AQUATIC BASELINE ASSESSMENT OF THE ENVIRONS OF LAKE WASHINGTON AT SAND POINT--WITH PREDICTIONS ON THE EFFECTS OF DEVELOPING A VESSEL DOCKING CENTER

By

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ABSTRACT

A portion of Sand Point, Lake Washington, Washington, has been acquired by the National Oceanographic and Atmospheric Administration and will be developed into a regional headquarters. Developmental plans include the construction of a docking center. This report describes the physical and biological environment of the lake from a 1-year study within the 50 ft contour; effects of development are also considered.

The bottom of the lake off the south and north part of Sand Point has a more gradual slope than is characteristic of the general body of the lake where sharp drops to 90 ft or more are normal. Substrate is of a compacted base of glacial till covered by sediments to 6 inches in depth. The lake edge wash zone is of sand and gravel. Toxic materials in the sediments are at low concentrations and should not affect aquatic life. Wind and convection currents maintain the lake in constant motion, creating strong currents (greater than 1 +mph) at times. Movement of drogues show that current direction frequently varies with that of the major driving force—the wind.

Important macroscopic organisms were identified and their seasonal abundances determined by broad categories of ecological association. The aquatic biota within the 50 ft contour of Sand Point has an annual cycle of abundance where biomass is maximal from May to September. This period encompassed the abundance maximals for fish, zooplankton, crayfish, and plants.

Direct effects of dredging will, in general, be least at the time of year when biomass is minimal. This is during November to March. Within this period, the least biological effects will probably take place from January to March. Suspended sediments from the glacial till bottom at concentrations of 37,000 to 5,000 ppm (observed range for each test) did not cause significant direct effects on the fish, crayfish, or caddis larvae tested during 96-h bioassays.

The long-term effect of dredging, constructing piers and operating ships may change the productivity of the affected area. The shallows at 10 ft are five times more productive in observed numerical biomass of benthos than the 30 ft zone. Increasing the bottom depth to 30 ft may permanently lower the biological productivity of the affected area. Shading of the water from the construction of piers will reduce the energy input into the lake by less than 0.0001%. Pilings will support epiphytic life, and their physical presence should attract certain species, especially fish. Prop wash from vessels could continuously disrupt the bottom thereby affecting productivity.

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INTRODUCTION

In 1969, the Navy declared approximately 300 acres of the Sand Point Naval Air Station as excess property. Of this, 100 acres will be used as the western regional headquarters of NOAA. Plans include relocating a NOAA vessel docking center to Pontiac Bay which will require increasing the depth of the existing shallows to 9.1 m (30 ft) and the construction of piers. This report considers these effects on the major standing aquatic species as partial fulfillment of the requirements for an Environmental Impact Statement. Included in this study are descriptions of the physical characteristics of the Sand Point area and of the major biota. In addition, predictions are made on the effects of dredging and of short- and long-term changes that could result from the proposed alterations of the physical environment.

PHYSICAL CHARACTERISTICS

The bottom slope of the work site is gradual for Lake Washington (Fig. 1). The bottom drops off rapidly to 27 to 55 m (90 to 180 ft) off the area between transects C and D and off transect E (Fig. 1). Areas adjacent to Sand Point have rapid drop-offs to 27 m (90 ft) or more.

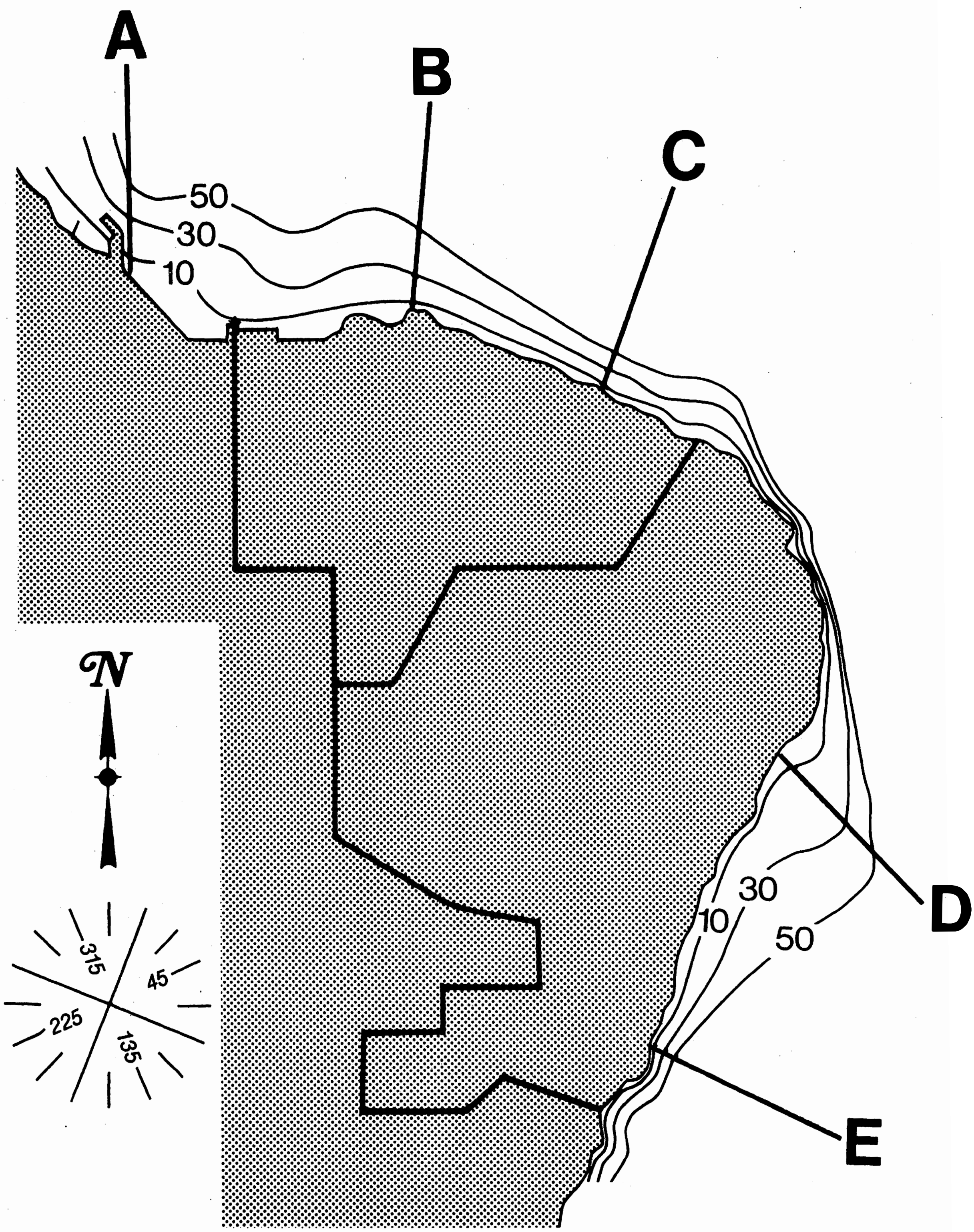

Figure 1.--The Sand Point Study area, Lake Washington, Seattle, Washington. Depth Contours are shown in feet. The northern portion has been alloted to NOAA and the south portion to the City of Seattle for the development of a Park.

The lake bottom surrounding Sand Point is composed of a thin sediment layer over a hard base, with a gravelly shore wash zone at some locations. Drill samples taken at the lake edge to a depth of 4.5 m (15 ft) were of glacial till. The hard bottom below the sediment layer observed at depths from shore to 15 m (50 ft) is probably glacial till, and some rocks on the top are tightly bonded. The sediment layer increases in thickness with depth and ranges from 0 to 15 cm (6 inches). At depths greater than 12 to 15 m (40-50 ft), the bottom assumes the nature of the profundal sediments that characterize most of the lake (Gould and Budinger, 1958). Along transect A (Fig. 1) the soft bottom is usually 6 to 14 cm (2.4 to 5.5 inches) in thickness, although some cobble outcroppings occur with a 1 to 2 cm (0.4 to 0.8 inch) sediment overlay. The bottom along transect B is most unusual because of a reduced sediment layer and extensive rock outcroppings. Thickness of the soft bottom ranges from 2 to 8 cm (0.8 to 3.9 inches); rocks in outcroppings range from 3 to 10 cm (1.2 to 4.0 inches) in dimension; frequent rocks of about 30 cm are found; and one boulder 3 x 1.5 x 1.5 m (9.8 x 5 x 5 ft) was observed. The soft bottom along transect C consists of two distinct layers totaling 12 to 15 cm (4.7 to 6.0 inches) in thickness; the top 6 cm (2.3 inches) layer overlies a 6 to 9 cm (2.3 to 3.5 inches) layer of compacted material.

Sediments in the area of transects A and B have a high organic content and can be generally characterized as having small average grain size.[1/] This leads to the hypothesis that this area acts as a sink or trap in which organic detritus and fine silts are deposited. Organic detritus decreases at transects C and D.

1/ McConnoha, Ms. thesis, Univ. Wash., in preparation.

Interestingly, the gravel base so evident at transects A and B does not extend to transect C. This area has a silt layer overlying a blue-grey plastic clay which shows bedding structures in some places.

Transect D displays a more sandy nature than does transects A through C. In addition, the sediments in this area are heterogeneous with some grab samples having large amounts of gravel, while others from the same depth showing considerably less.

The wash zone from 0.9 m (3 ft) to the shore normally ranges, with decreasing depth, from cobble and gravel to sand and gravel at the lake edge. Pontiac Bay has been altered with cement bulkheads and ramps (between transects A and B) and by placement of bulkheads of asphalt blocks, reducing or eliminating the wash zone. The wash zone is eliminated from the dock (transect A) eastward to the ramp. The ramp area has a cobble zone below the apron of the cement. The remaining portion of the Sand Point shoreline is generally of asphalt and rubble fill forming an abrupt lake edge.

Trace amounts of toxic materials are contained in the sediments (lead-Schell, 1974; arsenic and antimony-Crecelius, 1975; and a complete analysis from Sand Point--project contract by Northwest Consultant Oceanographers in 1974, Appendix C). Quantitatively, the trace materials are less in the zone less than 15 m (50 ft) deep in comparison with the central basin of the lake because of the relatively great thickness of the sediment layers in the depths (Gould and Budinger, 1958) and the increased deposition of toxic materials in recent years.

Unusual man-made features were found at two locations off Sand Point. Off the east end, where the bottom slope is precipitous, considerable debris is located at the 1.5 to 15 m (5 to 50 ft) depths. It is almost entirely metallic consisting of decomposed iron barrels and stainless steel components. In the area off transect E, some mounds of cobble were observed.

Currents in Lake Washington are constantly in motion basically as a result of winds and convection currents. Inlet streams and the lake's outlet may be important within a restricted area at times of heavy rains. The predominant winds are southerlies with northerlies occurring occasionally; winds from other directions are unimportant. Thus, the predominant winds follow the long axis of the lake. Wind velocity is usually less than 16 kilometer/h (10 mph); however, velocities may exceed 97 kilometer/h (60 mph), especially in the winter.

Lake current studies around Sand Point using drogues show that current directions are not entirely the same as that of the wind and that water velocities are often appreciable. Drogues released by NMFS and CH2M Hill[1/] often moved in directions different from that of the wind. Two drogues consisting of plastic garbage cans connected to surface floats with 1.5 and 12 m (5 and 40 ft) of twine were released at three to four locations around Sand Point under four wind conditions. A 5 kilometer/h (3 mph) southerly (out of 190° magnetic) resulted in a slow eastward drift of the 1.5 and 12.0 m (5 and 40 ft) drogues released at transect B

1/ CH2M Hill, Inc. 1974, Summer circulation studies of Lake Washington.

on August 30, 1975. With a 15 kilometer/h (9 mph) southerly (out of 190°), the current slowly moved in a northward direction (Fig. 2). A 20 kilometer/h (12 mph) southerly (out of 200°) caused a variey of directional movements (Fig. 3). The 1.5 m (5 ft) drogue at transect E was the only one moving in a northward direction; rate of movement in this case was great. The 12 m (40 ft) drogue released at transect E showed little or no movement. Dorgues released at transects A and B drifted eastward at a rate of over 1.6 kilometer/h (1 mph). An 11 kilometer/h (7 mph) northerly resulted in a general southward drift of drogues except that the 12 m (40 ft) drogue released at transect E drifted northward (Fig. 4).

Total suspended solids ranged from 15 ppm along the shore during a northerly of 18 kilometer/h (11 mph) to 1 ppm on a calm day. Sediments in the shallows stirred into suspension by wave and current action are largely removed to the depths (Gould and Buddinger, 1958).

