Completion Report

Monitoring Sediment Dredging and Overflow from Land Disposal Activities on Water Quality, Fish and Benthos in Lower Granite Reservoir, Washington

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Abstract

Sediment deposition in the upstream portion of Lower Granite Reservoir, Idaho-Washington, is threatening flood control and navigational uses of that system. Although numerous alternatives are being examined, sediment dredging is being considered as a management technique to alleviate sediment deposition. The inception of dredging in 1986 provided the opportunity to monitor effects of sediment dredging and overflow from land disposal ponds on selected water quality characteristics and fish and benthic community abundance. We also reviewed literature on effects of turbidity on aquatic systems.

Ten study stations were established; five associated with dredging and five with disposal. Stations ranged in location from ~~being~~ upstream of dredging and disposal to about 9.7 km downstream. All ten stations were sampled for benthos, whereas the two stations about 274 m downstream from the dredging and disposal stations were not sampled for fishes. For water quality sampling, we collected samples 100 m upstream, 90 and 425 m downstream from the immediate impact site.

Changes in selected water quality characteristics as a result of sediment dredging and disposal were minimal. Changes in temperature, dissolved oxygen and pH were slight 90 m downstream from the activity and undetectable at 425 m. Increases in turbidity and suspended solids were negligible downstream from the dredge. With the exception of a single peak of suspended solids (205 mg/l) and turbidity (82 NTU) in mid-February, overflow from land disposal had little effect on water quality 425 m downstream. Decreased depth of secchi disk readings reflected decreases in ambient water transparency with the onset of spring runoff.

The benthic community sampled by Ponar dredge at each of four sites at ten sampling stations exhibited low abundance of various taxons and was dominated by Oligochaetes and Dipterans (98.1 - 99.7%). Amphipods and molluscs were next highest in abundance although numbers were low compared to oligochaetes and dipterans. Variation in benthic abundance was high within a transect and among transects. Effects of dredging on benthos were measured at the dredge site and downstream at least 1.6 km. We did not observe any adverse effect of overflow from land disposal on the benthic community. Recovery of impacted benthic communities occurred by 6 months following dredging. Wide differences in benthic abundance were attributed to clumped distribution of organisms and differences in substrate characteristics.

The fish community at dredge and disposal stations was dominated by salmonid, cyprinid and catostomid fishes. Twenty species were collected from stations associated with dredging and 15 species from the disposal stations. A total of 2378 fish were collected. Relative abundance of fishes varied throughout the sampling period (January - April, 1986), but did not appear to be related to dredging and disposal activities. Numerous chinook salmon were collected, while dredging was undertaken. Fish activity at all stations was low at the inception of dredging but increased substantially during and following the completion of dredging. Gamefish abundance at half the stations was highest after dredging activities were curtailed but highest at the other stations before and during dredging. However, fewer fishes were collected before and during dredging and disposal activities. Catch rates of resident fishes were variable and, those for juvenile salmonid fishes increased following completion of dredging and disposal activities. Catch rates of salmonid fishes were not

affected by dredging and disposal although elevated catch rates of nongame fishes suggest possible attraction. Fish biomass sampled was high at the dredging site and at the overflow throughout the dredging and disposal activities. Data on fishes do not suggest adverse affects to the fish community.

Food items varied widely in proportional abundance which probably reflects their availability as prey. Chinook salmon and rainbow trout fed predominantly on plecopterans, ephemeropterans, dipterans and trichopterans. Incidence of predation by northern squawfish was high as salmonids accounted for 80% of the wet weight of food items.

Our results suggest that sediment dredging and overflow from land disposal activities had minimal affect on water quality and benthic and fish communities in Lower Granite Reservoir. Increases in turbidity and suspended solids were localized and within the range that has occurred during runoff in the Snake River system.

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INTRODUCTION

Concern over the flood control capabilities of the Lower Granite project has stimulated much interest among resource managers. High deposition rates of sedimentation from upstream sources have threatened flood control and navigational uses of Lower Granite Reservoir. Predictions made by personnel of the U.S. Army Corps of Engineers, Walla Walla, Washington, suggest that within less than two decades the height of the Lewiston Levees may be inadequate to pass a standard project flood. A number of alternatives have been proposed although each alternative has the potential to reduce project benefits. One alternative to lessen continuous deposition of material in the upper end of Lower Granite Reservoir is to annually dredge and dispose about 800,000 cubic yards of sediment. This alternative is presently being considered as a management technique to alleviate sediment deposition. Fisheries resource managers, however, have expressed numerous concerns over the environmental aspects of this alternative.

In late winter of 1986, the first dredging was conducted with the objective of removing about 800,000 cubic yards of material from the area surrounding the Port of Clarkston. Dredging commenced about 15 January and continued until 15 March, 1986. Dredging was conducted mostly by a hopper dredge although a smaller cutterhead dredge was used in shallow waters. Upland disposal was employed using holding ponds with a single stand pipe outlet returning water to Lower Granite. If these removal methods were to be conducted regularly, managers wanted to assess the possible impacts of the dredging and land disposal and overflow methods on the aquatic environment. The presence and operations of the dredge provided an ideal opportunity to evaluate effects of dredging on Lower Granite Reservoir. As a result, this study was initiated to monitor various aspects of the dredging and overflow from land disposal operations on selected water quality characteristics and benthic and fish communities.

OBJECTIVES

1) To collect, analyze and interpret water quality conditions at dredge and disposal sites.

2) To assess the effects of dredging and the resultant turbidity plume on benthos in Lower Granite Reservoir.

3) To assess the effects of dredging and the resultant turbidity plume on fishes in Lower Granite Reservoir.

4) To develop a comprehensive literature review on the effects of turbidity from dredging and disposal on aquatic biota.

STUDY AREA

The study area extended from above the confluence of the Snake and Clearwater rivers (about Mile 139.2) to approximately 29.3 km (12 miles) downstream from the confluence (Fig. 1). Ten stations were established for benthic sampling (C1 - C5 and W1 - W5) and eight for fish sampling (C1, C2, C4, C5 and W1, W2, W4, and W5). Station selection was based on sampling benthos above the dredging (C5) and disposal (W5) sites; we used these sites as examples of areas receiving no impacts from dredging and disposal. Station C4 was located in the dredging zone, whereas W4 was located at the overflow from the disposal ponds. Thus, stations C4 and W4 were located in the highest impact zone. To assess potential immediate downstream effects of dredging and disposal, we established stations C3 and W3 approximately 274 m (300 yards) downstream from the dredging site (C4) and the overflow (W4). The actual location of the station was measured downstream in a linear distance from the downstream limit of dredging activities for C3 and measured from the effluent for W3. Four additional stations were established to assess possible effects further downstream from the dredging and disposal sites. Two were approximately 1.6 km (1 miles) below the downstream limit of the dredging (C2) and effluent (W2), whereas the remaining two were about 8-9.7 km (5-6 miles) downstream (C1 and W1, respectively). The actual location of these stations was determined on maps and then transferred to field locations. Shoreline markers were used (painted stakes, boulders, etc.) to insure sampling at precise station locations.

Objective 1:

To collect, analyze and interpret water quality conditions at dredge and disposal sites.

METHODS

We measured water temperature, dissolved oxygen, water transparency, and total suspended solids at dredge and disposal sites. Water temperature (C) and dissolved oxygen (mg/l) concentrations were measured immediately below the surface, mid-water and at the bottom with a Yellow Springs Model 57 dissolved oxygen meter. Water transparency was measured to the nearest 0.1 m using a standard 20 cm secchi disk. Water samples for turbidity and total suspended solids were collected in 1 liter plastic bottles and transported to the University of Idaho water quality laboratory. Turbidity analysis was measured to the nearest 0.10 nephelometric turbidity unit (NTU) using a Hach turbidimeter. Total suspended solids (mg/l) were measured by filtration using a weighed standard glass-fiber filter dried to a constant weight at 103-105 C (APHA 1985). The increase in weight of the filter represented the total suspended solids.

RESULTS

Temperature

Water temperatures among dredging and disposal stations generally were similar (Appendix Table A-1). Temperatures from mid-January through mid-February changed little but nearly doubled from the third to fourth week in February. Although water temperatures generally were similar between dredging and disposal stations within a day, slight temperature differences (2C) in March were observed at the disposal stations. However, dredging and disposal had no significant affect on water temperatures.

Dissolved Oxygen

Dissolved oxygen concentrations ranged from 10.6 to 13.4 mg/l at the bottom to 10.8 to 13.9 mg/l at the surface (Fig. 2; Appendix Table A-2). Range of dissolved oxygen at mid-level was similar to surface concentrations. No differences in dissolved oxygen levels were found among dredging and disposal stations 100 m upstream compared with that of 90 m and 425 m downstream.

pH

Like dissolved oxygen, pH was relatively homogeneous throughout the monitoring (Fig. 3). pH at the bottom ranged from 7.67 to 8.34, while at the surface ranged from 7.6 to 8.33. Mid-level pH was similar (Appendix Table A-3). No consistent changes in pH were observed by depth or station.

Turbidity

Turbidity varied little with depth and time (Fig. 4). Highest turbidity was 82 NTU, 90 m downstream from the discharge as compared to 20 NTU 100 m upstream from the effluent. This significant increase in turbidity was the only peak observed throughout the monitoring. Few other differences were as different between upstream and downstream readings (Appendix Table A-4). For example, at dredge monitoring stations, turbidity was often lower 90 m downstream from that 100 m upstream from the dredge. The effluent from the disposal ponds was variable in the increase in turbidity ranging from 3-5 NTU's to 50-60 NTU's. Turbidity from the effluent after mid-February increased substantially from that observed from mid-January to mid-February. In general, turbidity was slightly higher 425 m downstream from that 100 m upstream.

Turbidity measured at fish sampling stations showed a gradual decrease in turbidity after early February (Fig. 5). Highest turbidity levels (<10 NTU) were measured at dredge stations C1 and C2; unfortunately, no samples were collected at a similar time at either C5 or C4. Turbidities were generally higher further downstream of the dredging (C2, C1) and disposal activities (W2, W1) than at the locations of maximum disturbance (C4, W4). Dredging and disposal increased turbidities about 2-4 NTU's above background levels (Fig. 5).

Suspended Solids

Suspended solids were considerably higher in the reservoir as a result of disposal than from dredging (Fig. 6). Highest levels of suspended solids were measured at mid-level and bottom from dredging and disposal activities. Suspended solids 90 m downstream from the dredge were elevated about 50 mg/l higher than 100 m upstream from the dredge. Highest solid levels were 205 mg/l 90 m below the effluent from the disposal ponds. This peak in suspended solids coincided with the peak in turbidity. On that date, suspended solids were about three times higher than ambient 425 m downstream but less than 70 mg/l (Appendix Table A-5). Suspended solids were linearly ($r^2 = 0.803$; $n = 96$) related to turbidity: $ss = -5.302 + 2.189\ turb$ where ss = suspended solids concentrations (mg/l) and turb = turbidity (NTU).

Secchi Disk

Secchi disk readings were highest 100 m upstream of dredging and disposal activities, lowest 90 m downstream and near ambient 425 m downstream (Fig. 7). Secchi levels were higher at dredge stations than those at disposal stations. Secchi readings generally decreased from highest in January to lowest in March as a result of increased ambient turbidities (Appendix Table A-1).

Objective 2:

To assess the effects of dredging and the resultant turbidity plume on benthics in Lower Granite Reservoir.

Four replicate benthic samples (total of five samples) were collected at each of four sites along a station transect using a Ponar dredge (239.25 cm^2). We sampled each of the ten stations during (February), 1 month (April), 3 months (June) and 6 months (September) following the completion of dredging and discharge from the disposal pond. For sampling site location, we divided the reservoir width into four equidistant sampling sites along each of the ten transects. Some sites were located within the original river channel. Because of the nature of the substrate in the river channel, we were unable to collect the five samples per site. If we could not collect a sample in five dredge attempts, we moved slightly and tried another five samples. If the second five samples were not successful, we went to the next sampling site. Therefore, a maximum of ten samples were attempted at any one site. Samples were strained through a U.S. Standard No. 30 sieve (0.595 mm openings), preserved in FAA and later identified to the lowest possible taxon.

Mean density of benthic organisms per site was calculated using four replicates. We took four replicates (total of five samples) at each site to allow for a two-fold statistical analysis. We used a factorial arrangement of a randomized complete block design.

1) to compare densities and species diversity channel-wide or comparisons within a station, and
2) to compare densities and species diversity reservoir-wide or comparisons among stations.

Estimates of abundance were expanded for an area of 1 m^2.

Results

Numerous taxa were collected in dredge and disposal stations in Lower Granite Reservoir (Tables 1-10). Dipterans and Oligochaetes were the most abundant organisms (98.1 - 99.7%) collected. Amphipods and molluscs were next highest in abundance.

Oligochaetes and dipterans accounted for a majority of the benthos during (February) and following (April, June and September) dredging and disposal operations. We found wide variation in abundance across each of the transects (Figs. 8-11). Oligochaetes were most abundant at all stations in February, of lesser abundance in April and June and increased in September. Oligochaete abundance at the dredge site, C4, was consistently low but demonstrated an increase in September. The effect of dredging was observed at station C4 in February (sampling was conducted late January and early February) and dredge stations C3 and C2 in April and June (Fig. 8). Oligochaetes were consistently more abundant at disposal stations than dredge stations. W4, the station immediately downstream of the effluent from the disposal pond, manifested Oligochaete abundance comparable to that of other stations within any of the sampling times. Dipteran abundance varied between dredge and disposal stations. For example, abundance was generally highest in September at dredge stations while highest abundance at disposal stations was measured in April. The change in abundance was the result of dredging activities. With the exception of dredge station C1, dipterans were low in abundance in April and June but increased at all stations in September. Dredging decreased abundance at sites A, B and C at stations C2, C3 and C4 (Fig. 10), whereas numbers were consistently low at site D in the original river channel. Recovery of dipterans appeared nearly complete by September, approximately 6 months following completion of dredging. Although dipteran density was lower at disposal stations, we did not observe any effect of disposal on dipteran abundance. High abundance at sites A and B at W4, immediately downstream from the effluent, in April support our interpretation. Benthic abundance at station C5, upstream from the dredging activities was generally low because of substrate characteristics and sampling difficulties. Substrate consisted of material larger than the Ponar dredge could effectively sample which accounts for the apparent low abundance of benthos (Figs. 8 and 10; Table 5).

Objective 3:

To assess the effects of dredging and the resultant turbidity plume on fishes in Lower Granite Reservoir.

METHODS

Fish were sampled at each of eight stations with horizontal gill nets and beach seine. Sampling was conducted prior to, during and one month following dredging and disposal activities. A total of three standardized seine hauls were taken along the shoreline at each of eight stations. As a result, 96 seine hauls were taken in this study. Beach seining was conducted using a 30.5 x 2.4 m seine constructed of 6.35 mm knotless nylon mesh with a 2.4 x 2.4 x 2.4 m bag. A standard seine haul was made by setting the seine parallel to the shoreline using 15 m extension ropes tied to the brails. Following positioning, the seine was rapidly drawn-in and fish removed.

Four horizontal gill nets were set perpendicular to the shoreline. Horizontal gill nets were either multifilament or monofilament material, 61 m long x 1.8 m deep, having 8 panels each 7.6 m long, at 1.25 cm, 2.54 cm, 3.81 cm, 5.08 cm, 6.35 cm, 7.62 cm, 8.89 cm, and 10.16 cm bar measurement. Two of the nets were floating sets and two were contour sets. Floating sets were checked approximately at hourly intervals over about a 7-8 hour period, while contour sets were checked every 2 hours. We used short term effort to preclude net mortality of anadromous fishes. Because of the added effectiveness, only night sets were made in this study.

Fish collected by seining and gill netting were identified to species and total lengths (mm) were taken (except anadromous adults). All adult anadromous salmonids were released immediately and never removed from the water. Total weights were calculated from weight - length relationships determined for fishes in Lower Granite Reservoir from an earlier study (Bennett and Shrier 1986). All anadromous salmonid smolts, smallmouth bass (> 200 mm), largemouth bass, crappies and yellow perch were anesthetized with tricaine methylsulfonate (MS-222) and their stomach contents sampled by lavage technique (Bennett and Shrier 1986). Contents of northern squawfish stomachs were determined by dissection as the lavage method was not effective in providing a representative dietary sample. Our lavage sampling technique consisted of a boat bilge pump (750 gph) connected to a pistol type garden hose shut-off that was attached to a modified flexible copper tube (1/4"). The tube was inserted into the stomach of the fish, via the esophagus, and stomach contents flushed into a bucket. Contents were strained through plankton netting (80 micron) and preserved in formalin-aceto-alcohol (FAA) (Pennak 1978).

Stomach contents of fish were identified with dissecting and compound microscopes. Aquatic organisms were identified to the lowest possible taxon, whereas terrestrial organisms were identified to order. Weights and numbers of unidentifiable insect parts were categorized under miscellaneous insects and arbitrarily assigned a numeric value. Digestion of various body parts often precluded species identification and, as a result, ingested food items were placed in the appropriate miscellaneous category (fish, insects, etc.).

Wet weights were measured on individual food items. Wet weights were measured by blotting each organism on a paper towel before weighing.

Weights for unidentifiable insect parts (miscellaneous insect category) were determined by averaging all insect weights per organism and dividing by eight (average number of insect body parts). Small organisms were counted and weighed as a taxonomic group. An average weight for an individual organism in each taxon was then computed. Mean weights were used to compute total weights of smaller organisms.

We compared fish numbers at each station. We also computed a species diversity index for each site using Brillouin's index (Brillouin 1962) and evenness.

RESULTS

Overall Fish Abundance

We collected individuals of 20 species from dredging stations and 15 species from disposal stations representing 1154 and 1224 fishes, respectively (Tables 11 and 12). Chinook salmon, redside shiners, chiselmouth and largescale suckers were the more abundant fishes at dredging stations (Fig. 12). In addition to these fishes, northern squawfish also were abundant at disposal stations (Fig. 13). Less abundant but about equally represented at dredging stations was the rainbow (steelhead) trout. Number of fishes collected at each station varied considerably among stations. The highest number of fish was collected at station C1, whereas the highest number of fish collected at a disposal station was at W4 (Tables 11 and 12). The lowest number of fishes were collected at dredging station C5, the station upstream from dredging activities. In comparison at the overflow stations, the second highest number of fishes was collected upstream from the overflow (W5), whereas the lowest number was collected at W2.

In general, sizes of fish collected at the various stations varied considerably (Figs. 14 and 15). The stations with the wider range in lengths were W4 and W5 at the disposal stations. Length distributions at the dredging stations generally were similar with a wide range of lengths represented.

Species diversity indexes were highest at station C1, while diversity at the remaining stations was similar (Fig. 16). Lowest diversity in fishes was found at overflow station W2. Evenness varied little among stations but was higher at overflow stations W5 and W2 (Fig. 17). Evenness was lowest at the dredge site and similar at other stations.

The proportion of salmonid fishes was higher at stations C1, C4, and W5 (Fig. 18). Lowest number of salmonids were collected at station W4. Of the salmonid fishes collected, chinook salmon was the most commonly represented species. Nearly 30% (n = 539) of all fishes collected (n = 2308) were chinook salmon.

The biomass of fish flesh sampled varied considerably among stations (Fig. 19). Higher biomasses were collected at stations C4 and W5. Gamefish biomass was low at all stations. The highest biomass of gamefish sampled was at station C1.

Dredging and Disposal Effects

Relative abundance of fishes varied among times but did not appear to be affected by dredging activities (Fig. 20). Two to three species generally were highly abundant at each of the stations before dredging activities. Species in abundance varied among stations and few trends were observed. For example, at station C1, bridgelip sucker was the most abundant, while at C2, rainbow trout was the most abundant. Northern squawfish was probably the most commonly collected species before dredging activities at stations C1-C5. During dredging at these stations, largescale sucker predominated at C1 and C4, while chinook salmon and mountain whitefish were abundant at C5. After dredging, chinook salmon and chiselmouth were more abundant.

Relative abundance at disposal stations also varied with time of year but did not appear related to disposal activities (Fig. 21). Before discharge, samples were only collected at stations W4 and W5; results showed an abundance of largescale suckers (W4 and W5) and peamouth (only W5). Collections during disposal, demonstrated differences in species among stations with largescale suckers, chiselmouths and redside shiners being more abundant. After dredging, chinook salmon were abundant with chiselmouth, largescale suckers and redside shiners. In general, salmonid fishes were more abundant following completion of dredging and disposal activities (Figs. 20 and 21).

Another measure of fish abundance at the various stations before, during and after dredging and disposal was the biomass of fish flesh sampled. Biomass sampled at dredging and disposal stations was consistently low among the four stations before dredging activities (Figs. 22 and 23). Only at station W4 was a significant amount of fish flesh sampled before dredging and disposal activities commenced. In general, biomass sampled increased during dredging and disposal which probably reflects an increase in fish activity not associated with dredging and disposal but associated with the advent of increased photoperiods and temperatures. Stations C5 and W2 consistently manifested low levels of fish biomass before and during dredging and disposal activities. After dredging and disposal activities were curtailed, more fish biomass was sampled at all stations than during previous periods. Biomass sampled at W2 and C2 was consistently low during all sampling periods which probably reflects habitat quality and/or sampling ineffectiveness.

Catch efficiencies of fishes were variable throughout the study (Appendix Tables B-1 - B-9). Catch rates of juvenile anadromous salmonid fishes increased significantly following completion of dredging and disposal activities.

Gamefish Abundance

Gamefish abundance was generally highest after dredging activities were curtailed and lowest before these activities (Fig. 24). Stations C2, C5, W1 and W4 were exceptions as the proportion of gamefish was higher at C2 and W4 before dredging and disposal and C5 and W1 during dredging activities. However, fewer fishes were collected before and during dredging and disposal activities as often less than 25 fish were collected.

Food Habits

Salmonid Fishes

Food habits of chinook salmon and rainbow trout demonstrated wide variation in diet among sampling areas and times. Because small numbers of these fishes were collected, we pooled all of the samples into pre and post dredging and disposal sites (Figs. 25 and 26). Chinook salmon fed predominantly on plecopterans, ephemeropterans, dipterans and trichopterans although the proportion of these items varied between during dredging and disposal and post dredging and disposal times and locations. These same food items were abundant in rainbow trout stomachs and similar variations were found as in chinook salmon. Also, two rainbow trout contained miscellaneous fishes in their diet.

Salmonid Predation

The incidence of predation was high in northern squawfish following disposal. Salmonids accounted for more than 80% of the wet weight of food items and miscellaneous fishes accounted for an additional 10% of the weight (Fig. 27). Only two squawfish were captured during dredging that contained food items. One contained terrestrial insects, whereas the other contained miscellaneous fish flesh.

