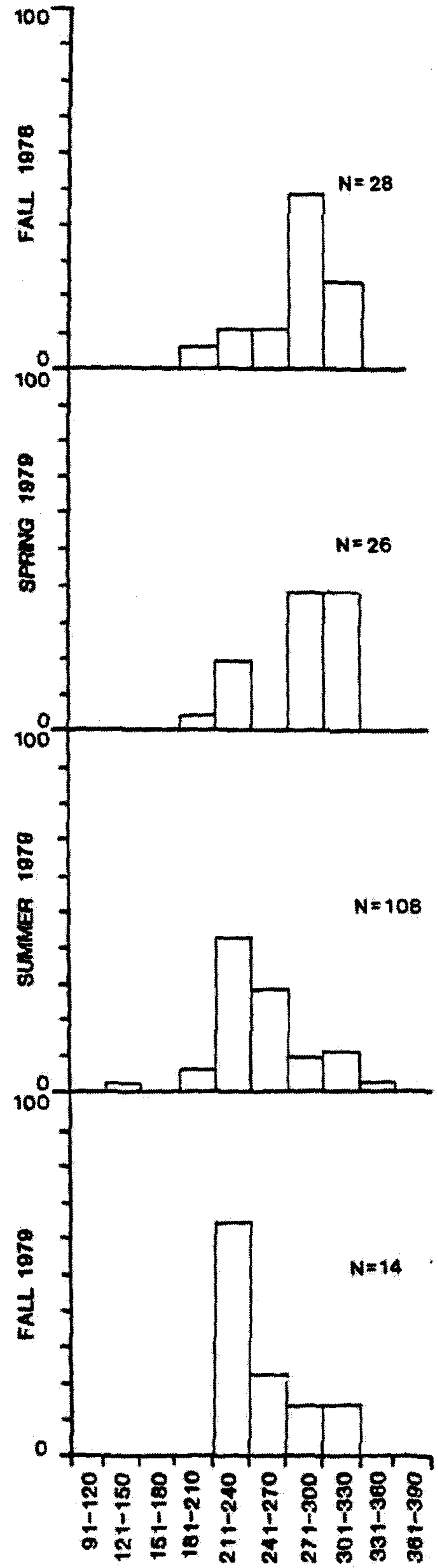


Figure 5.16. Length-frequency of chiselmouth (Acrocheilus alutaceus) collected by gill net near WNP-1, 2, and 4 by season.

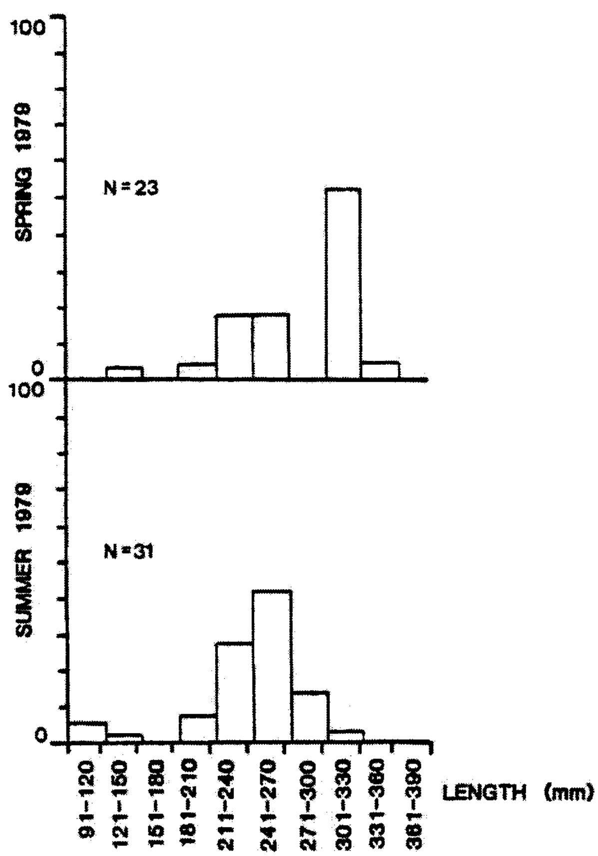


Figure 5.17. Length-frequency of peamouth chub (Mylocheilus caurinus) collected by gill net near WNP-1, 2, and 4 during spring and summer 1979.

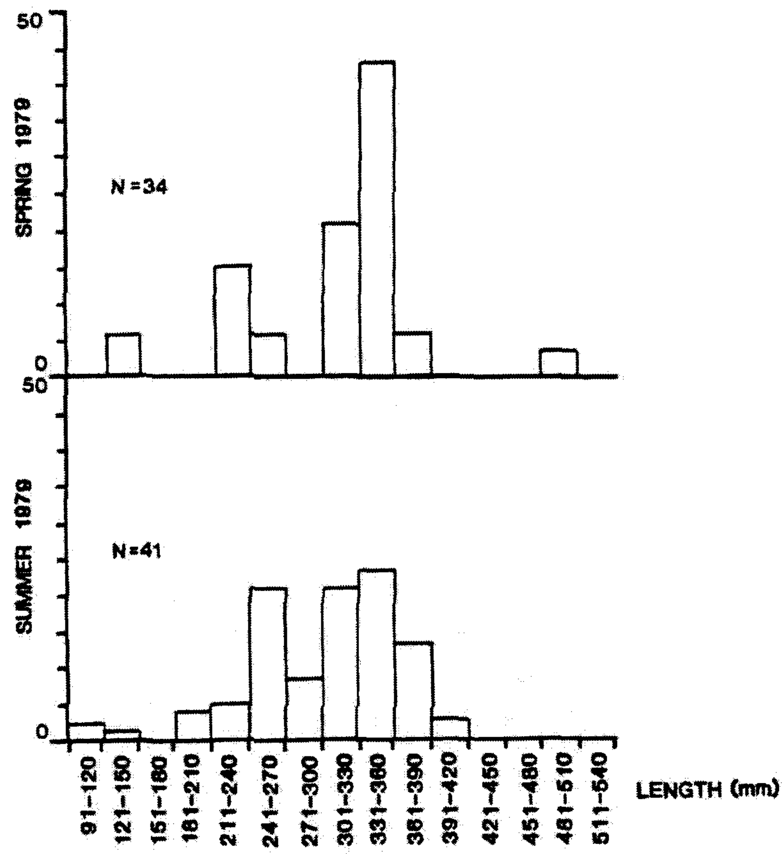


Figure 5.18. Length-frequency of northern squawfish (*Ptychocheilus oregonensis*) collected by gill net near WNP-1, 2, and 4 during spring and summer 1979.