Water Temperatures around Sand Point for 1974-75 are given by Shepard (1975; Appendix A).

DESCRIPTION OF BIOTA

The major animal life around Sand Point are the plankton, aquatic insects, fish, crayfish, oligochaetes, clams and snails. Each type was examined by ecological association under the divisions of plankton, benthos, and fish. Thus, the planktonic community, consisting of crustaceans and fish larvae, were collected in plankton nets; the benthic community composed of burrowing insects, oligochates, and pelecypods were captured by a "Ponar grab"; fish were captured with gill and fyke nets; and general observations on all animal life--especially the species of

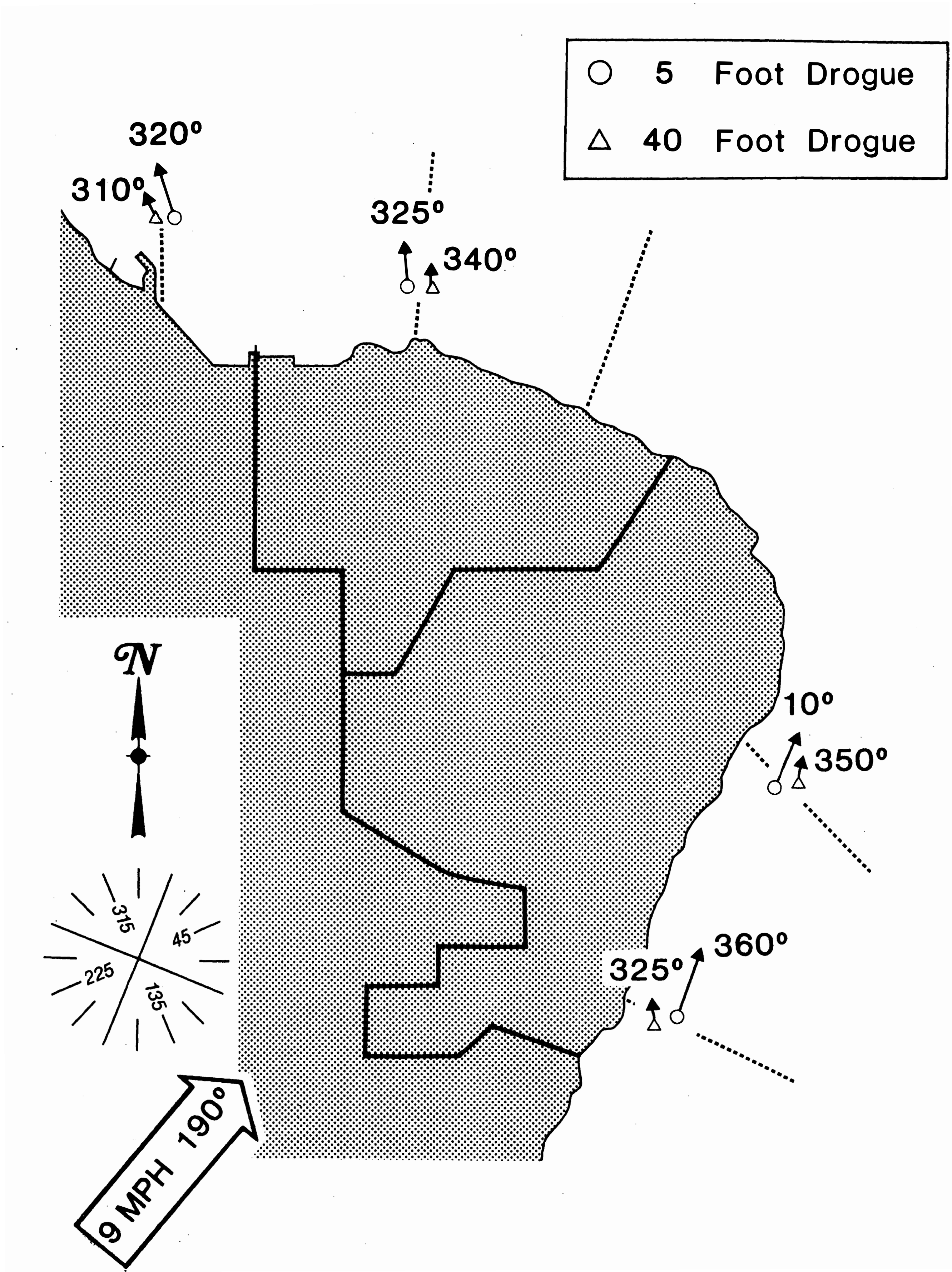

Figure 2.--Movement of drogues at depths of 1.5 and 12 m (5 and 40 ft) off Sand Point in July at the indicated wind velocity and direction. Length of arrow indicates relative velocity of current.

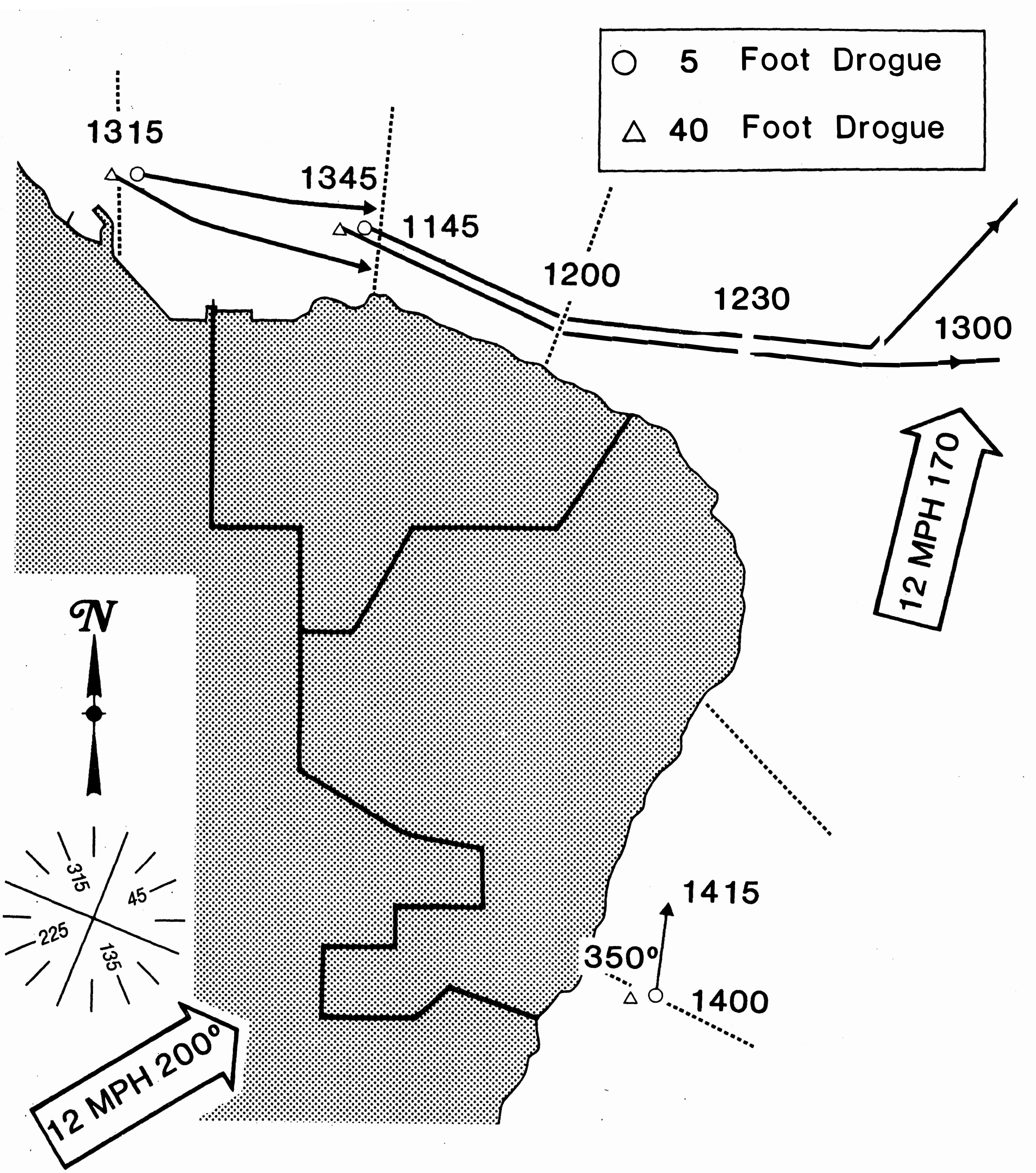

Figure 3.--Movement of drogues at depths of 1.5 and 12 m (5 and 40 ft) off Sand Point in August at the indicated direction and velocity of wind. The times shown are at the release of drogues, at intervals of drift and at the time of retrieval.

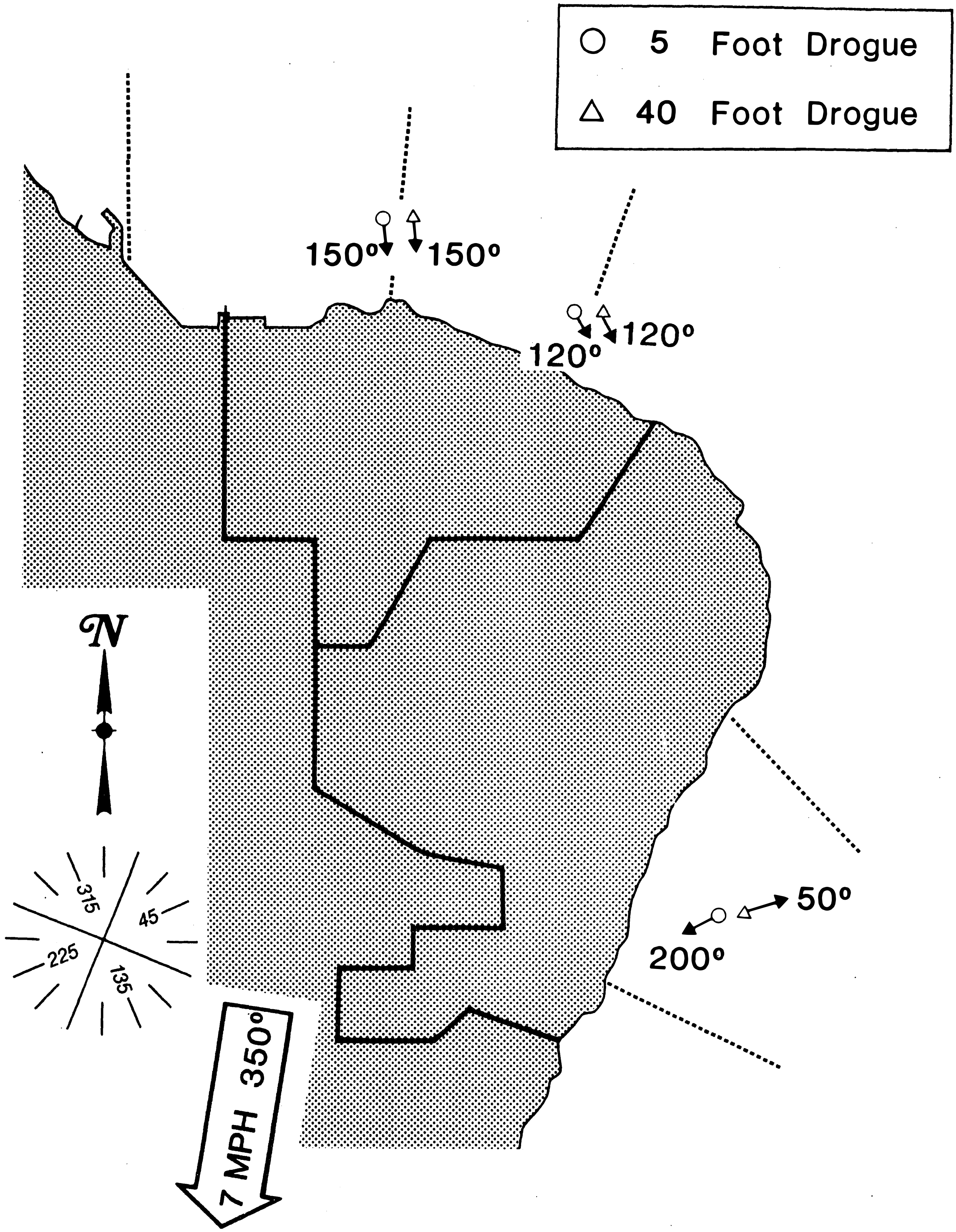

Figure 4.--Movement of drogues at depths of 1.5 and 12 m (5 and 40 ft) off Sand Point in May at the indicated direction and velocity of wind. Length of arrow indicates the relative velocity of current.

mysid, sculpins, and crayfish--were made by diver surveys. The fish study is contained under separate cover (Shepard, 1975; Appendix A). Sculpins were not adequately sampled by Shepard because of their small size and their habitat in waters 30 to 60 cm (1 to 2 ft) deep. Sculpins, 20 to 30 mm (0.8 to 1.2 inches), were abundant at depths from 0.7 to 15.0 m (2 to 50 ft) through the year. Aleutian sculpins, *Cottus aleuticus*, were sparse in the 60 to 90 cm (2 to 3 ft) depth zone and were in an approximate 30:1 ratio to prickly sculpin (*C. asper*).