One smallmouth bass was captured following dredging and disposal. Crayfish predominated (93.8%) followed by miscellaneous insects (6.15%). No smolts were found in the bass stomach.

Objective 4:

To develop a comprehensive literature review on the effects of turbidity from dredging and disposal on aquatic biota.

LITERATURE REVIEW

We examined published and unpublished literature on the effects of turbidity on biota. Special emphasis was placed on the effects of turbidity on fishes. Because of the limited information on turbidity generated from dredging and disposal on aquatic organisms, we reviewed all germane literature.

Turbidity is a commonly estimated water quality parameter in aquatic environmental assessments. A number of different measures have been used in the field and laboratory, some are related, others are not. For example, field biologists commonly measure transparency, using a secchi disk, as an index of turbidity or an approximation. The standard measure of turbidity, however, has been the candle turbidimeter (Stern and Stickle 1978) although this method has limitations over certain colored particles. Recently, other methods have been used and these are usually separated into two categories: gravimetric and optical measuring devices. The nephelometer has been widely adopted as the preferred measurement of turbidity (APHA 1976). The nephelometer measures scattered light as compared to transmissometers which measure light extinction. Candle turbidimeters measure light extinction in Jackson Turbidity Units (JTU), nephelometers measure scattered light in Nephelometric Turbidity Units (NTU), whereas transmissometers measure percent transmittance. Although results of methods are not perfectly correlated, each of these methods has support within the scientific community (Stern and Stickle 1978).

Turbidity is an optical property of water. Although some people use turbidity and the suspended sediment concentration interchangeably, Duchrow and Everhart (1971) found a poor correlation between the two for all materials tested. Their conclusion was that turbidity may be a reliable parameter as an index of suspended sediment in an individual water system, only if the sediment source remains constant.

Turbidity and excessive concentrations of suspended materials can affect aquatic biota several ways. These effects have been placed into four general categories (EIFAC 1964):

a. Action directly on the organism which either would kill or reduce growth rate and resistance to disease;
b. Prevention of the successful development of eggs and/or larvae;
c. Modification of natural movements and migrations;
d. Reduction in the abundance of available food.

Food Supply

Primary Producers

Phytoplankton and aquatic plants are primary producers in aquatic systems. The source of energy for photosynthesis is solar radiation. The quality, intensity and duration of light influence photosynthetic rates in aquatic plants. Therefore, any factor that limits light penetration in the water has the potential to affect primary production. Brylinsky and Mann (1973) reported that variables related to solar energy had a greater influence on production in waters from the tropics to the arctic than variables related to nutrient concentration. Turbidity can ostensibly influence solar energy input into aquatic systems.

In western Lake Erie, vernal pulses in phytoplankton were associated with variations in turbidity (Chandler and Weeks 1945). Although Verduin (1951) found phytoplankton biomass increased slowly in clearer and turbid areas of Lake Erie, diatom densities in turbid areas were less than 20% of those in clear waters. Turbidity in the lower Missouri River, often in excess of 300 PPM, resulted in low numbers of phytoplankton (Berner 1951).

Aquatic plants also can be limited by turbidity. Goldman and Wetzel (1963) reported restricted macrophyte development in Clear Lake, California. They found that primary production was almost exclusively limited to phytoplankton and bacteria because of turbidity.

Primary Consumers

Turbidity and suspended solids concentrations can adversely affect feeding and production of zooplankton. Sherk et al. (1976) reported that ingestion rates for Eurytemora affinis, a copepod, were significantly reduced at solids concentrations in excess of 250 mg/l; reductions in feeding were found at concentrations above 50 mg/l. The authors concluded that suspended solids would interfere with zooplankton feeding and ultimately affect the food chain. Paffenhafer (1972) found that a marine planktonic copepod's, Calanus helgolandius, ability to molt from larval to adult stages was reduced by concentrations of 10 mg/l "red mud". Also, ovarian development was absent in females and growth was adversely affected. However, Gregg and Bergersen (1980) reported that turbidities as high as 1558 had no adverse effect on survival of Mysis relicta although the effects of turbulence significantly affected survival.

Community Response

In the mid 1940's, fisheries in the Great Lakes were declining. Some people attributed that decline to increased agricultural activities in the watershed and increased turbidities in the lakes, especially in Lake Erie. Van Oosten (1945) could not attribute any general decline in the fishery to increased turbidities. His literature review concluded that: 1) clearwater forms live and thrive in muddy streams when turbidities range to 400 PPM; 2) fishes can move without injury through waters with high suspended levels; 3) fish production in ponds is not adversely affected by average turbidities of 100 PPM; and, 4) turbidity may favor survival of young fish as they may be protected from predators.

General Ecology

The physical condition of larval shad (Dorosoma sp.) was found to deteriorate with increased turbidities as a result of floods in 1981 and 1982. Secchi disk readings declined from 120 cm to 8-20 cm resulting in low zooplankton abundance (< 40/liter) and signs of cell and tissue atrophy and deterioration. In contrast, larval Pacific herring, Clupea harengus pallasi, were found to have higher feeding incidents and activity at moderate turbidities (500 and 1000 mg/l) (Boehlert and Morgan 1985). Boehlert and Morgan believed that particulates may enhance the visual contrast allowing herring larvae to better visualize their prey and/or that turbidities may cause decreased transparency of food (rotifers) items. Their findings for larvae are in contrast to those of Gardner (1981) who reported that increased turbidity resulted in decreased feeding rates in juvenile bluegill, Lepomis macrochirus. Feeding rates were about 50% at 190 NTU's as compared to those at 0 NTU's. Gardner (1981) did find, however, that size selectivity was independent of turbidity level. The probable reason for reduced feeding rates in bluegill was reduced prey availability. For example, Vinyard and O'Brien (1976) found that increased turbidity caused substantial reductions in reactive distances to prey items for all sizes of prey. The net effect of increased turbidity would be a decrease in food consumption and possible decreased growth and abundance. Sigler et al. (1984) found that at about 80 NTU's, densities and growth of steelhead trout and coho salmon juveniles were reduced as compared to those in clear water. In general, more fish stayed in test channels with clear water than those with turbid water and weight and length of steelhead and coho salmon increased faster. Feeding distances of coho salmon were reduced by turbidities of 60, 30 and 20 NTU's and a significant reduction in the percent of prey captured by dominant individuals (Berg and Northcote 1985). Ingestion rates of coho decreased below 50% at 60 and 30 NTU's but at 20 NTU's feeding was slightly affected. As important as feeding, Berg and Northcote (1985) found social behavior of coho salmon to be altered. Pulses of turbidity of 30 and 60 NTU's altered dominance hierarchies and territorial behavior and affected the holding position of some fish. Berg and Northcote concluded that the fitness of juvenile fish frequently subjected to sedimentation pulses may be impaired. In contrast, Gradall and Swenson (1982) reported that turbidities of 7.1-61.1 FTU did not alter the distribution of brook trout, Salvelinus fontinalis. However, at a mean turbidity of 7.1 FTU, brook trout used overhead cover less and spent less time associating with the bottom.

Suspended sediments at high concentrations can have adverse affects on incubating embryos and larvae. High concentrations of suspended sediments had little effect on either white perch or striped bass eggs and larvae (Morgan et al. 1983). Hatching delays for striped bass occurred at 2000 mg/l, while delays for white perch occurred at 5250 mg/l. Exposures of larvae to 1626-5380 mg/l for 24 hours resulted in 15-19% mortality for white perch. Striped bass larval mortality was higher (20-31%) at concentration of 1557-5210 mg/l.

Physiological Responses

Neumann et al. (1975) examined the effects of natural sediment suspensions on respiratory and hematological responses of toadfish. Toadfish held in 14.6 g/liter suspended solids for 72 hours manifested no significant difference in microhematocrit, hemoglobin, erythrocyte count and bloodosmolal concentration as compared to controls.

Horkel and Pearson (1976) found that green sunfish exposed to turbidities of 2359-3750 FTU's at 15C more than doubled their ventilation rates although by the third day ventilation rates returned to pretreatment levels. Oxygen consumption rates did not change. Their study showed rapid acclimation or physiological adjustment with continued exposures to turbid conditions.

GENERAL DISCUSSION

Water Quality

Our water quality data indicate that little water quality change occurred as a result of dredging and overflow from land disposal. For example, water temperature, pH and dissolved oxygen were virtually unaffected by these activities as close as 90m downstream (Appendix Tables A-1, A-2, A-3 and Figs. 2 and 3). Reductions in dissolved oxygen were less than 1/2 mg/l and concentrations were well above 10 mg/l throughout the duration of dredging and disposal. Differences in pH were not consistent among stations but were less than 0.1 pH unit.

Localized water clarity, however, did decrease as a result of disposal activities but little change resulted from dredging. Turbidity increases from dredging were not measurable and often our readings 425 m downstream of the dredge were lower than 100 m upstream. While collecting our samples, we observed periodic increases in turbidity in shallow waters that appeared to be caused by prop wash along the substrate. At these times, however, there was a noticeable turbidity increase at the water surface. Also, our turbidity data indicates that little difference occurred within the water column. For example, intensive monitoring of hopper dredging operations have shown significant increases in turbidity at the bottom (Raymond 1984) which we did not observe. In contrast to dredging, disposal did result in localized increases in turbidity especially 90 m downstream from the effluent of the disposal ponds (Appendix Table A-4, Fig. 4). Elevated turbidities were measured at times 425 m downstream. In all cases, however, turbidity levels were within the range that can occur in the reservoir during runoff (U.S. Geological Survey 1974). On 19 February, 1986, a slug of turbid water entered the reservoir from the discharge ponds. Turbidity up to 82 NTU's was measured at this time; duration was short lived as our samples taken the following week indicated that levels had decreased to near ambient (Fig. 4).

The overall influence of dredging and disposal on turbidity in the reservoir can be seen from our turbidity measurements at the fish collecting stations (C1-C5, W1-W5) which were as much as 9.7 km downstream of the operations. These data suggested that turbidity increases were in the range of 2-4 NTU's from dredging and disposal (Fig. 5).

In Lower Granite Reservoir, suspended solids manifested similar trends as that with turbidity (Appendix Table A-5, Fig. 6). Highest levels of suspended solids also were observed on 19 February (205 mg/l). As with turbidity, data collected after 19 February, indicated that suspended solids decreased and were about at ambient levels 425 m downstream throughout the remaining period of disposal. Although 205 mg/l of suspended solids appears high relative to upstream levels, this concentration represents about 5% of that determined to be lethal to rainbow trout fingerlings when maintained at that concentration for 21 days (Peddicord and McFarland 1978). Also, and more importantly to the Lower Granite system, concentrations of suspended solids have exceeded 500 mg/l naturally in the Snake River during runoff (U. S. Geological Survey 1974) but typically range from 160-200 mg/l during "normal" runoff events. Therefore, even though a spike of 200 mg/l concentration of suspended solids resulted from the disposal, the ecological effects of these sediments were probably similar to what occurs in the Lower Granite Reservoir system during runoff.

The gradual increase in turbidity as a result of spring runoff is most obvious from secchi disk data (Fig. 7). After early to mid-February 1986, general water clarity decreased substantially. Secchi disk readings were about 1.5 - 2.0 m prior to that time but dropped to about 1/4 m after mid February which coincided with the increase in flows from spring runoff which occurred early in Lower Granite in 1986.

Benthic Abundance

The influence of dredging and disposal on benthic communities was assessed by intensive sampling at four sites across the reservoir. Although up to ten samples were attempted per site, we found wide variation in the density of benthos. Variation resulted from two principal sources: one was the clumped distribution of organisms and that some of the sampling was conducted in the old river channel. The old river channel in several locations had a bedrock bottom which precluded effective sampling by a dredge. As a result, we were not able to have complete data at several sites which affected our ability to effectively analyze the data (Figs. 8-11).

Overall abundance of benthos was definitely weighted towards oligochaetes and dipterans. Over 98% of all organisms collected at each of the ten stations were oligochaetes and dipterans. In general, dipteran abundance was higher at dredge stations, while oligochaetes were more abundant at disposal stations (Figs. 8-11). Abundance of dipterans was highest in April at disposal stations, whereas highest abundance at dredge stations occurred in September. Our data suggest that dredging activities resulted in low abundance of dipterans at stations C2, C3 and C4.

Recolonization occurred in the summer and by September, the area affected by the dredging had become well established by dipterans.

Density of dipterans in September 1986 exceeded those sampled at the same location in fall 1985 (Bennett and Shrier 1986). Leathem et al. (1973) reported rapid recovery of benthos in the Delaware Bay following dredging and disposal. Little physical change in the bottom occurred. Others, however, have reported drastic reductions in number of species, number of individuals and biomass in a dredged channel, with no recovery within 11 months after dredging (Kaplan et al. 1974). Epifauna and infauna were reduced within 500 m of the dredge channel. Kaplan et al. (1974) attributed changes in the benthic community to the changing physical habitat. Low dipteran abundance at station C5, upstream from the dredging activities, was a result of our sampling difficulties in the main with a Ponar dredge and not the result of adverse affects of dredging. Abundance of oligochaetes at dredging and disposal stations followed similar patterns in abundance. Abundance was higher in February and September and low in April and June at dredge stations. Abundance of Oligochaetes followed similar patterns as that of dipterans at dredge stations. Changes in abundance at other stations reflect "natural" changes in benthic abundance. We found similar changes in abundance of oligochaetes and dipterans in Lower Granite Reservoir in an earlier study (Bennett and Shrier 1986).

Fish Abundance

Our data suggest that dredging and disposal activities had no affect on changes in abundance of fishes. We cannot compare directly among sampling times without caution (before, during and after) because of the "natural" increase in fish activity with the advent of longer days and rising temperatures. Because of differences in fishing effort, comparison of abundance should only be compared by examining catch per unit effort data for each of the stations (Appendix Tables B-1 - B-9). These data demonstrate that c/f increased in anadromous salmonids from the initiation of dredging through completion. Catch rates for resident fishes were variable and also increased for most species before, during and after dredging. Catch rates for salmonid fishes at stations W4 and W5 and C4 and C5 were similar which indicates salmonids were neither attracted nor repelled from the dredging and disposal activities. However, high catch rates for abundant nongame species (largescale sucker, peamouth, northern squawfish, bridgelip sucker and redside shiner) at W4 during disposal suggests possible attraction to the waters at higher turbidity. Catch rates of largescale suckers and northern squawfish also were higher at C4 than C5. These data suggest that dredging and disposal activities had limited effect on fish abundance or species composition. Fish biomass also was high at disposal (Fig. 23) and dredge stations (Fig. 22) during dredging and disposal. About 4% of the fish biomass collected during disposal activities at W4 were gamefish (Fig. 24); 4% gamefish was low compared to that from other stations in Lower Granite Reservoir (Fig. 24).

The biomass of fish flesh sampled during dredging at station C4, the site of dredging activity, was high which suggests that fish abundance was not impacted by dredging activities (Fig. 22). Fish abundance at C4 was assessed only by seining. In contrast, low fish abundance at C5 also was related to sampling (Fig. 22). We could not fish gill nets during dredging at C4 as a result of the extremely high flows and velocities and high densities of algae that occurred during the latter part of the dredging period. Several nets were lost or destroyed by the algae and high flows.

When comparing relative abundance of various fishes and community composition at the various stations prior to, during and after dredging, it is important to note that numbers of fishes collected varied widely with time and station. Often, less than 25 fish were collected at some of the stations and comparing the abundance of 25 fish with that of several hundred, can lead to false conclusions. Our data does show, however, that major fishes collected during the recommended dredging winter window (Bennett and Shrier 1986) consisted of nongame cyprinid and catostomid fishes. Salmonids consisted mostly of chinook salmon especially in the latter part of February and March. The apparent abundance of juvenile chinook salmon may be a result of some early upstream hatchery releases and may not represent the "norm" for winter conditions in Lower Granite Reservoir. With only one year of data, however, interpretation must be made cautiously.

Food Habits

Our food habits data does show that food items are present in the stomachs of juvenile chinook salmon and rainbow trout in the winter (Figs 25 and 26). Too few fish were collected to compare the abundance of food items among stations although wide variation was present. For example, during dredging, chinook salmon fed on plecoptera and diptera, whereas after the completion of dredging, trichoptera and ephemeroptera were more abundant. Similar variation was found in chinook salmon during and after disposal operations (Fig. 25). Because low water temperatures during January and February decrease digestion rates, these food items could have been in their stomachs for several hours or several days.

Predation

The magnitude of predation by northern squawfish on salmonid juveniles was surprisingly high (Fig. 27). Examination of 24 northern squawfish that contained food revealed that more than 80% of their food items was that of salmonid fishes. Low water temperatures may reduce digestion rates and feeding activity but predation continues through the winter based on these results. The second highest food item from these squawfish stomachs was that of miscellaneous fishes. Many of these could have been salmonids but digestion could have precluded more definite identification.

Our results suggest that dredging and land disposal and the resultant overflow into Lower Granite Reservoir had minimal adverse affects on water quality and the fish community. Benthic abundance declined as much as 1.6 km downstream from the dredging operation but recovery occurred after 6 months. Decreased benthic abundance was probably a result of substrate and organism removal at the dredge station (C4) and by covering of substrate by moving sediments further downstream (stations C2 and C3).

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Table 1. Density (Nos./m²) of benthic organisms collected during 1986 at station C1 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda																
Annelida																
Oligochaeta	1881	2541	2065		828	385	543	1398	1246		25	219	953	1154	1248	736
Polychaeta												8				
Nerpis succinea																
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.						25	25	25								
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.						17										
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda																
Sphaeridae																
Corbiculidae																
Corbicula sp.		8														
Diptera																
Chironomidae					8			8					8			
Phoenopsectra sp.					8				8				8			
Microsectra sp.																
Dicrotendipes sp.					125	75	844	970								
Tanytarsus sp.							25									
Chironomus chironomus		268	8	50	8			8					234		8	84
Chironomus sp.														8		
Cryptochironomus sp.			17						8							
Polypedilum sp.									42					8	8	
Procladius sp.		134	8	8					8				125	8		25
Simulidae						8	8									

Table 2. Density (Nos./m²) of benthic organisms collected during 1986 at station C2 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda													8			17
Annelida																
Oligochaeta	3553	3987			1112	42	67		1096	410	17	8	1990	794	1546	6311
Polychaeta																
Nerpis succinea																
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.					8											
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda																
Sphaeridae																
Corbiculidae																
Corbicula sp.									8						84	8
Diptera																
Chironomidae												8				
Phaenopsectra sp.		25													8	
Microsectra sp.																
Dicrotendipes sp.					50											
Tanytarsus sp.													8			
Chircromus chironomus	217	150			8				8	8			1195		109	385
Chironomus sp.													125			8
Cryptochironomus sp.														8		
Polypedilum sp.									33	33			8			
Procladius sp.	42	8							8				359	17	67	410
Simulidae																

Table 3. Density (Nos./m²) of benthic organisms collected during 1986 at station C3 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda																
Annelida																
Oligochaeta	3028	1705	1237	21	58	8	63		84	109	8	8	2500	418	568	360
Polychaeta																
Nerpis succinea																
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.																
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.						8										
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.		8														
Odonata																
Gomphidae																
Pelecypoda																
Sphaeridae																
Corbiculidae																
Corbicula sp.								21		6						
Diptera																
Chironomidae															8	
Phoenopsectra sp.	8															
Microsectra sp.																
Dicrotendipes sp.					8											
Tanytarsus sp.	8	8														
Chironomus chironomus	142	17	33										1254	42	67	
Chironomus sp.													17			
Cryptochironomus sp.														8		
Polypedilum sp.											8					
Procladius sp.	17		8										17	33		
Simulidae																

Table 4. Density (Nos./m²) of benthic organisms collected during 1986 at station C4 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda													8		8	
Annelida																
Oligochaeta	8	42	31						8	8			686	1267	669	
Polychaeta																
Nerpis succinea																
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.					25											
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.					8											
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.					8											
Odonata																
Gomphidae																
Pelecypoda																
Sphaeridae																
Corbiculidae																
Corbicula sp.																
Diptera																
Chironomidae													8			
Phoenopsectra sp.														8		
Microsectra sp.																
Dicrotendipes sp.																
Tanytarsus sp.																
Chironomus chironomus	8	8											192	1321	92	
Chironomus sp.														17		
Cryptochironomus sp.							8									
Polypedilum sp.																
Procladius sp.													134	33		
Simulidae																

Table 5. Density (Nos./m²) of benthic organisms collected during 1986 at station C5 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda																
Annelida																
Oligochaeta	945	493	627	970			192					176	2182	42		
Polychaeta																
Nerpis succinea																
Hirudinea																
Pharyngobdeilida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.							8		8							
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.								112								
Odonata																
Gomphidae																
Pelecypoda																
Sphaeridae																
Corbiculidae																
Corbicula sp.																
Diptera																
Chironomidae												8				
Phaenopsectra sp.	42											17				
Microsectra sp.																
Dicrotendipes sp.							10									
Tanytarsus sp.				8												
Chironomus chironomus	33	58		410									176			
Chironomus sp.													17			
Cryptochironomus sp.				25												
Polypedilum sp.												17				
Procladius sp.				25									33			
Simulidae																

Table 6. Density (Nos./m²) of benthic organisms collected during 1986 at station W1 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda		25														
Annelida																
Oligochaeta	2458	8410	10725	6303			3369	978	2232		1438	953	805		2107	2023
Polychaeta																
Nerpis succinea											8		8			
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura					67											
Glossiphoniidae																
Helobdella sp.	25															
Crustacea																
Copepoda																
Lepidoptera		8														
Collembola																
Hydracarina		8														
Amphipoda											8					
Corophium sp.	8	8					8				8				176	8
Insecta																
Coleoptera							8									
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda		25	25													
Sphaeridae															17	
Corbiculidae																
Corbicula sp.															117	33
Diptera																
Chironomidae		25						8			8					
Phaenopsectra sp.		42		8			8	33								
Microsectra sp.							995	652								
Dicrotendipes sp.																
Tanytarsus sp.		33						8								
Chironomus chironomus	17	100	242	376			58	92	17							
Chironomus sp.																
Cryptochironomus sp.			8								8	25				
Polypedilum sp.								8	8			8			8	
Procladius sp.	33	209	58										52		8	25
Simulidae																

Table 7. Density (Nos./m²) of benthic organisms collected during 1986 at station W2 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda								17								
Annelida																
Oligochaeta			3152	4957	752	276	326	736			100	853	376	3570	1483	1521
Polychaeta																
Nerpis succinea											8					
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.														176		
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda			8												6	
Sphaeridae																
Corbiculidae																
Corbicula sp.																
Diptera																
Chironomidae												8				
Phoenopsectra sp.																
Microsectra sp.																
Dicrotendipes sp.					1379	92		42				8				17
Tanytarsus sp.																
Chironomus chironomus			8	58							8	8		50	42	309
Chironomus sp.																
Cryptochironomus sp.				25		8		33						17		
Polypedilum sp.														8		
Procladius sp.			42	176									8			58
Simulidae																

Table 8. Density (Nos./m²) of benthic organisms collected during 1986 at station W3 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda																
						8				8						
Annelida																
Oligochaeta																
Polychaeta	1976	7231	6637	4148		1154	217	167		25	50	266	1923	8	2100	259
Nerpis succinea																
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.																
										8						
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Plecoptera		8														
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda						8							8			
Sphaeridae																
Corbiculidae																
Corbicula sp.	12	17											8			
Diptera																
Chironomidae												8				
Phaenopsectra sp.			25			17										
Microsectra sp.			8													
Dicrotendipes sp.						226		33								
Tanytarsus sp.						8										
Chironomus chironomus		8	58	50	42		17								42	
Chironomus sp.												8				
Cryptochironomus sp.			8					8					8			
Polypedilum sp.																
Procladius sp.	33	50	33												42	
Simulidae																

Table 9. Density (Nos./m²) of benthic organisms collected during 1986 at station W4 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda							17		8							
Annelida																
Oligochaeta	1881	7440	5802	11782	1714	822	1045	209	2433	217	125	303	1956	3260	510	1756
Polychaeta																
Nerpis succinea												10				
Hirudinea	8															
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.									284							
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.										8						
Odonata																
Gomphidae		17														
Pelecypoda		17	25													
Sphaeridae		67														
Corbiculidae																
Corbicula sp.	8										10			109		
Diptera																
Chironomidae			8		8										8	
Phaenopsectra sp.		8	25													
Microsectra sp.																
Dicrotendipes sp.					1112	1324	17	63					8			
Tanytarsus sp.																
Chironomus chironomus	17	17	42	75	50		8		17					8	25	17
Chironomus sp.																
Cryptochironomus sp.		17			8	8	8		17				42	25		
Polypedilum sp.									284	33			8			
Procladius sp.	8	33	25	58	33								33	25	17	67
Simulidae																

Table 10. Density (Nos./m²) of benthic organisms collected during 1986 at station W5 in Lower Granite Reservoir, Washington. Sampling was conducted using a PONAR dredge at four sites per station (A-D) each equidistantly positioned across the channel. Densities are generally represented by a mean value based on five samples per site.