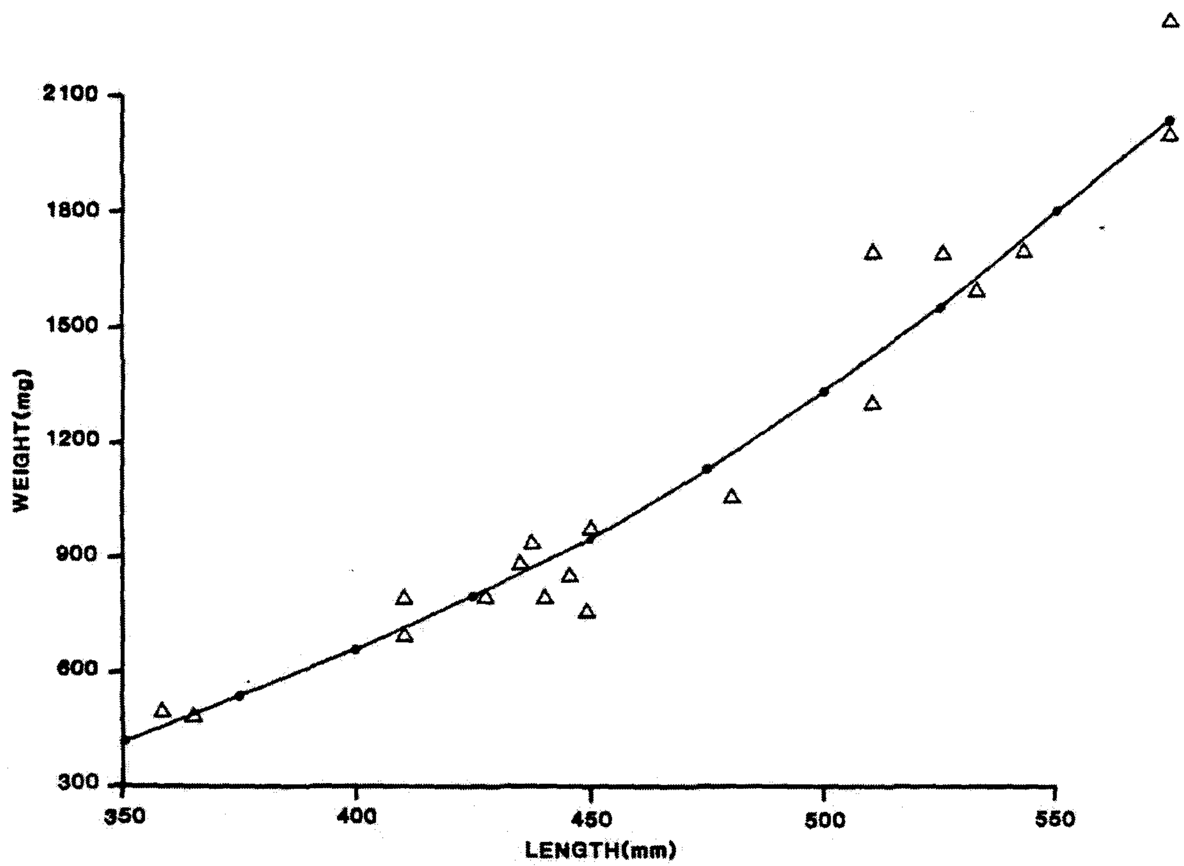


Figure 5.21. Length-weight relationships of largescale sucker (Catostomus macrocheilus) collected near WNP-1, 2, and 4 during the summer 1979 sampling period.

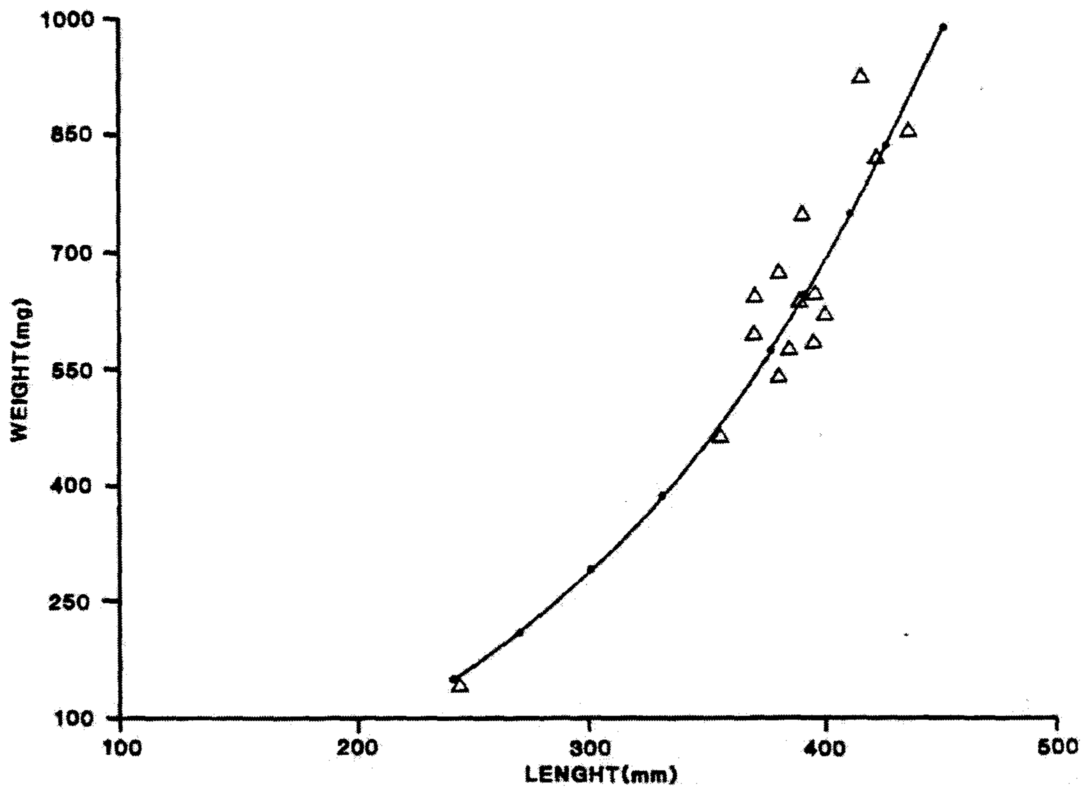


Figure 5.22. Length-weight relationships of bridgelip sucker (Catostomus columbianus) collected near WNP-1, 2, and 4 during the summer 1979 sampling period.

6.0 FISH-POWER PLANT INTERACTIONS

6.1 INTRODUCTION

Studies were conducted during the period August 1978-May 1980 to assess both the existing and potential effects of in-water WNP-2 power plant structures and operations on fishes. These studies included intake flow-field determinations, examination of intakes for fish impingement during intake operation, examination of intake water for entrained fish, and velocity-depth measurements in the area of the plant discharge plume. In addition, turbidity and suspended solids were monitored during WNP-1/4 intake and discharge construction.