BENTHIC INVERTEBRATES

The most striking feature of the benthic fauna around Sand Point is the greater numbers of organisms at the 3 m (10 ft) station than at deeper stations (Table 1, Fig. 5). The most likely explanation is the protection against currents afforded by the dense vascular plants that results in sedimentation, the rich food source provided by the attached macrophytes, and allochthanous (detritus of terrestrial origin) input.

Chironomidae (aquatic fly larvae)

The seasonal population dynamics of the chironomidae can be generally characterized as having an increase in numbers in the winter followed by a sudden decrease in population (Fig. 6 through 9). The apparent rise in population probably reflects an increase in the size of the larvae, enabling more and more to be trapped by the 0.5 mm sieve used to concentrate the field samples. The sudden decrease is assumed to be the result of the aquatic pupae emerging to become terrestrial adults. These trends are most dramatically demonstrated in the 3 m (10 ft) stations (Fig. 6 through 9). Small numbers within the sample tend to obscure these changes at the deeper stations.

Table 1.--Average numbers of benthic organisms per grab (529 cm^2) for samples taken at four transects, October 1974 and January, April, and July 1975.

Depth (ft)	10	30	50
Chironomidae	428.6	41.34	34.69
Oligochaeta	274.46	67.38	25.74
Amphipods: *Hyallela azteca*	31.30	-	-
Pontoporia affinis		.25	.50
Hirudinea	.5	1.0	1.0
Gastropods	1.0	-	-
Pisidium sp.	39.72	21.40	9.54

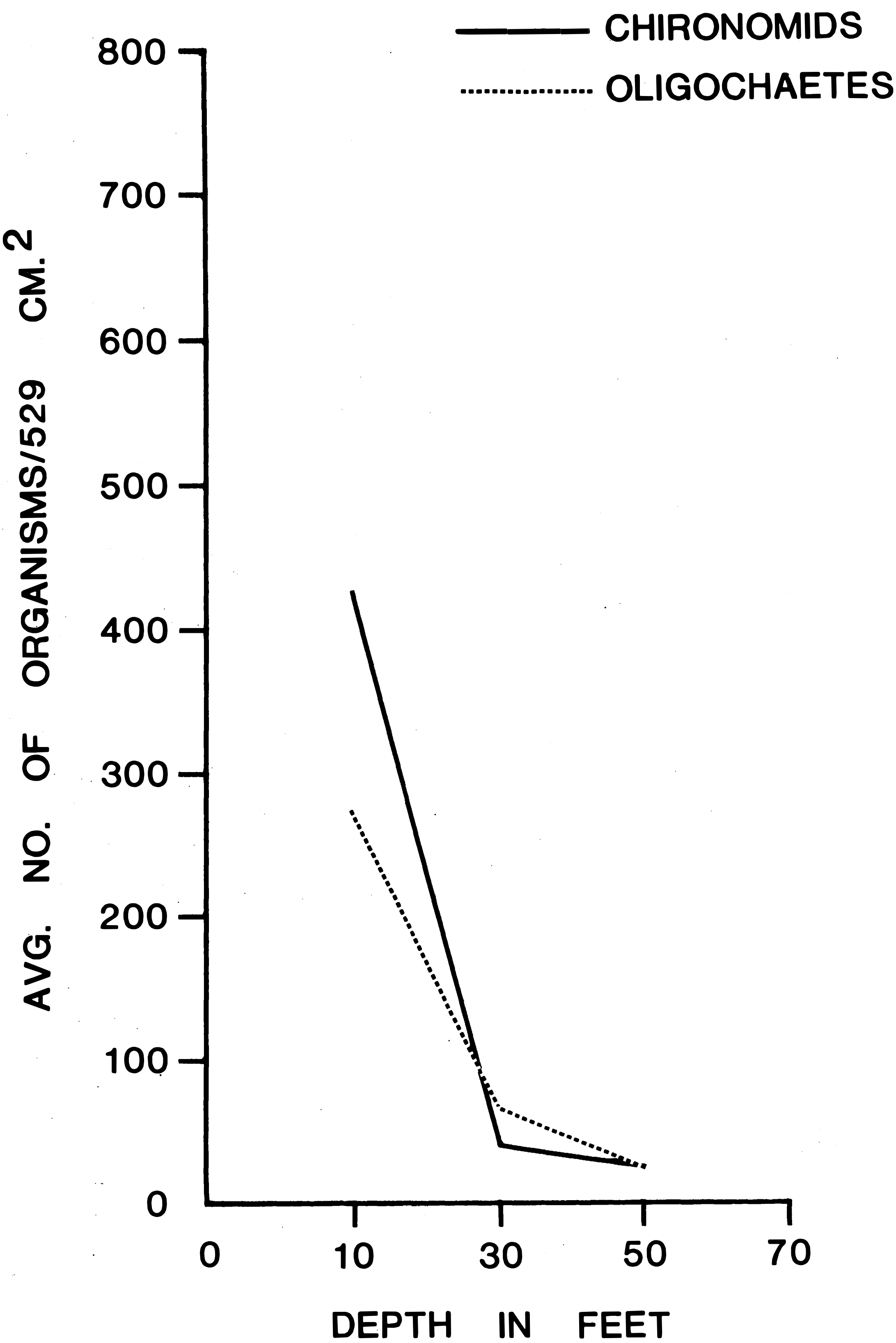

Figure 5.--Average numbers of chironomids and oligochaetes with depth at all transects.

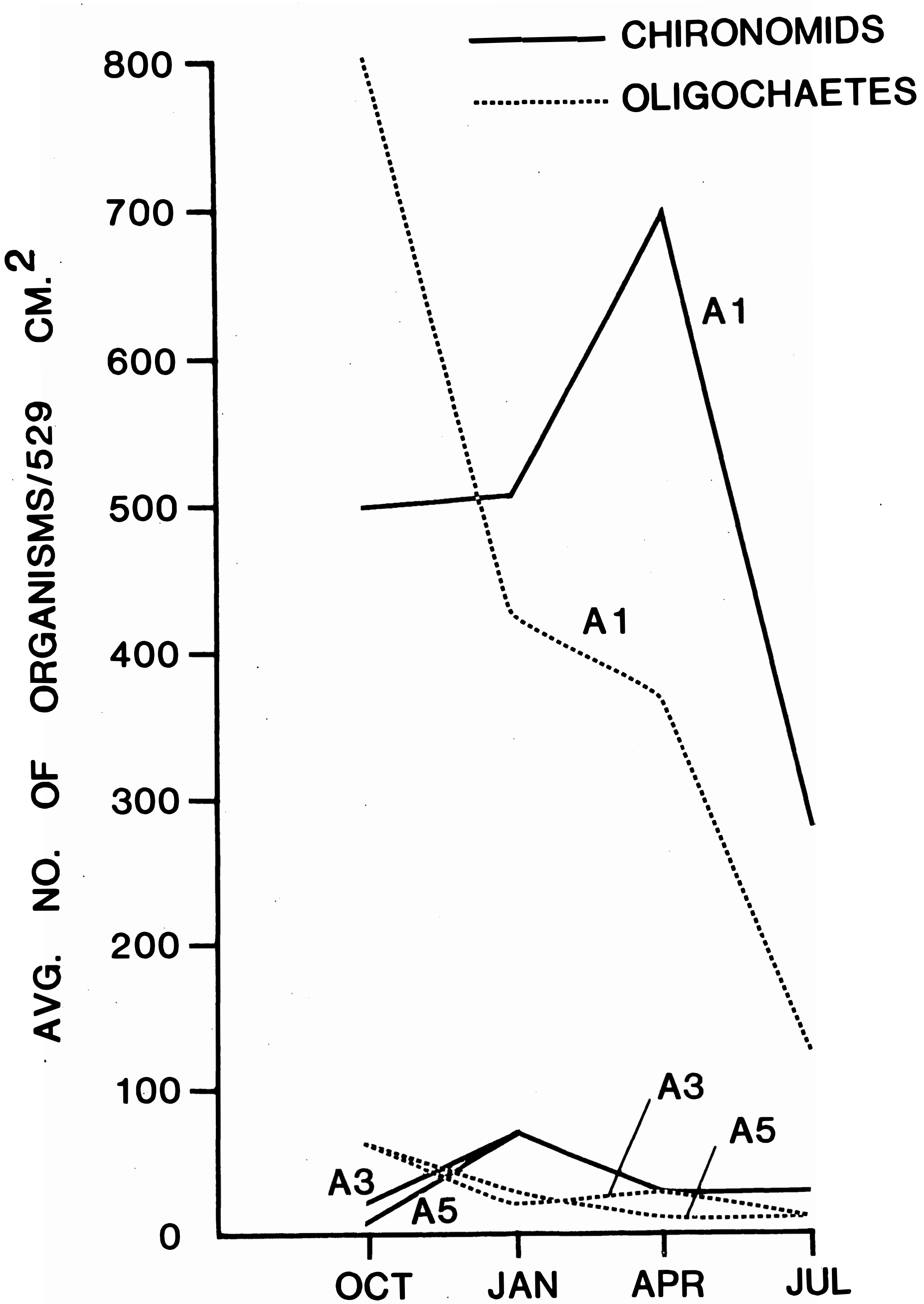

Figure 6.--Numbers of chironomids and oligochaetes by season along transect A at depths of 3 m (A1; 10 ft), 9.1 m (A3; 30 ft), and 15 m (A5; 50 ft).

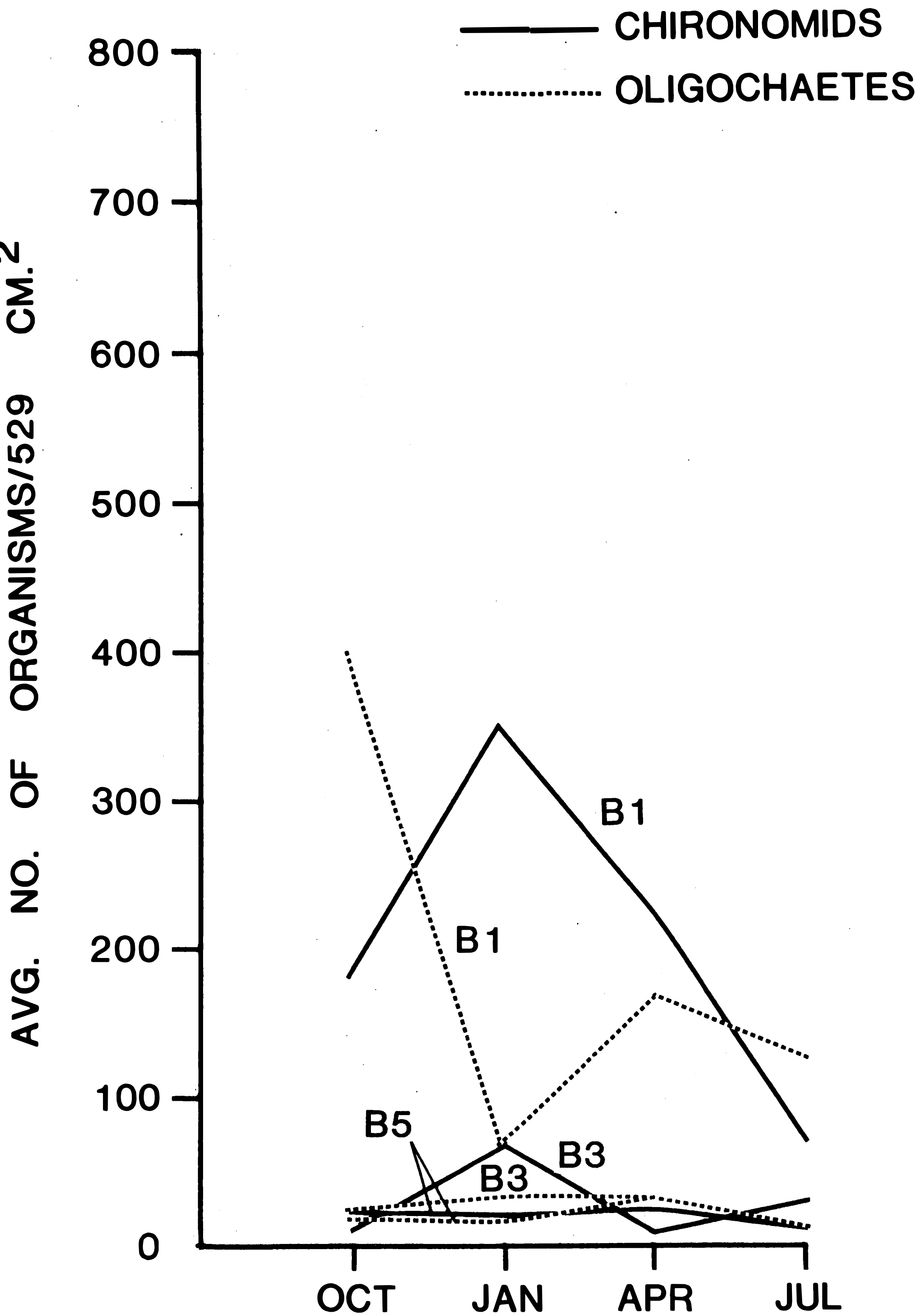

Figure 7.--Numbers of chironomids and oligochaetes by season along transect B at depths of 3 m (B1; 10 ft), 9.1 m (B3; 30 ft), and 15 m (B5; 50 ft).