	February				April				June				September			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Nematoda																
Annelida																
Oligochaeta	284		2675	397	1087	426	146	136	1432	384	401	476	1923	5	2100	780
Polychaeta																
Nereis succinea									10	8		17				
Hirudinea																
Pharyngobdellida																
Erpobdellidae																
Nephelopsis obscura																
Glossiphoniidae																
Helobdella sp.																
Crustacea																
Copepoda																
Lepidoptera																
Collembola																
Hydracarina																
Amphipoda																
Corophium sp.						17										
Insecta																
Coleoptera																
Ephemeroptera																
Ephemerellidae																
Ephemerella sp.																
Heptageniidae																
Rhithrogena sp.																
Tricorythidae																
Tricorythodes sp.																
Trichoptera																
Hydropsychidae																
Hydropsche sp.																
Odonata																
Gomphidae																
Pelecypoda													8			
Sphaeridae	31															
Corbiculidae																
Corbicula sp.								10					8			
Diptera																
Chironomidae					25	8										
Phaenopsectra sp.			21	21					21							
Microsectra sp.																
Dicrotendipes sp.					476				10							
Tanytarsus sp.					8											
Chironomus chironomus	33		10		58										42	
Chironomus sp.																
Cryptochironomus sp.	17		10										8			
Polypedilum sp.																
Procladius sp.			52	21	33				52						42	
Simuliidae																

Table 11. Relative abundance of fishes sampled from stations potentially affected by hopper dredging activities in Lower Granite Reservoir, Idaho-Washington in 1986. Station C5 was located upstream from the dredging, C4 was at the dredging site and C1 (8.0 km) and C2 (1.6 km) were downstream.

Species	C1	C2	C3	C4
Pacific lamprey	1 (0.20)			
white sturgeon	2 (0.40)			
sockeye salmon	1 (0.20)	3 (1.37)	5 (1.96)	1 (0.57)
chinook salmon	182 (36.11)	54 (24.66)	96 (37.65)	49 (27.84)
mountain whitefish	8 (1.59)		6 (2.35)	5 (2.84)
rainbow trout	40 (7.94)	4 (1.83)	3 (1.18)	2 (1.14)
chiselmouth	25 (4.96)	69 (31.51)	40 (15.69)	49 (27.84)
carp	8 (1.59)	9 (4.11)	4 (1.57)	6 (3.41)
peamouth	45 (8.93)	3 (1.37)	1 (0.39)	
northern squawfish	32 (6.35)	4 (1.83)	24 (9.41)	11 (6.25)
redside shiner	74 (14.68)	57 (26.03)	2 (0.78)	22 (12.50)
bridgelip sucker	16 (3.08)	6 (2.74)	1 (0.39)	8 (4.55)
largescale sucker	62 (12.30)	10 (4.57)	68 (26.67)	22 (12.50)
brown bullhead	2 (0.40)			
channel catfish			1 (0.39)	
tadpole madtom	2 (0.40)			
pumpkinseed	1 (0.20)			
smallmouth bass	1 (0.20)		2 (0.78)	1 (0.57)
yellow perch	2 (0.40)			
sculpin			2 (0.78)	
Totals	504	219	255	176

Table 12. Relative abundance of fishes sampled from stations potentially affected by discharge from settling ponds in Lower Granite Reservoir, Idaho-Washington in 1986. Station W5 was located above the effluent, W4 was located at the effluent and W1 (9.7 km) and W2 (1.6 km) were downstream.

Species	W1	W2	W3	W4
white sturgeon	2 (1.74)			
sockeye salmon	3 (0.61)			
chinook salmon	29 (25.22)	6 (16.67)	31 (4.23)	92 (33.95)
mountain whitefish	1 (0.87)		1 (0.14)	20 (7.38)
rainbow trout	4 (3.48)	3 (8.33)	8 (1.09)	12 (4.43)
chiselmouth	27 (23.48)	4 (11.11)	12 (1.64)	8 (2.95)
carp			13 (1.78)	12 (4.43)
peamouth	1 (0.87)		269 (36.75)	6 (2.21)
northern squawfish	18 (15.65)	8 (22.22)	93 (12.70)	50 (18.45)
redside shiner	4 (3.48)	11 (30.56)	49 (6.69)	23 (8.49)
bridgelip sucker	8 (6.96)	3 (8.33)	55 (7.51)	6 (2.21)
largescale sucker	18 (15.65)	1 (2.78)	194 (26.50)	41 (15.13)
brown bullhead			1 (0.14)	
channel catfish			1 (0.14)	1 (0.37)
tadpole madtom				
pumpkinseed				
smallmouth bass			5 (0.68)	
yellow perch				
sculpin				
Totals	115	36	732	271

Appendix Table A-1. Secchi Disk (m) and water temperature (C) readings as a result of dredging (C100 - 100m upstream of dredge; C90 - 90m downstream of dredge, C425-425m downstream of dredge) and disposal (W100-100m upstream of discharge; W90-90m downstream of discharge, and W425-425m downstream of discharge) activities in Lower Granite Reservoir, Idaho.

SECCHI DISK

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23	1.9	1.9	1.6	1	0.35	1
30		0.45	0.85	1.2	0.7	1.2
Feb 6	1.3	0.6	0.9	0.8	0.3	0.55
13	2		1.3	0.3		
19	0.5			0.5	0.15	0.15
26	0.2			0.2	0.1	0.15
Mar 12	0.2			0.4	0.1	0.3

WATER TEMPERATURE

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23	2	2	2	3	3	
30	2	2	2	2	2	2
Feb 6	2	2	2	2.6	2.6	2.6
13	2.8	2.8	2.8	1.9		
19	2.8			2.8	2.9	3
26	5.1			5.5	5.3	5
Mar 12	8	8	8	5.5	5.5	6

Appendix Table A-2. Dissolved Oxygen (mg/l) readings as a result of dredging (C100 - 100m upstream of dredge; C90 - 90m downstream of dredge, C425-425m downstream of dredge) and disposal (W100-100m upstream of discharge; W90-90m downstream of discharge, and W425-425m downstream of discharge) activities in Lower Granite Reservoir, Washington.

DISSOLVED OXYGEN AT THE SURFACE

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	11.6	11.6	11.5			
23	13.6	13.6	13.5	13.9	13.8	13.8
30	12.2	12.2	12.4	12.6	12.4	12.3
Feb 6	11.8	11.3	10.8	12.4	11.4	11.2
13	12	12.2	12	12.2		
19	12.6			12.4	11.8	12
26	12.3			12.2	12.2	12.2
Mar 12	11.4	11.4	11.4	12	12	12

DISSOLVED OXYGEN AT MID-LEVEL

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	11.3	11.2	11.5			
23	13.3	13.3	13.2	13.5	13.4	13.4
30	12.1	12.2	12.2	12.5	12.3	12.3
Feb 6	11.8	11.9	11.8	11.5	11.4	11
13	11.8	11.8	11.8	12		
19	12.4					
26	12.2					
Mar 12	11.4	11.4	11.4	11.9		

DISSOLVED OXYGEN AT BOTTOM

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	11	11.2	11.2			
23	13.4	13.3	13.3	13.5	13.4	13.4
30	12.2	12.2	12.2	12.6	12.3	12.3
Feb 6	11.7	12	11.2	11.4	11	10.6
13	11.6	11.8	11.8	11.7		
19	12.4			12.2	11	11.7
26	12.1			12.2		12.1
Mar 12	11.4	11.4	11.4	11.8		11.8

Appendix Table A-3. pH readings as a result of dredging (C100 - 100m upstream of dredge; C90 - 90m downstream of dredge, C425-425m downstream of dredge) and disposal (W100-100m upstream of discharge; W90-90m downstream of discharge, and W425-425m downstream of discharge) activities in Lower Granite Reservoir, Idaho.

pH AT THE SURFACE

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23						
30						
Feb 6	8.25	8.21	8.22	8.18	8.14	8.18
13	8.33	8.32	8.32	8.28		
19	8.23			8.14	7.98	8.13
26	8.15			7.9	7.94	7.9
Mar 12	8.1	8.1	8.08	7.68	7.66	7.6

pH AT THE MID-LEVEL

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23						
30						
Feb 6	8.26	8.25	8.24	8.29	8.1	8.17
13	8.31	8.3	8.27			
19	8.25					
26	8.18					
Mar 12	8.12	8.11	8.09	7.63		

pH AT THE BOTTOM

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23						
30						
Feb 6	8.2	8.2	8.21	8.29	8.13	8.16
13	8.34	8.32	8.3	8.28		
19	8.23			8.15	7.99	8.08
26	8.17			7.88		7.94
Mar 12	8.12	8.1	8.09	7.69		7.67

Appendix Table A-4. Turbidity (NTU) readings as a result of dredging (C100 - 100m upstream of dredge; C90 - 90m downstream of dredge, C425-425m downstream of dredge) and disposal (W100-100m upstream of discharge; W90-90m downstream of discharge, and W425-425m downstream of discharge) activities in Lower Granite Reservoir, Washington.

TURBIDITY AT SURFACE

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	1.5	1.5	1.5			
23	3.05	3.5	3.8	8.6	13	7.3
30	25.1	6.1	6.1	4.9	7.5	4.8
Feb 6	5.65	5.75	5.4	6.2	17.5	11
13	3.1	4.5	3.45	14.9		
19	13			19.5	75	31
26	25			28	39.5	28
Mar 12	19	20	21	16	18	18.5

TUBIDITY AT MID-LEVEL

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	1.9	2.4	2.4			
23	3.82	3.37	3.5	8.75	14.95	8.1
30	4.45	4.85	8.42	5.25	10.05	6.5
Feb 6	5.4	7.1	5.8	9.4	18.5	11
13	4	17.5	15			
19	14					
26	26.5					
Mar 12	21	20.5	24.5	23		

TURBIDITY AT BOTTOM

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16	2	2.25	1.9			
23	4.75	4.75	4.95	9.45	18	9
30	3.75	5.1	8.7	6.5	11	5.7
Feb 6	5	12	5.7	9.6	18	11
13	10	9.7	8.3	14.5		
19	14.5			20	82	41
26	27			31		28
Mar 12	21	22.5	24	16	19	

Appendix Table A-5. Suspended solids (mg/l) as a result of dredging (C100 - 100m upstream of dredge; C90 - 90m downstream of dredge, C425-425m downstream of dredge) and disposal (W100-100m upstream of discharge; W90-90m downstream of discharge, and W425-425m downstream of discharge) activities in Lower Granite Reservoir, Washington.

SUSPENDED SOLIDS - SURFACE

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23	3.87	3.67	5.87	7.6	28.57	4.47
30	25.71	8.48	8.61	5.73	10.5	5.06
Feb 6	7.99	16.4	17.53	10.59	20	13.9
13	3.73	18.55	4.6	47.2		53
19	19.67			29	179.39	
26	53.23			40	66.9	39.33
Mar 12	20.69	25.32	35.62	24.54	58.61	33.81

SUSPENDED SOLIDS - MID-LEVEL

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23	7.47	5.4	5.23	8.8	23.95	8.08
30	10.03	10.7	14.25	8.27	14.6	7.97
Feb 6	8.93	16.1	7.28	10.24	22.9	13.1
13	8.05	31.21	52.87			
19	32.95					
26	50.26					
Mar 12	26.93	29.03	37.96	43.45		

SUSPENDED SOLIDS - BOTTOM

Calendar Date	Dredge Stations			Disposal Stations		
	C100	C90	C425	W100	W90	W425
Jan 16						
23	9.73	13	7.2	7.67	29.8	20.8
30	8.8	1.34	9.64	12.66	17.76	9.6
Feb 6	8.73	58.5	15.67	11.8	22.9	15.1
13	15.18	52.8	32.6	33.2		
19	16.74			30.35	205.26	91.57
26	50.54			50.98		51.32
Mar 12	29.86	23.29	28.36	36.92		29.67

Appendix Table B-1. Mean catch per unit effort for individuals of species captured at station C1 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
white sturgeon	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
chinook salmon	0.09	0.10	0.05	0.00	0.04	0.10	0.00	8.0	83.33
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	0.00
rainbow trout	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	12.33
chiselmouth	0.00	0.00	0.18	0.00	0.24	0.69	0.00	0.00	0.00
carp	0.00	0.00	0.00	0.00	0.04	0.25	0.00	0.33	0.33
peamouth	0.00	0.10	0.09	0.00	0.00	0.00	0.00	11.33	3.67
northern squawfish	0.09	0.00	0.18	0.00	0.00	0.20	0.00	4.33	3.0
redside shiner	0.00	0.20	0.60	0.08	0.12	1.77	0.00	0.66	0.33
bridgelip sucker	0.09	0.00	0.05	0.08	0.00	0.05	0.00	1.0	3.0
largescale sucker	0.00	0.00	0.00	0.00	0.04	0.44	0.00	13.33	1.67
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.33	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Effort (min/hauls)	693	1215	1309	734	1473	1219	3	3	3

Appendix Table B-2. Mean catch per unit effort for individuals of species captured at station C2 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	0.00	0.00	0.00	0.00	0.00	No Effort	0.00	0.00
white sturgeon	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
sockeye salmon	0.00	0.00	0.051	0.00	0.00	0.055		0.00	0.33
chinook salmon	0.00	0.00	0.566	0.00	0.00	0.438		0.00	11.667
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
rainbow trout	0.00	0.00	0.103	0.053	0.038	0.00		0.00	0.00
chiselmouth	0.00	0.00	0.31	0.00	0.189	3.12		0.00	0.33
carp	0.00	0.00	0.051	0.053	0.113	0.164		0.33	0.00
peamouth	0.00	0.00	0.00	0.00	0.00	0.00		1.0	0.00
northern squawfish	0.00	0.00	0.051	0.00	0.00	0.00		0.667	0.33
redside shiner	0.00	0.091	0.36	0.00	0.00	1.04		9.333	0.00
bridgelip sucker	0.00	0.00	0.00	0.00	0.00	0.328		0.00	0.00
largescale sucker	0.00	0.00	0.00	0.00	0.189	0.274		0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
Total Effort (min/hauls)	642	1318	1166	1138	1588	1096	0	3	3

Appendix Table B-3. Mean catch per unit effort for individuals of species captured at station C4 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	No Effort	0.00	0.00	No Effort	0.00	0.00	0.00	0.00
white sturgeon	0.00		0.00	0.00		0.00	0.00	0.00	0.00
sockeye salmon	0.00		0.05	0.00		0.086	0.00	0.00	0.67
chinook salmon	0.00		0.05	0.00		0.128	0.00	2.0	27.33
mountain whitefish	0.00		0.00	0.00		0.00	0.00	2.0	0.00
rainbow trout	0.00		0.10	0.00		0.00	0.00	0.33	0.00
chiselmouth	0.00		0.399	0.093		0.128	0.00	0.00	0.00
carp	0.00		0.05	0.00		0.086	0.00	0.00	0.33
peamouth	0.00		0.00	0.093		0.043	0.00	0.00	0.00
northern squawfish	0.00		0.25	0.00		0.086	0.00	1.667	3.667
redside shiner	0.00		0.00	0.00		0.043	0.00	0.33	0.00
bridgelip sucker	0.00		0.00	0.00		0.00	0.00	0.33	0.00
largescale sucker	0.00		0.10	0.00		0.857	0.00	15.00	0.33
brown bullhead	0.00		0.00	0.00		0.00	0.00	0.00	0.00
channel catfish	0.00		0.00	0.00		0.00	0.00	0.33	0.00
tadpole madtom	0.00		0.00	0.00		0.00	0.00	0.00	0.00
pumpkinseed	0.00		0.00	0.00		0.00	0.00	0.00	0.00
smallmouth bass	0.00		0.00	0.00		0.00	0.00	0.67	0.00
yellow perch	0.00		0.00	0.00		0.00	0.00	0.00	0.00
sculpin	0.00		0.00	0.00		0.00	0.00	0.67	0.00
Total Effort (min/hauls)	603	0	1202	646	0	1401	3	3	3

Appendix Table B-4. Mean catch per unit effort for individuals of species captured at station C5 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	No Effort	0.00	0.00	No Effort	0.00	0.00	0.00	0.00
white sturgeon	0.00		0.00	0.00		0.00	0.00	0.00	0.00
sockeye salmon	0.00		0.05	0.00		0.00	0.00	0.00	0.00
chinook salmon	0.00		0.249	0.00		0.230	0.00	1.667	12.333
mountain whitefish	0.00		0.00	0.00		0.00	0.00	1.667	0.00
rainbow trout	0.00		0.05	0.00		0.057	0.00	0.00	0.00
chiselmouth	0.00		0.796	0.00		1.897	0.00	0.00	0.00
carp	0.00		0.149	0.00		0.115	0.00	0.33	0.00
peamouth	0.00		0.00	0.00		0.00	0.00	0.00	0.00
northern squawfish	0.00		0.199	0.00		0.287	0.33	0.33	0.00
redside shiner	0.00		0.547	0.00		0.575	0.00	0.33	0.00
bridgelip sucker	0.00		0.149	0.00		0.287	0.00	0.00	0.00
largescale sucker	0.00		0.398	0.00		0.345	0.67	1.33	0.33
brown bullhead	0.00		0.00	0.00		0.00	0.00	0.00	0.00
channel catfish	0.00		0.00	0.00		0.00	0.00	0.00	0.00
tadpole madtom	0.00		0.00	0.00		0.00	0.00	0.00	0.00
pumpkinseed	0.00		0.00	0.00		0.00	0.00	0.00	0.00
smallmouth bass	0.00		0.00	0.00		0.00	0.00	0.33	0.00
yellow perch	0.00		0.00	0.00		0.00	0.00	0.00	0.00
sculpin	0.00		0.00	0.00		0.00	0.00	0.00	0.00
Total Effort (min/hauls)	720	0	1206	718	0	1044	3	3	3

Appendix Table B-5. Mean catch per unit effort for individuals of species captured at station WI in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
	Before	During	After	Before	During	After	Before	During	After
Species									
Pacific lamprey	No Effort	0.00	0.00	No Effort	0.00	0.00	No Effort	0.00	0.00
white sturgeon		0.00	0.00		0.00	0.106		0.00	0.00
sockeye salmon		0.00	0.00		0.00	0.053		0.667	0.00
chinook salmon		0.00	0.563		0.00	0.319		0.667	3.00
mountain whitefish		0.00	0.00		0.00	0.00		0.333	0.00
rainbow trout		0.00	0.00		0.00	0.00		0.667	0.667
chiselmouth		0.00	0.704		0.980	0.213		0.00	0.00
carp		0.00	0.00		0.00	0.00		0.00	0.00
peamouth		0.00	0.00		0.00	0.00		0.00	0.333
northern squawfish		0.00	0.563		0.00	0.319		0.00	0.00
redside shiner		0.00	0.00		0.122	0.106		0.333	0.00
bridgelip sucker		0.00	0.00		0.00	0.319		0.00	0.00
largescale sucker		0.00	0.141		0.00	0.638		1.0	0.00
brown bullhead		0.00	0.00		0.00	0.00		0.00	0.00
channel catfish		0.00	0.00		0.00	0.00		0.00	0.00
tadpole madtom		0.00	0.00		0.00	0.00		0.00	0.00
pumpkinseed		0.00	0.00		0.00	0.00		0.00	0.00
smallmouth bass		0.00	0.00		0.00	0.00		0.00	0.00
yellow perch		0.00	0.00		0.00	0.00		0.00	0.00
sculpin		0.00	0.00		0.00	0.00		0.00	0.00
Total Effort (min/hauls)	0	336	1278	0	490	1128	0	3	3

Appendix Table B-6. Mean catch per unit effort for individuals of species captured at station W2 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
	Before	During	After	Before	During	After	Before	During	After
Species									
Pacific lamprey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
white sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
chinook salmon	0.00	0.106	0.00	0.00	0.042	0.039	0.00	0.00	0.667
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rainbow trout	0.00	0.00	0.130	0.00	0.00	0.039	0.00	0.00	0.00
chiselmouth	0.00	0.00	0.00	0.00	0.084	0.079	0.00	0.00	0.00
carp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
peamouth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
northern squawfish	0.00	0.00	0.00	0.00	0.00	0.197	0.00	0.00	0.00
redside shiner	0.00	0.477	0.195	0.00	0.084	0.00	0.00	0.00	0.00
bridgelip sucker	0.00	0.00	0.00	0.00	0.065	0.079	0.00	0.00	0.00
largescale sucker	0.00	0.00	0.00	0.00	0.065	0.00	0.00	0.00	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Effort (min/hauls)	1810	1131	921	673	1433	1523	2	3	3

Appendix Table B-7. Mean catch per unit effort for individuals of species captured at station W4 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	0.00	0.00	0.00	0.00	0.00	No Effort	0.00	0.00
white sturgeon	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
chinook salmon	0.00	0.00	0.00	0.00	0.00	0.00		2.333	0.00
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.00		0.333	0.00
rainbow trout	0.00	0.00	0.00	0.115	0.00	0.00		0.333	0.00
chiselmouth	0.00	0.00	0.00	0.00	0.077	0.00		0.00	0.00
carp	0.00	0.00	0.00	0.00	0.077	0.00		0.333	0.00
peamouth	0.00	0.00	0.00	0.00	0.00	0.00		80.667	0.00
northern squawfish	0.00	0.087	0.00	0.00	0.154	0.00		24.333	0.00
redside shiner	0.00	0.087	0.00	0.115	0.00	0.00		9.333	0.00
bridgelip sucker	0.00	0.087	0.00	0.00	0.00	0.00		7.000	0.00
largescale sucker	0.123	0.781	0.00	0.115	0.00	0.00		34.000	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00		0.333	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00		0.333	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
Total Effort (min/hauls)	488	691	1264	521	780	1503	0	3	3

Appendix Table B-8. Mean catch per unit effort for individuals of species captured at station W5 in Lower Granite Reservoir, Idaho-Washington, 1986. Effort for gill nets was one hour, while seine effort was one standardized haul.