Methods employed and results of each of the aforementioned studies are summarized below. Methods utilized for field and laboratory measurements and subsequent data analysis are fully outlined in Standard Operating Procedure (SOP) manuals specific to each task element. Similarly, study results have been detailed previously in Data Reports (DR), Topical Reports (DTR), and/or Final Reports for each task element. Related data are contained in the Appendices.

6.2 METHODS AND MATERIALS

6.2.1 Intake Flow Field

Intake flow field determinations and analyses were conducted according to SOPB08-01 and SOPB08-02, Flow Field Measurements. Experiments were conducted in May, June, and twice in December 1979 to allow assessment across seasonal river flow variation and with plant pumps on (June, December) and off (May, December). Replicate readings of current velocity and the corresponding current direction were obtained at 186 sample locations around the WNP-2 intake structures (Figure 6.1) with a Marsh-McBirney Model 201 portable flow meter. Approximately 10% of the readings were noted simultaneously by two independent observers and compared to assure accuracy. Measurements were made on each sample date at four depths (surface, above-structure, mid-structure, and beneath structure) and information

was recorded on a data form, an example of which is shown in Figure 6.2. Additional measurements were made as close as possible to the intake structures' surface in June and December. The SCUBA diver noted the approximate numbers, size, location, and kinds (when possible) of fish occurring near the intakes and any sensations he may have experienced near the intakes while positioning the flow meter sensor.

Data were analyzed and the flow field characterized using statistical tests (Hollander and Wolfe 1973) and graphical presentations of velocity-direction vectors relative to the structures at each sampled depth and date. The volume of flow around the intakes with velocities less than 2 fps and which should therefore allow small fish of a size similar to chinook salmon fry to potentially hold position for a short time without being washed downriver was also determined for each survey.

6.2.2 Intake Structure Inspection

Inspections of the WNP-2 intake structures with respect to maintenance requirements and potential and actual impingement impact on fish were performed by SCUBA observations according to SOPB05-01, Intake Structure Monitoring. Surveys were conducted in December 1978 and May 1979, prior to regularly scheduled test-pumping periods, and monthly from June through October and in December 1979 during test-pumping withdrawal operations. The diver noted any maintenance needs of the structures, surrounding interferences (such as accumulation of submerged debris or attached periphytic algae), and the numbers, size, location, and kinds (when possible) of fish in the immediate area of the intakes.

6.2.3 Intake Entrainment

Potential entrainment of fishes during withdrawal operations was assessed according to procedures described in SOPB06-01, SOPB06-02, and SOPB06-03, Intake Entrainment Monitoring. Routine monitoring involved inspection of sampling cages in the pumphouse (Figures 6.3 and 6.4) which were designed to collect entrained fish through the WNP-2 intake structures (Figures 6.5 and 6.6). These inspections

appeared unaffected by intake operation. Although unable to identify all fish species, divers did verify the presence of sculpin (*Cottus* spp.), sucker (*Catotomus* spp.), northern squawfish (*Ptychocheilus oregonensis*), and American shad (*Alosa sapidissima*). No salmonids were reported except in October when four rainbown trout approximately 300 - 380 mm long were observed immediately upriver of the intake structures.

Inspections revealed no damage or irregularities involving the structure and only a minimal accumulation of debris around the base areas. Growth of algae (periphyton) and sponge (probably *Spongilla lacustris*) on the structures was evident in summer and early fall. Divers reported feeling no suction when placing a hand over the screened portion of either intake during withdrawal operations.

Flow rate of the Columbia River past the intakes during the observations ranged from approximately 49,000 cfs in September to 135,000 cfs in December. The estimated rate of simultaneous pump withdrawal, which was sometimes through one intake and sometimes through both, ranged from 4,000 gpm (9 cfs) in October to 11,500 gpm (26 cfs) in June. This compares to a withdrawal of 15,463 gpm (34 cfs) which has been projected for plant water use during maximum power operation (WPPSS 1977). Water withdrawal was limited during pre-operational testing by the lack of cooling tower evaporation and the physical limitations of the discharge pipe. Results are detailed in Data Reports (DRB05-01) for each month.

6.3.3 Intake Entrainment

Results of entrainment studies have been presented previously in Data Reports (DRB06-01). Corresponding data are contained in Appendix H.

6.3.3.1 Routine Monitoring

Entrainment samples were collected on 69 occasions from May 1979 through May 1980 and contained no fish eggs or larvae. Approximately 30% of the total volume of water entrained between the start of pumping and May 14, 1980 was

sampled. Beach seining indicated that chinook salmon fry were in the vicinity of the WNP-2 intakes from at least March through May during sampling. Thirty coho salmon fry which had been introduced during the sampling efficiency tests (discussed below) were collected, twenty-three on top of the cage and seven inside the cage. Additionally, one carp and two prickly sculpin which had probably entered the pump house prior to installation of the intake screens were collected on top of the cage.

6.3.3.2 Sampling Efficiency of the Collection Cages

The sampling efficiency experiments conducted in May and June 1979 showed a relatively high percentage retention of coho salmon fry after 12 hours of test pumping. Averaging the mid-May and late June experiments gives a percentage retention of 77.8% for live coho fry and 84.6% for dead coho fry. Statistically significant differences between May and June retention values occurred for both live and dead specimens in cage A (southernmost cage); however, these differences were influenced by size differences in coho fry, operational differences in lowering the cages into place, and pumping rate differences. No significant differences between cages A and B on the same date were observed. Based on these results, we assume that 80% approximately represents the long-term average retention of live and dead fry for a 12-hour period.

Future projections of water use at WNP-2 indicate that from 0.01 to 0.09 percent of the river water could be drawn through the intake structures. Under maximum power operation, a total of 15,463 gpm would be withdrawn. This amounts to approximately 0.01% of river flow under mean maximum river flow, 0.03% under average river flow, and 0.09% under minimum licensed river flow. This withdrawal rate (approximately 1 m^3/sec) is approximately twice the rate experienced during the routine entrainment monitoring in 1979. However, closure of one gate during entrainment monitoring resulted in near-maximum flows (approximately 1/2 m^3/sec) through that intake from which samples were being collected.

6.3.4 Discharge Plume

Discharge plume data are contained in Appendix I. River velocity measurements at the five sampling locations varied from 3.2 - 7.1 fps. They generally decreased from surface to bottom depths, except at two stations where mid and bottom-depth readings were similar. Mean velocities at each depth were generally greatest at stations located in deeper water. This pattern was most noticeable at surface and bottom depths at the station located nearest midriver.

River discharge at time of sampling was 135,250 cfs and the WNP-2 discharge was 8,000 gpm (18 cfs). The plant discharge was evidenced as air bubbles visible from the point of discharge to approximately 60 ft. downriver.