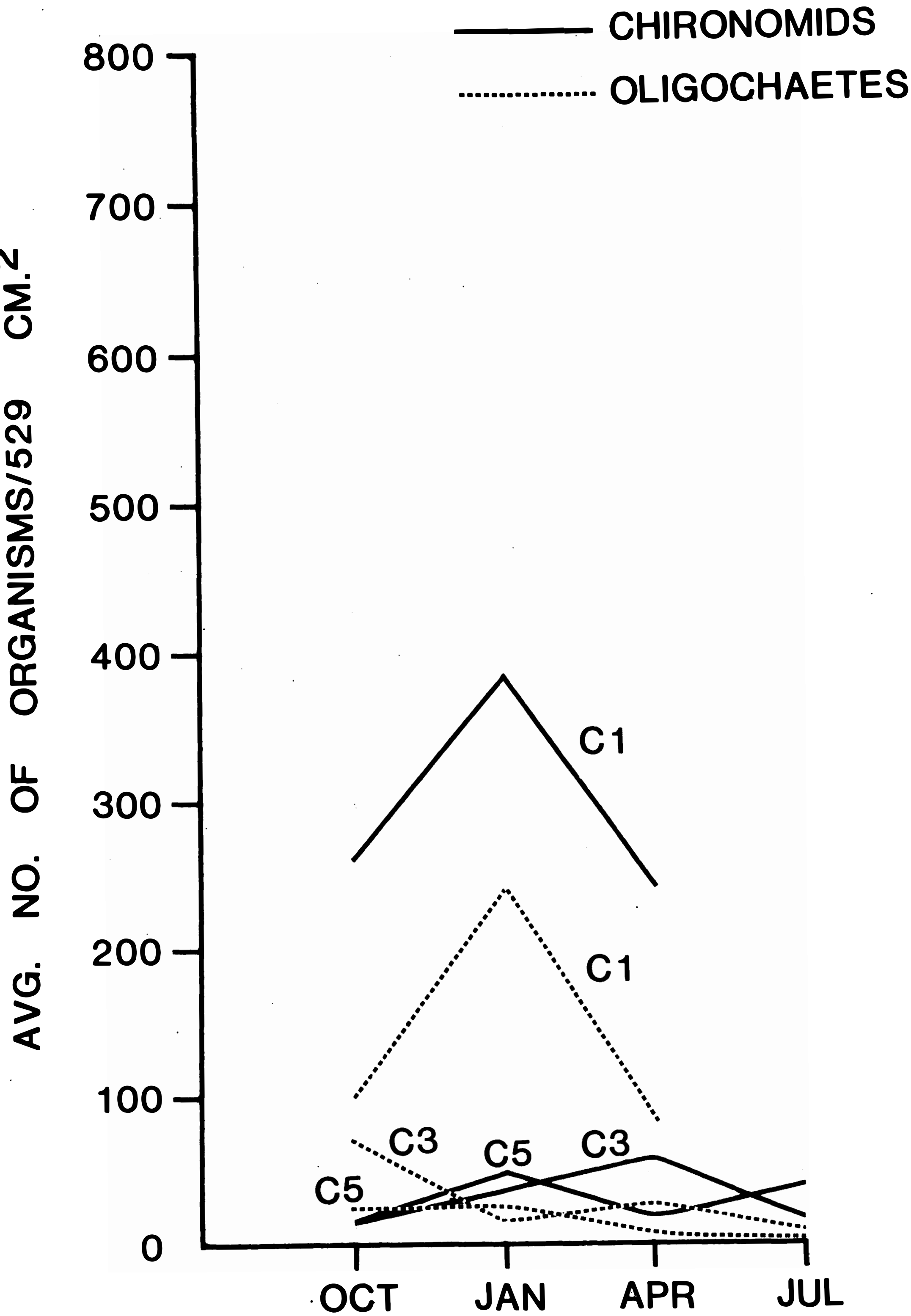

Figure 8.--Numbers of chironomids and oligochaetes by season along transect C at depths of 3 m (C1; 10 ft), 9.1 m (C3; 30 ft), and 15 m (C5; 50 ft).

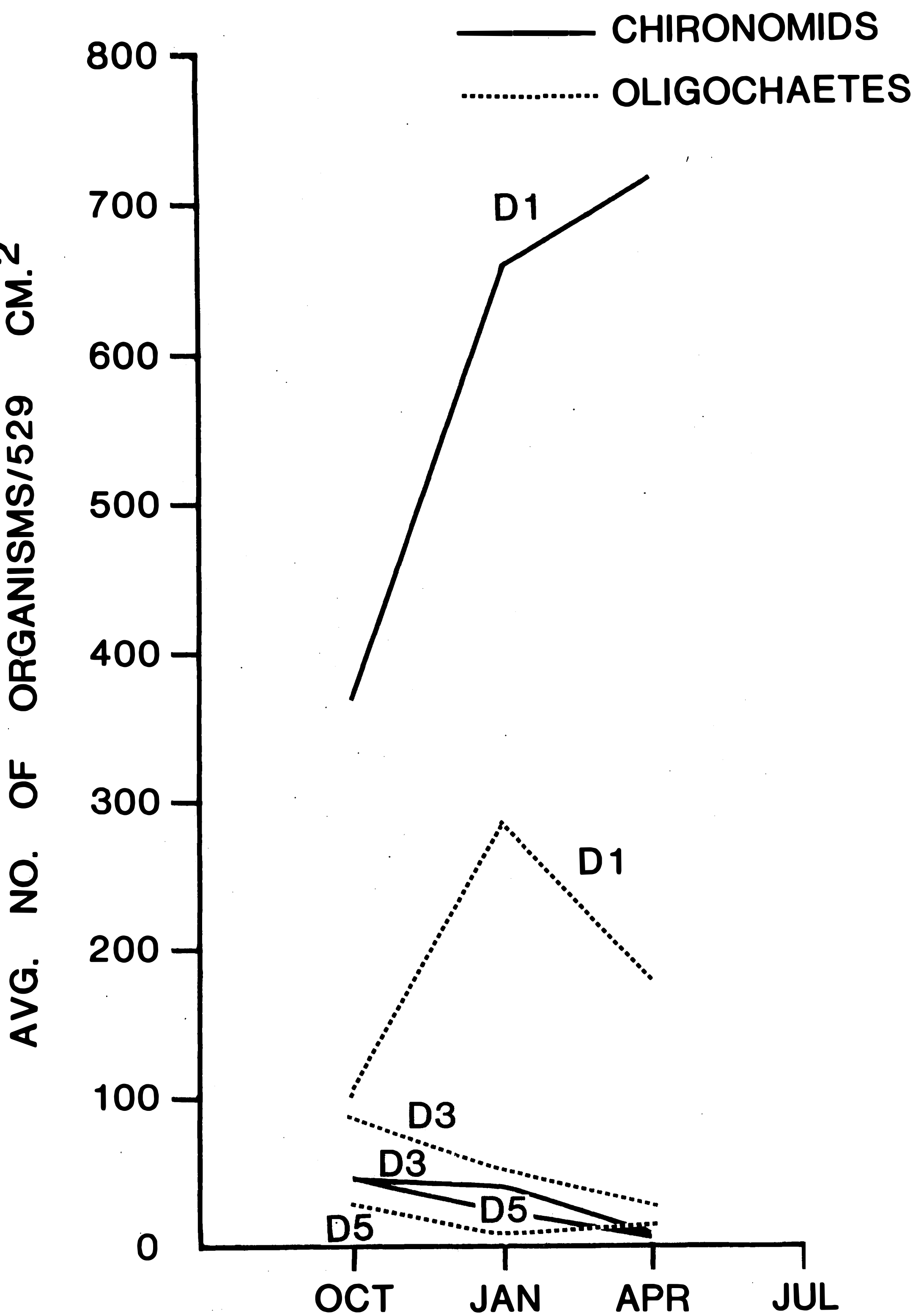

Figure 9.--Numbers of chironomids and ologochaetes by season along transect D at depths of 3 m (D1; 10 ft), 9.1 m (D3; 30 ft), and 15 m (D5; 50 ft).

Emergence of the chironomids centered within two time periods--January to April and April to July. This is especially interesting in view of the differences in generic composition at the 3 m (10 ft) stations between the north and south sides, the latter being dominated by the genus *Glyptotendipes* sp. and the former dominated by *Endochironomus* sp.

Oligochaetes (worm)

The oligochaetes had a general decline in numbers at the 3 m (10 ft) stations during the course of the sampling period, especially at transect A (Fig. 6). This trend, although to a lesser degree, occurred at the other 3 m (10 ft) stations (Figs. 7 through 9). The season that oligochaetes increased in number at the 3 m (10 ft) depth varied between transects. The deeper stations, while exhibiting similar population levels, had no overt seasonal variation.

Hyallela azteca (amphipod)

This organism was found exclusively at the 3 m (10 ft) stations where it occasionally formed a significant portion of the biomass (Table 1). The heaviest concentration of *H. azteca* was observed in the October samples at 3 m (10 ft) where an average of 85 per 529 cm^2 grab sample were collected.

Pontoporia affinis (amphipod)

This amphipod was much rarer than H. azteca in the study area and was exclusively found at the deeper stations, particularly the 15 m (50 ft) stations (Table 1). It was never found in significant numbers although Thut (1966) found it to be significant in the profundal benthos of Lake Washington.

Neomsis mercedis (mysid)

Mysids were rare in grab samples, although dive observation during fall, winter, and spring revealed great numbers hovering just off the bottom. Their distribution did not seem affected by depths at these times and was common to the deepest depth surveyed, approximately 21 m (70 ft).

Pisidium sp. (Clam)

Other than the chironomids and oligochaetes, the only organism to appear ubiquitously around the point was the finger nail clam, Pisidum sp. Large numbers of this clam were at all depths although there was a decline at the 15 m (50 ft) stations (Table 1). A slight decline in population was also noted in the January and April samples with some recovery shown in the July samples.

Other forms

Planispiral and hi-spiral gastropods appeared in the 3 m (10 ft) samples and had their greatest concentration at A-1, approximately 80 per grab.

Leeches (Hirudinea) were collected sporadically in low numbers throughout the study area, although highest concentrations were taken at the shallower stations.

Occasional damsel fly larvae (Fam. Coeagrionidae) and trichopteran larvae (Fam. Limnephilidae) were found in the grab samples from 3.0 and 9.1 m (10 and 30 ft). Trichopterans were commonly seen in the rocky shoreline area. A few mayfly larvae (Fam. Caenidae) were also found in the grab samples.