	Horizontal Floating Gill Nets			Horizontal Contour Gill Nets			Seine		
Species	Before	During	After	Before	During	After	Before	During	After
Pacific lamprey	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
white sturgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sockeye salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
chinook salmon	0.00	0.00	1.137	0.00	0.00	0.943	0.00	0.333	13.667
mountain whitefish	0.00	0.00	0.00	0.00	0.00	0.036	0.00	6.333	0.00
rainbow trout	0.00	0.00	0.047	0.00	0.101	0.109	0.00	0.333	1.667
chiselmouth	0.00	0.00	0.190	0.00	0.050	0.109	0.00	0.00	0.00
carp	0.00	0.00	0.047	0.00	0.00	0.218	0.00	1.667	0.00
peamouth	0.00	0.00	0.00	0.00	0.00	0.00	0.333	1.667	0.00
northern squawfish	0.00	0.055	0.806	0.00	0.151	0.725	0.00	2.000	1.000
redside shiner	0.00	0.055	0.284	0.00	0.454	0.145	0.00	0.667	0.00
bridgelip sucker	0.00	0.00	0.095	0.00	0.00	0.145	0.00	0.00	0.00
largescale sucker	0.00	0.00	0.190	0.170	0.454	0.580	0.00	3.667	0.00
brown bullhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
channel catfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.333	0.00
tadpole madtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
yellow perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sculpin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Effort (min/hauls)	313	1085	1266	360	1190	1655	3	3	3

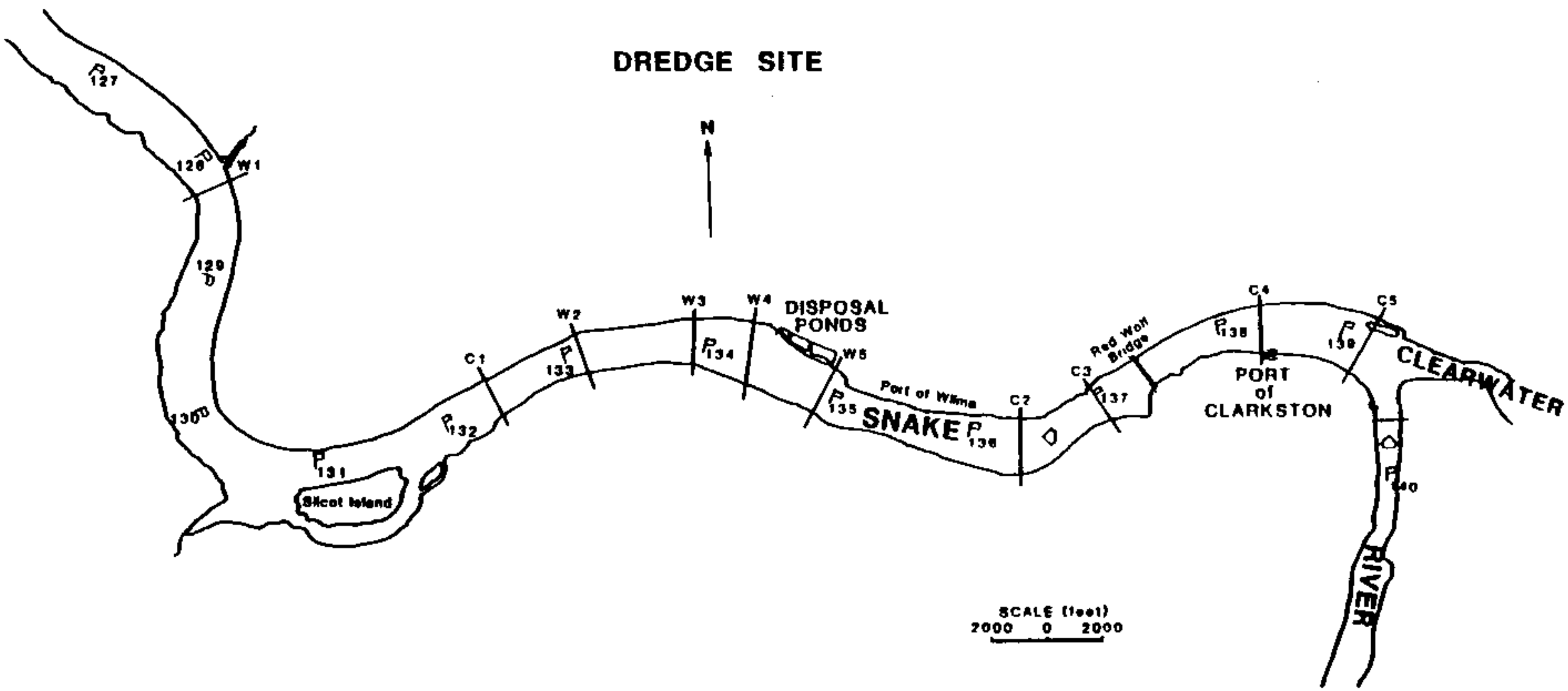

Figure 1. Study areas for assessing sediment dredge and disposal effects in Lower Granite Reservoir, Washington, during December-April, 1986. Stations C1-C5 were surveyed to evaluate effects of dredging and stations W1-W5 to evaluate effects of overflow from disposal ponds. Dredging occurred at the Port of Clarkston (C4) in 1986. Stations C3 and W3 were sampled for benthos but not for fish community assessments. Numbers associated with "flags" indicate distance above Ice Harbor Dam.

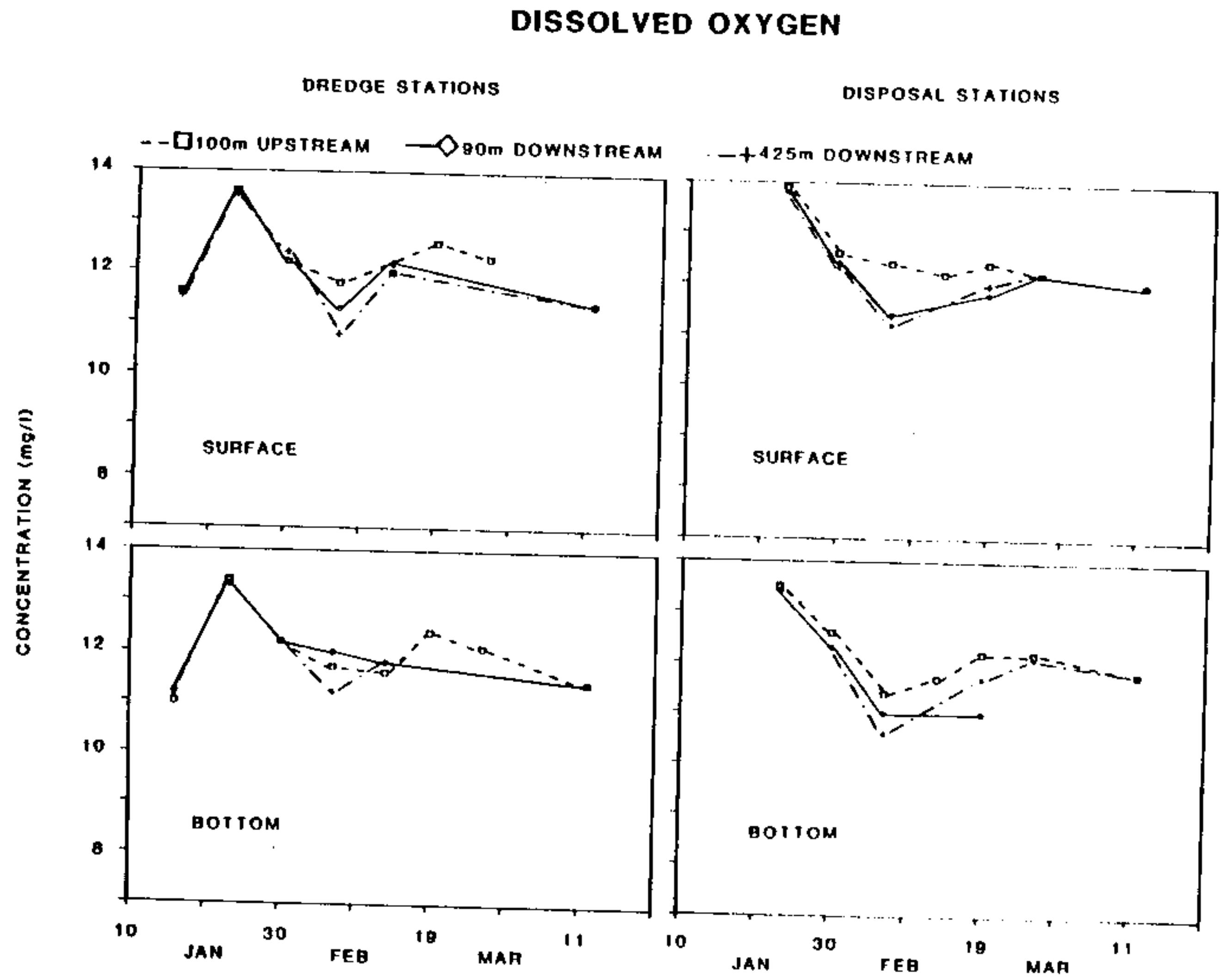

Figure 2. Dissolved oxygen concentrations at dredge and disposal sites in Lower Granite Reservoir, Washington, January-March, 1986. Samples were collected 100 m upstream, 90 m downstream and 425 m downstream of dredge and effluent from disposal ponds.

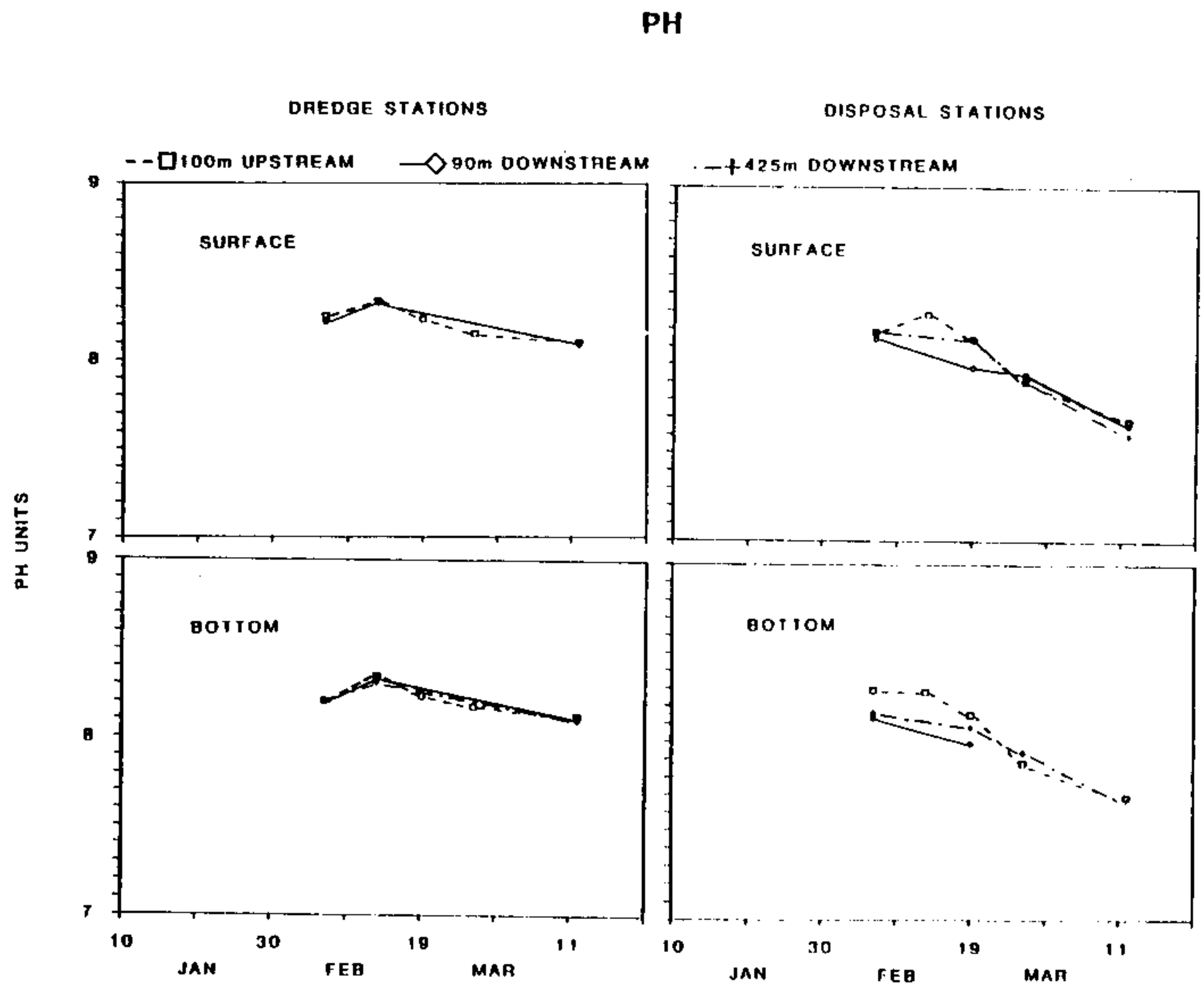

Figure 3. pH values at dredge and disposal stations in Lower Granite Reservoir, Washington, January-March, 1986. Samples were collected 100 m upstream, 90 m downstream and 425 m downstream of dredge and effluent from disposal ponds.

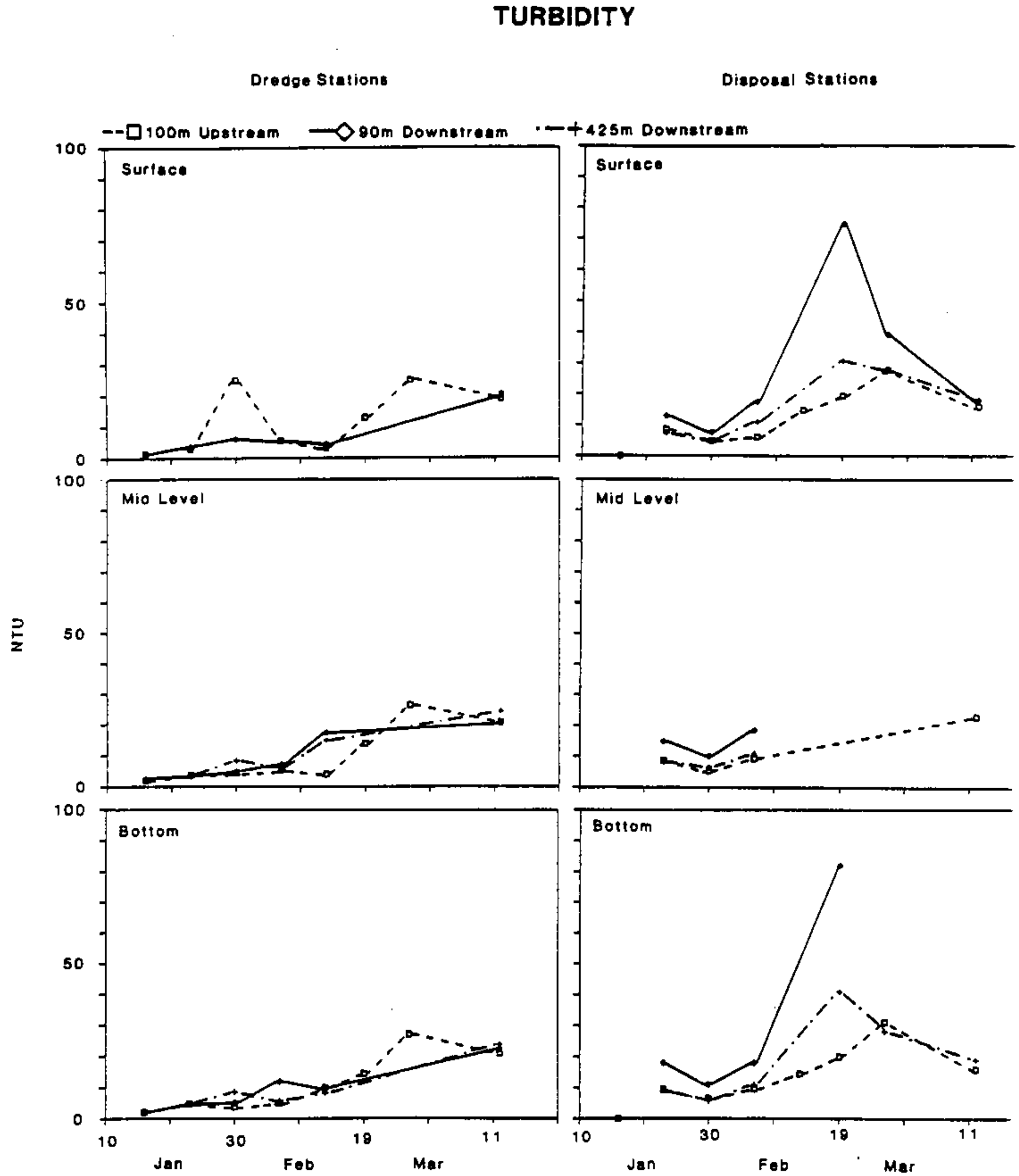

Figure 4. Turbidity (NTU) at dredge and disposal sites in Lower Granite Reservoir, Washington, January-March, 1986. Samples were collected 100 m upstream, 90 m downstream and 425 m downstream of dredge and effluent from disposal ponds.

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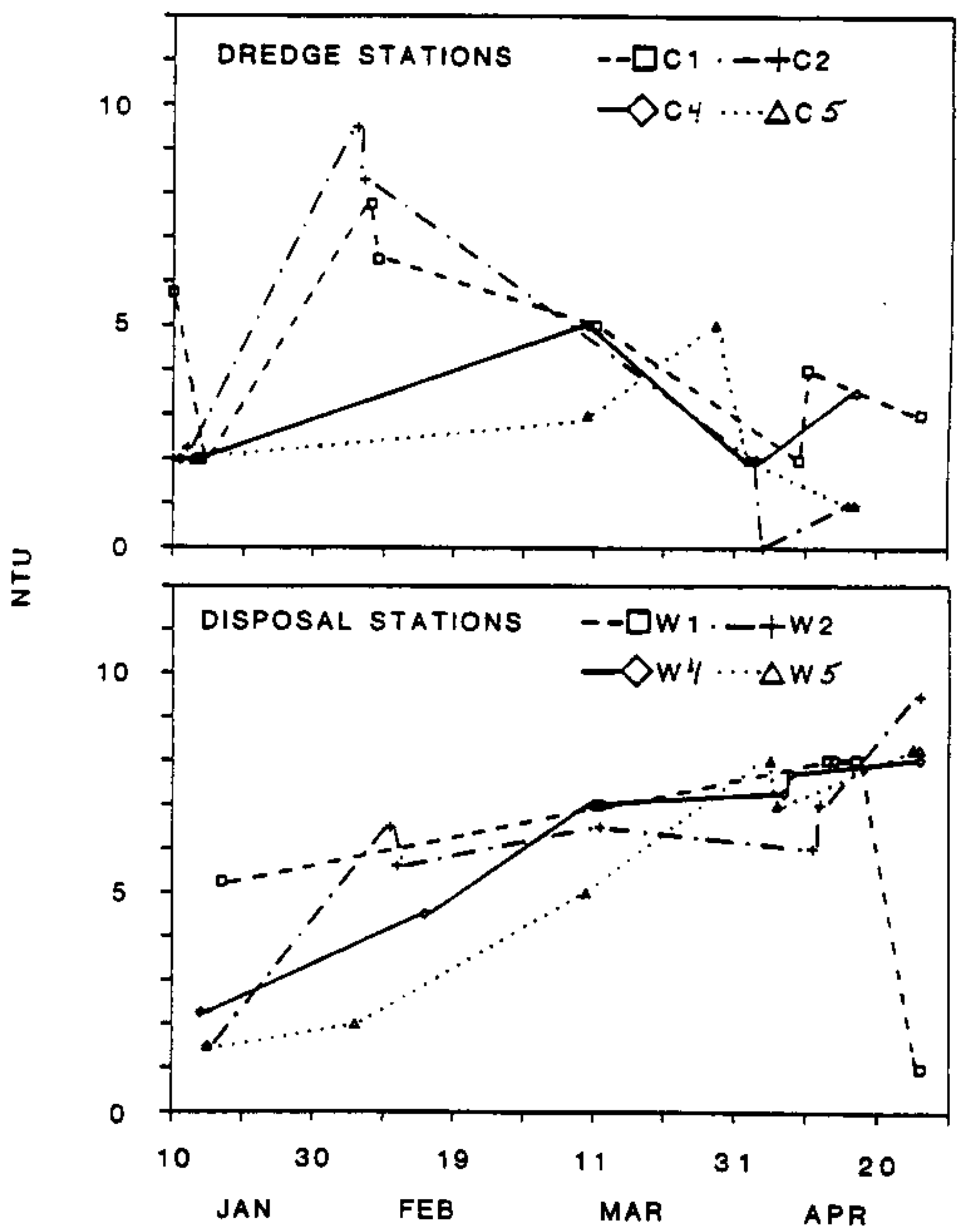

Figure 5. Turbidity (NTU) at dredge (C1-C5) and disposal (W1-W5) sites in Lower Granite Reservoir, Washington. Samples were collected upstream from dredging (C5) and overflow from land disposal ponds (W5), 1.6 km (C2 and W2) and 8-9.7 km downstream (C1 and W1) from the impact area.