6.3.5 Turbidity and Suspended Solids

Daily measures of turbidity and suspended solids are presented in the Final Report for Turbidity and Suspended Solids Studies in the Columbia River at the WNP - 1/4 Intake and Discharge Construction Site, FRTSS and in Appendix J. Means and ranges for turbidity and suspended solids at the three sampling stations were as follows:

	Turbidity (JTU)		Suspended Solids (mg/l)	
	Mean	Range	Mean	Range
Station 300 ft. upriver	1.3	0.5 - 2.7	3.5	0.4 - 5.8
Station 300 ft. downriver	2.3	1.0 - 9.7	6.5	0.6 -35.0
Station 1 mile downriver	1.7	0.8 -14.3	4.3	0.4 -17.5

All turbidity values measured downriver of the construction area were less than 15 JTU above upriver ambient levels. Turbidity values measured 300 ft. downriver of the construction area were less than 10 JTU above ambient. Ninety-four percent of turbidity values 300 ft. downriver of the construction area were less than 5 JTU above ambient. Suspended solids levels generally followed the same patterns as turbidity levels.

6.4 SUMMARY AND CONCLUSIONS

6.4.1 Intake Flow Field

The effect of the WNP-2 intake structures on fish populations under the range of conditions observed during 1979 flowfield studies appeared negligible. The diver detected no intake flow when placing his hand directly on the perforated pipe, indicating intake velocities were quite low. While fish were sometimes observed near the intakes and may have been attracted to areas of reduced velocities, they were generally few in number and none were observed to be impinged against the intake pipes. This suggests that areas of reduced velocities around the intakes do not harbor dense concentrations of fish nor are intake velocities great enough to cause fish impingement. Similarly, the absence of fish eggs, larvae, and fry from entrainment samples during May - December 1979 indicates that the flow field had not been modified in a manner which would have a detrimental effect on recruitment of juveniles to the fish populations of the Columbia River.

6.4.2 Intake Structure Inspection

Inspections of intake structures by SCUBA observation revealed no incidents of fish impingement, damage, or other irregularities. Minor accumulations of debris, some algal periphyton, and sponges were noted on and around the structures. Divers could detect no suction through intake screens during withdrawal. Peak rate of withdrawal during inspections was approximately 75% of that projected during maximum power operation.

6.4.3 Intake Entrainment

Entrainment sampling during a period when chinook salmon fry were abundant in the river failed to produce any evidence of entrainment. A substantial proportion of withdrawn water was sampled during daylight and darkness, although most sampling occurred during daylight due to pumping schedules. Sampling efficiency data indicated that approximately 80 percent of entrained fish can

be expected to be retained in the entrainment sampling cages during a 12-hour sampling period. These data indicate entrainment is not likely to be a serious problem at WNP-2 with the present intake design and placement, and that a 12-hour sampling interval using the existing sampling devices provides sufficient coverage to detect and measure future entrainment.

6.4.4 Discharge Plume

Differences in velocity-depth profiles among sampling stations appear related to river depth and/or proximity to shore and not proximity to the point of discharge. Field observations while sampling similarly suggest no apparent effect of the WNP-2 discharge on river velocity at the sampling locations.

6.4.5 Turbidity and Suspended Solids

Turbidity and suspended solids measured in the Columbia River downriver from the WNP-1/4 intake and discharge line construction site were generally higher than ambient levels measured immediately upriver. However, the frequency and magnitude of elevated turbidities which appeared due to construction were well below the temporary water quality turbidity standard established by EFSEC. Elevated turbidities and suspended solids were observed primarily during the initial week of excavation.

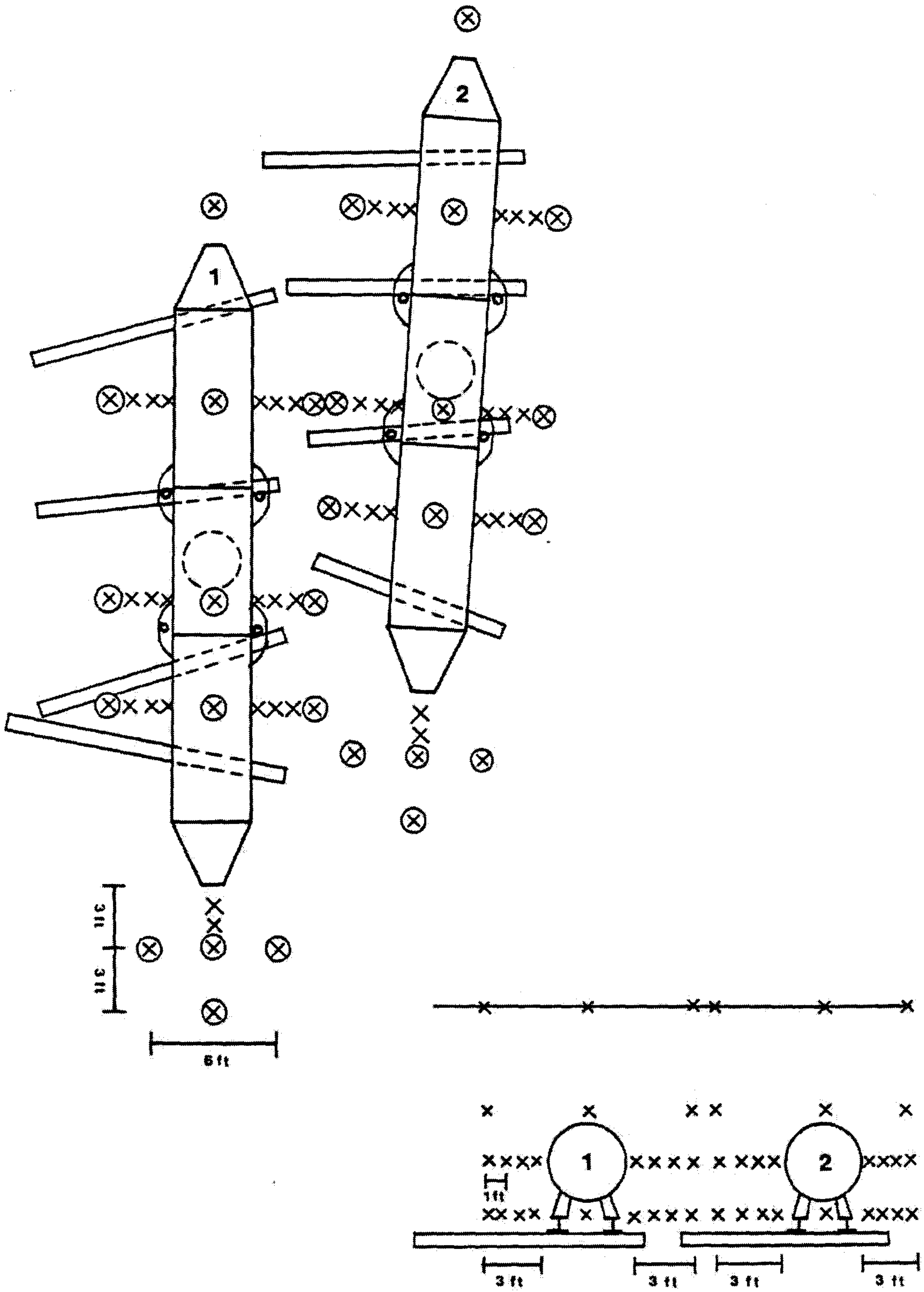


Figure 6.1. Vertical and cross sectional views of flow-field sampling locations, x. In the vertical view, ⊗ represents a station which was sampled at the surface.