ZOOPLANKTON

Colletions for zooplankton were made to determine the annual biomass through the water column from the shore to a depth of 15 m (50 ft) encompassing the area to be affected by the dredging. The procedure was to tow a 12.7 cm (5 inch) Clarke-Bumpus net having #10 mesh netting for 5 min for each sample. The netting has 0.13 mm aperatures but the collection cup had 0.26 mm apertures; therefore, only the larger planktonic life was taken. Each month 48 samples were collected with 12 taken at each quarter of the day (0600, 1200, 1800, and 2400 h standard time). Six samples were taken between transect A and B and between transects D and E during each time period (Fig. 1). Hauls were the same at both areas and consisted of tows 1.5 m (5 ft) deep along the 3 m (10 ft) bottom contour, tows

1.5 and 7.6 m (5 and 25 ft) deep along the 9.1 m (30 ft) bottom contour, and tows 1.5,7.6 and 13.7 m (5-, 25-, and 45 ft) deep along the 15 m (50 ft) bottom contour. Some irregularities occurred in the sampling schedule because of specific study objectives and bad weather. Collections taken beyond July 1975 consisted only of the 1200 h samples. Preliminary studies indicated that a single 5-min tow was as reliable as triplicate 5-min tows (Table 2).

Biomass of zooplankton had a general period of increased abundance from April to October (Fig. 10). Clustering of zooplankton occurred and may have resulted from patchiness (apparent gregariousness) or from a combination of water current and plankton movement. Monthly levels of biomass were similar (1) through a 24-h period; (2) between transects AB and DE; (3) between all collections made at 1.5 m (5 ft); and (4) between collections made at 1.5 and 7.6 m (5 and 25 ft) (Table 3). Biomass was lower at 13.7 m (45 ft) than at 7.6 m (25 ft) and above during the period of peak abundance from April to October. Populations of _Diaptomus_ were 25 to 300 times greater in the epilimniom (30 m) than below it (Comita and Anderson, 1959). Biomass was similarly low through all strata inshore from the 15 m (50 ft) contour from November through March. During this period, biomass was one-third to one-tenth that of the productive spring and summer months. In 1974, biomass was low in July and increased in September in an apparent second peak of the year (assuming a peak in spring). Biomass was considerably higher and appraoching a peak in July 1975, indicating a significant yearly difference between July 1974 and July 1975.

Table 2.--Biomass of wet weight of zooplankton collected in Pontiac Bay, Lake Washington, 1100 to 1400 h on 30 July 1974. Samples were collected in a 5-inch Clarke-Bumpus net towed for 5 minutes where consecutive triplicate tows were made at a given station and depth.

Transect	Bottom contour feet	Depth of net feet	Biomass of zooplankton gm/m^3 water
AB	10	5	1.900
AB	10	5	1.478
AB	10	5	1.293
BC	10	5	.578
BC	10	5	.395
BC	10	5	1.181
AB	50	5	1.141
AB	50	5	1.770
AB	50	5	2.216
AB	50	45	.813
AB	50	45	.813
AB	50	45	.743
AB	30	25	.816
AB	30	25	1.148
AB	30	25	1.312

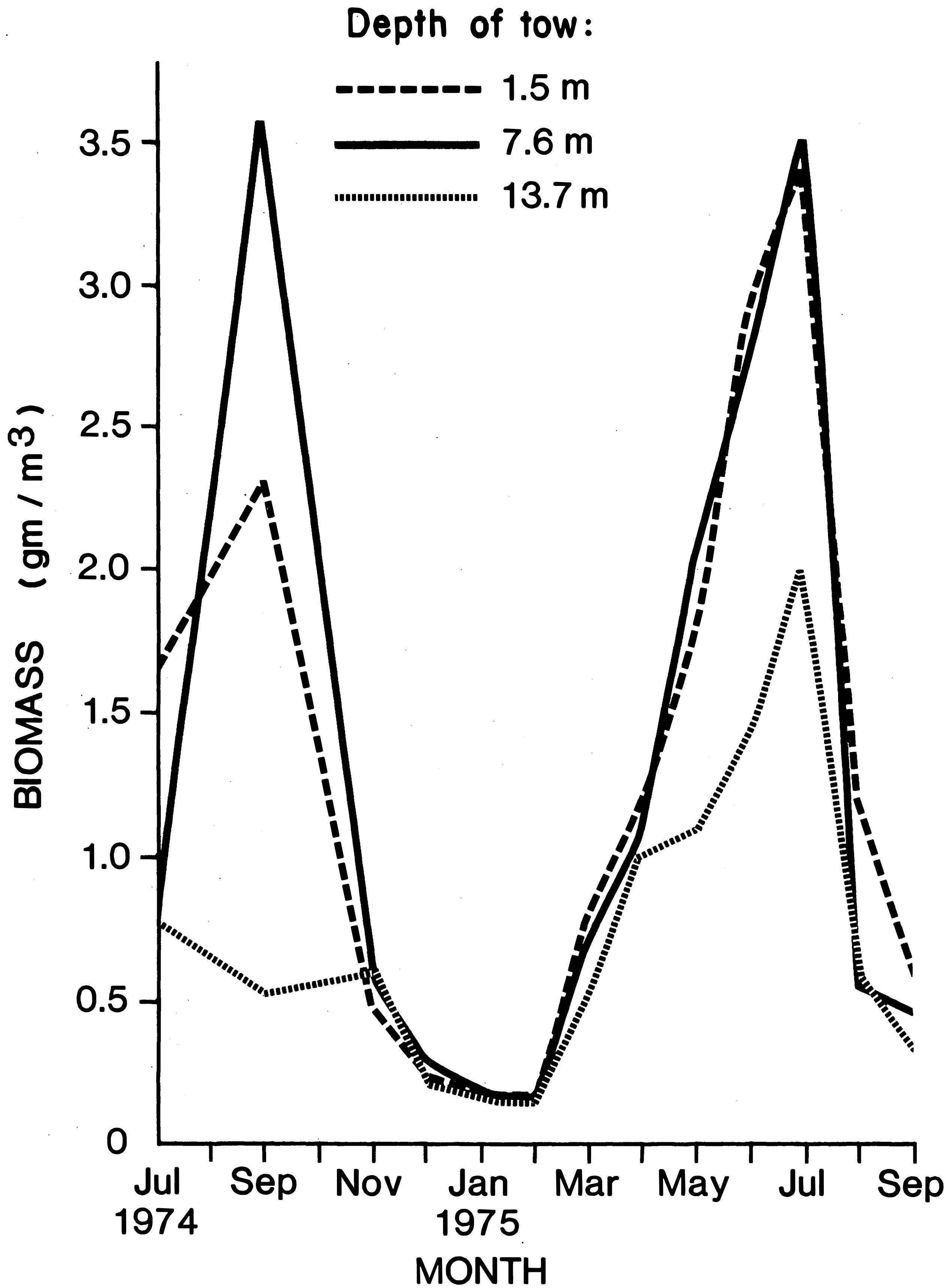

Figure 10.--Seasonal biomass of zooplankton (wet weight) off Sand Point averaged by depth of tow and location. Collections were made with a 12.7 cm (5 inch) Clarke-Bumpus plankton net.

Table 3.--Biomass of wet weight of zooplankton in grams/m^3 between transects AB at the north (Pontiac Bay) and transects DE at the south sides of Sand Point. Plankton tows were taken at one to three depths along three bottom contours at both stations. The basic data are averages of four 5 minute tows taken at 0600, 1200, 1800, and 2400 h. The straining efficiency of the Clark-Bumpus net was calculated at 0.86.

Transect	Bottom contour feet	Depth of net in feet	1974 July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	1975 March	April	May	June	July	August
AB	10	5	1.55		1.607		.739	.299	.155	.114	.913	.844	1.558	2.484	2.774	.996
AB	30	5			2.852		.384	.293	.191	.200	.832	1.150	1.715	3.029	3.761	1.496
AB	50	5	1.710		2.518		.545	.239	.218	.252	1.141	1.300	1.212	3.260	3.352	2.268
DE	10	5					.526	.257	.159	.138	.440	.791	1.187	2.230	2.985	.435
DE	30	5					.414	.218	.164	.193	.770	1.435	2.381	3.110	4.383	1.020
DE	50	5					.341	.197	.187	.200	.679	1.658	2.534	3.166	2.951	.645
Averages		5	1.632		2.326		.491	.250	.179	.183	.796	1.194	1.764	2.880	3.369	1.143
AB	30	25	1.092		3.569		.548	.282	.174	.165	.561	1.071	1.977	2.420	3.256	.667
DE	30	25					.576	.280	.189	.153	.826	1.106	2.084	2.914	3.699	.443
Averages	30	25	1.092		3.569		.562	.282	.181	.159	.693	1.088	2.030	2.667	3.479	.555
AB	50	25			3.459		.749	.321	.189	.219	.809	2.420	1.626	2.108	3.427	.442
DE	50	25					.682	.273	.172	.148	.544	1.240	1.806	2.705	3.396	.626
Averages	50	25			3.459		.716	.297	.181	.183	.676	1.830	1.716	2.407	3.322	.534
AB	50	45	.790		.522		.441	.252	.237	.173	.586	.938	1.185	1.550	2.194	.579
DE	50	45					.774	.246	.135	.128	.467	1.044	1.109	1.307	1.850	.535
Averages	50	45	.790		.522		.607	.249	.186	.150	.527	1.044	1.051	1.430	1.023	.557

Scheffer and Robinson (1939) found bimodal peaks of biomass with peaks in May and in October to November in the offshore 0 to 30 m (0 to 98 ft) zone. Biomass in the 30 to 60 m (98 to 196 ft) stratum was one-fourth that of the overlying stratum. They noted that sampling stations at two locations in the lake had the same trends in biomass.

The percentage composition of the prominent species of zooplankton was determined from subsamples of collections that would indicate diel and seasonal variation. Collections subsampled were the 1200 and 2400 h hauls taken along the AB transect at the 1.5 m (5 ft) depth along the 3 m (10 ft) bottom contour and at the 1.5, 7.6, and 13.7 m (15, 25, and 45 ft) depth along the 15 m (50 ft) bottom contour. Subsamples were placed in a petri dish,organisms were identified to species or genus and the numbers recorded. The number of individuals of a given species divided by the total subjects in a subsample were used to determine the relative percentage composition of a species. The category of "other" mainly consisted of juveniles and secondarily consisted of fragmented animals.

Numerically, the zooplankton was dominated by *Diaptomus ashlandi*; *Cyclops bicuspidatus* (a few *C. vernalis* may have been included within this species); *Diaphanosoma leuchtenbergianum*; and *Bosmina longispina* (Figs. 11 and 12). Species of lesser importance were *Epischura nevadensis*, *Daphnia* sp. and *Leptodora kindti*. *Diaptomus* was variable in relative abundance and was of greater importance at 1200 h than at 2400 h. *Cyclops* was the most stable of the dominant species in relative numerical abundance; they were the most numerous species at 7.6 and 13.7 m (25 and 45 ft) at 1200 h and at all depth strata at 2400 h. *Diaphanosoma* were the dominant