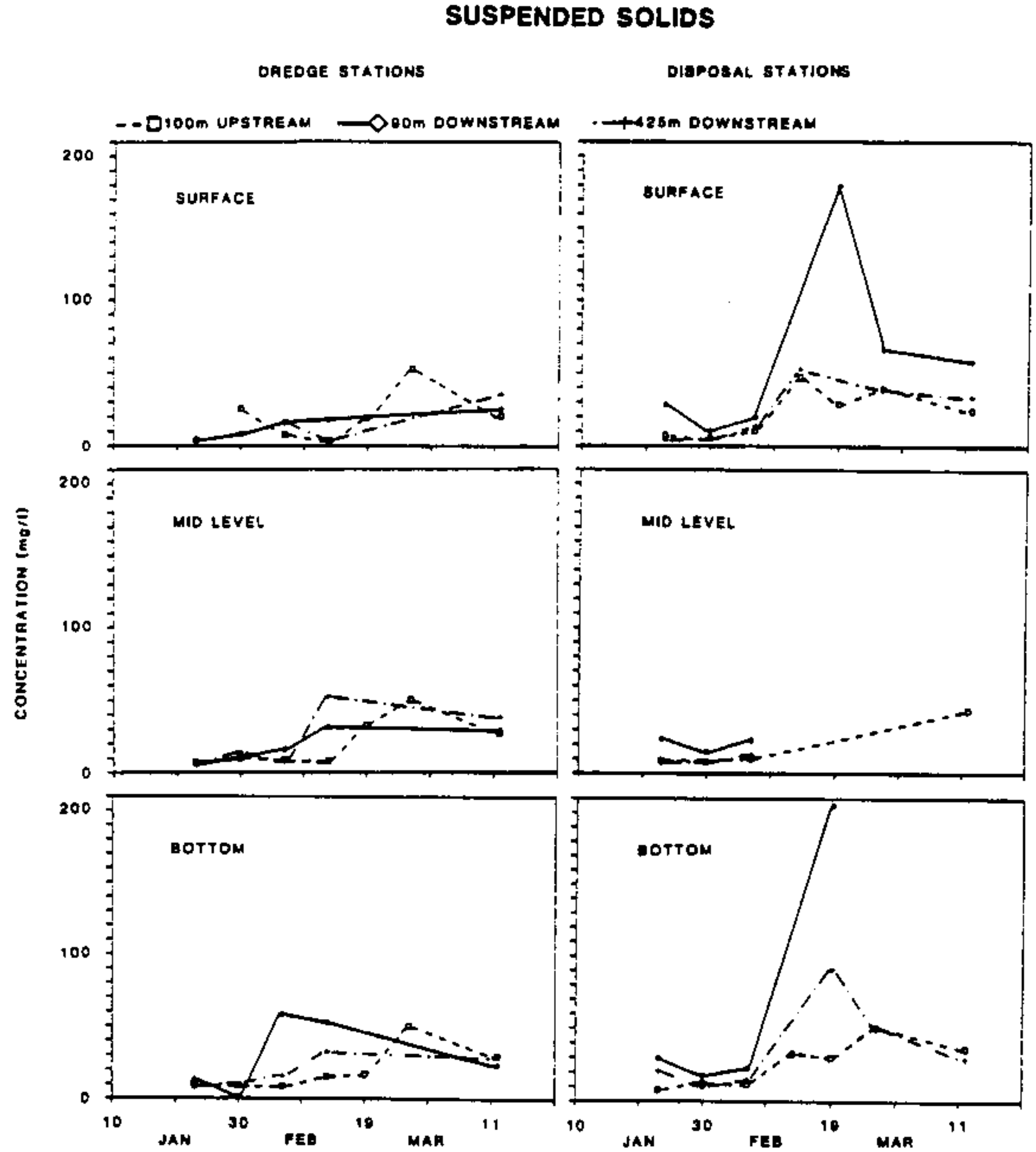

Figure 6. Suspended solids (mg/l) at dredge and disposal sites in Lower Granite Reservoir, Washington, January-March, 1986. Samples were collected 100 m upstream, 90 m downstream and 425 m downstream of dredge and effluent from disposal ponds.

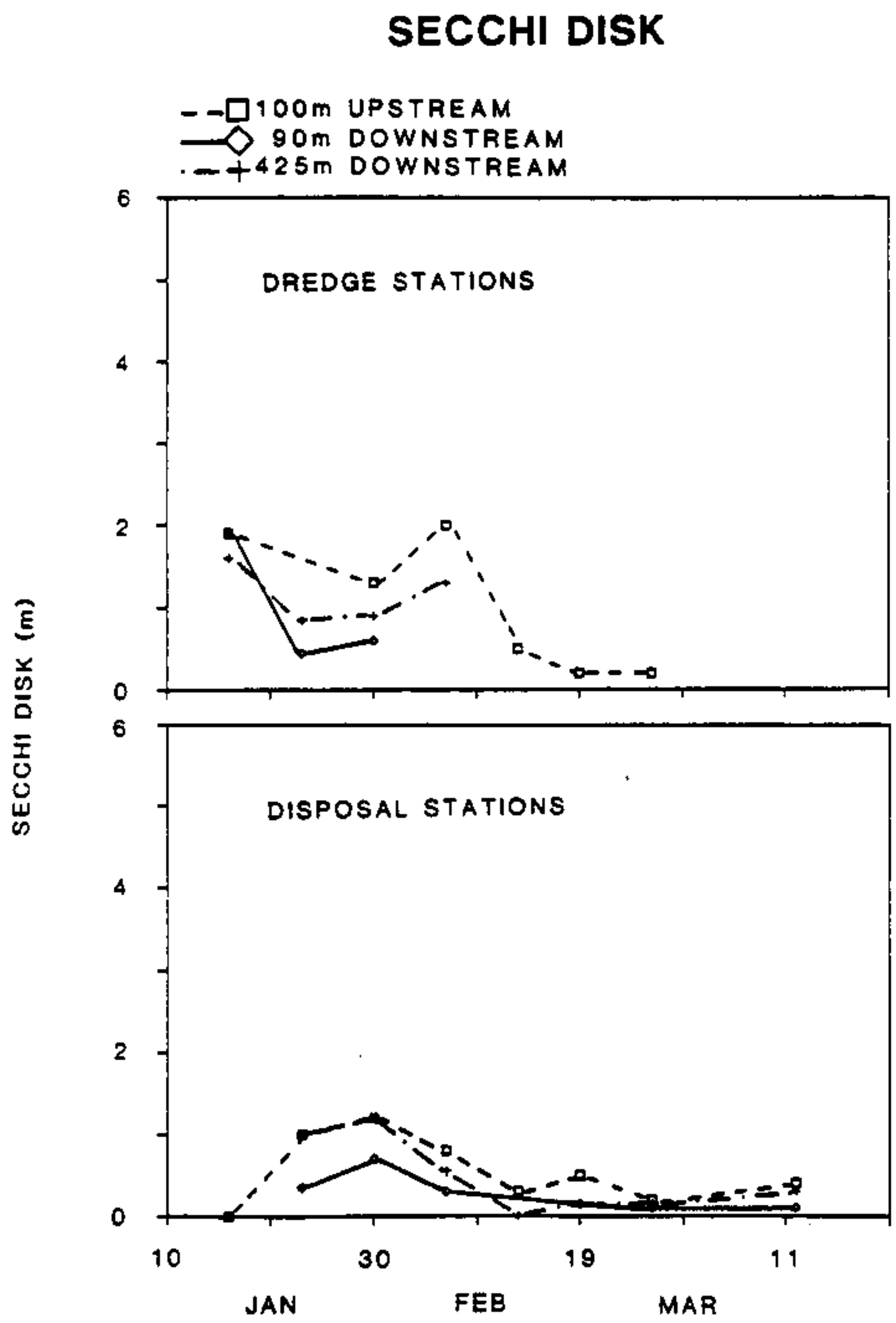

Figure 7. Secchi disk readings (m) at dredge and disposal sites in Lower Granite Reservoir, Washington, January-March, 1986. Samples were collected 100 m upstream, 90 m downstream and 425 m downstream of dredge and effluent from disposal ponds.

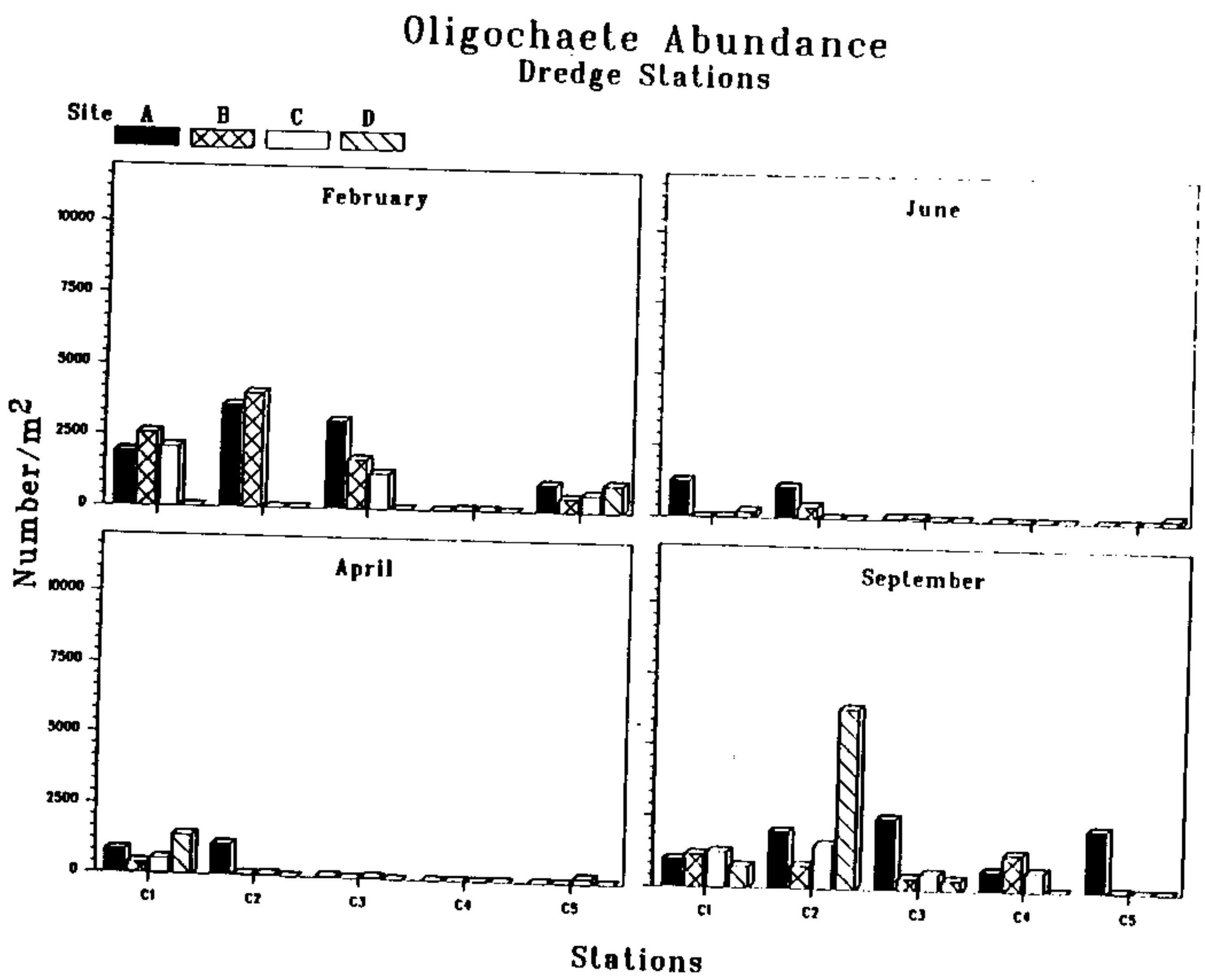

Figure 8. Mean density (No./m^2) of Oligochaetes at dredge stations in Lower Granite Reservoir, Washington during 1986. Means were determined from about five samples per site. Sites A, B, C and D were located equidistantly across the reservoir and ran from the south to the north side of the reservoir. Dredging occurred at station C4.

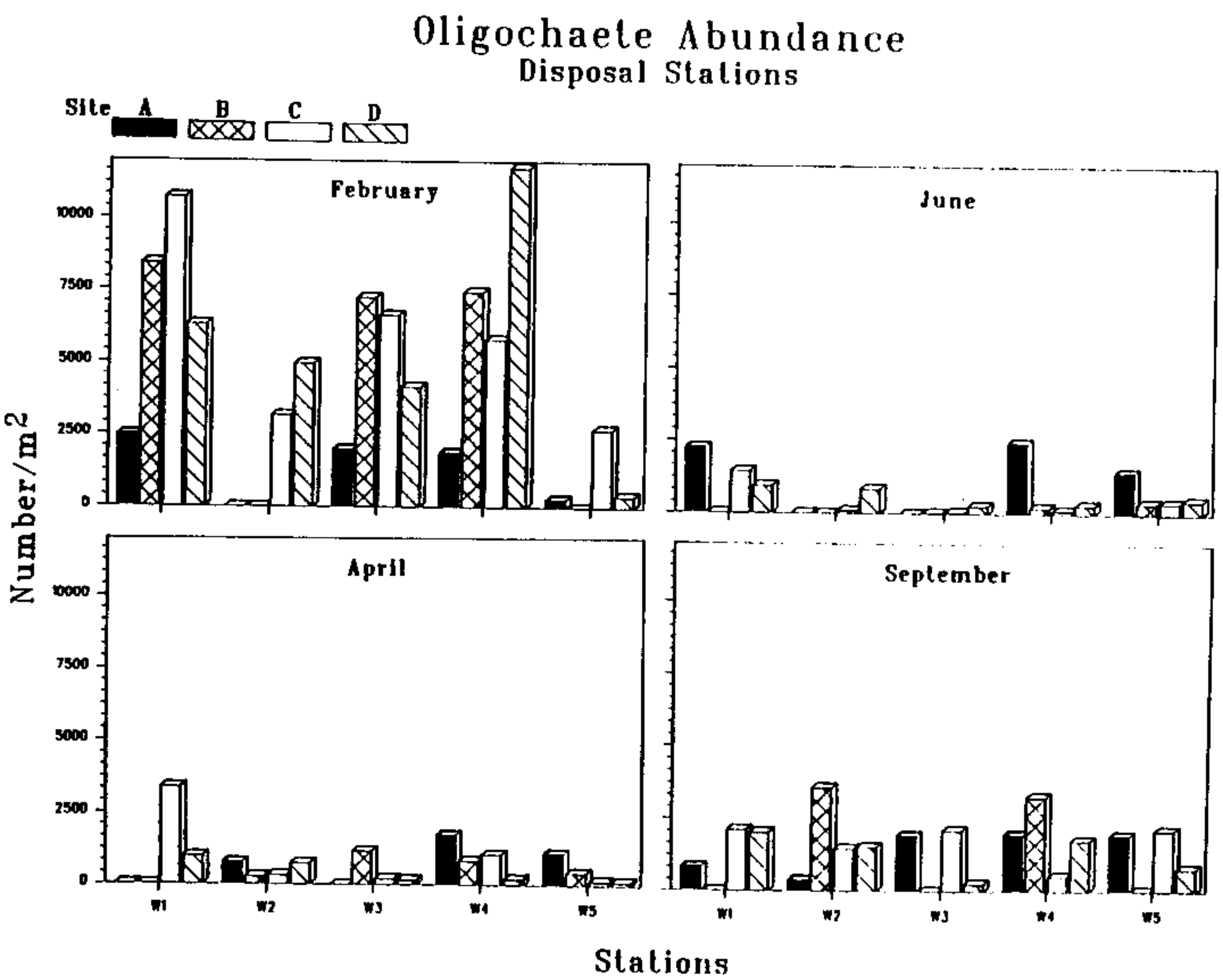

Figure 9. Mean density (No./m^2) of Oligochaetes at disposal stations in Lower Granite Reservoir, Washington during 1986. Means were determined from about five samples per site. Sites A, B, C and D were located equidistantly across the reservoir and ran from the north to south side of the reservoir. W4 was the effluent station.

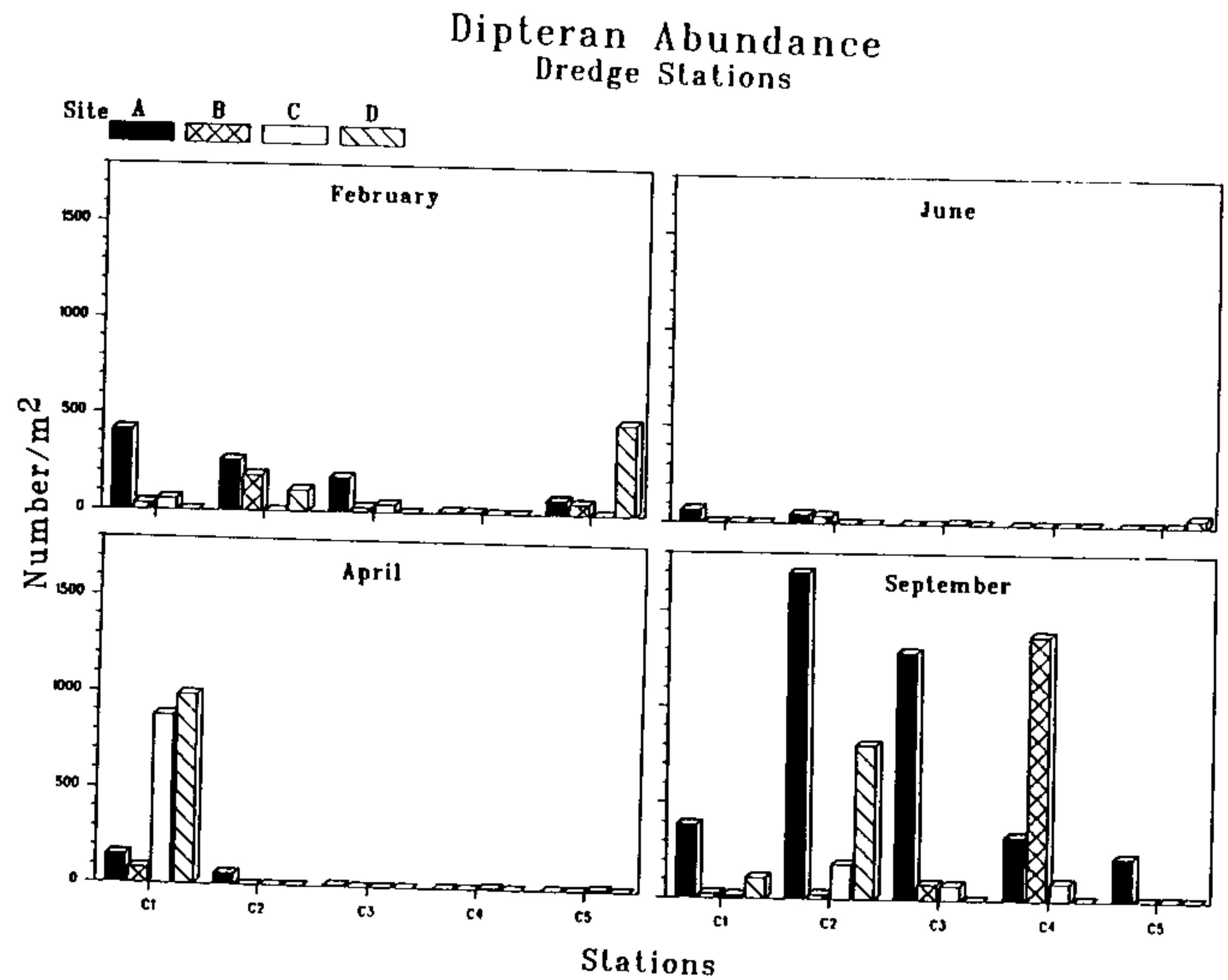

Figure 10. Mean density (No./m^2) of Dipterans at dredge stations in Lower Granite Reservoir, Washington during 1986. Means were determined from about five samples per site. Sites A, B, C and D were located equidistantly across the reservoir and ran from the south to the north side of the reservoir. Dredging occurred at station C4.