Depth: Surface

Series	2 ft Upstream Vel.	Dir.	Head Vel.	Dir.	Middle Vel.	Dir.	Tail Vel.	Dir.	1 ft Downstream Vel.	Dir.	2 ft Downstream Vel.	Dir.	3 ft Downstream Vel.	Dir.	6 ft Downstream Vel.	Dir.
3 ft inshore			7.0	168	7.6	168	7.1	168					7.1	168		
2 ft inshore																
1 ft inshore																
3 in inshore																
centerline	7.1	168	6.5	168	6.5	168	6.7	168					6.7	168	7.3	168
3 in offshore																
1 ft offshore																
2 ft offshore																
3 ft offshore			6.8	168	7.0	168	7.1	168					7.2	168		

Depth: Above

Series	2 ft Upstream Vel.	Dir.	Head Vel.	Dir.	Middle Vel.	Dir.	Tail Vel.	Dir.	1 ft Downstream Vel.	Dir.	2 ft Downstream Vel.	Dir.	3 ft Downstream Vel.	Dir.	6 ft Downstream Vel.	Dir.
3 ft inshore			4.2	180	4.3	180	3.6	180					-	-		
2 ft inshore																
1 ft inshore																
3 in inshore																
centerline	4.3	150	1.6	180	1.6	150	1.5	160	3.8	180	4.2	180	4.2	180	4.6	180
3 in offshore																
1 ft offshore																
2 ft offshore																
3 ft offshore			4.6	180	4.1	180	4.8	180					3.3	180		

Depth: Mid

Series	2 ft Upstream Vel.	Dir.	Head Vel.	Dir.	Middle Vel.	Dir.	Tail Vel.	Dir.	1 ft Downstream Vel.	Dir.	2 ft Downstream Vel.	Dir.	3 ft Downstream Vel.	Dir.	6 ft Downstream Vel.	Dir.
3 ft inshore			4.2	150	3.2	180	3.7	150					3.8	180		
2 ft inshore			4.5	180	4.0	150	4.6	180								
1 ft inshore			4.4	180	4.2	180	3.5	180								
3 in inshore			2.9	180	4.5	180	1.8	180								
centerline	4.2	120							-0.3	-	1.6	180	3.4	180	2.2	180
3 in offshore			1.2	180	1.6	180	1.0	180								
1 ft offshore			2.9	180	3.3	180	3.0	180								
2 ft offshore			4.3	180	4.3	180	3.5	180								
3 ft offshore			4.4	180	4.2	180	3.3	180					1.4	210		

Depth: Under

Series	2 ft Upstream Vel.	Dir.	Head Vel.	Dir.	Middle Vel.	Dir.	Tail Vel.	Dir.	1 ft Downstream Vel.	Dir.	2 ft Downstream Vel.	Dir.	3 ft Downstream Vel.	Dir.	6 ft Downstream Vel.	Dir.
3 ft inshore			2.6	150	0.8	150	2.8	150					0.1	-		
2 ft inshore			2.7	150	2.0	180	1.7	180								
1 ft inshore			1.5	180	1.7	180	1.6	180								
3 in inshore			0.6	150	1.3	180	1.4	180								
centerline	0.6	150	0.1	180	0.0	-	0.3	-	0.2	270	0.2	270	0.0	240	0.8	210
3 in offshore			0.2	210	0.1	180	-0.3	-								
1 ft offshore			0.6	210	1.1	150	1.3	210								
2 ft offshore			0.8	180	2.8	180	1.8	180								
3 ft offshore			1.1	180	2.6	180	2.2	210					0.1	210		

Figure 6.2. Flow field velocities and directions at intake structures: Structure 2, December 12, 1979.
(Velocity = feet/second; Direction = degrees; Upstream end of structure = 0°)