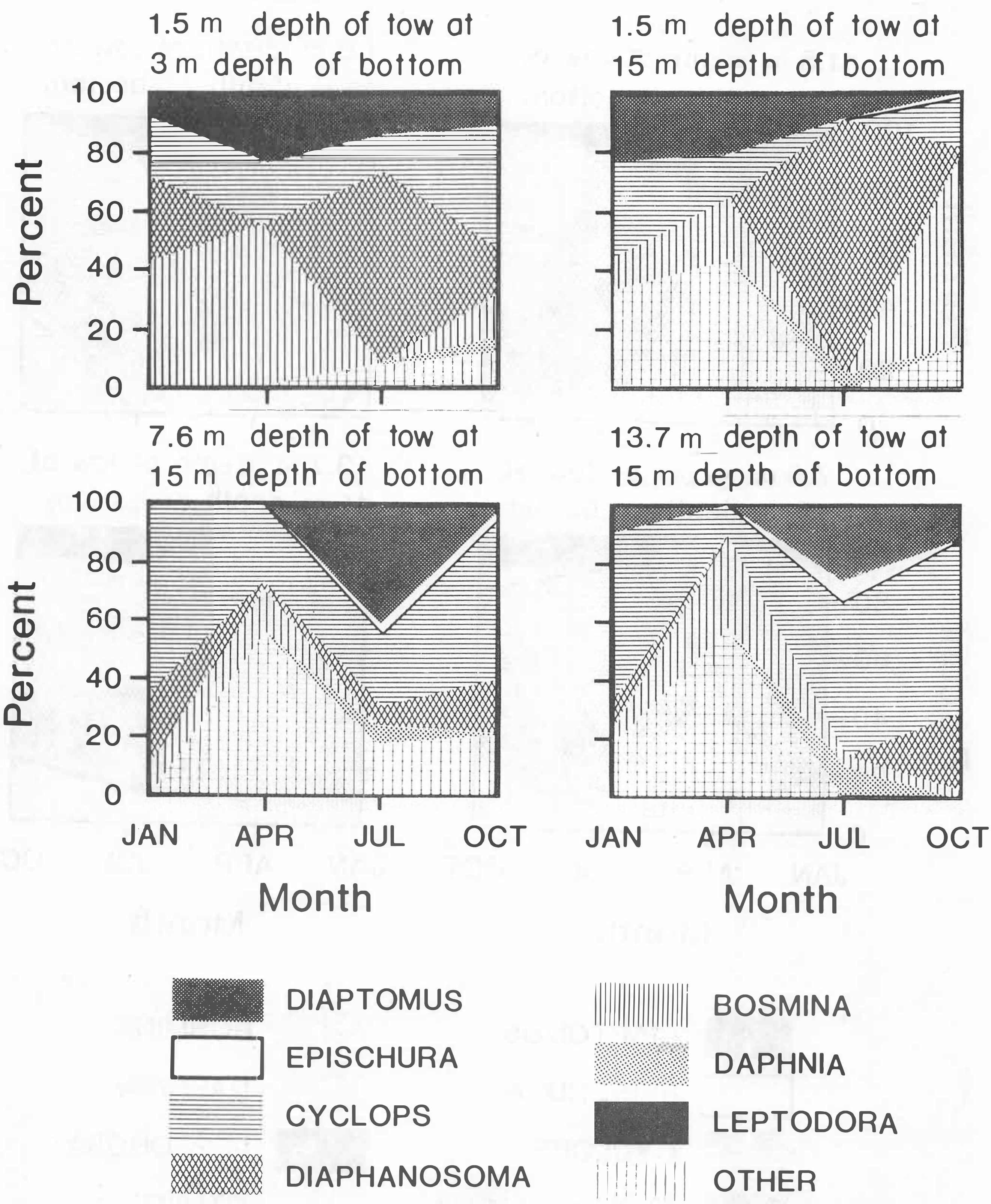

Figure 11.--Percentage composition of the more numerous species of zooplankton by depth of net tow over a given bottom depth by season at 1200 h.

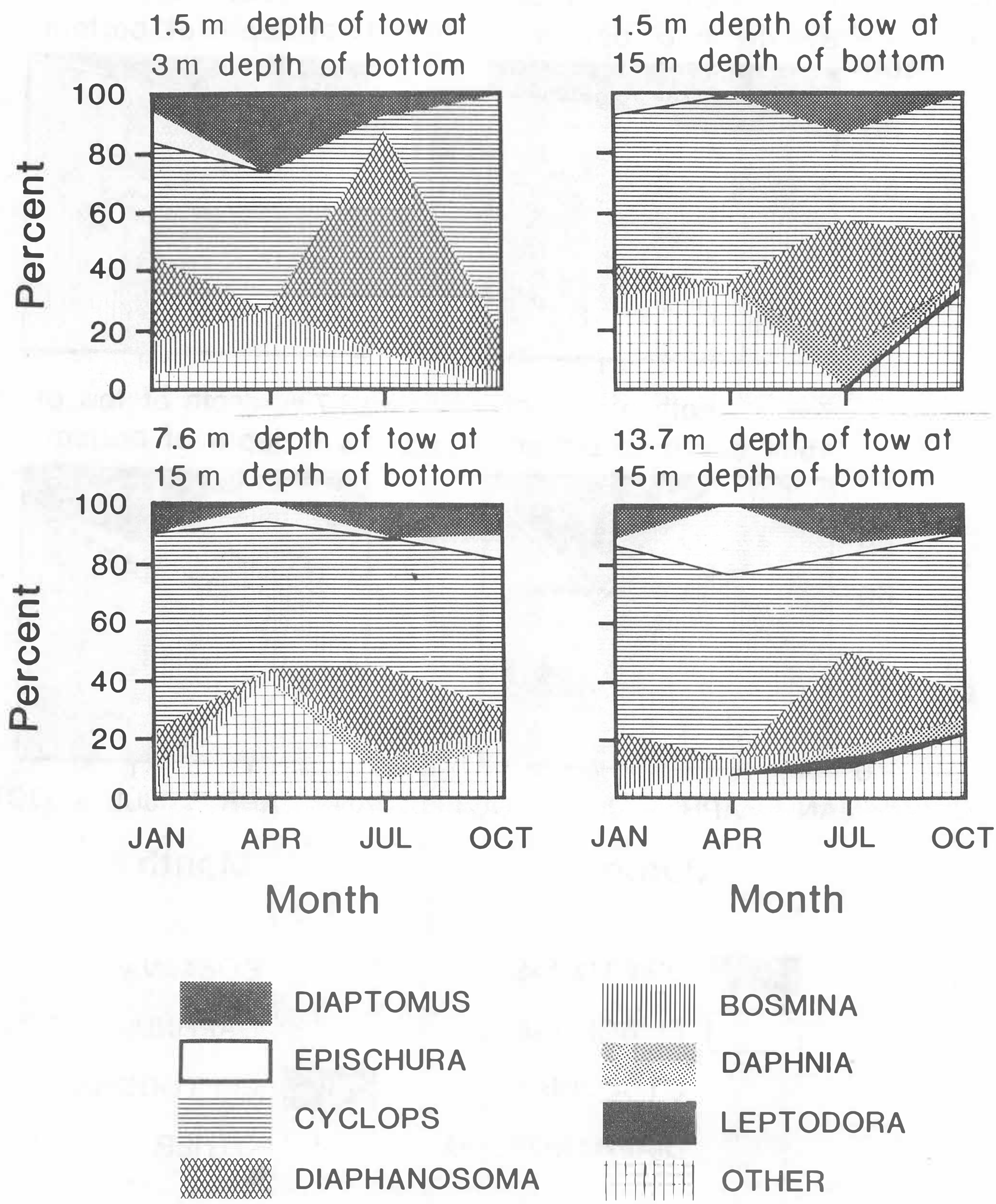

Figure 12.--Percentage composition of the more numerous species of zooplankton by depth of net tow over a given bottom depth by season at 2400 h.

species during July at the 1.5 m (5 ft) depth at 1200 and 2400 h and were more abundant at the 7.6 and 13.7 m (25 and 45 ft) depth at night than by day. Bosmina were dominant in April at the 1.5 m (5 ft) depth at a 3 m (10 ft) bottom contour and in October, at the 1.5 m (5 ft) depth along the 15 m (50 ft) bottom contour. This species had consistently low relative abundances at night. Large numbers of juveniles were in the offshore and deeper stations in April during the day.

Some zooplankters, prominent by their size (biomass), were not well represented numerically in catches of the Clarke-Bumpus net. Leptodora kindti were in great abundance in samples taken near the surface in a meter net for the bioassay studies in August 1975. Neomysis and fish larvae were never collected in great numbers. In general, Neomysis were taken only at night. Hauls for ichthyoplankton with a meter net yielded mysids at all stations (surface along the 3 and 15 m depth contour and at 13.7 m along the 15 m depth contour). The larger species of zooplankton may have been better able to evade capture in the Clarke-Bumpus net than the smaller species. Therefore, the sampling method may have provided an adequate index of biomass of the smaller species but underestimated larger ones.

Biomass of zooplankton was greatest in July, least in January, and at intermediate stages in the annual cycle of abundance in April and October (Fig. 10). The July peak in biomass coincides with the great numerical dominance of Diaphanosoma (Figs. 11 and 12). Cyclop was perhaps of equal importance and Diaptomus was dominant in July at the 7.6 m (25 ft) strata along the 15 m (50 ft) contour. If species composition of zooplankton was similar for the months of the peak biomass, centered on July, then the greatest species contribution in biomass was shared by

Cyclops and Diaphanosoma, with Diaptomus third in importance within the samples. Comita and Anderson (1959) determined populations of Diaptomus to be most abundant from July to September. The status of Leptodora is uncertain because it was not well sampled in the Clarke-Bumpus net. Judging from the great biomass of Leptodora observed in a meter net, this species could have been a major part of the Lake Washington zooplankton in the summer.

Species of crustacean zooplankton that were numerically dominant in the present study were also the dominant species in 1933-35, throughout the strata to 60 m (200 ft) (Scheffer and Robinson, 1939). Cyclops, Diaptomus, Epischura and Diaphanosoma were abundant species in their studies; however, Diaphanosoma was in greater abundance in the summer of 1974.

Neomysis mercedis, the largest crustacean of the planktonic community was prominent by size and moderate in number; but, they were not well sampled by the plankton net. Diver observations showed their daytime behavioral and seasonal trends in depth of habitation and abundance. Neomysis were pelagic within 7.5 cm (3 inches) off the bottom and they frequently contacted the bottom. Some observations showed that on these bottom contacts they were picking up bits of material and holding them for a period before dropping them--this may have been a feeding activity. This species is known to feed mainly on bottom materials of detritus and diatoms in an estuary (Kost and Knight, 1975). Although Neomysis was common when observed (2-50 individuals/m^2), diver observations did not provide an accurate index of their abundance because of small size, poor visibility and darkness. Minimum depth distribution varied through the year. From September to April, they were common to 3 to 4.6 m (10 to 15 ft), the approximate limit of the heavy vegetative growth that forms an abrupt, dense vertical wall 1.5 to 2.1 m (5 to 7 ft) high. In May, they were common to 60 cm (2 ft) over a sand to muck bottom but not over rocks; in June and July their minimum depth was greater than 12.2 m (40 ft), but by the end of July some were at 6.1 m (20 ft).

Ichthyoplankton was sampled with horizontal hauls of a meter net at 1200 h between transects AB and DE from February to August, the period of fish spawning activities. The net had mesh openings of 0.78 mm and the mesh of the cup was 0.330 mm. Tows of specified durations were made 1.5 m (5 ft) deep along the 3.0 m (10 ft) bottom contour between transects AB and DE and at 1.5 and 13.7 m (5 and 45 ft) between transects AB. Except for six specimens, all fish larvae were sculpins (Table 4). numbers at 13.7 m (45 ft) along the 15 m (50 ft) bottom contour and numbers were less at the 1.5 m (5 ft) depths especially along the 15 m (50 ft) contour (Fig. 13). Three larvae, presumed to be longfin smelt, Spirinchus thaleichthys, were taken in 1.5 m (5 ft) (two fish) and 13.7 m (45 ft) (one fish) hauls; another three larvae were unidentified. Lengths of sculpins ranged from 6 to 13 mm, and the smelt ranged from 10 to 15 mm. Meristic counts of some of the larger sculpins fit those of Cottus asper.

CRAYFISH

The crayfish (Pacifastacus leniusculus) observed remained in deep water during winter and were abundant in the shallows during summer. Populations predominantly of berried females with advanced embryos or carrying young were first observed in May in the shallows 0.3 to 3.0 m (1 to 10 ft) deep. In May, and the first part of June, the young of

Table 4.--Numbers of fish larvae/m^3 taken in a meter net between transects AB at the north (Pontiac Bay) and transects DE at the south sides of Sand Point from March to August 1975.