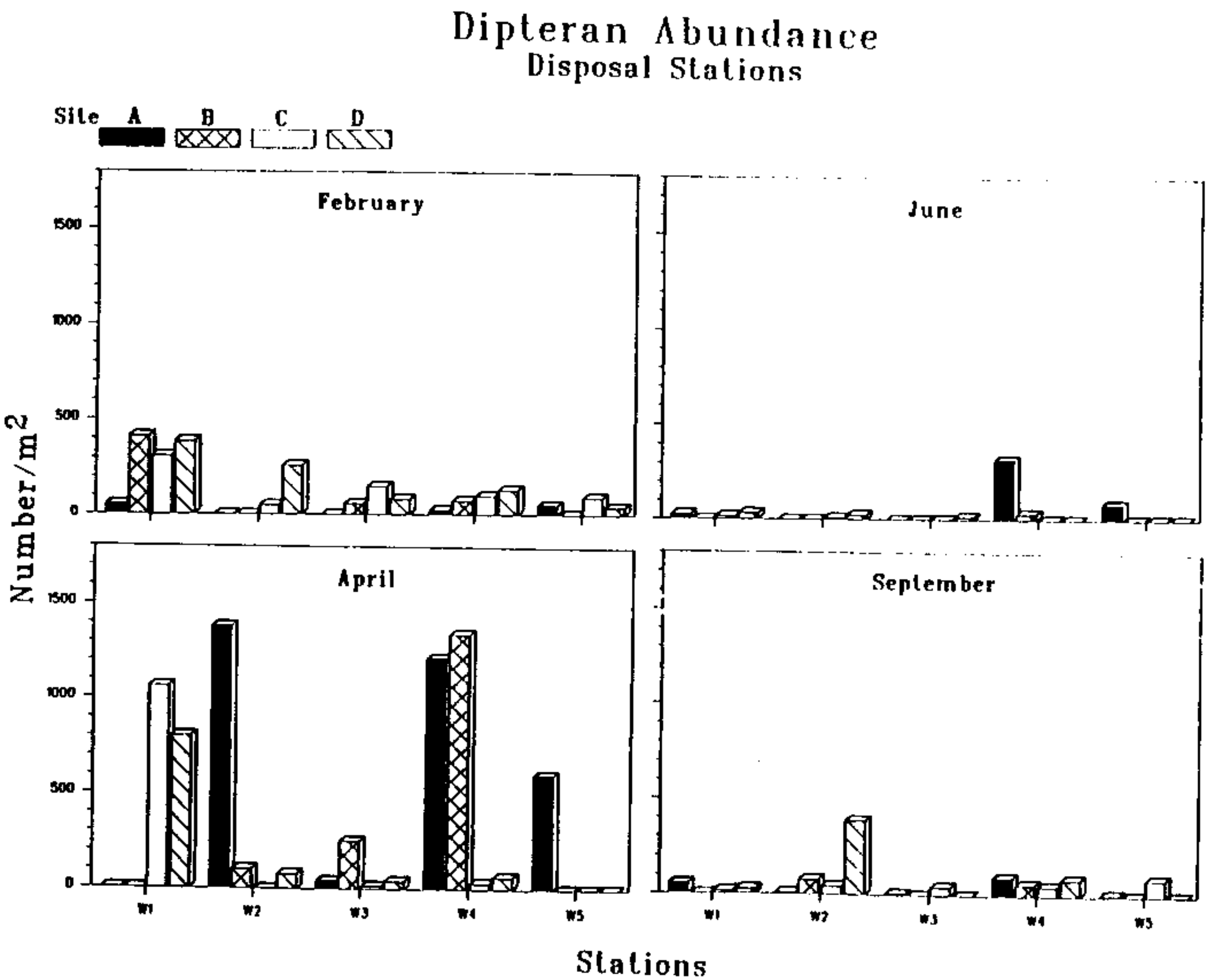

Figure 11. Mean density (No./m^2) of Dipterans at disposal stations in Lower Granite Reservoir, Washington during 1986. Means were determined from about five samples per site. Sites A, B, C and D were located equidistantly across the reservoir and ran from the north to south side of the reservoir. W4 was the effluent station.

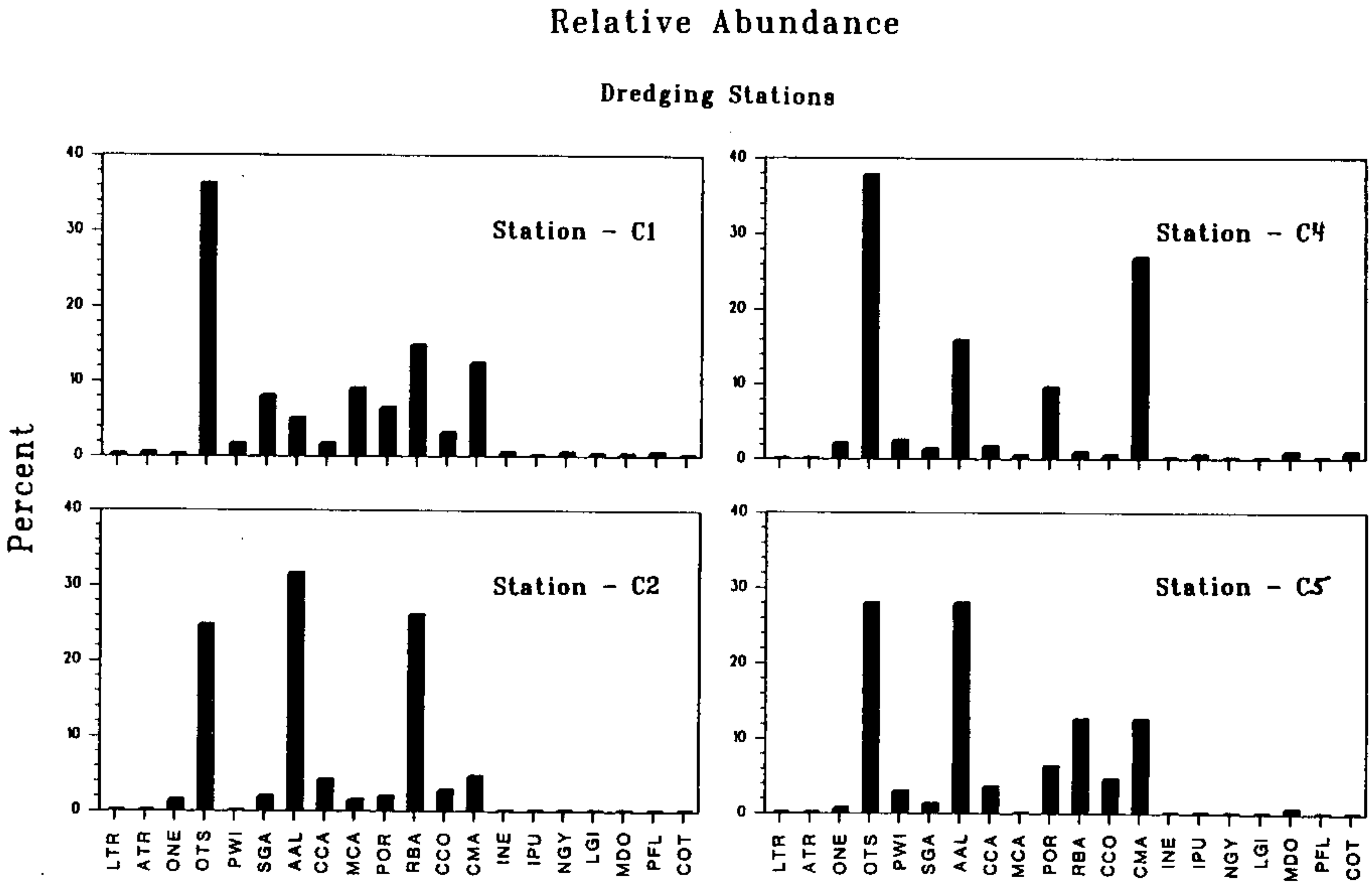

Figure 12. Percent relative abundance of fishes at dredging stations (C1-C5) in Lower Granite Reservoir, Washington from January through mid-April, 1986. Species abbreviations are: LTR - Pacific lamprey; ATR - white sturgeon; ONE - sockeye salmon; OTS - chinook salmon; PWI - mountain whitefish; SGA - rainbow trout; AAL - chiselmouth; CCA - carp; MCA - peamouth; POR - northern squawfish; RBA - redside shiners; CCO - bridgelip sucker; CMA - largescale sucker; INE - brown bullhead; IPU - channel catfish; NGY - tadpole madtom; LGI - pumpkinseed; MDO - smallmouth bass; PFL - yellow perch; and, COT - sculpin.

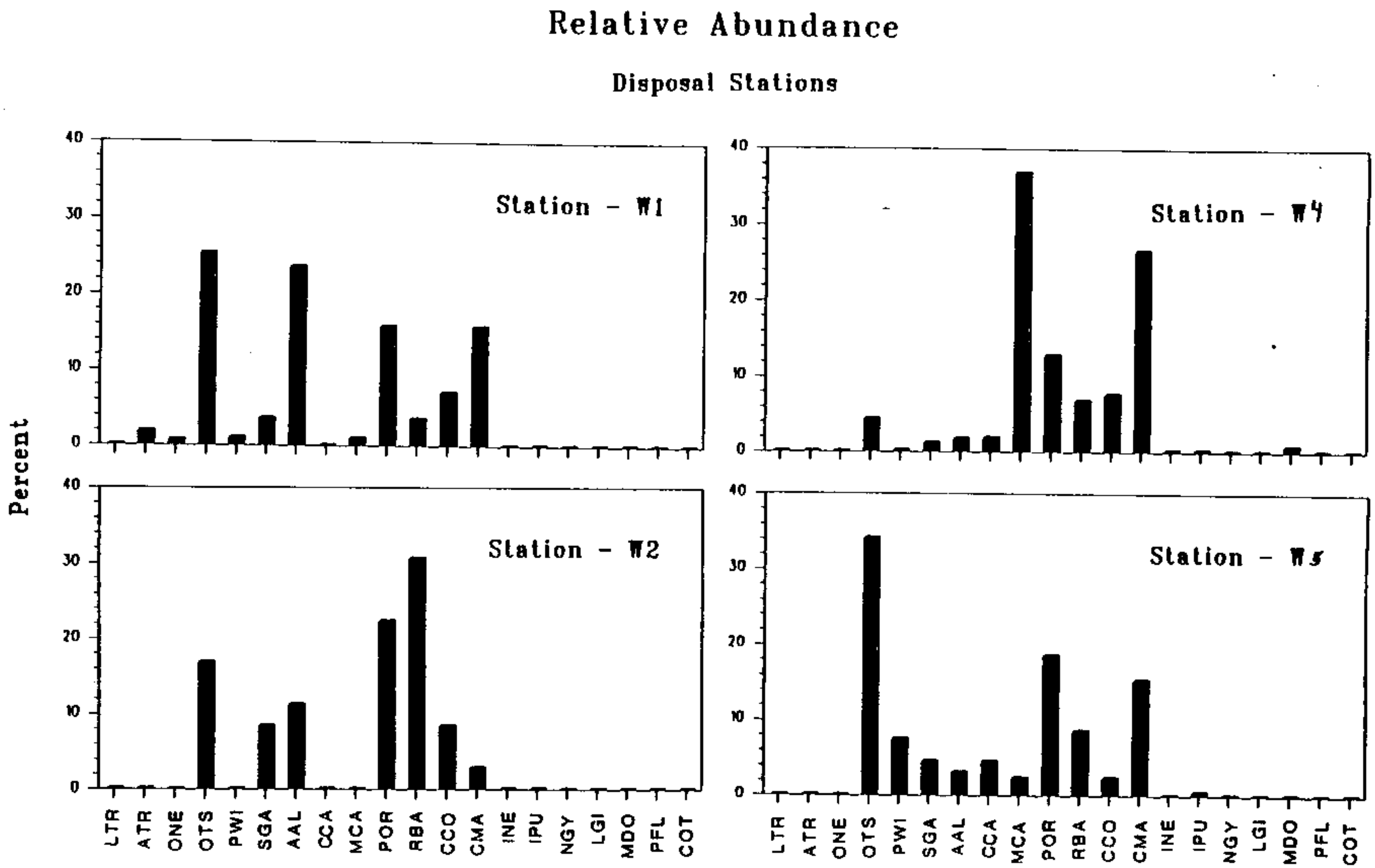

Figure 13. Percent relative abundance of fishes at disposal stations (W1-W5) in Lower Granite Reservoir, Washington from January through mid-April, 1986. Species abbreviations are: LTR - Pacific lamprey; ATR - white sturgeon; ONE - sockeye salmon; OTS - chinook salmon; PWI - mountain whitefish; SGA - rainbow trout; AAL - chiselmouth; CCA - carp; MCA - peamouth; POR - northern squawfish; RBA - redside shiners; CCO - bridgelip sucker; CMA - largescale sucker; INE - brown bullhead; IPU - channel catfish; NGY - tadpole madtom; LGI - pumpkinseed; MDO - smallmouth bass; PFL - yellow perch; and, COT - sculpin.

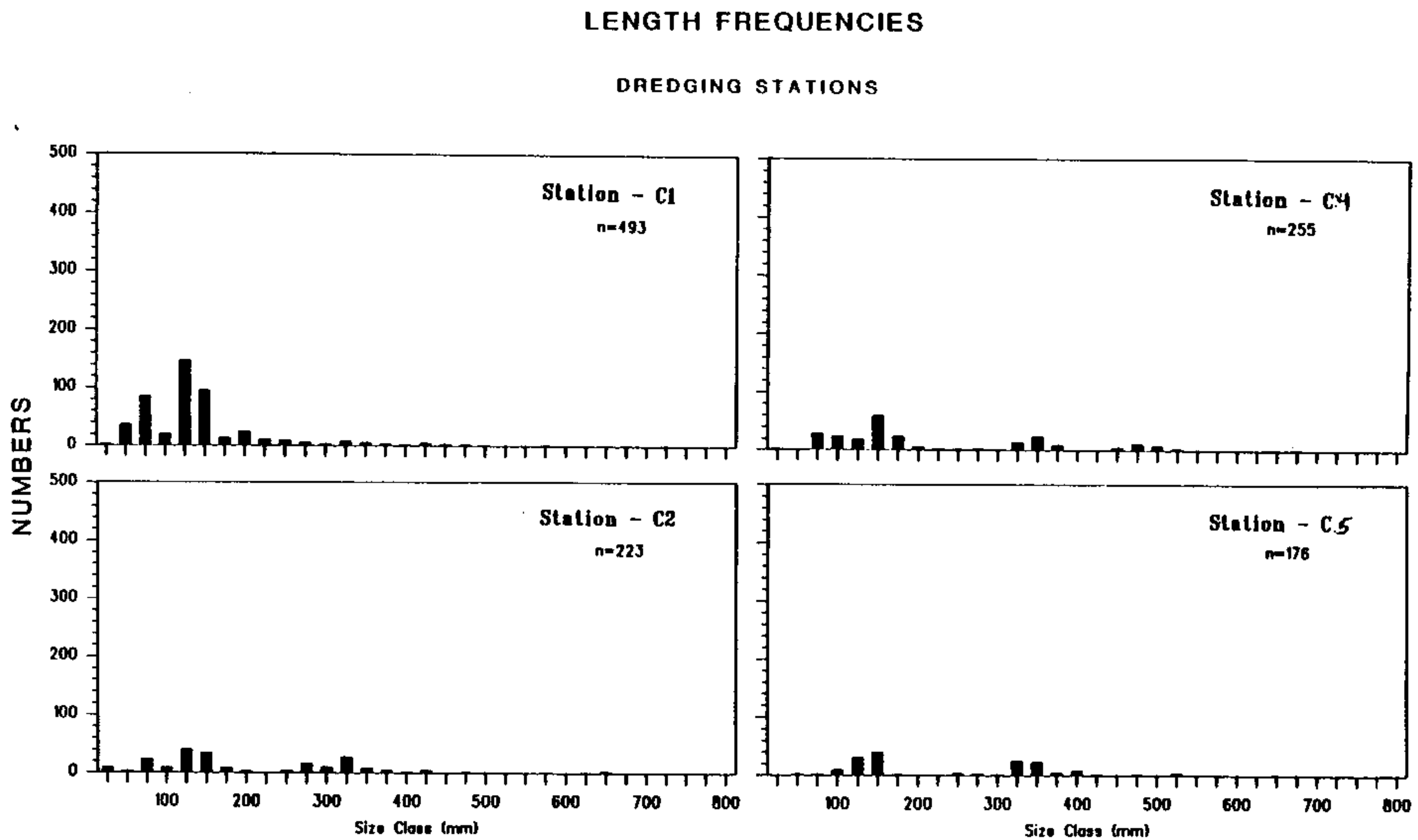

Figure 14. Length frequencies of fishes collected at dredge stations in Lower Granite Reservoir, Washington from January through mid-April, 1986. Dredging occurred at station C4 while C5 was upstream, C2 was 1.6 km and C1 was 8.0 km downstream from the dredging.

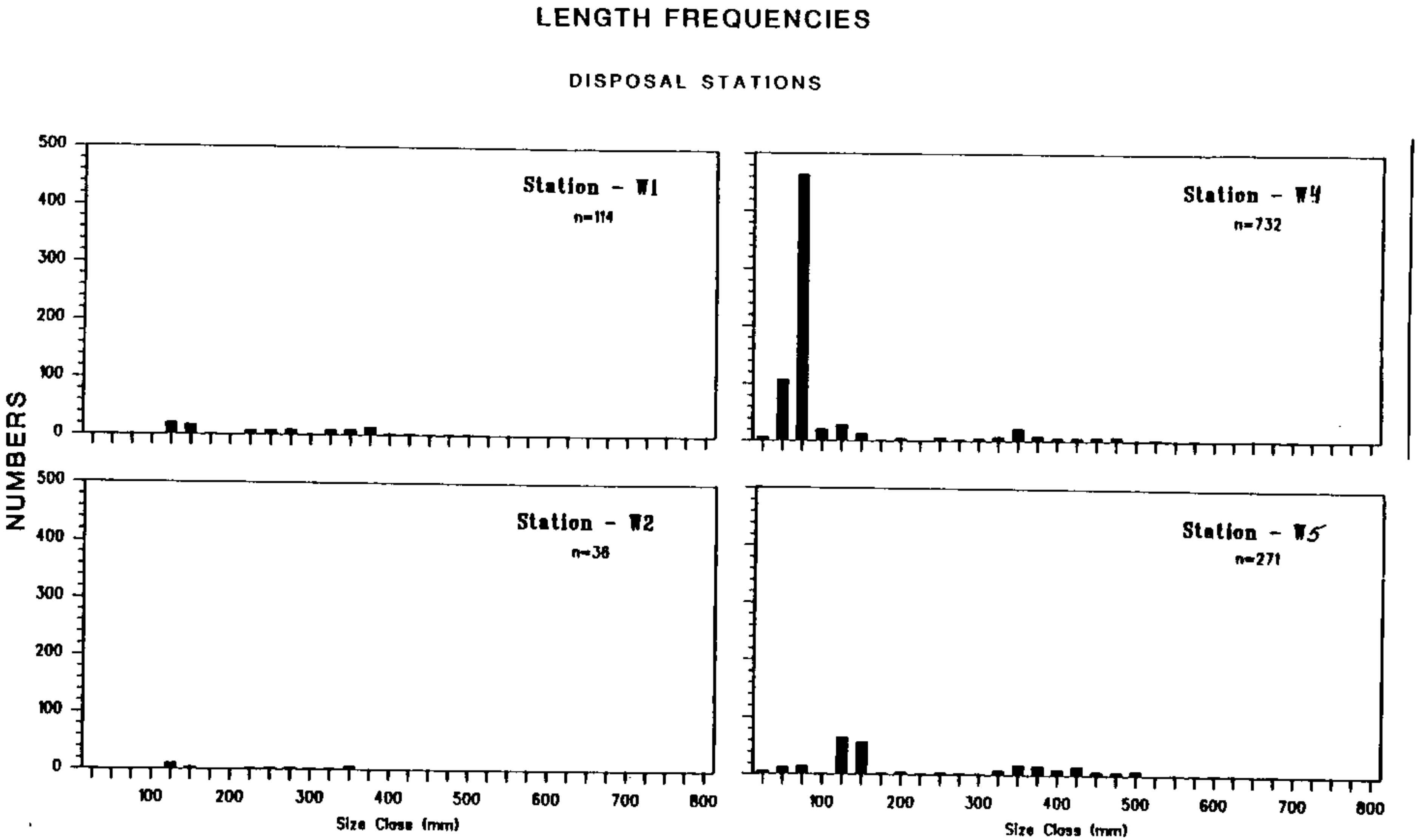

Figure 15. Length frequencies of fishes collected at disposal stations in Lower Granite Reservoir, Washington from January through mid-April, 1986. W5 was upstream from the effluent, W4 was the effluent station, while W2 was 1.6 km and W1 was 9.7 km downstream from the effluent.

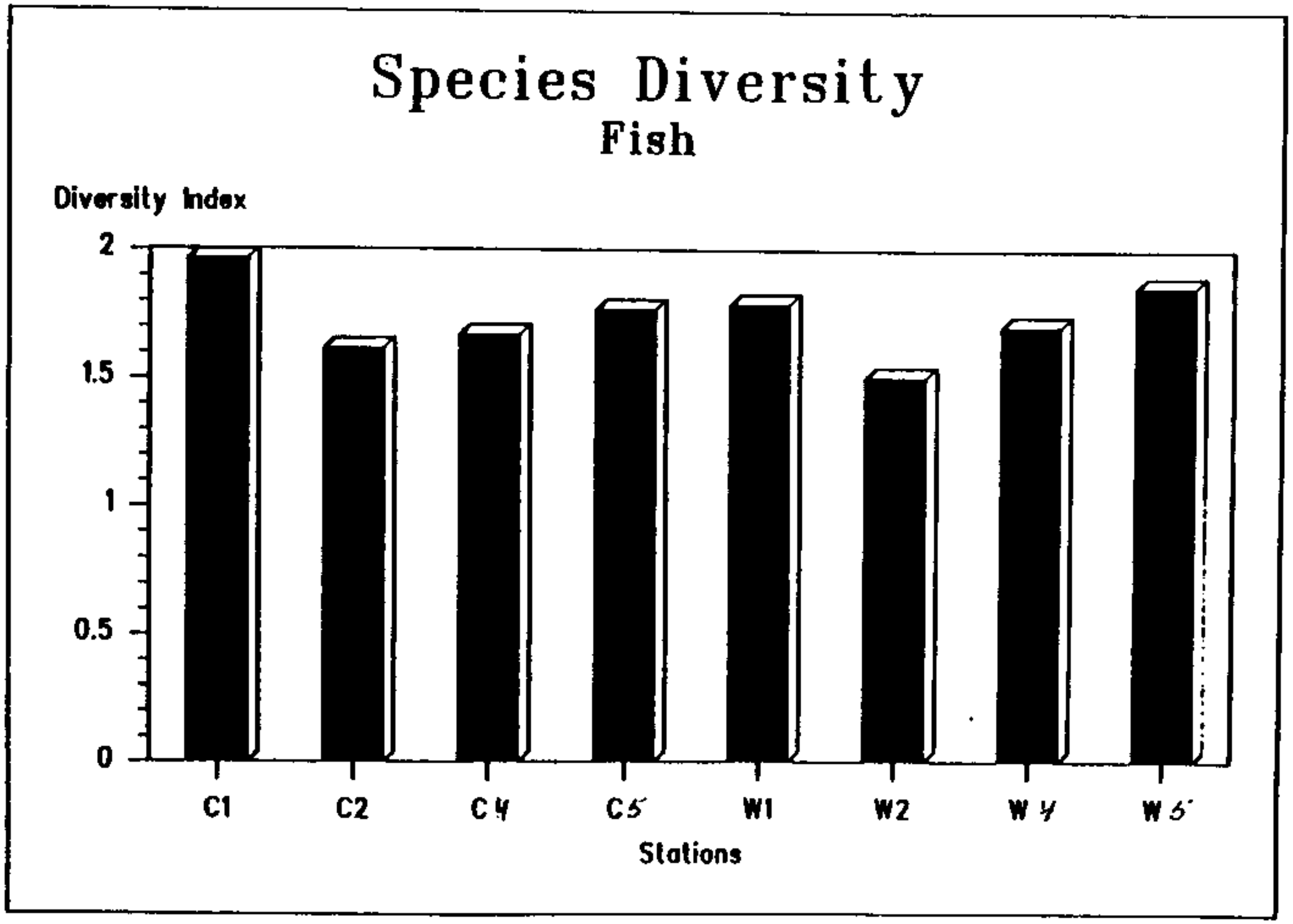

Figure 16. Species diversity indexes (Brillouin 1962) for fishes collected at dredge (C1-C5) and disposal (W1-W5) stations in Lower Granite Reservoir, Washington during January through mid-April, 1986. C4 was the dredging site, while W4 was the effluent station.