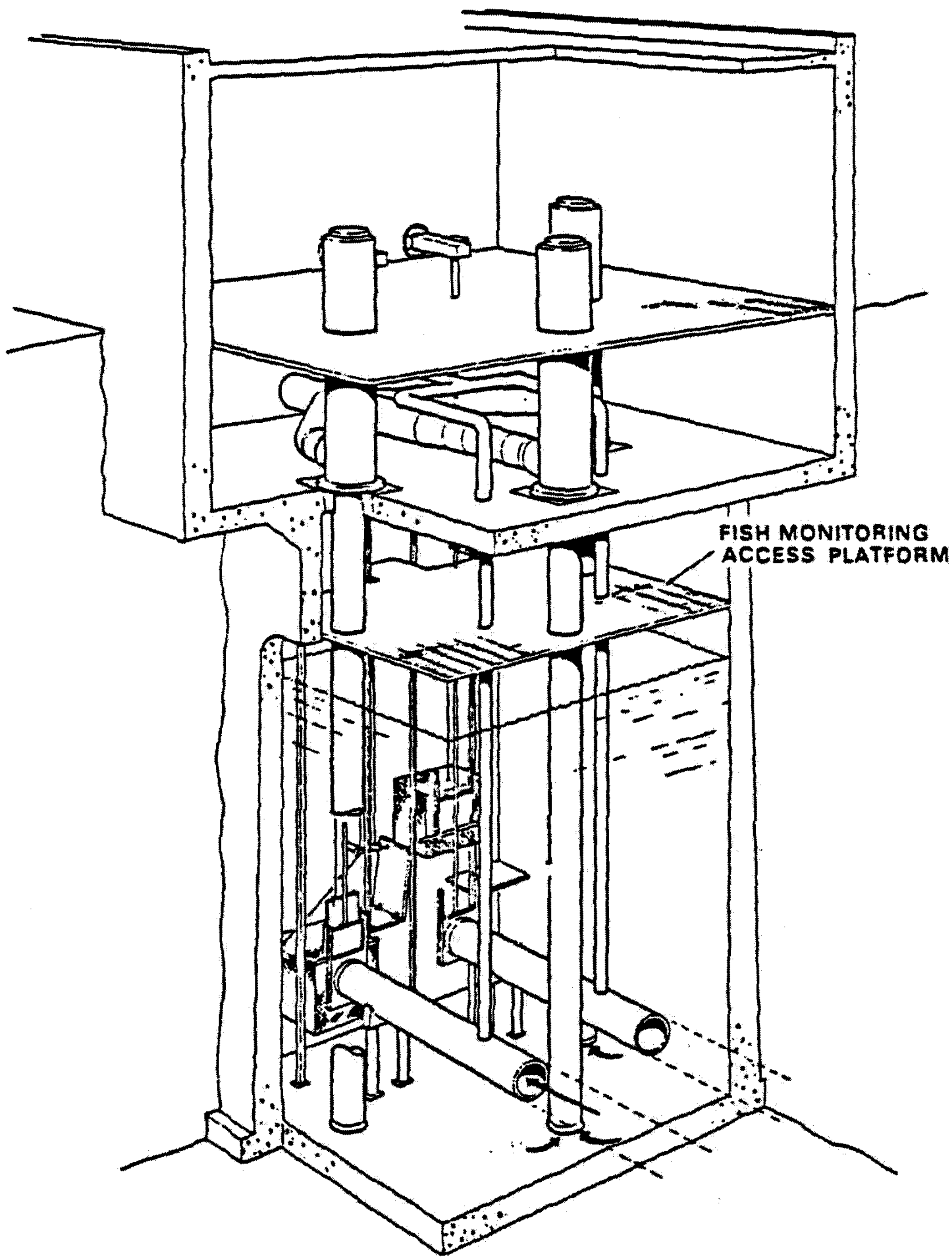


Figure 6.3. WNP-2 make-up water pumphouse fish monitoring facilities (from WPPSS 1978).

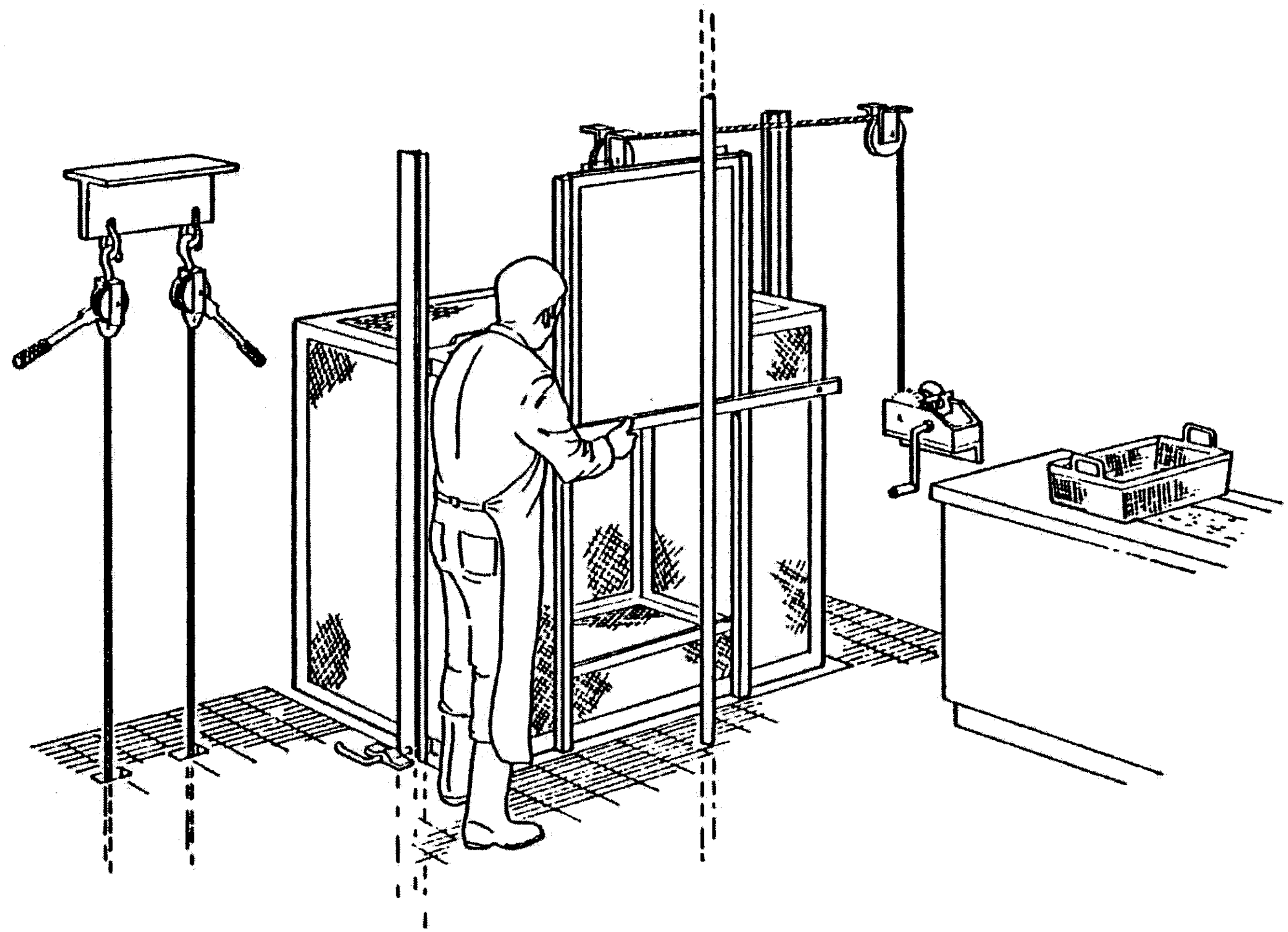


Figure 6.4. Entrainment sampling cage in the raised position (from WPPSS 1978).