Date	Transect	Bottom contour feet	Depth of net	Volume of water strained in m^3	Species of fish: Sculpins (*Cottus*) Number	Sculpins (*Cottus*) Length range in mm	Sculpins (*Cottus*) Number per m^3	Longfin smelt (*Spirinchus thaleichthys*)	Unidentifiable
3-28	AB	10	5	217	18	7-13	.083	-	-
	AB	50	5	217	3	8-9	.014	-	-
	AB	50	45	434	130	7-11	.300	-	-
	DE	10	5	217	10	6-7	.046	-	-
5-2									
	AB	10	5	217	15	7-10	.069	2 (9.5 mm)	-
	AB	50	5	217	5	7-8	.023	-	-
	AB	50	45	347	68	6-12	.196	1 (15 mm)	-
	DE	10	5	217	6	8-10	.028	-	-
6-16									
	AB	10	5	217	3	6-7	.014	-	1
	AB	50	5	217	5	6-9	.023	-	-
	AB	50	45	347	167	6-11	.481	-	-
	DE	10	5	217	-	-	-	-	2
7-17									
	AB	10	5	217	1	9	.005	-	-
	AB	50	5	217	-	-	-	-	-
	AB	50	45	347	9	6-9	.259	-	-
	DE	10	5	217	1	10	.005	-	-
8-7									
	AB	10	5	217	4	9-11	.018	-	-
	AB	50	5	217	5	8-9	.023	-	-
	AB	50	45	347	15	6-9	.043	-	-

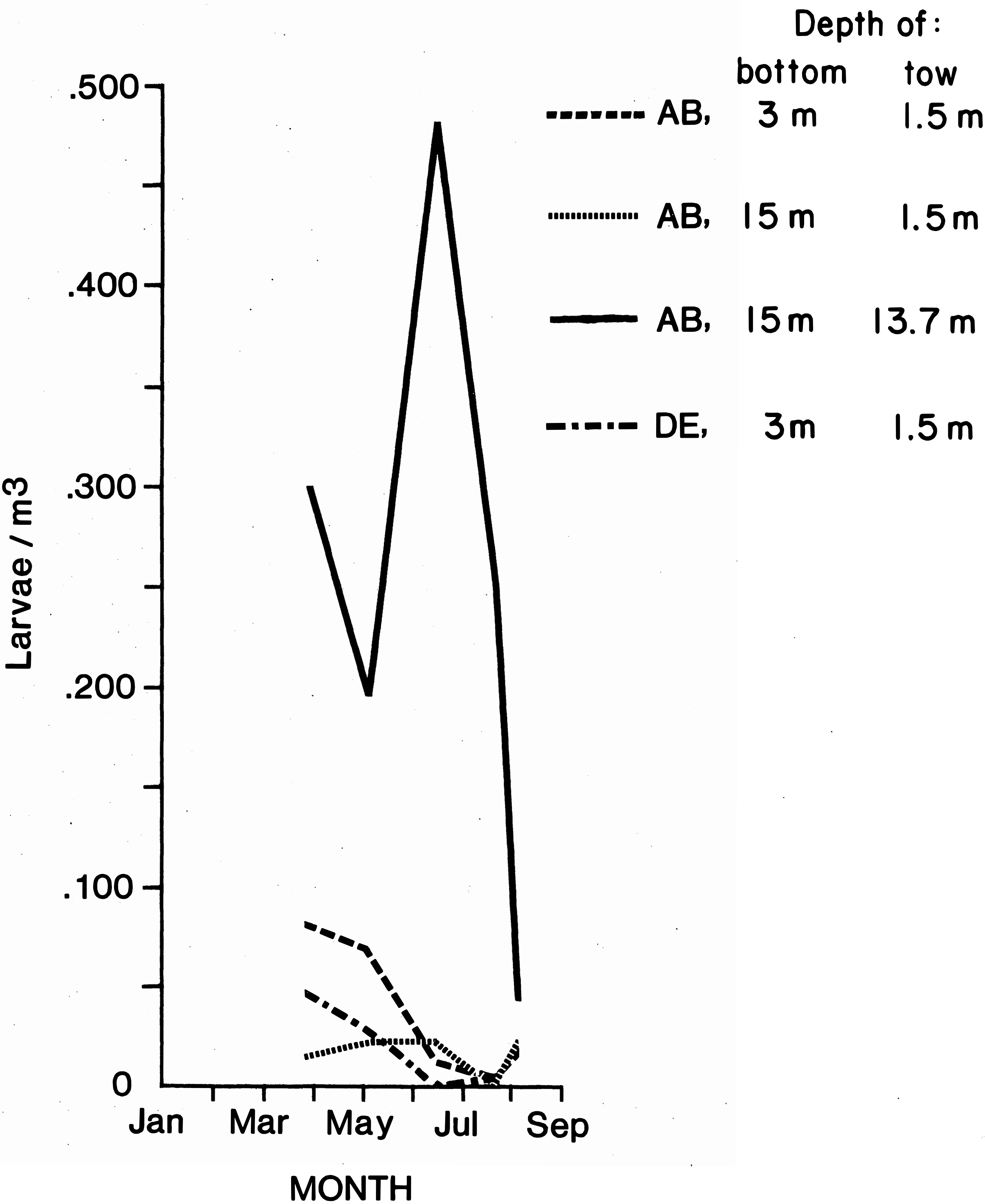

Figure 13.--Numbers of sculpin larvae (probably Cottus asper) collected in a meter net at four transect and depth locations, April to August, 1975.

the year commenced a solitary existence under rocks as did older individuals. Crayfish were abundant in rocky areas at depths less than 3 m (10 ft) but few were seen from depths of 3 to 15 m (10 to 50 ft), and these were always associated with rubble. Some of the females were berried in October. The crayfish moved to depths of about 27 m (90 ft) in November where they dwelled in burrows until the following spring (David Anderson, personal communication).

PLANT LIFE

Periphyton and rooted vascular plants have maximal growth in spring and summer (Benson, 1967). From October through April, stones were covered with a brown algae and vascular plants were indicated by stubs in the substrate. In May, green algae covered rocks and some of the vascular plants at depths of 0.6 to 1.2 m (2 to 4 ft). Growth zones of vascular plants were evident in May; they were dense within the depth zones of 0.6 to 3.7 m (2 to 12 ft). In May, their height had reached 15 to 25 cm (6 to 12 inches). In June, heavy growths of epiphytic algae had covered all physical objects including the vascular plants. Light penetration was low in May and especially in June, apparently because of a dense plankton bloom, but by July water transparency had increased. Vascular plants appeared to have grown little until the end of July. By August, the vascular plant growth had reached a maximum with the three floating species having heights of 1.8 to 2.0 m (6 to 7 ft). Growth of these plants was reduced at their maximum depth of 3.7 to 4.3 m (12 to 14 ft). Some patches of green algae-hydra associations were observed at 3.7 to 4.6 m (12 to 15 ft) depths through the year. Plant life in the 0 to 3.7 m (0 to 12 ft) zone was deteriorating by the end of September.

SUMMARY OF THE BIOTA

The aquatic biota within the 15 m (50 ft) contour of Pontiac Bay had an annual cycle of abundance of biomass where biomass was maximal during May to September for most life. This time period encompassed the abundance maximals for fish (Fig. 14), zooplankton (Figs. 10, 11, and 12), crayfish, and plants. Benthic invertebrates had high abundances in winter and the chironomid individuals reached maximum size in the period from January to April when emergence occurred.

PREDICTED DREDGING EFFECTS

Proposed development of the docking center includes the dredging of 260,000 cubic yards of bottom to establish a 9.1 m (30 ft) depth over an area of 570,000 square feet. The impact of dredging on the biota involves seasonal abundances of life within the 9.2 m (30 ft) contour, their tolerance to and avoidance of water with solid particulate content and the transportation of dredge spoils beyond the work site by lake current.

SEASONAL ABUNDANCE

Possible effects on the biota from dredging would be least at the time of year when the biota is least susceptible to destruction or biomass is lowest. In a dredging project, the benthic fauna would be the most directly affected group. Destruction of benthos in the immediate area of dredging will be complete and unavoidable. The benthic fauna adjacent to the dredge site could be protected by proper timing of the dredging.

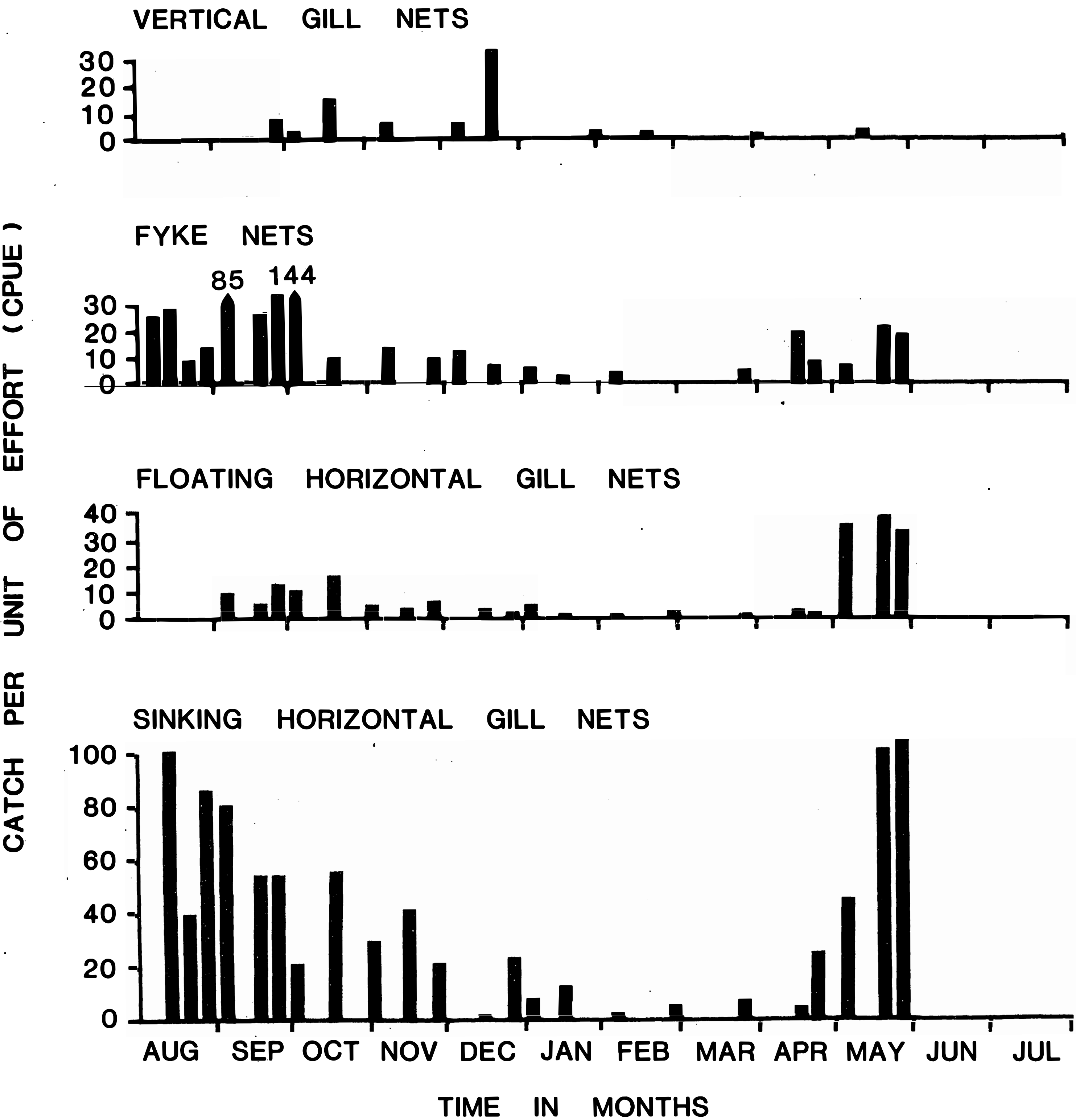

Figure 14.--Catch per unit of effort of all species of fish captured in four types of nets off Sand Point in 1974 and 1975.

Chironomid larvae reach peak size sometime between January and April. When they are at their maximum size they would be most able to survive the main disturbance, i.e., fallout of suspended sediment. Small, early instar larvae may be covered by sediment but the exact effects of this is unknown. Oligochaetes are probably sufficiently mobile in the sediment to avert suffocation from burial. It is impossible to say how the minor components of the fauna would fare, such as the finger nail clams, since no data are available at this time on their digging abilities or growth rates.

The annual cycle of biomass at the dredge site, described in the previous section and by Shepard (1975; Appendix A) for fish, indicates that the period from November to March has a sustained low level of animal and plant life in Pontiac Bay. Within this time period, dredging will probably have the least biological effects from January to March. Dredging at this time would subject one-third to one-tenth of the biomass of certain species that occur in spring and summer to sedimentation from dredging.

TOLERANCE AND AVOIDANCE

Certain types of life would be present during dredging operations within and adjacent to the dredge site. Of these, some may be removed, others will tolerate the sedimentation, and motile species would probably avoid the affected area.

Heavy loads of suspended solids would probably have no direct effect on some of the animal life that became associated with it. Several species were subjected to suspended sediment from the glacial till lake bottom for 96 h bioassay tests (Appendix B). Coho salmon and prickly sculpin had complete survival during and for 5 days after testing (Table 5). Test and control crayfish were not significantly different in survival. All caddis larvae (Family Limnephilidae) held in the stock mixture of sediment for 96 h survived. Plankton species did not survive test or control conditions well, which negates their bioassay results. Cyclops and Bosmina both survived lake water better than water mixed with bottom sediments (Table 5).

Some organisms were tested to determine if there was an avoidance reaction to (1) water with a high sediment suspension and (2) a bottom composed of glacial till. Coho salmon and prickly sculpin but not crayfish avoided the higher concentrations of sediment in water (Table 6). The benthic prickly sculpin and crayfish were tested for their preference of substrate type between glacial till and sterilized lake bottom substrate; no preferences were noted (Table 7).