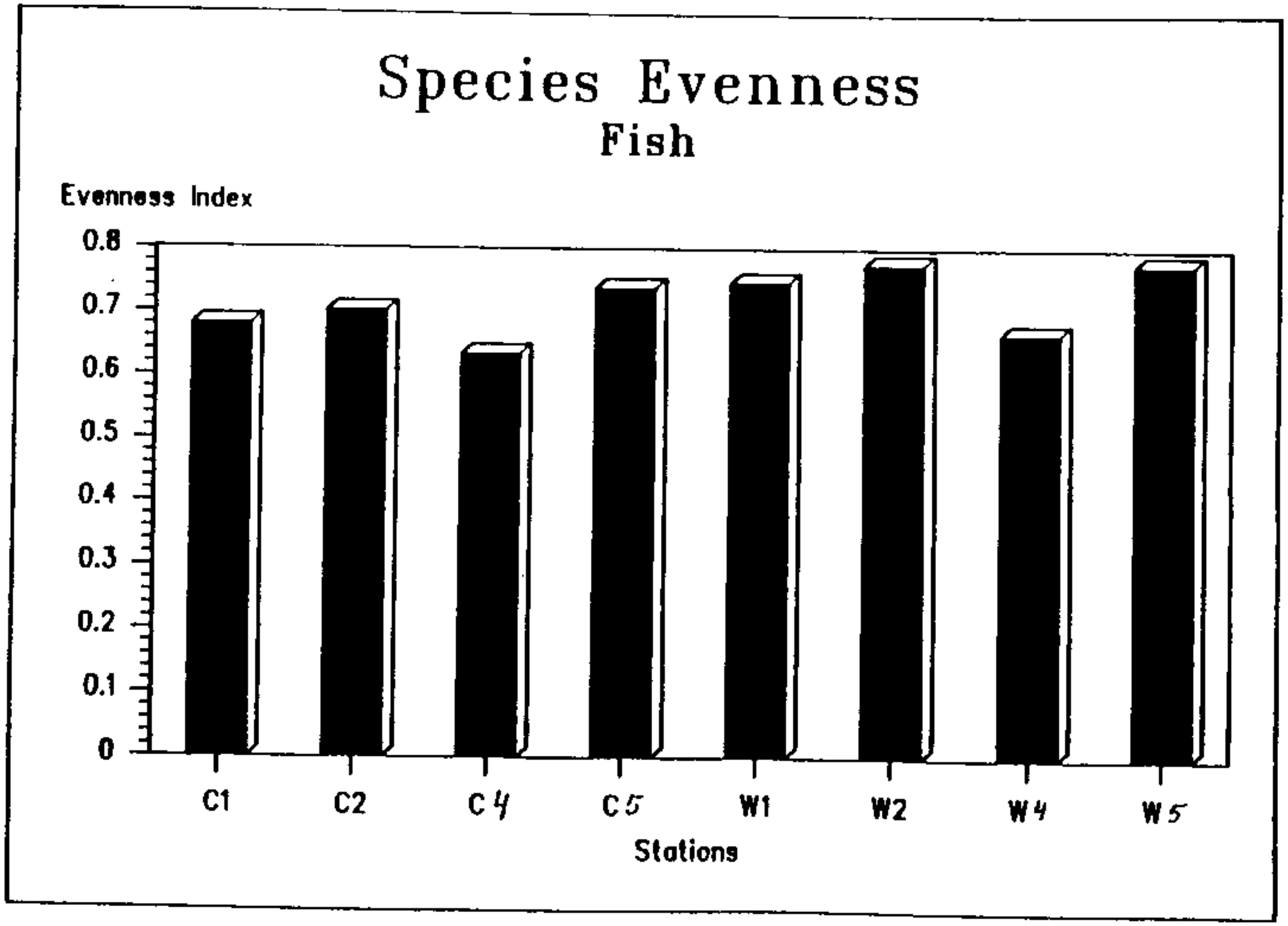

Figure 17. Species evenness indexes for fishes collected at dredge (C1-C5) and disposal (W1-W5) stations in Lower Granite Reservoir, Washington during January through mid-April, 1986. C4 was the dredging site, while W4 was the effluent station. Evenness indexes were calculated using Brillouin's species diversity index (Brillouin 1962).

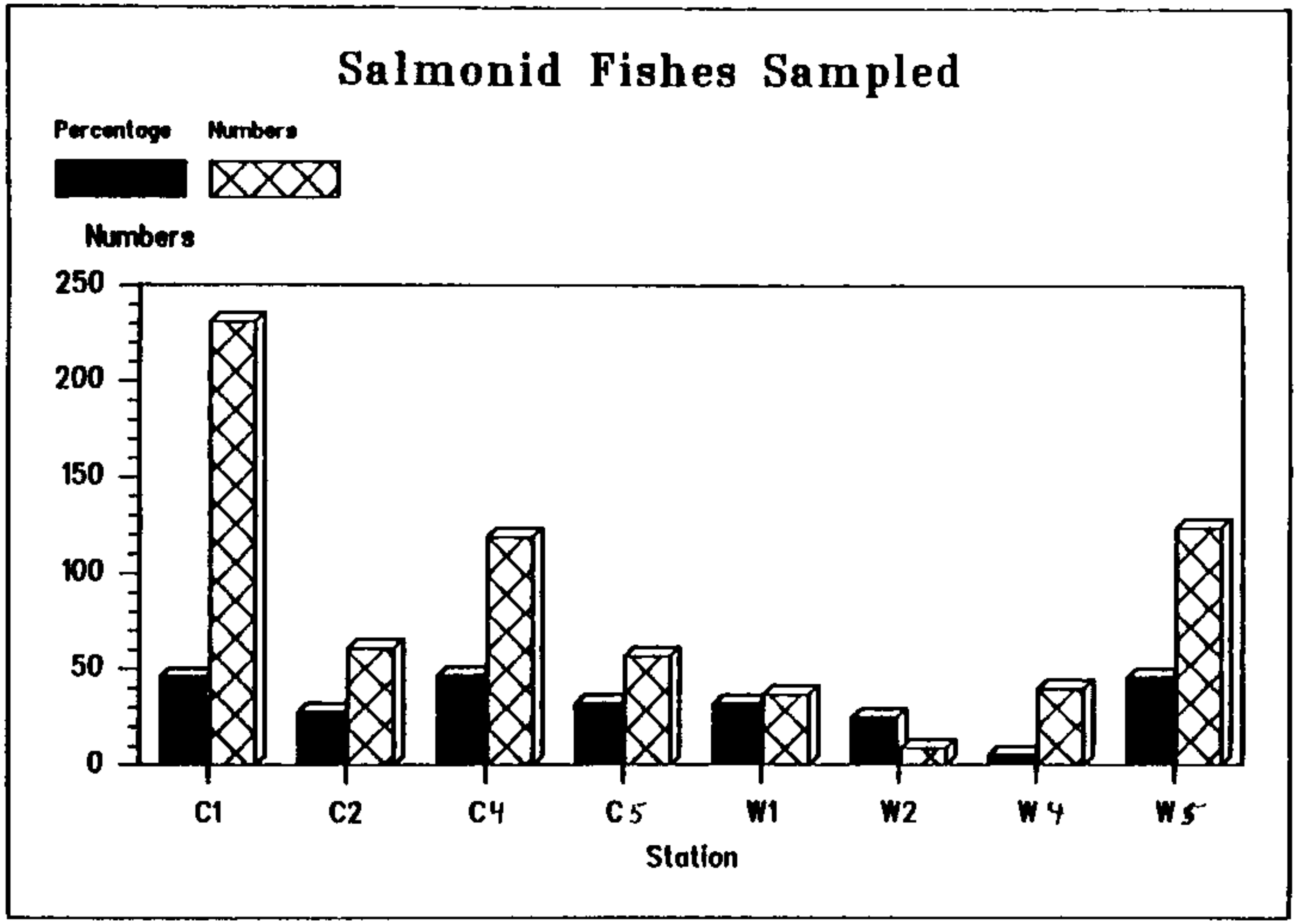

Figure 18. Abundance (numbers and percentage) of salmonid fishes sampled at dredge (C1-C5) and disposal (W1-W5) stations in Lower Granite Reservoir, Washington during January through mid-April, 1986. C4 was the dredging site, while W4 was the effluent station.

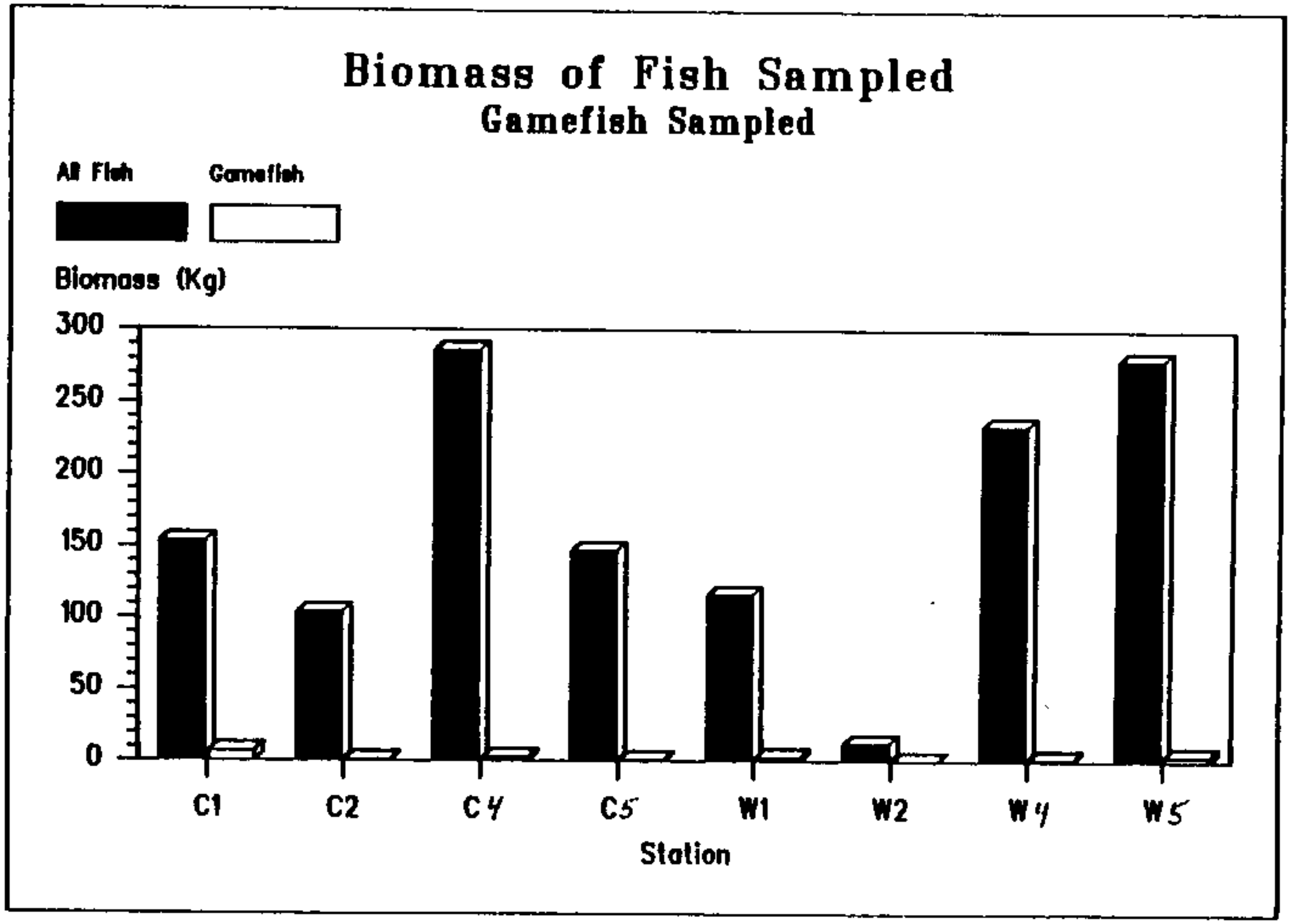

Figure 19. Biomass of all fishes and gamefishes sampled at dredge (C1-C5) and disposal (W1-W5) stations in Lower Granite Reservoir, Washington.

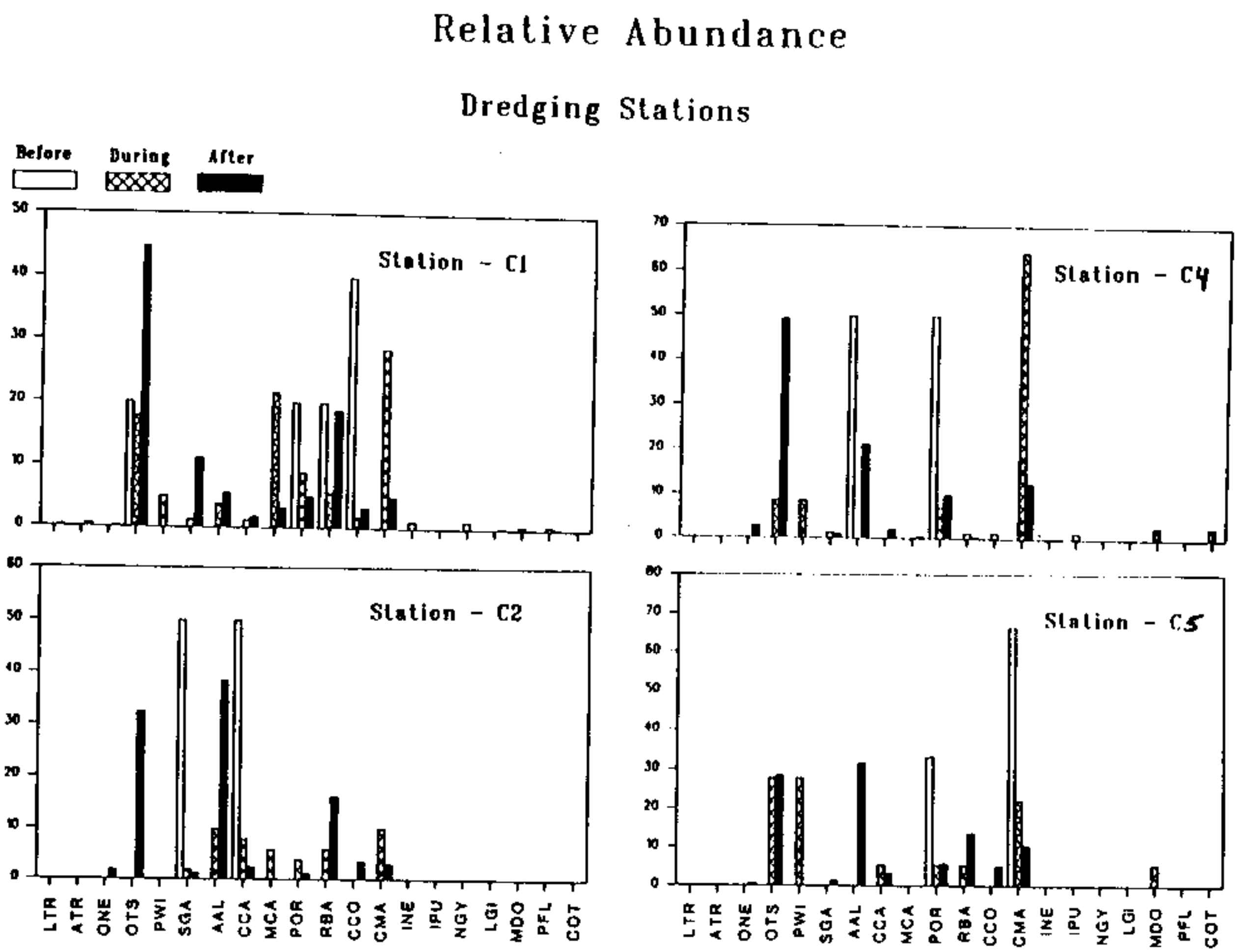

Figure 20. Percent relative abundance of fishes at dredging stations (C1-C5) in Lower Granite Reservoir, Washington before, during and after dredging (January through mid-April, 1986). Species abbreviations are: LTR - Pacific lamprey; ATR - white sturgeon; ONE - sockeye salmon; OTS - chinook salmon; PWI - mountain whitefish; SGA - rainbow trout; AAL - chiselmouth; CCA - carp; MCA - peamouth; POR - northern squawfish; RBA - redside shiner; CCO - bridgelip sucker; CMA - largescale sucker; INE - brown bullhead; IPU - channel catfish; NGY - tadpole madtom; LGI - pumpkinseed; MDO - smallmouth bass; PFL - yellow perch; and, COT - sculpin.

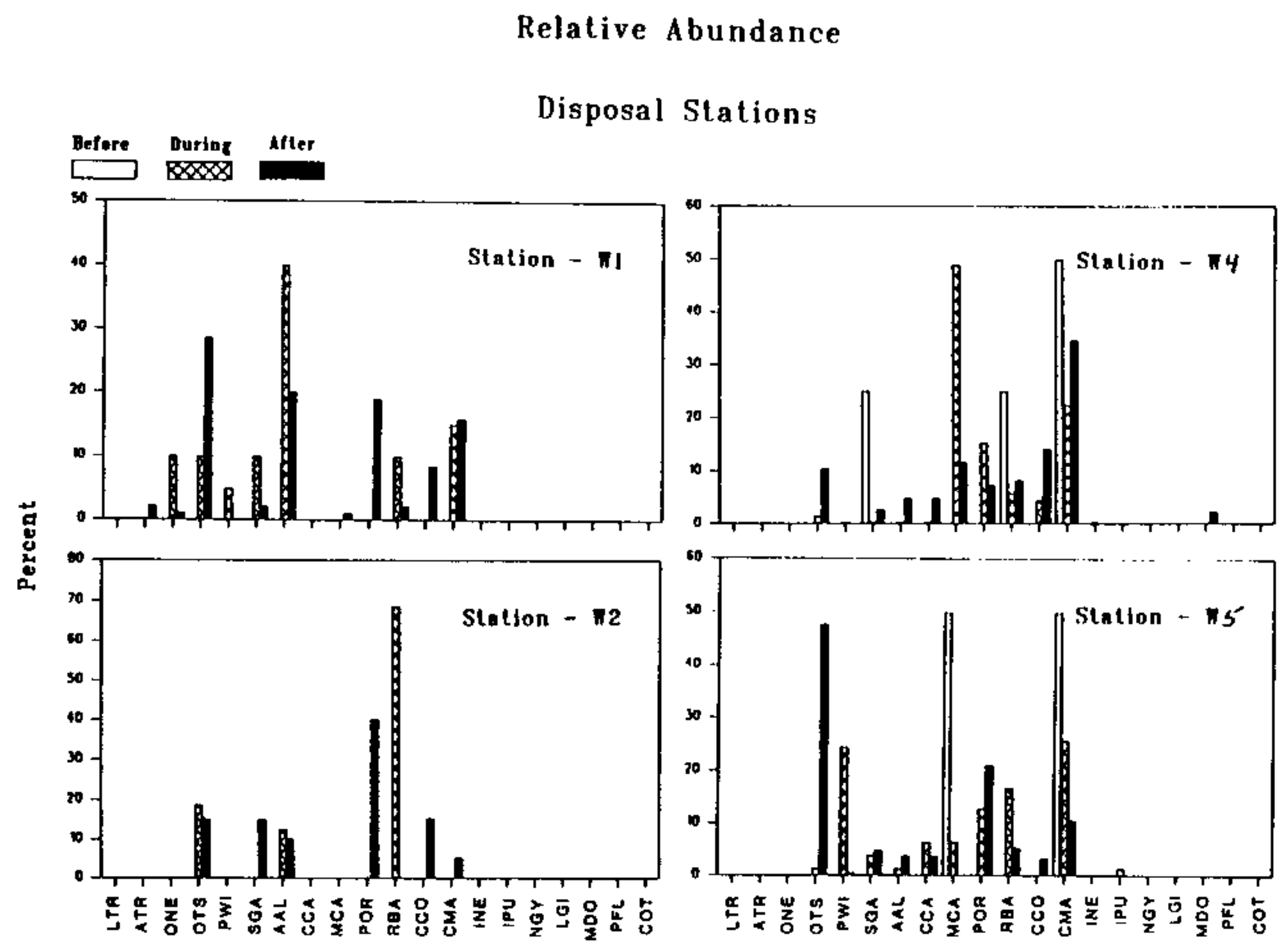

Figure 21. Percent relative abundance of fishes at disposal stations (W1-W5) in Lower Granite Reservoir, Washington before, during and after dredging (January through mid-April, 1986). Species abbreviations are: LTR - Pacific lamprey; ATR - white sturgeon; ONE - sockeye salmon; OTS - chinook salmon; PWI - mountain whitefish; SGA - rainbow trout; AAL - chiselmouth; CCA - carp; MCA - peamouth; POR - northern squawfish; RBA - redside shiner; CCO - bridgelip sucker; CMA - largescale sucker; INE - brown bullhead; IPU - channel catfish; NGY - tadpole madtom; LGI - pumpkinseed; MDO - smallmouth bass; PFL - yellow perch; and, COT - sculpin.