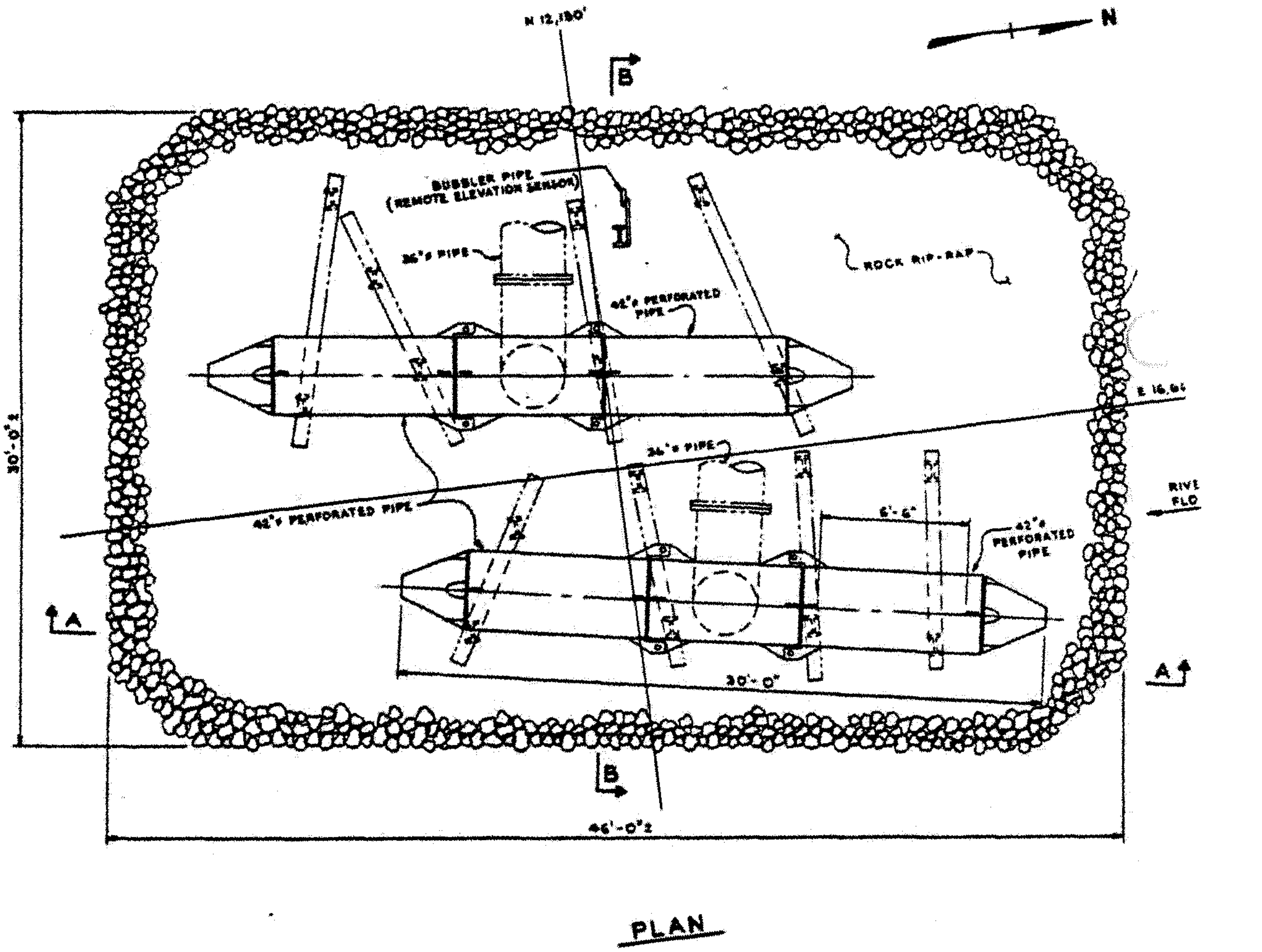
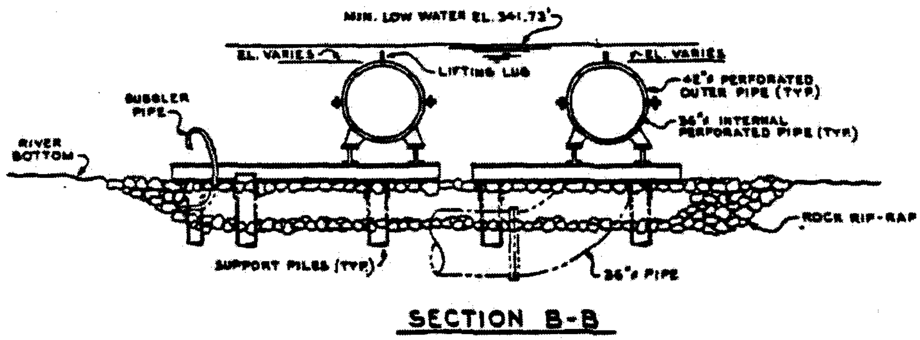


Figure 6.5. Perforated intake plan (from WNP-2 Environmental Report WPPSS 1978).



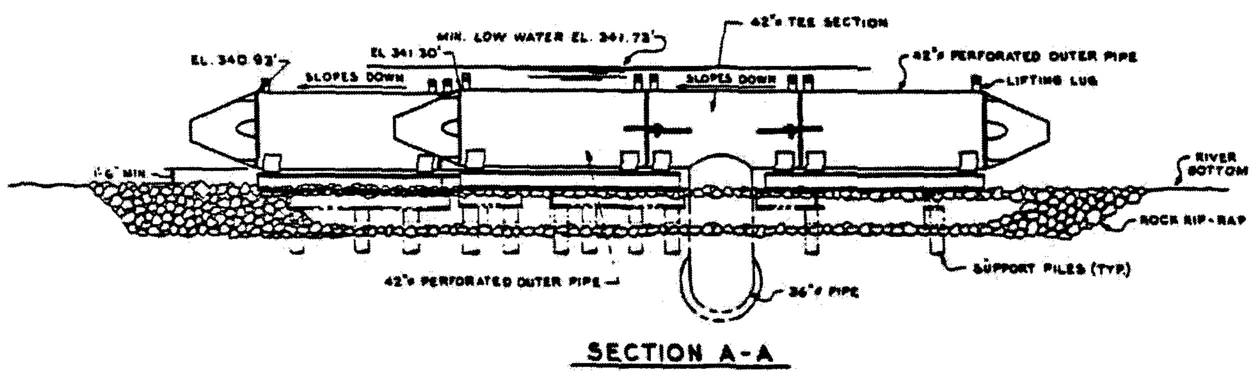


Figure 6.6. Perforated intake sections (from WNP-2 Environmental Report WPPSS 1978).