Biological attraction related to feeding would be eliminated for a short term until detritus and the associated life becomes established over the new, biologically sterile bottom. If dredging were accomplished during late fall or winter, for example, the only numerous mobile animals present would be the sculpins and the mysids. Both types apparently depend on the bottom for food. Sculpins may avoid the area because of the possible absence of food and mysids may not inhabit the work site if their presence were dependent on food. The reaction of mysids to water mixed with sediment is unknown.

Table 5.--Bioassay of selected aquatic animals common in the Pontiac Bay, Lake Washington study site, where the test mixture was of suspended solids mixed from a glacial till, at a starting concentration of 37,000 (see Appendix A).

Species	Treatment	Pretest Number	Average Length in mm	Post test Survivors, Numbers
Coho salmon	Test	12	47.4	12
Oncorhynchus kisutch	Control	12	47.0	12
Prickly sculpin	Test	12	55.2	12
Cottus asper	Control	12	56.8	12
			Length Range	
Crayfish	Test	12	18-170	8
Pacifastacus leniusculus	Control	12	12-162	10
Caddis larvae	Test	8		8
Limnephilidae				
Copepod	Test	40		13
Cyclops	Control	24		11
Leptodora	Test	13		0
	Control	15		0
Daphnia sp	Test	27		0
	Control	28		10
Daphnia sp	Test	51		0
	Control	44		0

Table 6.--Preference of three species of animals to lake water with and without a heavy load of suspended sediment. Numbers of subjects observed in the half of a tank receiving lake or silt water are given for the two tanks and replicate tests.

Coho salmon (Oncorhynchus kisutch)

Tank	Water type	Replicate 1	Replicate 2	Tests of significance
North	Sediment	6	5	G_T^2 (p=0.05, 4 d.f. =9.488) = 13.643
	Lake	14	15	Reject hypothesis of equal distribution of fish in tanks; Fewer fish were observed in sediment water
South	Sediment	7	6	
	Lake	13	14	

Prickly sculpin (Cottus asper)

G_T^2 (p= 0.05, 4 d.f.=9.488) = 26.51
Reject hypothesis of equal distribution of fish in tanks; fewer fish were observed in sediment water.

Tank	Water type	Replicate 1	Replicate 2
North	Sediment	5	5
	Lake	15	15
South	Sediment	5	3
	Lake	15	17

Crayfish (Pacafastacus leniusculus)

Tank	Water type	Replicate 1	Replicate 2	Tests of significance
				G^2 (p=0.05, 4 d.f.=9.488) = 12.015
North	Sediment	3	8	Hypothesis of homogeneity of results
	Lake	15	3	between tanks, replicates and water type is rejected; data is inconsistent.
South	Sediment	7	10	Crayfish did not consistently select one
	Lake	10	8	type of water.

Experimental procedure:

Table 6 (continued)

Experimental procedure: Forty subjects were used per species. Prickly sculpin were collected prior to testing; crayfish and coho salmon were obtained from hatchery stocks maintained at the NMFS Northwest Fisheries Center. Length range for the coho salmon was 47 to 74 mm; lengths averaged 57.2 mm. For prickly sculpin, the range was 37 to 110 mm, and lengths averaged 67.4 mm. For the crayfish, lengths from tip of telson to rostrum ranged from 22 to 77 mm and averaged 38.6 mm. Within a species group of sculpins or crayfish the larger individuals were tested together to prevent canabalism.

Two identical test tanks 14 by 48 by 12 inches high were used on simultaneous tests. Water was introduced at each end of a tank and drained through screened side ports located at the middle. An 11 inch baffle centered in the middle of the 14 inch wide tank helped prevent intermixing of the two types of water introduced at each end of a tank. Two submersible pumps supplied water to a tank at the rate of 4-liters/minute so that 2-liters/minute was introduced at each end.

Forty subjects were placed in a tank with running water. Black polyethylene sheeting sealed off all light and was intended to prevent escape of the crayfish, although some did escape. After the subjects had been in the tanks 24 hours, one of the pumps was placed in a container of sediment water that had just been mixed. Thus, each tank was receiving lake water at one end and at the other end, lake water mixed with sediment. The center drains and the baffle plate in the middle partially maintained each type of water in a specific half of the tank.

Thirty minutes after the introduction of the sediment water, a vertical slide was released that sealed off each half of a tank. The polyethylene sheet was removed and numbers of subjects in each half of the tank were counted as the basic data. The vertical slide was then raised, the polyethylene sheeting was resealed, clear lake water was run into the tanks and the same subjects were ready for the replicate tests to be done 24 hours later. The procedure for the replicate test was identical except that the ends of a tank receiving sediment and lake water were reversed. Water temperatures during testing was 72°F.

Table 7.--Preference of the prickly sculpin, Cottus asper, and crayfish, Pacafastacus leniusculus, between sterilized Lake Washington bottom substrate and glacial till from Lake Washington bedding substrate obtained by core drilling. Data show numbers inhabiting a bottom type where two substrates were equally available within a test aquaria.

Prickly sculpin

Replicate	Type of bottom: Sterile mud	Type of bottom: Glacial till	Test of significance
1	3	7	Test of homogeneity of distribution of sculpin over substrates: X^2 ($p = 0.05$, 1 d.f. $= 3.841$) $= 3.266$, selection between substrates was random.
2	6	4	
3	2	8	
4	4	6	
5	2	8	
6	6	4	
Totals	23	37	

Crayfish

Replicate	Type of bottom: Sterile mud	Type of bottom: Glacial till	
1	7	3	Selection between substrates was random.
2	5	5	
3	1	3	
4	3	6	
5	4	3	
Totals	20	20	

DISPERSION OF SEDIMENT

Disruption of the site by dredging may create heavy loads of suspended solids in the water with settling at the work site and over a broad area adjacent to the construction depending on the vectors of currents. Dispersion of the suspended solids would be related to settling rate and lake current. Settling rates of a mixture of glacial till substrate at 37,000 ppm total suspended solids at 17°C (62°F) in an Imhoff cone show two stages of settling. The larger particulate fraction settled in 1-1/2 hours resulting in 1,600 ppm total suspended solids. Smaller particles remained in suspension for a prolonged duration. Since settling was essentially complete in 1-1/2 h in the 35 cm (14 inch) Imhoff cone, it would require 19 h for this settling to occur in a 4.5 m (15 ft) column of water. Lake currents would disperse the sediment over a broad area, distances that may be described in miles, depending on direction and velocity of wind and on convection currents (Figs. 2 to 4). A deposit of sediment over the lake bottom, especially at depths of 15 m (50 ft) or less, could act to reduce bottom productivity. This is because detritus and the associated bacteria over the bottom that provide a primary energy source for the benthic community (Hall and Hyatt, 1974) could be smothered in the fallout of particulate matter. Sedimentation adjacent to dredging activities could affect the biota, but the extent and the exact loss would be difficult to predict because of many unknown contingencies.

The ultrafine component of the glacial till sediment could remain in suspension for a prolonged period reducing the transparency of the water.

TOXICANTS IN SEDIMENTS

Trace amounts of toxic materials in the sediment (Crecelius, 1975; Schell, 1974; Appendix C) may be placed in suspension by dredging activities. The effect of this over pre-dredging levels may be unimportant to the biota. This is because the toxic materials are in low concentrations and the burrowing invertebrates have long been in contact with the contaminated substrate. The greater portion of the resettlement of the disturbed sediment will probably occur in the deep central basin by convection currents.

DREDGE PROCEDURE RECOMMENDATIONS

Two dredge procedures can be used: (1) conduct open water dredging or (2) fence in the dredge site with sheeting sealed at the bottom to insure that all sediment fallout will occur within the work site. Maintaining sediment deposition over the work site with a fence will help protect life in adjacent areas and help establish a soft substrate that may be more attractive to the benthos than a hard bottom.

INCREASING THE DEPTH

A deepened bottom should have little effect on the primary planktonic community; however, the benthic community, so important to the fish as food, may be affected. At the onset, the standing (pre-construction) benthic community would have been lost during construction. Further loss of production of biomass will occur during the period of recovery after dredging. Lastly, the benthic community may have a permanently altered productivity as influenced by the deeper bottom.

Faunal recolonization of the disrupted bottom will require a period of unknown duration to reach equilibrium. The present community, dominated by oligochaete worms and chironomid larvae, is dependent upon the microbial populations inhabiting organic particles for a food source. After dredging, the exposed bottom will present a relatively sterile environment, unsuitable for recolonization by most benthic forms. Tube dwelling chironomids that filter feed on phytoplankton, diatoms, or detritus may be present initially. Recolonization by oligochaetes, chironomids, and benthic crustaceans would be delayed until the organic content of the sediment rises and an organic flock settles out on top of the sediment. Detritus settles on the bottom of the central depths at the rate of 3 mm/year (Crecelius, 1975), but the rate will be lower in the shallows because of convection currents (Gould and Budinger, 1958). Use of the area by fish will increase in some proportion to increases of species and abundance of benthic life.

Prop wash from vessel movement activities could affect the benthic community within the docking area. This washing could periodically disrupt the soft bottom and associated life within certain areas.

The biomass of the benthic community may not be altered because of loss of the highly productive shallows if the dredge area is not deepened beyond 4.5 m (15 ft). For example, the reduction in numbers of invertebrates from 3.0 to 9.1 m (10 to 30 ft) was about 10:1 for chironomids, 4:1 for oligochaetes and 2:1 for clams. The amphipod, Hyallela, did not occur as deep as 9.1 m (30 ft), and other species were unimportant (Table 1). The benthic faunal concentration at the 3 m (10 ft) depth is presumed to indicate a higher benthic productivity than that at greater depths around Sand Point. This is probably valid considering the allochthonous input and the autochthonous (detritus produced in lake) entrapment of sediment associated with weed zones. White (1975) also determined that the benthos usually decreases in numbers of organisms per unit area with depth. His results did not show consistent population density trends but, in general, the lowest populations were at 1 m (3.3 ft); highest populations were at 3 m (10 ft) and the populations were slightly more numerous at 5 to 15 m (17 to 50 ft) than at 1 m (3.3 ft).

The observed standing crop of benthic organisms are not entirely indicative of production because of removal of the benthos by fish and other animals for food. For example, Hayne and Ball (1956) determined that in a year fish may remove between 8 and 27 times the standing crop and that the overall effect of predation on the benthos was to increase their annual productivity. Miller (1941) noted an Ontario lake to have a greater standing crop of chironomids in the shallows and that the standing crop was replaced 8 to 9 times a year in the shallows but only 2 to 3 times a year in deeper waters. These citations indicate that the standing crop may only be an estimate of annual production where production is more underestimated in the shallows than in deeper waters.

PIERS

Piers and the associated docking of ships may alter the aquatic biota by shading the phytoplankton, introducing toxic materials into the lake, influencing movement of fish, increasing periphyton growth, reducing current flow, and diminishing the wave action. Some of these effects on the biota could be beneficial and others harmful to life.

Shading could affect the productivity of the phytoplankton in the lake in proportion to the ratio of the lake covered by the piers to the surface area of the lake; less than 0.0001% of the lake surface would be shaded by the piers that are proposed. Furthermore, periphyton growth on the pilings will partially compensate for this loss--many benthic organisms are able to inhabit such periphytic growth, thereby causing a vertical extension of the benthos.

The study of White (1975) showed a reduction of light under piers; however, he did not find the populations of the benthos or of fish to be affected by the presence of established piers in Lake Washington. White (1975) found that numerical population densities of the benthos were variable in relation to the influence of piers for different locations. Apparently factors controlling the density of the benthos are not strongly related to the presence of piers. Since piers did not notably influence the benthos, the fish dependent on them for food were likewise unaffected.

Toxic and undesirable materials could enter the water from the use of preservatives on pilings. Pilings treated with creosote or pentachlorophenol may support populations of algae (White, 1975) but should be avoided because the preservatives are toxic (McKee and Wolf, 1963).

Generalized use by fish of the docking center can be predicted but precise changes from the present usage are difficult to foresee in all cases. Feeders on the benthos include important species such as the sculpin, peamouth, northern squawfish, and yellow perch. In the spring, coho salmon juveniles are present in Pontiac Bay, apparently actively feeding on the hatches of chironomids from the benthos. Largemouth bass are attracted to piers and may increase in population within this area. Adult salmon and steelhead trout that move around Sand Point on their home stream migrations should not be affected.

The physical presence of the pilings will reduce current flow. Even at times of light winds, the lake waters are in movement. The major effect of a reduced current flow should be an increase in autochthonous input. This would tend to enrich the bottom and increase the productivity of the benthos within the immediate vicinity of the piers.

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