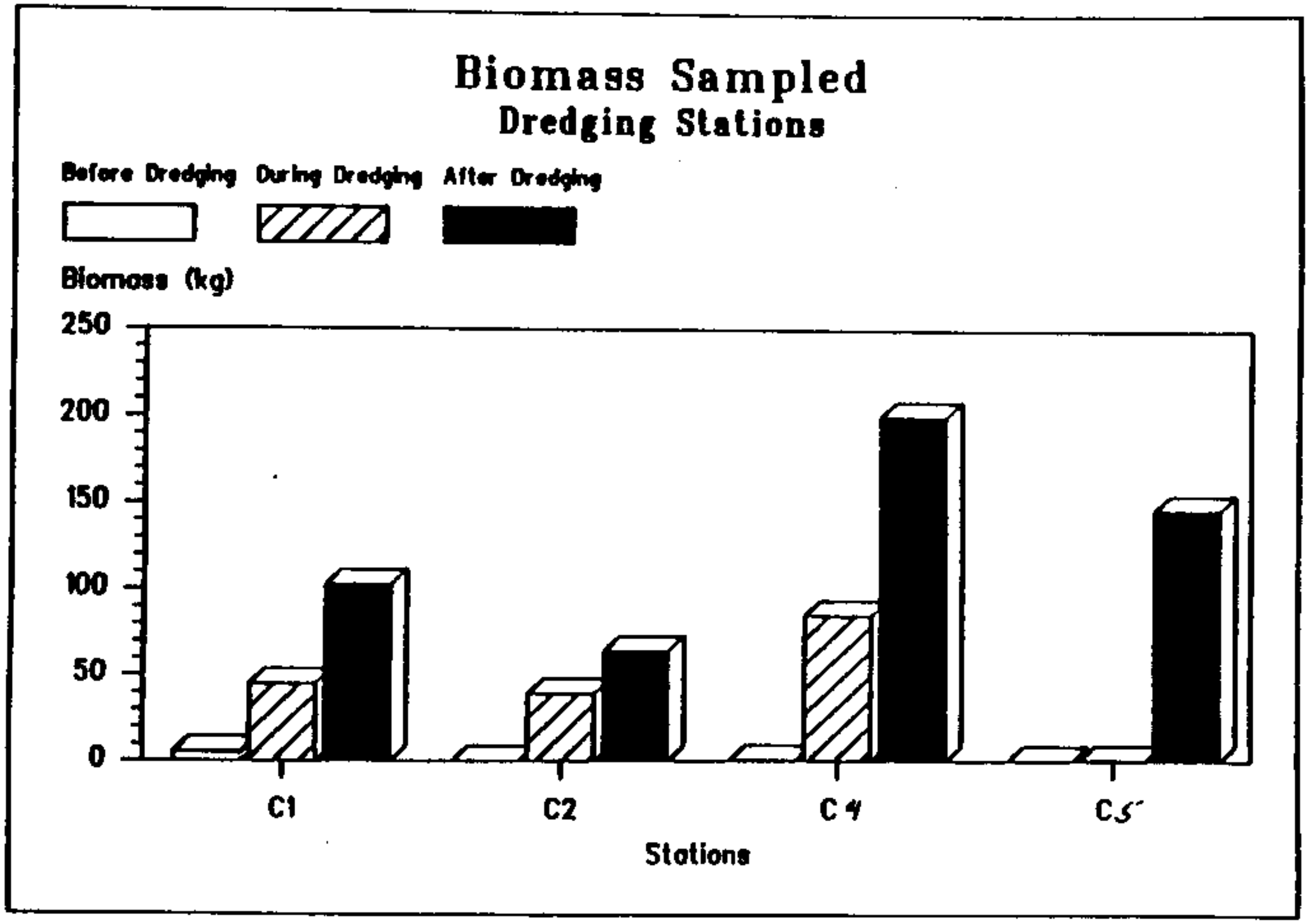

Figure 22. Biomass of fishes sampled before, during and after sediment dredging (January through mid-April, 1986) in Lower Granite Reservoir, Washington.

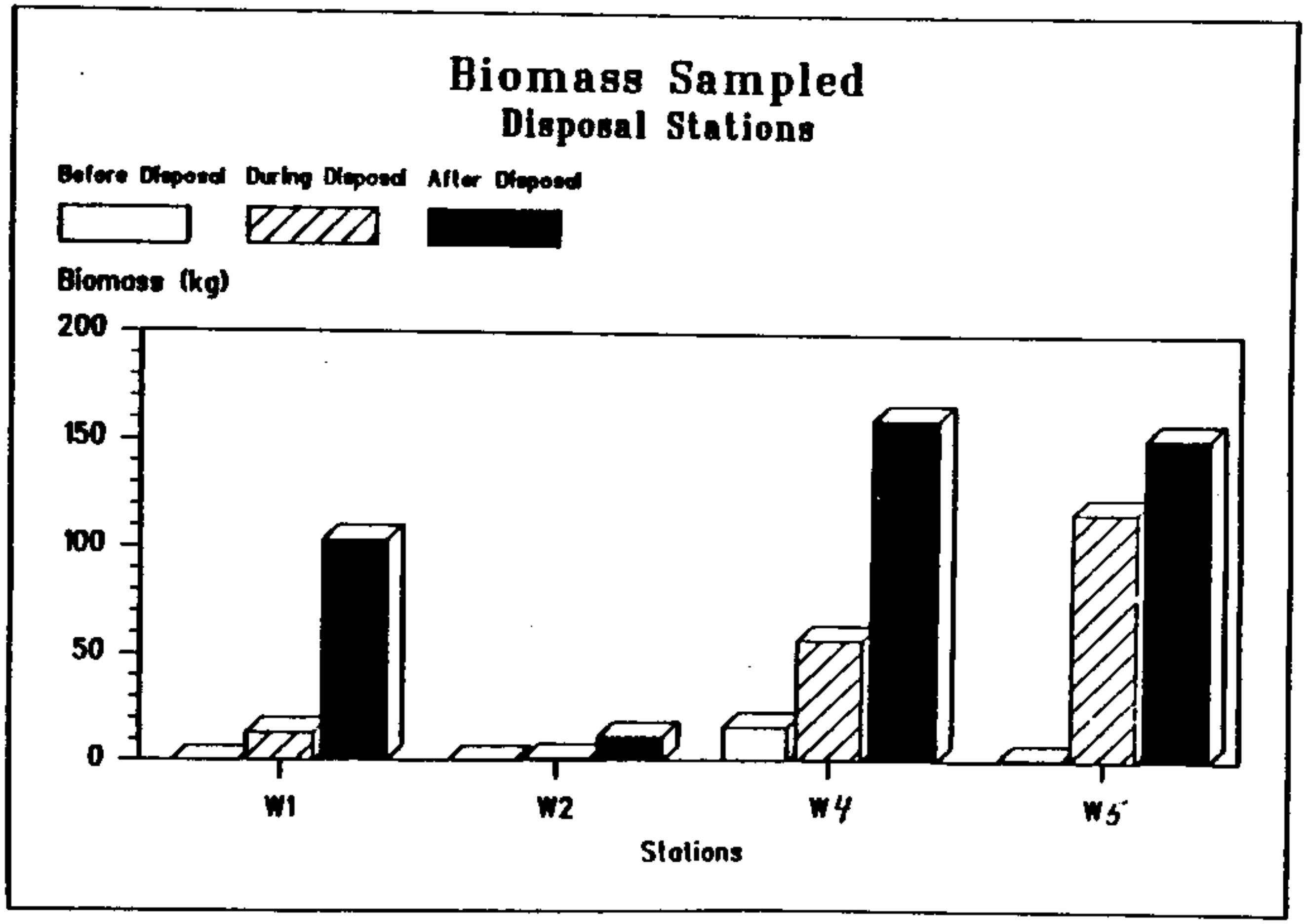

Figure 23. Biomass of fishes sampled before, during and after overflow from land disposal (January through mid-April, 1986) in Lower Granite Reservoir, Washington.

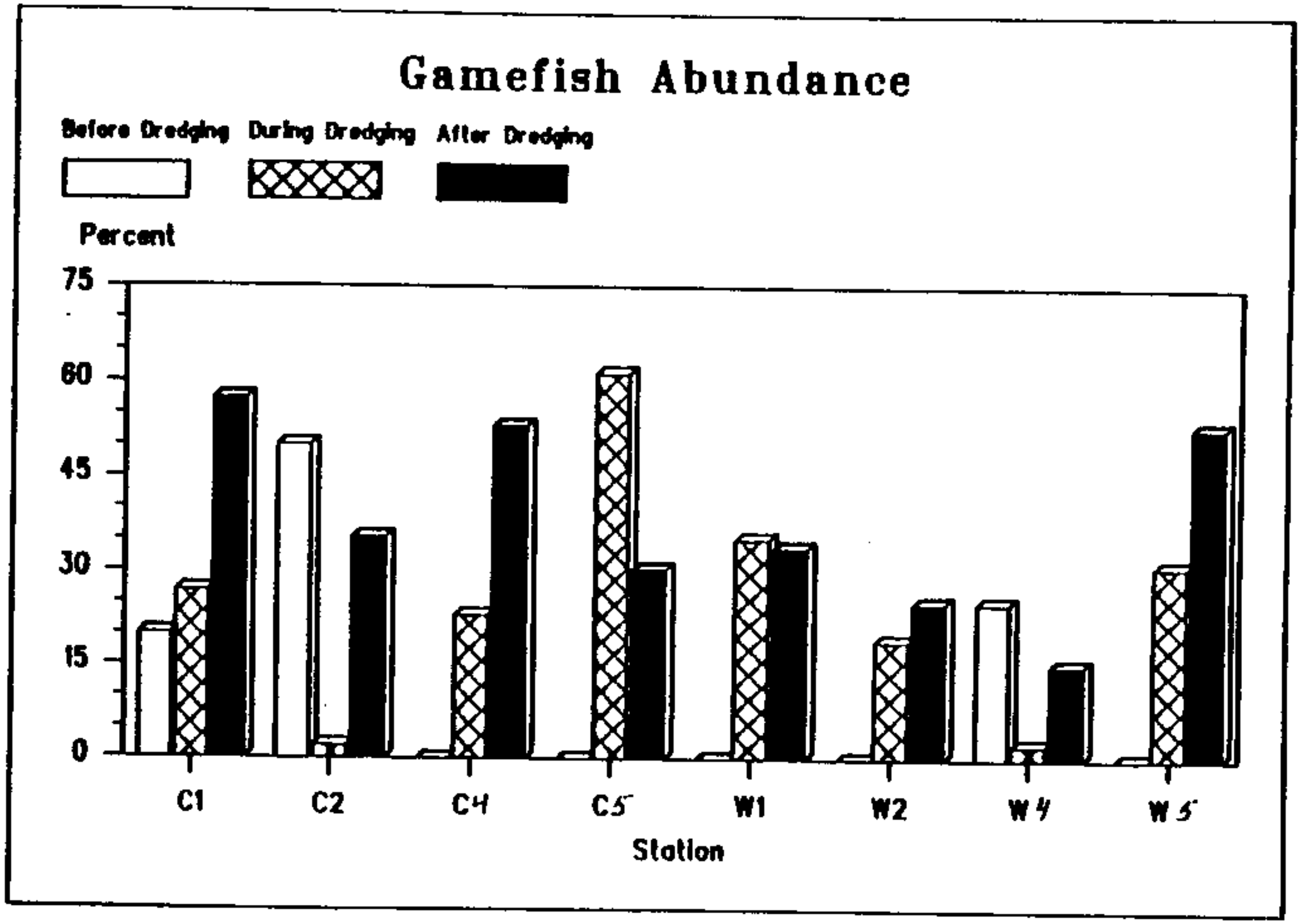

Figure 24. Percent game fish abundance before, during and after sediment dredging (January through mid-April, 1986) and overflow from land disposal in Lower Granite Reservoir, Washington.

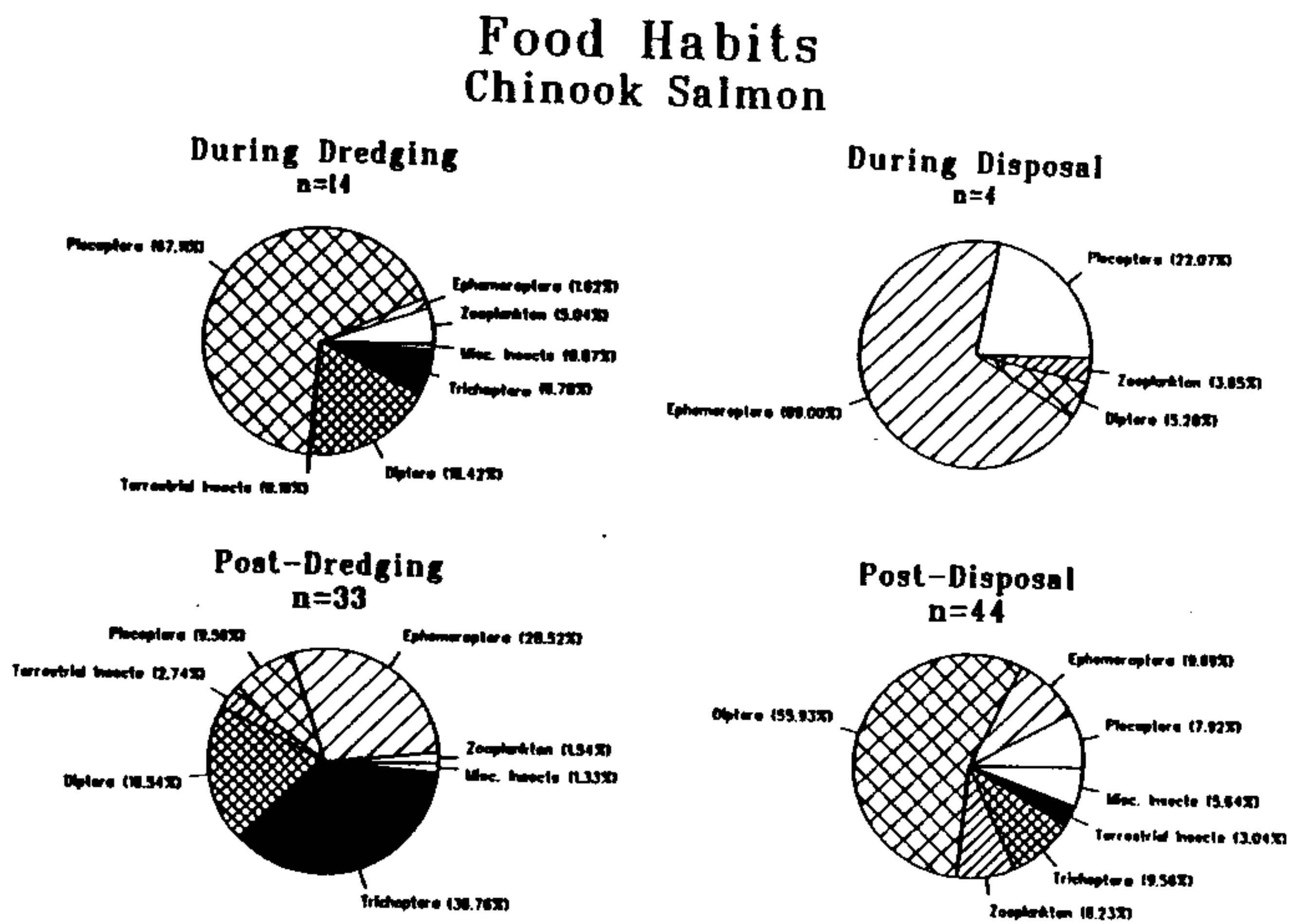

Figure 25. Food items of juvenile chinook salmon during and following sediment dredging and disposal in Lower Granite Reservoir, Washington, 1986. Salmon were collected at dredging and disposal sites to 9.7 km downstream.

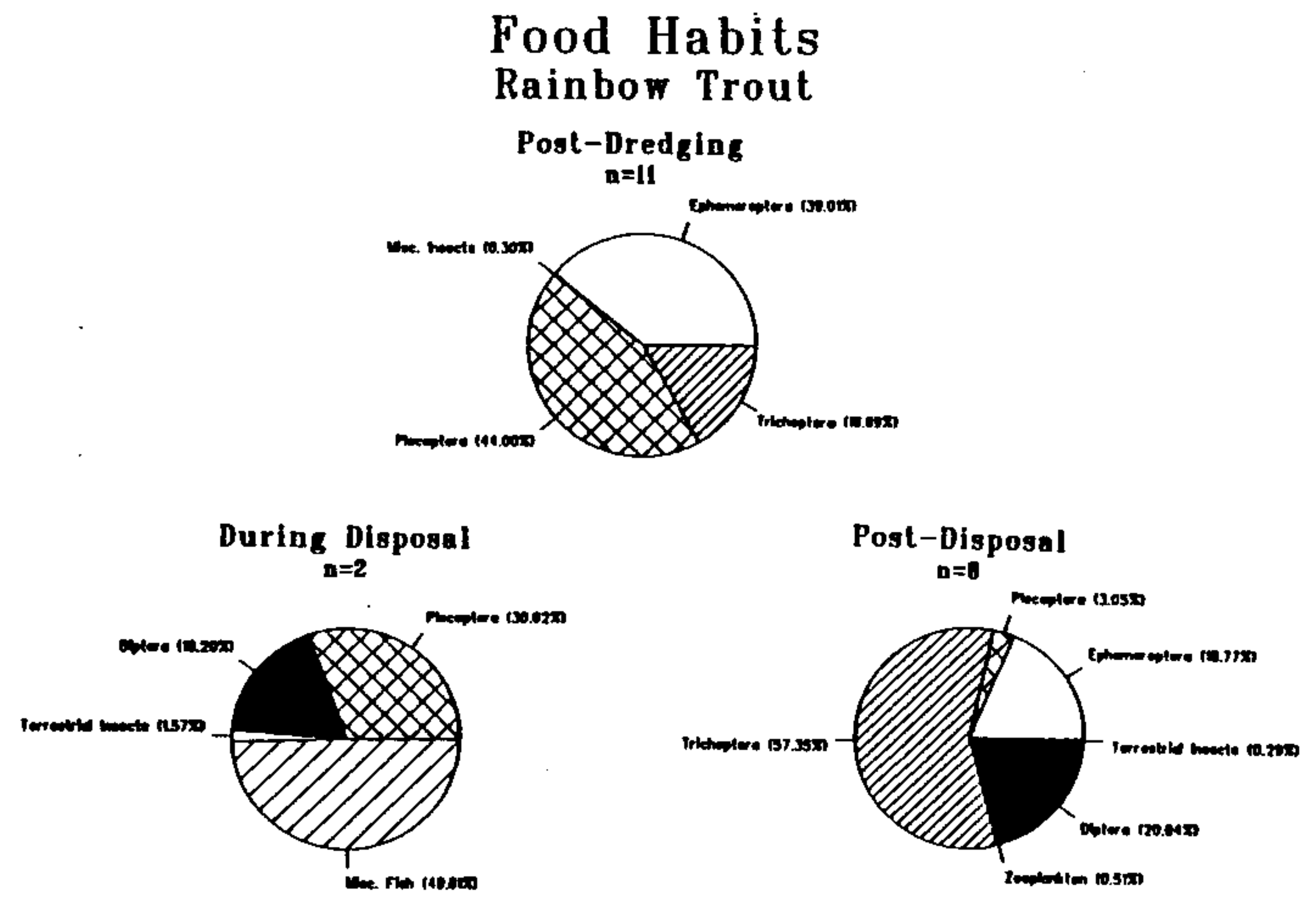

Figure 26. Food items of juvenile rainbow trout following completion of sediment dredging and during and following completion of disposal in Lower Granite Reservoir, Washington, 1986.

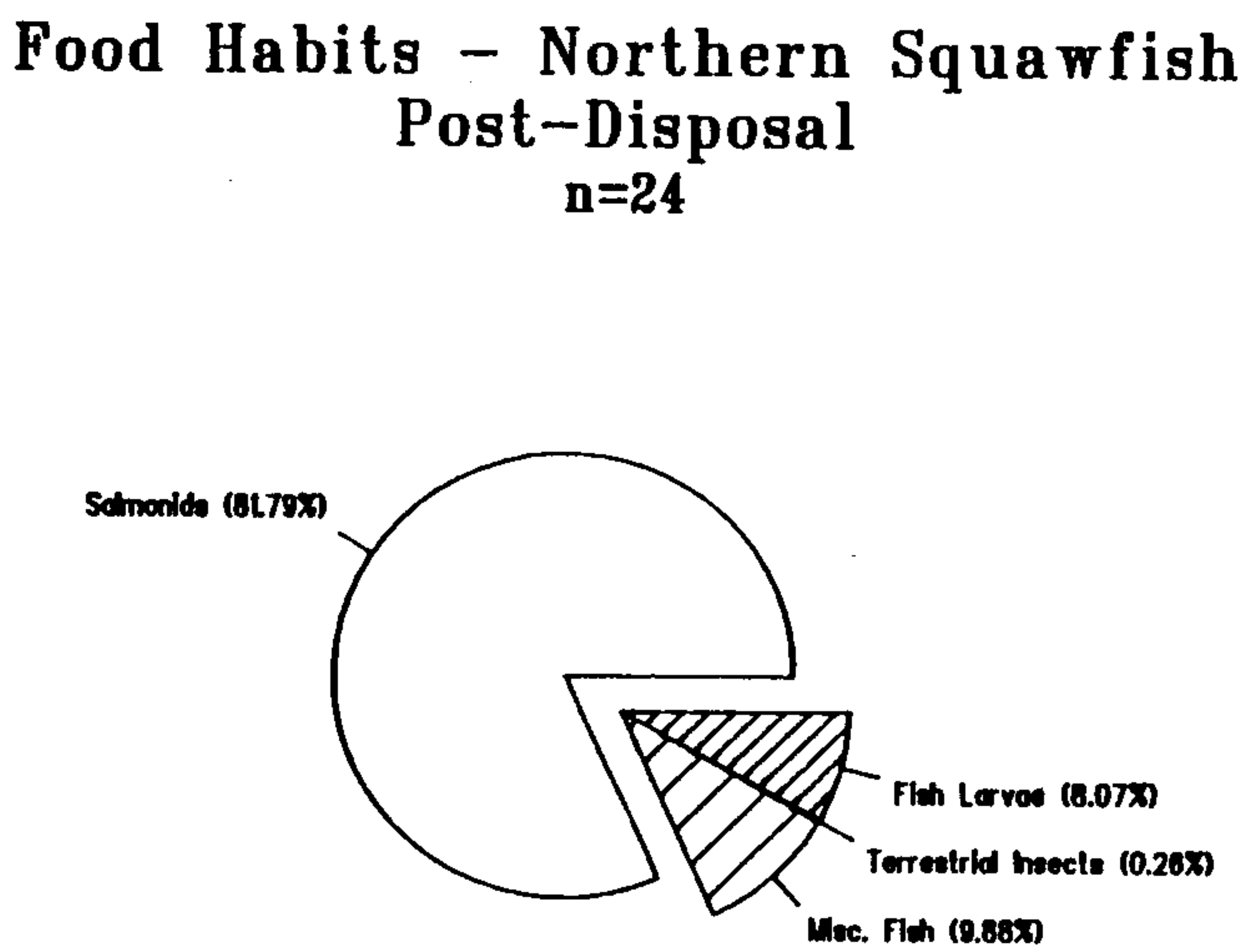

Figure 27. Food items of northern squawfish collected following completion of sediment disposal activities in Lower Granite Reservoir, Washington, 1986.