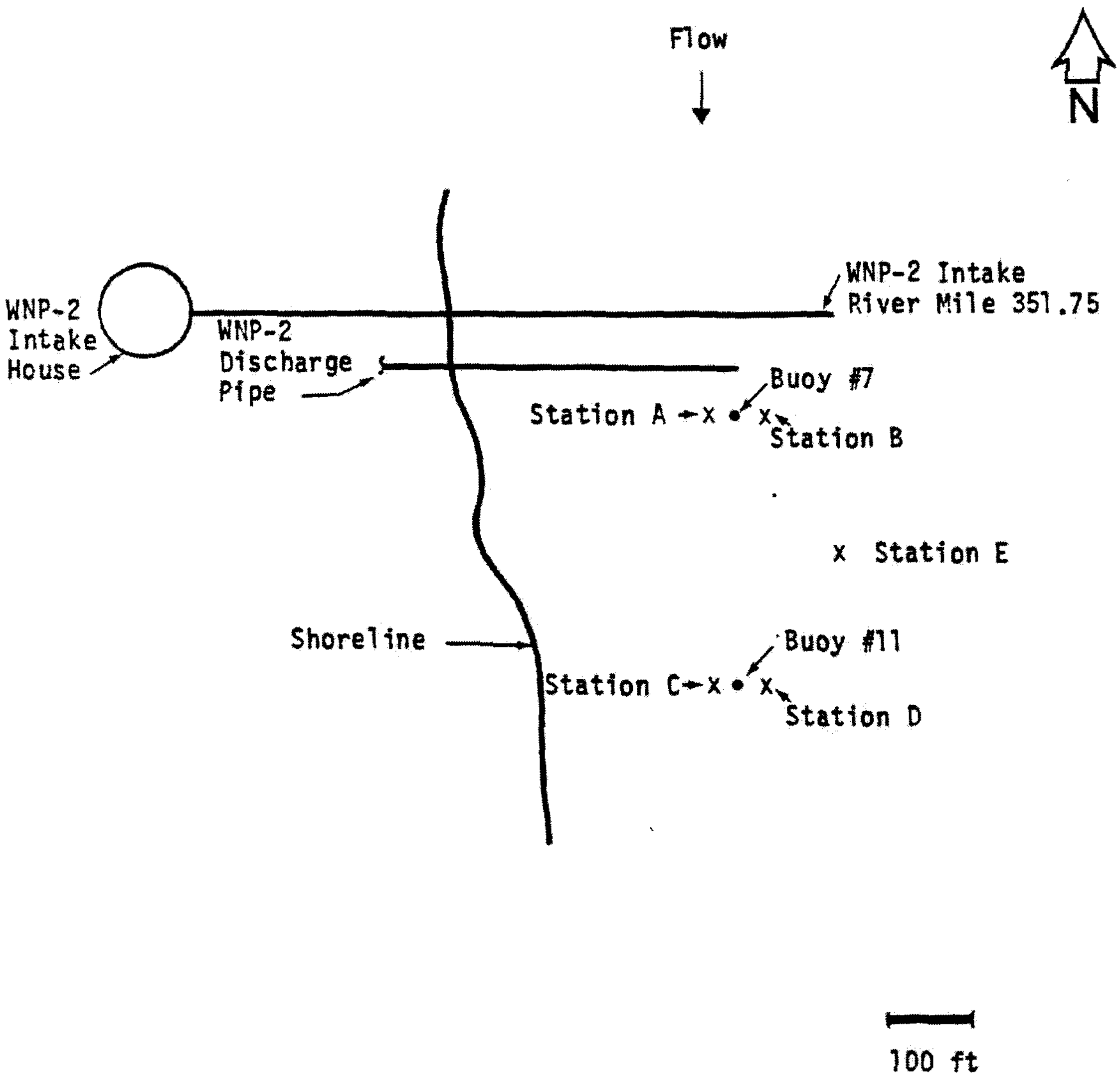


Figure 6.7. Locations of sampling stations for velocity measurements in the Columbia River near the WNP-2 discharge, December 12, 1978.

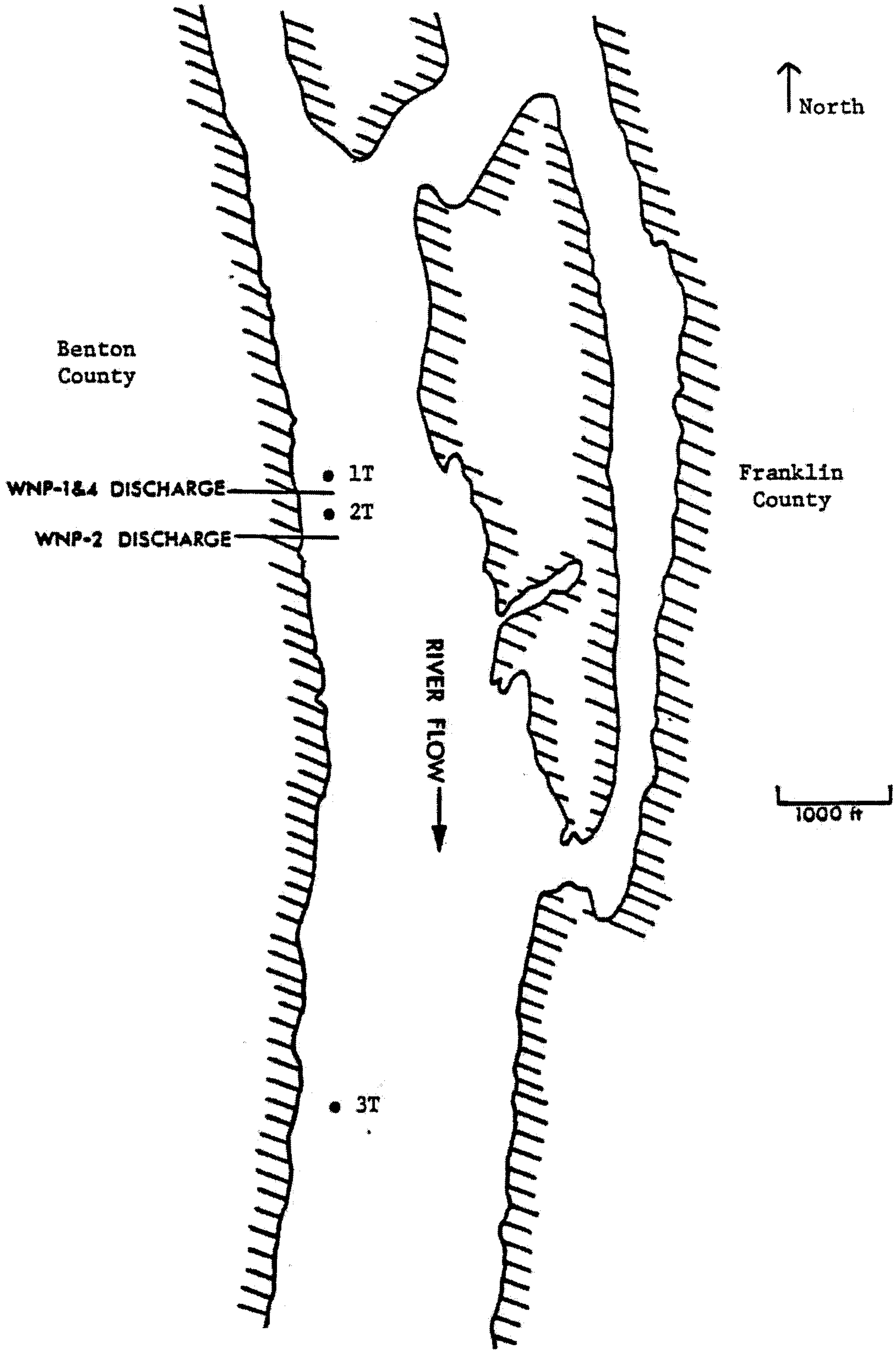


Figure 6.8. Turbidity and suspended solids sample station locations.

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